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Comparisons of Physical Activity and Dietary Components in an Overweight/Obese Population and their Normal Weight Controls Matched for Gender, Age and Height

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Comparisons of Physical Activity and Dietary Components in an Overweight/Obese Population and their Normal Weight Controls Matched for Gender, Age and Height

by

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Dedication

To Jason:

My Husband, and my Best Friend

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Comparisons of Physical Activity and Dietary Components in an Overweight/Obese Population and their Normal Weight Controls Matched for Gender, Age and Height

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The objectives of this study were: 1) to assess differences in voluntary physical activity and dietary components between an overweight/obese population and normal weight matched controls; 2) to assess the accuracy of commonly used activity factors, i.e., indices that represent physical activity in predictive equations for energy, established by the World Health Organization (WHO) and the Institute of Medicine (IOM) in the Dietary Reference Intakes (DRIs). Adults, aged 19-69 years, 53 overweight/obese and 53 normal weight subjects matched for gender, age (± 1 year) and height (±1 inch) were recruited from the local area and university community. Diets were assessed by the Block 60-item food frequency questionnaire, physical activity by the Yale Physical Activity Survey, and body

composition by the dual energy X-ray absorptiometry. Resting energy expenditure was obtained by indirect calorimetry and later multiplied by a conversion factor to yield basal energy expenditure. A sub-sample of 62 adults, 31 in each group, wore an accelerometer, an instrument that detects body movement, for seven consecutive days.

Accelerometer data showed that overweight/obese adults were less physically active, expended fewer kilocalories per kilogram of body weight, recorded fewer accelerometer counts throughout the week, and spent less time in moderate or greater intensity activity than their normal weight controls. Overweight/obese subjects consumed more total fat, saturated fat and cholesterol and less carbohydrate, complex carbohydrate and dietary fiber than controls. Reported intakes of dietary fiber and carbohydrate were inversely related to percent body fat with and without controlling for potential confounding factors, i.e., age, gender, physical activity-related energy expenditure and other macronutrients. Activity factors derived from accelerometers were significantly lower than those determined by the WHO and DRI methodology for normal but not overweight/obese subjects, suggesting that energy needs for many adults may be overestimated by using these prediction equations. In summary, limited physical activity-related energy expenditure, especially time spent in moderate intensity or greater activity, diet composition, especially low dietary fiber, and overestimation of energy needs by current prediction methodology are implicated in the etiology of obesity. These findings indicate areas of interest for future research and program development aimed at weight management and obesity prevention.

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Chapter 1: Introduction

For decades controversy has existed over what factors influence the discrepancy between energy intake and energy expenditure that results in weight gain. Dietary intake and physical activity address two sides of this equation. The overall goal of this research is to assess differences in dietary components and voluntary physical activity and the relationship of these factors to body weight and composition in an overweight/obese population and their normal weight controls matched for age, gender, and height.

Statement of Problem

Obesity has reached epidemic proportions for adults living in the United States. Results from the 1999-2000 National Health and Nutrition Examination Survey (NHANES), using body mass index (BMI) standards, found that approximately 64% of the U.S. adults are either overweight (BMI 25.0-29.9 kg/m^2) or obese (BMI $\geq$ 30 kg/m^2) (1). In 1991, one out of every eight Americans was considered obese; the prevalence of obesity dramatically increased to 1 out of every 5 Americans by 1998 (2).

The Centers for Disease Control (CDC) determined in 1991 that in only 4 out of 45 participating states was the prevalence of obesity (BMI $\geq$30) 15 to 19%. By 2001, all of the 50 states, with the exception of Colorado, had obesity prevalence rates higher than 15%; in 22 of them obesity prevalence rates were over 20% (3). The prevalence of obesity in the United States increased an alarming 74% from 1991 to 2001 (4).

Obesity related diseases have caused approximately 300,000 deaths each year in the U.S (5). In 2000, the total economic cost, both indirect and direct, of obesity was about $117 billion dollars (6). Direct costs include all medical costs associated with diseases attributable to obesity and indirect costs represent the value of lost output caused by morbidity and mortality related to obesity (6). Individuals who are overweight or obese are much more likely than their normal weight counterparts to develop various health problems including heart disease, type 2 diabetes, stroke, high blood pressure, certain types of cancer, asthma, osteoarthritis and sleep apnea (3, 7). Diseases caused from obesity may be as great as those caused from poverty, smoking or alcohol consumption (8). A 10-year epidemiological study of 123,750 adults found obese individuals, with BMIs > 35.0 kg/m^2, were 20 times more likely to develop diabetes compared to age and gender matched normal weight individuals, with BMIs 18.5 to 24.9 kg/m^2. Overweight adults, with BMIs between 25-29.9 kg/m^2, were 3 times as likely to develop diabetes than their matched controls (7). A study by Galanis et al. (9) showed that a weight gain of 10 to 20 pounds resulted in an increase of coronary heart disease of 25% and 60% for women and men.

Body weight can be attributed to an interaction between genetic, environmental and psychosocial factors. The rapid rate in which obesity is increasing in the current epidemic points to environmental and behavioral changes rather than genetic modifications as the primary causes. Weight gain ultimately occurs because of a chronic modification of the energy balance equation, i.e., total energy intake chronically exceeding total energy expenditure (10). If unchecked, a small increase in dietary intake or a small decrease in physical activity will result in steady weight increases over one year and eventually to morbid obesity over several years.

Total Energy Expenditure (TEE) consists of three components: thermic effect of food, resting energy expenditure (REE), and physical activity. The thermic effect of food accounts for approximately 10% of the TEE, while REE accounts for an estimated 40-75% (11, 12) and physical activity which accounts for 5 to over 50% (10). Body composition, especially fat-free mass which is more metabolically active than fat tissue, plays a role in determining REE (13). Various studies have shown that 60-80% of the variation in REE is explained by differences in fat-free mass (FFM) (9, 14, 15). Since FFM, e.g., organ mass, skeletal muscle, etc., is largely determined by genetic factors, many researchers believe that only small changes in REE are possible and that such change will have little if any effect on improving weight status (15, 16). That leaves the component of physical activity as the most likely source of large individual differences in TEE as shown in several investigations (10, 16, 17).

Many Americans have adopted sedentary lifestyles and are not even remotely approaching the new physical activity recommendations, established by the National Institute of Medicine (IOM) in 2002, for 60 minutes of moderate intensity physical activity each day (18). Less than one third of American adults participate in the recommended amounts of physical activity, and in fact, 40% of adults do not participate in any leisure-time physical activity (6). On average, obese individuals reportedly spend less time engaging in physical activity than their normal weight counterparts (10, 19). However, these findings have been largely based on diary or survey methods, which may not accurately depict energy expenditure for overweight/obese subjects or their controls due to the chronic overestimations. Another common theory in literature is that obese individuals who attempt to increase their physical activity end up subsequently increasing their food intake (10).

Dietary intake continues to be yet another well-documented and controversial area of obesity research. Over the past 3 decades the national food surveys have shown a decrease in fat consumption and total energy intake despite the growing prevalence of obesity (20, 21) Admittedly, accurately assessing dietary patterns is extremely difficult, and fat and total kilocalorie intake might have just appeared to go down due to the likelihood of under-reporting, especially in obese persons (22). To date, there is not a practical and inexpensive way of measuring dietary intake. Despite the limitations presented in assessing energy intake, investigators continue to find obesity to be highly related to diets high in fat and added sugars, convenience foods, meals eaten away from home and low intakes of fruits and vegetables, fiber and dairy foods (23-27).

Although progress has been made in obesity research, the fact remains that energy intakes exceed energy expenditures for many people. Until this equation is balanced, individuals will continue to gain weight, and obesity will persist. Two major concerns with obesity research are 1) there are very few objective methods for accurately assessing voluntary physical activity or dietary intake patterns and 2) equations for estimating total energy needs are limited by subjective components; thus it is difficult for the general public to use them to estimate how many calories are needed to maintain or change weight status.

Overview of this research

The purpose of this study is to compare and evaluate dietary components, and voluntary physical activity of overweight/obese adults with normal weight, gender, age and height matched controls, and relate these components to body composition and total energy expenditure (TEE). Body composition will be measured via Dual Energy X-ray Absorptiometry (DXA) and resting energy expenditure (REE) will be measured via indirect calorimetry. This research will employ a well-validated Block food frequency questionnaire to assess differences in food intake between overweight/obese subjects and their normal weight controls. A combination of the Yale Physical Activity Survey (YPAS) and accelerometers, which are instruments designed to detect human movement and will be worn by a sub-sample of the participants, will assess differences in voluntary physical activity between overweight/obese and their normal weight counterparts. These values will be compared to 1995 and 2002 national physical activity recommendations. Activity factors derived from accelerometers and those published by the World Health Organization (WHO) and as part of the

Dietary Reference Intakes (DRIs) for energy will be compared within and between groups.

Hypothesis

Substantial differences in dietary intake and physical activity patterns between overweight/obese persons and their normal weight controls will be observed. Discrepancies between measured activity factors and predicted activity factors will be identified both within and between groups. The knowledge gained from this study, along with the unique measurement tools/devices, will be beneficial in developing valid methodology for weight management and offers suggestions for future research.

Chapter 2: Review of Literature

Many governmental health initiatives are directly targeting the prevention and treatment of obesity. Despite endless efforts to hinder and stop the obesity epidemic, the prevalence in the U.S. continues to rise dramatically. Over the past century, many theories have been developed in an attempt to explain the etiology of obesity, but in the end the answer seems to revolve around the timeless fact that people eat more and exercise less.

Weight gain occurs when the energy balance equilibrium i.e., energy intake = total energy expenditure, is altered to energy intake = total energy expenditure + energy stored. One of three scenarios may explain this imbalance: 1) energy expenditure decreases without a proportional decrease in energy intake, 2) energy intake increases without a proportional increase in energy expenditure, or 3) energy expenditure decreases in the presence of increased intake (10). Therefore, accurate estimations of both energy needed and energy expended are needed for this equation to stay balanced.

The first step is to examine the components of total energy expenditure (TEE). TEE is compromised of 3 major parts; resting energy expenditure (REE), thermic effect of food (TEF), and physical activity. The breakdown of percentages that each component contributes to TEE is 40 to 75% for REE, 10% for TEF, and the most variable, 5 to over 50% for physical activity (10).

RESTING ENERGY EXPENDITURE

REE remains the most widely studied component of TEE. Currently, indirect calorimetry, which measures O_2 consumption and CO_2 production, is the most popular technique used to measure REE. Direct calorimetry methods, which measure heat produced by the way of change in water temperatures in a whole-room chamber, are not as readily used due to availability, expense and time constraints (28). In the past, several studies have shown that about 40 to 85% of the variance in TEE could be explained by REE (10, 13, 29). Until recently, accurate and precise methodology for measuring TEE was not readily available. Now, with the use of doubly labeled water measurements (DLW), researchers can accurately determine TEE rates. A meta-analysis of 13 published studies including 162 individuals examined TEE, as measured by DLW, and REE, as measured by indirect calorimetry, and determined that REE explains <50% of the variance in TEE (12). These results suggest that the influence that REE has on TEE might be much less than the widely assumed and accepted 60 to 85%.

Resting Energy Expenditure and Body Composition

Body composition plays a major role in determining REE rates. Research has routinely found that fat-free mass (FFM) is the major determinant and best predictor of REE (30, 31). There is strong evidence to support that FFM is much more metabolically active than fat-mass (FM) (32, 33). Research has found that variations in the size of FFM explains 65 to 90% of the between-subject variation in REE (13, 14, 32). A recent study by Kistorp et al. (2000), on 35 healthy weight subjects, found that FFM, as determined by dual-energy x-ray absorptiometry (DXA), explained 89.8% of the variation in REE (34).

Gains in technology allow researchers more accuracy in differentiating between components of body composition. In the past, most analyses of body composition employed skin-fold calipers, bioelectrical impedance and densitometry. Densitometry has been the most widely used and accepted laboratory procedure for measuring body composition. This method requires an individual to sit on a suspended chair attached to a scale while being submerged and expiring all air possible in an underwater tank. The principle behind this methodology is that a body immersed in a fluid is acted on by a buoyancy force and the density of FM and any air in the lungs contributes to this buoyancy force while density of FFM and bone cause the person to sink (28). Although densitometry is still considered the gold standard technique for measuring FM and FFM, it is not very practical for large studies or for some populations, especially children, the elderly, or obese persons (35). Imaging technologies, e.g., magnetic resonance imaging (MRI), computer tomography (CT) and dual-energy X-ray absorptiometry (DXA) are all new precise and accurate measures used to study fat-free mass and adipose tissue distribution. In particular, DXA has recently gained popularity because it is extremely easy to administer, fast, precise and suitable for all populations (36). DXA employs a full-body scan that allows the simultaneous measurement of three body compartments, e.g., the trunk, legs and arms. Body composition analyzed with the DXA correlates very highly (r=0.94) with that of densitometry (35). With the use of these improved and subject friendly methods of assessing body composition, researchers have been able to more fully investigate the relationship of FFM and FM on REE.

Numerous studies have shown REE to be higher in obese than non-obese individuals because the obese have more FFM to support their larger amounts of FM. A study by Amatruda et al. (1993), on 33 obese and 14 non-obese subjects, found that obese subjects had an average of 14% more FFM, determined from ^{40}K counting and DLW, than the non-obese. Mean REE, determined from indirect calorimetry (37) was 12% higher among obese versus non-obese subjects. Another study by Nelson et al. (1992) found a similar 12% increase in REE for obese subjects when compared to normal weight controls (13). Although the REE initially appears higher for overweight/obese individuals, when it is expressed as a ratio of REE to FFM, some investigators have reported the REE values for obese and non-obese individuals to be comparable (13, 14), while others argued that

REE/FFM is lower in obese individuals when compared to normal weight individual (13, 38, 39).

THERMIC EFFECT OF FOOD

The thermic effect of food (TEF), which is the increase in energy expenditure resulting from consuming food, is reported to account for approximately 10% of TEE (40, 41). The TEF is directly related to the type and amount of food consumed (42, 43). Studies have found that when an individual eats more, the TEF is increased. Researchers have also investigated the thermic response to single macronutrients, e.g., carbohydrate, protein and fat. The evidence is strong to support the theory that increased protein and carbohydrate intake results in an increased thermic effect, also called oxidation, for that macronutrient (44, 45), while investigators advocate that fat oxidation is not increased as readily for fat intake (44, 46, 47). However, research has repeatedly found that meal size has a greater influence on TEF than the macronutrient composition (48).

Although the TEF is directly related to the amount and type of food eaten, the TEF may be affected by weight status. For the past 3 decades the relationship between obesity and TEF has been extensively investigated. Granata and Brandon reviewed 50 studies that examined the affects that obesity has on TEF and thirty of these investigations reported a reduction in TEF with obesity, whereas the remaining reported no reduction (49). On average the studies that did find a decrease in TEF with obesity, reported only a small decrease of 1-2% (13, 49). Overall the contribution of TEF to TEE remains relatively small and subject to little variation; therefore, the impact of TEF to the etiology of obesity is minimal.

PHYSICAL ACTIVITY

Physical activity varies from nearly 0% (total inactivity) to over 50% (elite athletes) of the TEE in humans, and is the most variable component in the energy balance equation (10). Physical activity, all work performed by the body, includes exercise (activity performed for the purpose of improving fitness), and spontaneous activity (activity spent for the purpose of carrying out everyday tasks). On a daily basis the physical activity can vary considerably between individuals and can vary even within the same individual (50). Several studies found that the energy expended in physical activity between individuals, as determined from 24-hour whole-room calorimetry, varied from approximately 200 to 1000 kcal/d, a 5-fold variation (14, 50). However, these physical activity levels were measured in a carefully controlled environment where individuals were confined to a small room for extended periods of time and may not accurately reflect free-living conditions. Rising et al. (51) assessed physical activity in free living conditions using DLW and found activity levels, ranging from 1510 to 3000 kcal/d, or a 2-fold variation. Since physical activity is the most variable component of TEE, it has the potential of being a key player in the etiology and treatment of obesity.

In 1995, the Centers for Disease Control and Prevention (CDC) and the American Academy of Sports Medicine (ACSM) established physical activity recommendations of at least 30 minutes of moderate intensity exercise preferably every day of the week (or $\geq$150 min/wk) (40). National data collected from 1990-1998 by the CDC revealed a 25% compliance rate among American adults; 29% of those surveyed reported no leisure time regular physical activity (52). In the fall of 2002 the Institute of Medicine (IOM) increased recommendations for physical activity to at least 60 minutes of moderate intensity every day of the week (18). To date, there are no reports on compliance rates for these recommendations; however, because relatively few adults met the less stringent 1995 physical activity recommendations, it is unlikely that many are meeting the new standard.

Assessment of Physical Activity

The controversial role that physical activity plays in energy expenditure is partly due to the difficulties associated with objectively measuring physical activity in free-living subjects. Recently, two objective methods have become mainstream for measuring physical activity and energy expenditure under free-living conditions: doubly labeled water (DLW) and accelerometers. DLW methodology was developed in the late 1940s (53), but only recently has it become perfected and simplified for widespread use in research settings. The principle behind DLW involves consumption of a specific quantity of water with a known concentration of isotopes of hydrogen and oxygen, different than those concentrations naturally occurring in nature. In a matter of hours the isotopes distribute themselves in equilibrium with body water. The labeled hydrogen then gradually leaves the body as water ($^2H_20$) primarily in the form of sweat, urine, and water vapor. The labeled oxygen leaves the body as water ($H_2{}^{18}0$) but also as carbon dioxide ($C^{18}0_2$). From the difference in elimination rates of the two isotopes, the production of carbon dioxide can be calculated (28). The CO_2 production can then be used to predict TEE by standard indirect calorimetry equations (54). The REE, from either direct or indirect calorimetry, is then subtracted from the TEE to yield energy expenditure from physical activity. Validation studies comparing DLW to direct and indirect calorimetry and to dietary balance studies in which caloric intake is determined have found DLW to be 97 to 99% accurate over 1 to 3 week intervals (55-57). DLW has widely been accepted as the gold standard technique for measuring all attributes of energy expenditure and intake (28). However, expense ($400-600 per subject) and the complex administration procedure makes this method impractical for most settings (28).

Accelerometers are small portable instruments designed to recognize and record acceleration and deceleration of human movement. Two models of accelerometers are used commonly in most research settings; the uniaxial and the triaxial models. The triaxial accelerometer measures accelerations in the anteroposterior, mediolateral, and vertical directions of the trunk, while the uniaxial only measures vertical movement. Most studies have found the triaxials and uniaxials accelerometers to be similar in their ability to detect activity (58-60). Many types and models of accelerometers are used in research today, but only a few are capable of storing large amounts of accelerometer data in memory and later downloading it to a computer. The CSA uniaxial accelerometer (Computer Science and Applications, Inc., Shalimar, FL), also called an ActiGraph, has a real-time clock that allows data to be analyzed anywhere from 1 second to 22 consecutive days (28).

Numerous validation studies have been conducted on the various types of accelerometers. Some studies had participants wear portable indirect calorimetry machines, heart rate monitors and accelerometers (both uni- and triaxial) while performing a variety of activities, including walking, running, housework, yard work, and recreational activities. These investigators found high correlations between accelerometer counts and indirect calorimetry and heart rate measurements for walking and running (r=0.62 to r=0.89), and lower correlations for all other daily and recreational tasks (r=0.45 to r=0.62) (59, 61). A few studies have compared accelerometer data to the gold standard DLW technique. Bouten et al. (62) and Westerterp et al. (63) found that the triaxial accelerometers were highly related to physical activity determined by DLW (r=0.63 to r=0.80). Fogelholm et al. (64) found that the uniaxial accelerometer data agreed very well with DLW results on a group level, but individual differences between accelerometer and DLW data were found, some of which were as large as 800 kcal/d.

Some activity monitors, including the CSA ActiGraph, have recently been tested and validated in laboratory and field settings to allow the user to express these activity counts as caloric expenditure (kcal-min-^{1}) (59, 64-66). These validation studies involved participants wearing portable indirect calorimetry machines and accelerometers while performing a variety of exercises ranging in different intensity levels. Regression analyses were performed to develop equations predicting metabolic cost for activity counts for each individual. The equations were rearranged to determine what count cut off values corresponded to the predetermined and commonly used MET categories (59, 65, 66). These equations provide a simple template to convert counts-per-minute ranges into activity intensity categories (i.e., light, moderate, hard, very hard) (65). Such data are useful and allow investigators to more accurately assess not only total physical activity but also proportioned expenditure at various levels of intensity. With these reports, investigators can determine how many and which individuals are meeting recommended physical activity objectives for moderate intensity exercise.

A major limitation is that caloric expenditure has only been assessed and validated when accelerometers are worn on the waist. To date, accelerometers are unable to detect extra energy expenditure from activities that require large arm movements. This phenomenon would explain why accelerometers have been shown to be highly accurate for detecting moderate intensity level activities such as running and walking, and less accurate when looking at activities that involve greater arm movements (59). Although the accelerometers do not detect all arm movement activity they do detect some activity because when the arms move the torso also usually moves. Also most activities that produce greater energy expenditure rely to a large extent on leg movement. For example, basketball requires both arm and leg movement, but the majority of the energy expenditure from this sport is going to come from running and/or walking up and down the court.

In addition these accelerometers cannot be used for swimming or other water activities. If an individual is a swimmer, their activity will be greatly underestimated. The intensity of certain activities, e.g., walking on graded surfaces or intense resistance on a bike, will also be underestimated by accelerometers. However, if the individual were to record time spent swimming and in activities that require excessive arm movements, the energy expended could be appropriately adjusted (59) by using the Compendium of Physical Activities (67) .

In the past, investigators relied on subjective instruments, such as physical activity recalls, records and questionnaires, to evaluate physical activity levels. Although reported measures are easy to administer and cost effective, individuals, especially the obese, often overestimate physical activity levels. A study by Lightman et al. (1992), who compared reported physical activity to DLW for 224 obese adults, found that obese subjects overestimated their physical activity by 30 to 51%, or approximately 130 to 250 kcals/d (68). Another study with 50 overweight subjects found similar physical activity overestimations of 45% (69). Conway et al. (2002) found that normal weight individuals also overestimated physical activity levels, but to a lesser extent. Results from this study showed that reported physical activity, was approximately 8% higher for 7-day records and 30% higher for 7-day recalls when compared to energy expenditure as measured by DLW (70). A possible explanation for higher levels of overestimation of physical activity by overweight/obese individuals might be the need obese individuals feel for social acceptance, e.g., they may feel obligated to report a larger amount of physical activity to justify that their weight status is not related to inactivity.

In contrast, a few studies have shown that energy expenditure derived from some subjective physical activity instruments compares closely to the DLW techniques. Bonnefoy et al. (2001) compared ten different physical activity questionnaires to DLW techniques in 19 healthy elderly men and found that the 7-day physical activity recall and the Yale Physical Activity Survey (YPAS) best predicted energy expenditure. The 7-day physical activity recall only overestimated energy expenditure by 10.8% and the YPAS by 11.3% when compared to DLW; neither difference was statistically significant (71). Another study conducted by Starling et al. (1999) on 67 older normal weight adults revealed similar differences in energy expenditures as determined by the YPAS and DLW (72). This evidence is promising, considering the YPAS is short, e.g., completion time is less than 20 minutes, easy to administer, and results in minimal subject burden. To date, the YPAS is the only short questionnaire tested that appears to evaluate energy expenditure nearly as accurately as DLW. Although 7-day records/recalls also accurately assess energy expenditure, they are not always practical for large populations and require substantial subject compliance.

Physical activity and body weight / composition

The relation of body composition to energy expenditure is not clear. To date, few studies have been conducted comparing physical activity levels, using accelerometer or DLW methodology, and body weight or composition, using DXA or densitometry, in overweight/obese adults to their normal weight counterparts, and only one that employed matched controls. A study by Rising et al. (1994) who measured 30 Pima Indians with DLW, found a slight decrease of 24 kilocalories for each percent of increased body fat, independent of body weight (51). In contrast, a study by Prentice et al. (1986) compared physical activity for obese (n=9) and their height, gender, and occupation matched normal weight controls (n=13) in a controlled setting, whole room calorimetry for 36 hours, and in a free living setting, DLW for 14-31 days. Obese subjects showed a trend, although not significant, for increased physical activity levels in the controlled settings, even after making the adjustments for body weight. With the DLW technique, obese subjects had a higher energy expenditure for physical activity when compared to controls (825 vs. 541 kilocalories/day), but no difference was noted between activity levels after accounting for body weight (73). Another study by Meijer et al. (1992) on 11 obese and 11 normal weight adults (not matched) revealed that there were no differences in physical activity between the groups as measured by the DLW technique (74).

Review of studies evaluating physical activity levels using accelerometer methodology are seen in Table 2.1. Using accelerometer counts per minute, Cooper et al. (19) and Rutter et al. (75) both found that obese adults were less active compared to normal weight adults, while Meijer et al. (74) and Tyron et al. (76) found no difference in activity between obese and normal weight individuals. Richards et al. (2000) compared the kilocalorie expenditure, as determined by accelerometers, of 134 severely obese adults and their normal weight siblings. When energy expenditure was expressed per kilogram of body, activity expenditure was 3.5 kcal/kg lower in the severely obese than in normal weight participants (*P* <.0001) (77).

Table 2.1 Review of studies evaluating physical activity levels using accelerometer methodology

Author	Subjects	Methods	Brief Results
Richards et al., 2000 (77)	145 sibling pairs (n=290) 1 sibling severely obese (BMI>35) and 1 sibling healthy weight (BMI<27).	Physical activity questionnaire Caltrac accelerometers - 3 d Willette 61-item FFQ REE – indirect calorimetry Ht and wt was reported by 50% of subjects.	• Avg. TEE as determined by REE + accelerometer data for 1 d was 350 kcal higher per day for obese but after TEE was adjusted for BW was 7.5 kcal/kg of BW lower than normal wt siblings. • Total daily activity EE (acc data) was 3.5 kcal/kg of BW lower in obese.
Cooper et al., 2000 (19)	84 adults (18-64y) 36M/48F - 41 normal wt (BMI< 25) - 32 overwt (BMI 25-30) - 12 obese (BMI>30)	CSA accelerometer – 6/7 d BMI – measured ht and wt	• No difference in PA (counts /min) or in time spent in moderate intensity or > activity btwn normal wt and overwt •Obese subjects were less active (counts/min) than non-obese during weekends and weekday evenings, but not at work. • Obese spent less time in activity of moderate intensity or > than non-obese on weekends, but not during the week. • 58.3% of obese and 81.9% of non-obese met the 1995 CDC/ACSM recommendations

Table 2.1 continued

Author	Subjects	Methods	Brief Results
Rutter et al., 1994 (75)	39 F students (17-21y) - 30 normal wt (BMI<25) - 6 overwt (BMI 25-30) - 3 obese (BMI>30)	Measured ht & wt; Skin-folds, BIA, & circumferences Caltrac - 6 d REE prediction equations	• Negative correlations between BMI and total and hourly EE (as derived from Caltrac for 4-6 d). •Obese were less active compared to normal wt for 4-6 d, but not for 1-3 d.
Tyron et al., 1987 (76)	31 students (18-23 y) 13 overwt & 18 underwt	Actometers worn on each wrist and ankle for 24 hrs/d for 14 d	• All groups were equally active.
Meijer et al., 1992 (74)	22 adults (21-42 y) - 11 lean (6M/5F) - 11 obese (4M/7F) - >25% body fat	REE – whole room indirect calorimetry DLW; Densitometry 14 d food diary Accelerometer -7 d	• Activity related EE tended to be higher in obese (NS), but was similar for both groups and sexes when adjustments were made for FFM. • No differences btwn accelerometer counts for obese and lean.
Ekelund et al., 2002 (78)	18 obese adolescents (BMI>30),(14-19 y) 8M/10F 18 age and gender matched healthy wt adolescents (BMI<27)	DLW REE – indirect calorimetry CSA accelerometers - 14 d DXA AEE =0.9 TEE-REE, with the 10% TEF correction. PAL = TEE/REE	•After adj. for body comp, there were no difference btwn REE, TEE or AEE. •PAL was lower for obese group. • Obese showed less time in physical activity of moderate intensity, and spent less time continuously at such a physical activity. • Total counts•min^{-1}•hr^{-1} over 14 d were lower for obese than for controls

M = male; F = Female; day = d; PA = physical activity; EE = energy expenditure; BW = body weight; BIA = bioelectrical impedance; NS = non significant; AEE = activity-related EE; PAL = physical activity level

Only two studies to date have reported time spent in different intensity levels derived from accelerometers by obese and normal weight individuals. Ekelund et al. (78) employed both accelerometers and DLW methods and found that obese adolescents spent significantly less accumulated time in moderate intensity physical activity when compared to normal weight controls matched for height and age, but their physical activity-related energy expenditure did not differ significantly from the normal weight group. Cooper et al. (19) found that obese adults (n=12) spent significantly less time in activity of at least moderate intensity than non-obese adults (n=72) on weekends and on weekdays. These investigators were also the only ones, to date, to compare accelerometer data to recommended physical activity levels. They found that 41.7% of obese subjects and 18.1% of non-obese subjects did not meet the 1995 physical activity recommendations of ≥150 minutes of moderate-intensity physical activity. At present, no studies have been published that compare overall physical activity levels and time spent in different intensity levels using an overweight/obese population and their healthy weight matched controls. Nor has any study been conducted comparing accelerometer data to the newer physical activity guidelines of 60 minutes of moderate intensity physical activity each day (18). A need exists for research to be conducted, using objective measurements, that compares overall physical activity, time spent in different intensity levels and percentage of individuals meeting new physical activity guidelines, in an overweight/obese population and their normal weight controls matched for gender, age and height.

Physical Activity and Energy Expenditure

Energy expended while performing the physical activity might not be the only factor to assess when evaluating energy expenditure. Much controversy exists regarding whether energy expenditure returns to baseline immediately following the physical activity. Some researchers believe that post-exercise elevation of metabolic rates account for more energy expenditure than the actual exercise duration (79). Experts argue that the increase in post-exercise elevation of metabolism rate is proportional to the intensity of the bout of exercise and lasts somewhere between 4 and 24 hours. The magnitude of the increase in metabolism also has been extensively debated, with values ranging from 2 to 15% of REE. However, most common observations have been on the lower end, between 3-5% increase in REE (10). One group reported energy expenditure immediately following the exercise to be about 15% of the cost of the exercise itself, which equates to approximately 15 extra kilocalories burned for every 100 kilocalories expended (80). In contrast, Freedman et al. (81) found that energy expenditure returns to baseline within 5-40 minutes after moderate-intensity exercise and accounts for only 1 to 30 additional kilocalories expended beyond the exercise bout itself. Individuals who are capable of performing high-intensity, long-duration exercise will have higher elevations of post-exercise metabolic rates for longer periods of time. This phenomenon may be a more significant contributor to energy expenditure for lean athletic individuals than for overweight sedentary individuals. However, because of the cost of moving the excess weight carried by overweight and obese individuals, lower intensity activities for normal weight individuals may be considered higher intensity activities for obese individuals.

Several additional considerations are necessary when assessing physical activity levels. First of all, adding physical activity to a person's lifestyle may subsequently decrease their spontaneous activity throughout the rest of the day, especially for obese persons (50). To date, only been a few studies have assessed this phenomenon in an overweight/obese population. By using accelerometers, Cooper et al. (19) found that obese participants had 31% less spontaneous activity during work hours and 56% less during evening hours every day when compared to non-obese participants. In contrast, Ravussin et al. (14) found that energy expenditure from spontaneous activity, as measured by accelerometers worn on the wrist and radar motion sensors in a whole-room calorimetry chamber, increased as body weight increased. These investigators suspected that since heavier subjects require more energy to move their larger bodies, even less or equal spontaneous activity will result in the same or greater energy expenditure as compared to thin individuals. The second consideration is that the energy expended by physical activity is often counterbalanced by an increase in energy intake. At least when some individual increase their exercise levels, they tend to increase their food intake as well (50).

ENERGY INTAKE

The other component of the energy balance equation that individuals directly control is the energy intake, or food consumed. Although food intake is only one part of this equation, it is indisputable that dietary habits play a key role in the development of obesity. Excess energy intake is known to promote weight gain, but recent research indicates that specific dietary components appear to contribute to the development of obesity.

Dietary Fat

For years the relationship of dietary fat to obesity has been studied. Dietary fat is the most energy dense macronutrient and provides approximately 9 kcal/g, whereas carbohydrate and protein both provide around 4 kcal/g. A substantial body of evidence has shown that high fat diets result in higher energy intake, which in turn leads to rapid weight gain and fat accumulation. An extensive review of animal studies conducted by Warwick et al. (82) found that in 28 out of the 30 rat studies where fat intake was increased, energy intake was also increased and weight gain occurred. Human studies demonstrated this phenomenon through weight loss interventions where the dietary fat was reduced and markedly lower energy intakes were consumed (83, 84). Westerterp et al. (85), in a weight loss intervention study on 217 subjects, placed on either a reduced fat diet or a full fat diet for six months, found that the reduced fat diet was significantly lower in kilocalories, approximately 240 kcal/d less, as compared to the full fat diet. This lower fat and energy diet resulted in a weight loss of 2.4 pounds and a reduction in fat mass of 1.1 pounds, as measured by total body water content. A meta-analysis by Astrup et al. (86) found similar results in a much larger population, 16 weight loss trials involving 1,910 individuals. These results showed that a mean 10.2% reduction in dietary fat resulted in a substantial reduction in energy intake (mean of 273 kcal/day; range of 135 - 410 kcal/day) and in a spontaneous weight loss of 3.2 kg or more.

One explanation for this increased energy intake on high fat diets is that individuals eat the same volume or bulk of food, regardless of the composition (87-90). Lissner et al. (90), one of the first investigators to assess this phenomenon, studied 24 normal weight women three different times for 14 days each. Each time a different dietary treatment was administered to each subject that either consisted of low-fat (LF), medium-fat (MF), and high-fat (HF) diets, 15-20%, 30-35%, and 45-50%, respectively, of the energy derived from fat and overall energy of 2087, 2352, and 2714 kcal/d. Each meal, however, ranked similarly for appearance and palatability. Subjects were not told the nutrient composition of any of the diets and were encouraged to eat as much or as little of any food they desired. Relative to their energy content on the MF diet, the subjects consumed 11.3% less energy on the LF diet and 15.4% more on the HF diet. The average weight change for each 2-week treatment period was -0.88 lbs for LF, -0.07 lbs for MF, and +0.7 lbs for HF diets. Stubbs et al. (88) found similar results when covertly manipulating the fat content of foods. They confined six healthy men to a large whole room calorimeter for three periods of 7 days each. Subjects from this study consumed ad libitum diets that looked identical externally but were secretly manipulated to contain 20%, 40%, and 60% energy from fat. Each subject received all three variations of the diet during each 7-day period. Energy intakes increased with percent fat in meals, producing average daily balances above measured energy needs of 65, 185, 620 kcal/d during low, medium, and high fat diets, respectively (88). In both of these hallmark studies, subjects continued to consume the same bulk of food regardless of the varied fat contents, so individuals on the high fat diets inevitably consumed more overall energy.

This passive over-consumption of energy on high fat diets is termed high-fat hyperphagia (91). Many researchers attribute hyperphagia to the lack of satiating power of dietary fat. Satiation is defined as the satisfaction of appetite that develops during the course of eating and can be quantified by the duration of the meal and/or the size of that meal or subsequent meals (92). Numerous studies have shown that satiety signals from fat are much slower than the signals from protein and carbohydrate (90, 91, 93-95). Duncan et al. (94) fed 20 obese and 20 non-obese individuals a high fat diet and a low-fat diet, and asked each subject to eat until they reached satiety, or comfortable fullness. Subjects, independent of weight status, ate an average of 1570 kcals/day on the low-fat diet and 3000 kcals/day on the high fat diet to reach the same level of satiety, which equated to 52% more energy per day (94). Individuals often consume larger amounts of dietary fat, and invariably energy intake, to achieve the same satiety, or perceived fullness, that would accompany consumption of other macronutrients (91). However, McCrory et al. (2000) argue that the low dietary fiber content in most high fat diets is a more probable cause for low satiety ratings (96).

In contrast, few investigators have found no difference between the satiating efficiencies of dietary fat to other macronutrients (97-99). De Graaf et al. (99) gave 29 normal weight females either a high protein, fat, or carbohydrate liquid breakfast and measured satiety ratings and intakes at subsequent meals that day. They found that neither energy content nor macronutrient composition of the breakfasts had any effect on satiety ratings or energy and macronutrient intakes during any other subsequent meals

Recently scientists have investigated macronutrient consumption and oxidation under careful metabolic conditions, and many agree that short-term fat intake is not readily oxidized and favors fat storage over other macronutrients (44, 100-103). Most notably, Flatt has shown that oxidation of carbohydrate and protein matches intake, even if in excess, while fat oxidation is decreased with excess fat intake, thereby promoting body fat storage (44, 104). Results from two studies show that it takes 3 to 7 days for fat oxidation to catch up to fat intake, and over time the continual rise in dietary fat along with the delayed increase in fat oxidation leads to small but steady increases in fat storage (46, 104). Research has shown that fat oxidation is further hindered when carbohydrate intake is high because of the body's tendency to make carbohydrate oxidation the first priority (47). Other investigators have shown that obese subjects have an even lower rate of fat oxidation than lean subjects (103, 105). Overall, many researchers agree that the oxidation rate of macronutrients plays a relatively small role in the energy balance equation (44, 50).

Epidemiological data from Continuing Survey of Food Intakes by Individuals (CSFII) has shown a notable decrease in fat intake, 42% of energy intake from fat in 1970 vs. 32.7% in 2000, without a similar decrease in obesity

(24). However, this value still exceeds recommendations of diets comprising less than 30% kilocalories from fat. Also CSFII data have shown that total fat intake is actually increasing even though percent energy from fat is decreasing. This phenomenon is primarily due to a significantly higher carbohydrate intake, e.g., sugars, which results in a higher overall energy intake and subsequently makes the fat intake only appear to decline (106). Another explanation for this phenomenon is an increase in under-reporting, especially when it comes to fat intake due to the negative public view for fat.

Dietary Carbohydrate

Complex carbohydrate and dietary fiber have been extensively studied and found to be inversely related to body weight and body fat percentages (26, 107-109). Investigators have identified several mechanisms by which dietary fiber may reduce risks for developing obesity. The physical properties of dietary fiber, e.g., bulk/volume, viscosity, and water-holding capacity, enable it to slow digestion and absorption of nutrients, control rapid rises or falls in blood glucose, enhance satiety, and suppress energy intake (92, 94, 110). Also foods high in dietary fiber are usually low in fat and energy. By increasing consumption of dietary fiber, one may subsequently decrease intake of other energy/fat dense foods. The complete effects of dietary fiber on weight loss are not entirely clear, but some studies show that subjects found it easier to adhere to a weight loss diet when foods high in fiber were included in the dietary regimen (92, 111).

The term glycemic index (GI) is often used to describe the affect that carbohydrate containing foods have on absorption and blood glucose responses. The GI is determined by comparing the blood glucose response of a particular carbohydrate with that of a reference food, e.g., white bread or glucose (112). Foods that are high in dietary fiber generally have a low GI and include legumes, grain products, nuts, fruits and vegetables, while foods that are low in dietary fiber generally have a high GI and include white breads, potatoes, and simple sugars. Several studies have shown that diets containing low GI, high dietary fiber carbohydrate produce greater reductions in weight (113, 114) and in body fat (115, 116) than diets containing high GI, low dietary fiber carbohydrate. A likely explanation for the reductions in body fat is that low GI, high fiber carbohydrate foods have been repeatedly found to increase satiety and decrease dietary intake at the current meal or subsequent meals (94, 117-119). A review of literature evaluating the effects of carbohydrate and dietary fiber on body weight and/or composition is seen in Table 2.2.

Table 2.2 Review of studies evaluating dietary components

Author	Subjects	Methods	Brief Results
Nelson et al., 1996 (120)	203 men (21-71y) 14 ±5.3% body fat	Block FFQ PA questionnaire & single-stage sub-maximal treadmill test Skin-fold thickness	Multiple Regression: •After controlling for age, fitness, & BW, EI was positively related to %BF. • After controlling for age, EI & fitness, carbohydrate intake (g & % of energy), complex CHO (g & % of energy), and fiber (g) were negatively related to % BF .
Miller et al., 1994 (26)	78 adults (46 M/32 F): - 23 lean M (15% BF), - 23 obese M (25% BF) - 17 lean F (20% BF), - 15 obese F (25% BF) Not matched	Diet: 24-hr recall, 2-d food diary & the Right Byte FFQ Densitometry	MANOVA: • No differences btwn lean & obese subjects for EI or total sugar intake • Obese vs. lean subjects derived a greater % of energy from fat (33.1 vs. 29.1 for M & 23.6 vs. 29.6% for F). • Obese derived a greater % of sugar intake from added sugars than lean subjects. • Dietary fiber was lower for obese M & F when compared to lean subjects (20.9 vs. 27.0 g for M & 15.7 vs. 22.7 g for F).

Table 2.2 continued

Author	Subjects	Methods	Brief Results
Tucker et al., 1992 (121)	205 females (35 ±13 y) 23.3 ±5.3% BF	Block FFQ PA questionnaire & step test Skin-fold thickness	Multiple regression: • After controlling for age, EI, exercise, other macronutrients & smoking, dietary fat was (+) related to % BF (explained 2.1% of variance). • Obese F consumed more total energy, g of fat and protein, % of energy from fat & less % energy from CHOs compared to lean F.
Kennedy et al., 2001 (122)	10,014 adults from the 1994-1996 CSFII	24-hr diet recall Ht, Wt, & BMI 3 popular diets: 1) low CHO (LC) = <20% CHO; 2) very-low fat (VLF)=<15% fat; 3) moderate-fat/high CHO (MFHC) = 20-30% fat, >55%CHO	• Total body fat % is increased on the LC diet, & sat fat is twice as high on the LC compared to MFHC. • MFHC dieters consume more food by wt but less total energy. • BMI are sig. decreased on MFHC & increased on LC
Lovejoy et al., 1992 (107)	45 adults - 22 lean (7M/15 F; BMI<27); - 23 obese (4M/19F; BMI>27)	Ht, Wt, waist circumference Block FFQ	• t-tests: obese subjects consumed less fiber and CHO & higher % fat than lean subjects. • Obesity was positively related to % fat & negatively related to % CHO. • BMI was not related to total energy, protein or fiber intakes.

Table 2.2 continued

Author	Subjects	Methods	Brief Results
Lovejoy et al., 2001 (123)	n=149 post-menopausal women (77.4 ±.2 y); 52 African Americans (AA) & 97 Caucasian	DXA PA recall/ 24-hr PA record Triaxial accelerometer - 4 d 4-d food records 24-hr EE – whole room calorimetry (n=56 women)	GLM was used to assess differences between AA and white females: - Protein was higher in whites - PUFA were higher & fiber, Ca, Mg intakes were lower in AA • positive correlations were found for total fat, mono, sat. fat & cholesterol with %BF • negative correlations were found for fiber, Ca and Mg (white only) Multiple Regression • Dietary fiber was the strongest individual predictor of %BF (12% of variance), exercise was the 2nd strongest predictor (9% of variance) •The best model accounted for 21% of variance in %BF and included fiber, sat. fat, exercise & stairs climbed.
Dreon, et al. 1988 (108)	n=55 overwt M (30-59 y) 120-140% std wt for ht. 18.6 - 40.3%BF	7-d food records PA questionnaire & graded treadmill exercise test Densitometry	Spearman correlations: • Plant protein, CHO, fiber (g/d) & CHO (g/1000 kcal) were negatively related to %BF. • Total fat, sat FA and mono FA as g/1000 kcal were positively related to %BF

Table 2.2 continued

Author	Subjects	Methods	Brief Results
Kromhout et al., 2000 (124)	Cross-cultural study of 16 cohorts - 12,763 men (40-59 y) data collected from 1958-1970	Ht, Wt, BMI Sub-scapular skin-fold All men were classified according to their job-related habitual physical activity pattern Weighed food records	Multiple regression (no control for confounding variables) • PA index was negatively related to BMI & sub-scapular thickness • average fat intake was positively related to BMI but not sub-scapular thickness • fiber was negatively related to BMI & sub-scapular thickness. • PA index & fiber together explained 90% of variance in skin-fold thickness.
Ludwig et al., 1999 (125)	Population based CARDIA study - 2909 healthy black and white adults (18-30 y); data collected from 1985-1996.	FFQ - ~700 foods Ht, wt, waist/hip circumference Insulin levels, blood pressure	Multiple regression (controlled for confounding variables) • Fiber predicted insulin levels, wt gain and other CVD risk factors more strongly than total or saturated fat intake
Westerterp-Plantenga et al., 1996 (126)	96 women (20-50 y) - 34 overwt/obese (BMI >25) - 34 non-obese (BMI < 25) - matched for age	Ht, wt, BMI 3-d food diaries Estimated EE – HBE X 1.5 AF for obese and 1.6 AF for non-obese	•Comparing estimated EE to food diaries: 9% of obese and non-obese underreported intakes. • ANOVA: % CHO was lower and % fat higher among obese than among non-obese (39 vs. 46 for %CHO; 44 vs. 37 for %fat)

Table 2.2 continued

Author	Subjects	Methods	Brief Results
Alfieri et al., 1995 (109)	150 adults (18-65 y) - 50 normal wt (BMI<27) - 50 moderately obese (BMI 27-39) - 50 severely obese (BMI>40)	Wt, Ht, BMI 3-d diet records Health survey	• t-tests: Normal wt consumed more total fiber, fiber/1000 kcal, and CHO, but less fat than obese groups • Multiple Regression: Fiber was negatively related to BMI after adj. for sex, age, education& income

M = males; F = females; EI = energy intake; g = grams; %BF = percent body fat; MANOVA = multiple analysis of variance; PA = physical activity; CHO = carbohydrate; GLM = General Linear Model; PUFA = polyunsaturated fatty acids; AA = amino acids; EE = energy expenditure; CVD = coronary vascular disease; HBE = Harris Benedict Equation

Consumption of excessive sweets and added sugar has received a lot of attention and is being identified as another important culprit in increased obesity (26, 127). There appears to be an inverse relationship between consumption of dietary fat and carbohydrate, in particular simple sugars. Researchers dubbed this relationship the "fat-sugar see-saw" (86). Individuals tend to counterbalance a reduction in fat with an increase in simple sugars, sometimes called added sugars. National food consumption surveys indicate Americans increased added sugar intake from 27 tsp/day per person in 1970 to 32 tsp/day in 1996, an increase of 19% (27). Consumption at each period of measurement grossly exceeded the 2000 National Dietary Guidelines for 6-18 tsp/day of added sugars (59). Krebs-Smith et al. (127) analyzed the national surveys and found that the largest category of added sugars was non-diet soft drinks, which accounted for one-third of the noted increase (127). Other categories of added sugars in ranked order included sweets and candy, sweetened grains (cookies, cakes), and sweetened juices. Together these four categories accounted for approximately three-fourths of all added sugar intake. The extra energy consumed from added sugars, above and beyond recommended kilocalorie intake, ranged from 100-250 kcal/d (127). Miller et al. (26) found that obese subjects derived a greater percentage of their sugar intake from added sugars than normal weight subjects (33.1 $\pm$2.6% vs. 25.2 $\pm$2.0%, respectively for men; 47.9 $\pm$8.0% vs. 31.4 $\pm$3.4%, respectively for women). In their subjects, added sugars are likely to be a major underlying cause for the increased total energy intake causing excessive weight gain in their population.

In order to apply these results to practical settings, e.g., weight loss interventions, one must look also at individual foods and food groups. Bowman et al. (128) who analyzed the 1994-1996 CSFII data found that individuals who consumed the most added sugar, e.g., >18% of energy, had markedly lower intakes of fruits, vegetables and whole-grains than all other individuals. Analysis of National Food Supply Data showed that fruit and vegetable consumption increased by 27% from 1970 to 1998 and that individuals are consuming an average of 5.3 servings of fruits and vegetables a day (including legumes). However, vegetables accounted for 74% of those servings, nearly 4 servings/day, whereas fruit only accounted for 1.4 servings/day. In 1998, more adults than in 1970 met vegetable serving recommendations of at least 3 servings/day, but failed to meet fruit recommendations of at least 2 servings/day. In addition the vegetable intake was primarily from starchy vegetables, specifically potatoes, rather than from dark green or deep yellow vegetables (127). Starchy vegetables dominated by potatoes made up over 40% of these vegetable servings (127).

Dietary Protein

Strong evidence has found that protein provides a greater satiating efficiency compared to carbohydrate and fat (129-131). Studies have shown that meals that are higher in protein content provide greater satiety responses than meals higher in fat and carbohydrate content both during and directly after the meal and maintain the satiety effect for some hours after a meal (130-132). Latner et al. (133) found that subjects consuming a high-carbohydrate lunch reported greater pre-dinner hunger and motivation to eat and subsequently consumed 31% more kilocalories at dinner than those consuming a high-protein lunch (133).

The satiating power of protein enables many individuals to lose weight without the feelings of deprivation. Some investigators have found that higher protein diets produce greater weight loss in participants compared to traditional diet plans. In a six-month dietary intervention study conducted by Skov et al. (134), 65 overweight or obese subjects were randomly assigned to one of three diets: 1) high-protein (HP) diet - 25% of energy as protein, 45% as carbohydrate, and 30% as fat, 2) high-carbohydrate (HC) - 12% of energy as protein and 58% as carbohydrate, and 30% as fat, and 3) and no diet. Subjects following the HP diet had more weight loss and fat loss when compared to subjects following the HC diet (19.6 lb vs. 11.2 lb, P <.001; 16.7 lb vs. 9.46 lb, P <.0001). A similar study by Parker et al. (135) found that women placed on a moderately high protein diet (28% of total calories) lost significantly more total fat (11.6 vs. 6.2 lb) and abdominal fat (2.9 vs. 1.5 lb) compared to women placed on a lower protein diet (16% of calories).

A major concern with increasing protein in the diet is corresponding increases in total fat, saturated fat, and cholesterol consumption. However, studies have shown that adults who substitute low-fat dairy products and lean meats for higher-fat protein sources have low intakes of total fat, saturated fat, and cholesterol (30, 136). A cohort study by Hu et al. (137) on 80,082 adult women found that those who regularly consumed more lean meat and low-fat dairy had a much lower risk of developing coronary heart disease over those women who regularly consumed high-fat meats and dairy foods. Peterson et al. (136) analyzed 3-day intake records on 7,076 adults and found that individuals who consistently consumed reduced-fat food items, e.g., low-fat dairy, meat, sweets, dressing, etc., had reduced intakes of energy, total fat, saturated fat, cholesterol, and sodium than individuals that consumed the full-fat foods. The positive health benefits stemming from lean protein intake has recently prompted the Food and Nutrition Board of the Institute of Medicine as part of the Dietary Reference Intakes (DRIs) to increase upper limit protein recommendation from 25% to 35% of total daily energy intake (138).

For the past twenty years, dietary calcium has been extensively studied and found to reduce blood pressure (139, 140), but only recently has the influence of dietary calcium on weight status been studied. Most notably Zemel et al. (141-143) conducted several animal and human studies all of which found that increasing dietary calcium intake resulted in reductions in body weight and fat. More pronounced reductions in weight and fat occurred when calcium intake came from dairy sources rather than supplemental sources (141). Zemel et al. (142) found that obese African-Americans who consumed two servings/day of yogurt, which subsequently increased dietary calcium from 400 to 1,000 mg/day, while maintaining similar caloric intakes for one year, lost an average of 11 pounds of body fat. Similarly, Davies et al. (144) found that a 1,000 mg/day increase in dietary calcium intake in 780 women was associated with a reduction in body weight of 17.6 pounds. Findings consistently support the hypothesis that increasing dairy intake, specifically low-fat dairy, helps promote weight loss and reduce chances of developing obesity (142, 144).

Statistical Analyses of Dietary Components

Much of the research conducted to determine which dietary components enhance or prevent obesity have used primarily correlational statistical techniques and limited methodology, such as the use of imprecise body fat measures and unmatched sample populations. Numerous epidemiological studies have found various dietary components to be either positively or negatively correlated to body weight and/or BMI status (122, 124, 125, 145), but none of these investigations employed more sophisticated measures of adiposity, such as densitometry or DXA scans, and/or used more advance statistical analysis. Few studies have used multiple regression techniques to assess the effects that dietary components have on percent body fat (120, 121, 123, 124) and only two of these studies controlled for confounding variables (120, 146). Tucker et al. (146), when studying 205 women, used multiple regression, controlling for age, total energy intake, exercise levels, other macronutrients, and smoking, and found that dietary fat accounted for 2.1% of the variance in percent body fat. Nelson et al. (120), who employed similar multiple regression techniques on 203 men, found that , after controlling for similar confounding variables, dietary fat was not a significant predictor of percent body fat but carbohydrate, complex carbohydrate and dietary fiber were significantly and inversely related to body fat, accounting for 1.9, 1.9 and 2.9% of the variance in body fat, respectively. Limitations in these studies were examinations of one gender and only skin-fold measurements rather than densitometry or DXA to assess body fat percentages.

Surprisingly, few studies have been conducted that compare dietary components between overweight/obese adults and their normal weight controls (26, 107, 126); only one of these investigations used matched controls (85).

Westerterp-Plantenga et al. (126) found that 34 overweight/obese women consumed a significantly larger percentage of their energy from fat and a smaller percentage from carbohydrate when compared to their normal weight controls matched for age (126). Miller et al. (26), Lovejoy et al. (107), and Alfieri et al. (109), none of whom matched overweight/obese subjects with those of normal weight, found that overweight/obese adults derived a greater portion of their energy from fat and consumed less dietary fiber than normal weight adults.

Assessment of Dietary Intake

Diet records are the most traditionally used method for measuring food intake and involve participants recording the type and amount of every food consumed as well as the time and location that food was eaten over 3 to 7 days. Several studies suggest that 7-day diet records are the most accurate, but 3-day records produce similar results and may yield better compliance (147, 148). Recently, two investigations compared 3-day and 7-day diet records to the DLW technique and found reported energy intake to be underestimated by 20-34% (70, 149). Diet records are labor intensive and require that subjects be highly motivated. Multiple day diet records are often not feasible for large epidemiological studies due to time and motivation constraints. Often larger studies will use 24-hour recalls to assess dietary intake, but this method may not provide a valid reflection of an individual's usual diet though it may adequately reflect the population as a whole (150).

The development of the food frequency questionnaires (FFQ) provides a retrospective view of usual food or nutrient intake over extended periods of time. The Block and the Willett FFQs are the most extensively studied and widely used in research today. The original Block FFQ (1986) was developed from 11,658 adult respondents from the NHANES II data and later expanded and/or shortened to meet the needs for different populations. The relative validity of the Block FFQ has been tested in a clinical setting using 3 day records (151), in epidemiological studies using 24-hour recalls (150), 7-day food records (152), and multiple 4-day records (153, 154). All of these investigations yielded high correlation coefficients, between 0.50 and 0.70.

The original Willett FFQ was developed and validated from a large sample of nurses and later expanded and validated in a population of male health professionals. Similar to the Block FFQ, high correlations were found between Willett FFQs and diet records/recalls (138, 155), but these studies were fewer in number and conducted on smaller, less diversified populations as compared to the populations used in the Block FFQ validation studies. Both FFQs organize foods into groups that have common nutrients, then the participants record the frequency of food groups consumed over the past week or month. The primary difference between these questionnaires is the Block FFQ asks the respondent to identify portion sizes, e.g., small, medium, or large, whereas the Willett FFQ assigns an average portion size for each response. Some researchers believe that the lack of portion sizes on the Willett FFQ has resulted in significant underestimations of overall energy intake by respondents (156).

Few studies have compared energy intakes assessed with FFQ to those assessed with DLW. Results from a study by Sawaya et al. (157) revealed data from Block and Willett FFQs correlated better with individual values for TEE, as measured by DLW, than data from 7-day dietary records and 24-hour recalls.

FFQs are inexpensive, self-administered, and easy to analyze, with optical scanning, which make them ideal for use in epidemiological or large studies measuring usual or long-term intake. The downside is that FFQs are often inflexible with regard to unusual food intake patterns, are quickly outdated under conditions of constantly changing product availability, and are subject to food groupings being misclassified.

Under-reporting of Dietary Intake

A major dilemma in determining which dietary factors influence weight gain is the large discrepancy between self-reported dietary intake and actual intake. Overweight and obese individuals are more prone to under-reporting their dietary intake compared to normal weight individuals (68, 73, 158). Researchers are now able to use DLW to confirm self-reported dietary intake under free-living conditions. Substantial evidence, using DLW techniques, shows that normal weight adults under-report dietary intake by approximately 18% (159-162), whereas obese subjects under-report by more than 50% (68, 73, 163). A study by Lightman et al. (68) compared 14-day dietary records with DLW on obese subjects divided into two groups: 1) diet resistant, individuals who reported difficulty losing weight on a 1200 kcal diet (n=16) and 2) control group (n=208). Subjects in group 1 reported their dietary intake to be around 1030 kcals, whereas their actual energy intake was 2080 kcal, an under-reporting error of 47%. Subjects in group 2 also underreported their dietary intake, but to a much lesser extent of 19% (2380 kcal reported vs. 2650 kcal actual). Prentice et al. (73), who studied 22 obese and 13 normal weight subjects, found that the obese had an even larger underestimation of reported intake, 67% or ~815 kcal/d, when compared to actual intake, but saw no difference between reported and actual intake for normal weight subjects. Studies have shown that individuals are more likely to under-report high fat and sugar foods (164, 165). Researchers believe that normal weight subjects have less reason for concealing their true intake, while overweight/obese subjects may feel pressured to report an intake that is acceptable by societal standards (73). In contrast, some studies conducted primarily on normal weight subjects, have found self-reported dietary intake measures to accurately estimate energy expenditure (166, 167).

ENERGY PREDICTION EQUATIONS

Currently, the indirect calorimetry method is still the most widely used technique to measure REE. Indirect calorimetry measures REE by determining the oxygen consumption and carbon dioxide production of the body over a given period of time. The volume of O_2 and CO_2, which are computed at minute intervals, are then applied to the Weir formula to determine REE in kcal/min (54). One major concern is that many investigators actually measure individuals under basal conditions but still refer to their results in terms of REE. In this review, results from these indirect calorimetry studies will use the term specified by that investigator.

Although gains in technology have allowed researchers to more accurately investigate and determine REE values, testing individuals with these instruments in everyday settings or even most clinical settings is not practical. For decades, clinicians have relied on data, such as height, weight, age, and gender, to estimate energy needs. The two most popular protocols for estimating energy needs include equations such as the Harris Benedict equation (HBE) (168), which estimates BEE, and those developed for Dietary Reference Intakes (DRIs) (18), which estimate total energy expenditure (TEE).

Harris and Benedict used an early model of the indirect calorimeter to assess the BEE of 136 healthy normal males and 103 healthy normal females.

Participants ranged in age from 15 to 74 years, with a mean of 29 years and ranged in BMI from 12.3 to 34.6, with a mean of 21.5 (169). By using a partial correlation analysis they determined that weight, height, and age were independently correlated with REE and so were incorporated to yield the equations in use today:

Men: BEE (kcal/d) = 66.5 + 13.75 (wt in kg) + 5.0 (ht in cm) - 6.78 (age in yr)

Women: BEE (kcal/d) = 655 + 9.56 (wt in kg) + 1.85 (ht in cm) - 4.68 (age in yr)

In 2002, the subcommittee for macronutrients that developed Dietary Reference Intakes (DRIs) for energy cited doubly labeled water (DLW) studies that they believed to more accurately assess and determine total energy expenditure than the earlier work. The DRIs employed DLW studies on 760 subjects, 407 normal weight adults, e.g., BMI 18.5-24.9; 169 males and 238 females 19 years or older, and 360 overweight/obese adults, e.g., BMI >25; 165 males and 195 females 19 years or older. DLW was employed to determine the ratio of total energy expenditure to basal energy expenditure (TEE/BEE), otherwise referred to as the physical activity level (PAL), for age and BMI status. Regression equations, using age, height and weight, and physical activity were developed for the estimated energy requirements published as part of the DRIs.

Activity Factors

Refer to Table 2.3 for a review of studies assessing the accuracy of activity factor methodology**.** The WHO equations require dietetic practitioners to assign an activity factor to an individual, a decision generally based on that person's reported voluntary exercise level and occupation, in order to estimate that individual's energy needs. The WHO activity factors were based on many studies conducted over 3 decades ago and remain the most likely values used in research and clinical settings today. Originally these factors were based on type and time spent in occupational activities for young women and men, 18-30 years of age. Individuals were classified based on 8 hours spent at different occupations, which involved either light, moderate, or heavy physical activity. The average calories expended for each level of occupation was calculated and converted to an occupational activity factor. The remaining 16 hours of a day were divided into 8 hours of sleep and 8 hours of discretionary and residual activities. Discretionary activities, which included exercise, leisure-time activities, and household tasks, were then calculated and converted to a factor for different individuals from each of the three occupational levels. Residual time included any remaining time and was estimated at a standard 1.4 X REE. The total kilocalories expended throughout the day for individuals in different occupations were then divided by their REEs, derived from ages and body weights, to yield different activity factors

(170). A few years later the activity factors were expanded to include a wider range of occupations and leisure-time activities, which include a very light and exceptional activity level. To date, the activity factors for very light, light, moderate, heavy, and exceptional activity remain: 30, 50, 60, 90, and 120% of BEE, respectively, for women and 30, 60, 70, 110, and 140% of BEE, respectively, for men (171).

Table 2.3 Review of studies assessing the accuracy of activity factor methodology

Author	Subjects	Methods	Brief Results
Black et al., 1996 (172)	n= 574 (ages 2-95 y) 255 M/319 F - 26.9% overwt M - 35.5% overwt F.	DLW REE - indirect calorimetry Some hts/wts were reported. TEE/REE = PAL	• Sedentary subjects PAL=1.2 • Extreme athletes PAL ranged from 2-4.7 • PAL ranged from 1.2-2.5 for general pop. • 84% of subjects had PALs btwn 2-2.5. • AF derived from this data: - Chair bound 1.2 - Seated work with no moving 1.4-1.5 - Seated work with some mvmt and little leisure activity 1.6-1.7 - Standing work (e.g., housewife) 1.8-1.9 - Significant amts of sport or leisure activity +0.3 -Strenuous work or large amts of active leisure activity 2-2.4 • AF compared favorably to the WHO AF.
Conway et al., 2002 (70)	24 men (ages 27-65 y)	Subjects stayed at center. DLW; DXA; Whole room calorimetry PA recalls & Stanford 7-d questionnaire TEE/REE = PAL	• 7 d PA records overestimated EE by 8%. Stanford questionnaire overestimated EE by 31%. •PAL = 1.58-2.05, almost identical to predicted AF for light, moderate, and heavy activity which were 1.56, 1.78, and 2.10.

Table 2.3 continued

Author	Subjects	Methods	Brief Results
Vinken et al., 1999 (173)	93 adults (18-81y) 44 M/49 F BMI - 18-32, mean 25.3	DLW Densitometry Caltrac accelerometer - 7 d, 7 d activity diary, Minnesota Leisure Time Activity quest. REE – indirect calorimetry	• DLW - PAL ranged from 1.21-2.57 • TEE regression equations were developed: 1. ht, age, wt, & sex 2. accelerometer data, %BF & REE 3. accelerometer data, age, wt, ht, & sex • Equations 1& 2 both improved est. TEE as opposed to DLW. • accelerometer data can be useful in predicting energy needs. • AF obtained from DLW were significantly higher than those proposed by WHO.
Asbeck et al., 2002 (31)	83 adults (20-33 y) 28M/55F; BMI = 22 ±2	REE – indirect calorimetry 7-d diet records/PA records DLW for a sub-group (n=7) TEE derived from Std 1 = REE+PA from records Std 2=REE*AF (WHO 1.55)	• There was an association btwn self-reported EI and Std 2, but not Std. 1 • Standard 1 & 2 TEE were sig. lower from DLW, but Std 2 avoided high levels of over-reporting. •Std 2 appeared more accurate than std. 1
Roberts et al. 1992 (174)	15 normal weight men (>69 y); BMI = 24.1 ±0.9	DLW REE – indirect calorimetry & WHO prediction equations PA diary; TEE/REE = PAL	• Measured REE were slightly lower (~3%) than those predicted REE from WHO. •PAL = 1.75 ±0.05, which were substantially higher WHO values

Table 2.3 continued

Author	Subjects	Methods	Brief Results
Roberts et al. 1991 (175)	n=14 primarily normal weight men (19-26 y)	DLW Physical activity diary REE – indirect calorimetry TEE/REE=PAL	• PALs ranged from 1.6-2.6, mean of 1.98. • PA diaries - most men were engaged in sedentary occupations & spent an average of 34 min/d in active-leisure activities •PALs were significantly higher than WHO AF for light and moderate levels of activity.
Withers et al. 1998 (176)	24 normal wt women (50-70 y) 12 long-term exercisers (LE) 12 long-term non-exercisers (LNE)	DLW; REE Sub-maximal test of aerobic fitness 7-d diet records/ PA records TEE/REE = PAL	• LE PAL = 2.48; LNE PAL = 1.87 •There was no sig. difference btwn 7 d activity EE & DLW •Intake was underestimated by LE, LNE, and combined group by 40.8%, 17.0, and 30.8%, respectively when compared to DLW. •PALs were higher than those proposed by WHO
Rothenberg et al. 1998 (177)	20 older adults (73 y) 12F/8M; BMI (21-31; mean 25 ±3)	DLW –12 subjects (9 F/3M) 24-hr recall, that included FFQ data (DH) BEE – predicted HBE REE – indirect calorimetry 4-d HR monitoring 4-d activity diary (AD)	• DH underestimated intake by 12% when compared to DLW. • For sub-sample: PAL = 1.73, HR/REE = 1.55; AD/BEE = 1.51 • For entire: HR/BEE=1.62, AD/BEE=1.58 *PALs were much higher than WHO values

M = Male; F = Female; PA = physical activity; PAL = physical activity level; AF = activity factor; d = day; EE = energy expenditure; BF = body fat; EI = energy intake; HR = heart rate; DH = diet history

Over the past decade, concerns have been raised regarding the accuracy of using WHO activity factor methodology for estimations of TEE (25, 31, 70, 172). Recently, investigators have found activity factors derived from DLW techniques, i.e., TEE/BEE, to be substantially higher than those proposed by the WHO. Many of these measured AF for sedentary to moderately active individuals ranged from 80 to 150% of BEE, which are considerably higher than the WHO activity factors of 30 to 70% of BEE for sedentary and moderately active individuals (25, 31, 174-177). In contrast, two groups found that TEE derived from WHO activity factor methodology and DLW were similar to one another (70, 172). Investigators who found high values for activity factors derived from DLW believed that a person's energy needs would be severely underestimated using the WHO activity factors (25, 31, 174-177). Based on these DLW studies, the 2002 DRIs for energy were developed with the objective of more accurately estimating physical activity related energy expenditure and TEE.

The DRI employed DLW to determine the ratio of TEE/BEE, also called PAL. Based on the measured PAL values, BMI and age categories, physical activity intensity categories were assigned to reference adults. The PAL intensity categories are sedentary, low active, active, and very active and ranged from 23 to 109% and 29 to 106% of BEE for normal weight females and males, respectively, and 25 to 104% and 27 to 110% of BEE for overweight/obese females and males, respectively. Regression equations were based on this PAL index, age, height and weight to yield TEEs. Although the DRIs are derived from DLW data, dietetic practitioners are still responsible for classifying the intensity level of a particular individual's activity before the energy calculation can be performed.

Since many of these studies found higher values for activity factors derived from DLW, many researchers believe that a person's energy needs will be severely underestimated using the WHO activity factors (25, 31, 174-177). However, one must consider the practical implications of these findings. If estimations of energy were to increase, clinicians and dietitians would essentially be prescribing and educating clients and or patients to consume substantially more daily total energy. With the majority of our population already being overweight or obese, increasing estimations of energy needs have the potential to worsen the obesity problem.

The development and recent advances in accelerometry technology provides investigators with a relatively inexpensive and easy to administer instrument to measure free-living energy expenditure (58-61, 65, 66). To date, no investigation has directly compared physical activity-related energy expenditure derived from accelerometers to popular activity factor methodology promoted by the WHO and DRI. Vinken et al. (25), the only other investigator to our knowledge to employ accelerometer methodology to assess activity factors, developed several regression equations to predict energy needs based on either age, height, weight, and gender, or body composition and accelerometer data, or a combination of all these factors and compared these values to TEE derived from DLW and to the 1989 Recommended Dietary Allowances (RDAs) for energy (171). The RDAs include the WHO activity factor in the TEE. Results indicated that the regression energy equations using accelerometer data were more comparable to TEE derived from DLW than to the RDAs for energy. However, Vinken et al. never directly compared the activity-related energy expenditure derived from accelerometer to WHO activity factors. Further research using accelerometers to test the accuracy of predicted activity factors, i.e., WHO and DRIs, is warranted.

Despite decade long controversies over what factors influence weight gain, research keeps returning to a discrepancy between energy intake and energy expenditure. Limited physical activity-related energy expenditure, especially limited time spent in moderate or greater intensity, and unhealthy dietary habits play a key role in the etiology of obesity. In addition, inaccurate estimations of energy needs by current prediction methodology fails to provide practitioners appropriate information for educating clients on balancing energy intake and output. Hopefully, the knowledge gained from this study along with the unique measurement tools/devices will be extremely beneficial in developing future weight maintenance/loss interventions.

Chapter 3: Overweight/obese adults are less active than their normal weight controls matched for gender, age and height

ABSTRACT

Background: Research comparing physical activity measured by accelerometers of adults carrying excess weight and their normal weight counterparts are limited. None have addressed compliance with the 2002 Institute of Medicine (IOM) exercise recommendations for 60 minutes of moderate intensity exercise daily.

Objectives: Research objectives were to compare activity measured with accelerometers to activity reported by questionnaire in an overweight/obese population and their gender, age and height matched controls, to compare physical activity between these two groups and to assess their compliance with the 1995 Centers for Disease Control and Prevention and American College of Sports Medicine recommendations of ≥30 minutes of physical activity most days of the week and the 2002 IOM recommendations of ≥60 minutes of physical activity daily.

Design: Overweight/obese subjects included 31 adults, 12 males and 19 females, ages 25-69 years, who had BMI ≥25 and their normal weight controls, BMI 18.5 to 24.9, matched for gender, age and height. Body composition was assessed via dual energy X-ray absorptiometry. Physical activity was estimated with a 40-item investigator administered Yale Physical Activity Survey and measured with accelerometers worn by each participant for 7 consecutive days.

Results: Compared to activity measured with an accelerometer, normal weight

subjects overestimated their activity on the Yale survey by 90% versus an overestimation of 60% by overweight/obese subjects. Accelerometer data indicated that adults with excess weight were less physically active, expended fewer kilocalories per kilogram of body weight, recorded fewer accelerometer counts throughout the week, and spent less time in moderate or greater intensity activity, than their normal weight age, gender, and height matched counterparts. An average of 71% of the overweight/obese and 94% of the normal weight subjects met 1995 exercise recommendations, but only 13% of overweight/obese subjects and 26% of normal weight participants met 2002 exercise recommendations.

Conclusions: These results suggest that physical activity-related energy expenditure and the amount of time spent in moderate intensity activity or greater is associated with weight status.

INTRODUCTION

The role of physical activity in total energy expenditure is difficult to measure objectively in free-living subjects. Two methods available are doubly labeled water (DLW) and accelerometers. Validation studies comparing DLW to direct and indirect calorimetry and to dietary balance studies in which caloric intake was determined have found DLW to be accurate within 97 to 99% over 1 to 3 week intervals (55-57). However, expense, $400-600 per subject, and the complex administration procedure make this method impractical for most settings (28). The development of the accelerometer provides investigators a more practical and inexpensive objective measure for assessing physical activity under free-living conditions. Data from a few of the motion sensors have been directly correlated with kilocalorie expenditure. Some accelerometers are capable of providing estimates of the amount of time individuals spend at different intensity levels, i.e., sedentary, moderate, hard and very hard. Such data are useful and allow investigators to more accurately assess both total physical activity and partitioned expenditure at various intensities. The data also allow investigators to assess whether individuals are meeting recommended physical activity objectives for moderate intensity exercise.

In 1995, the Centers for Disease Control and Prevention and the American College of Sports Medicine (CDC/ACSM) established physical activity recommendations for health benefits of at least 30 minutes of moderate intensity activity preferably all days of the week (178). National data collected from 1990-1998 by the CDC revealed a 25% compliance rate among American adults; 29% of those surveyed reported no leisure time regular physical activity (52). In 2002, the Food and Nutrition Board of the National Institute of Medicine (IOM), interested primarily in the benefits of activity in weight management, increased recommendations for physical activity to at least 60 minutes of moderate intensity every day of the week (138). To date, there are no reports on compliance with the 2002 recommendations; however, since few adults met the less stringent 1995 physical activity recommendations, it is unlikely that many are meeting the new standard.

So far, few studies have been conducted using accelerometers to compare physical activity of obese adults and their normal weight counterparts. None of the limited body of work has employed normal weight subjects matched for gender, age and height. This design would allow direct comparisons of individuals, with theoretically similar energy needs, one group having maintained their weight within normal limits and another being overweight or obese. The present study was designed to 1) compare reported activity from the Yale Physical Activity Survey and activity measured by accelerometers in an overweight/obese population and their normal weight, gender, age, and height matched controls; 2) compare time spent in activity of moderate intensity or greater by these two groups; and 3) compare the percentage of individuals from each group meeting the 1995 and 2002 recommendations for physical activity.

METHODS

Subjects

Subjects were recruited by posting flyers at local gyms, hospitals, sporting activities, and health centers and by sending out a campus wide e-mail to University faculty and staff. Out of the original 106 recruited subjects, a convenience sub-sample volunteered to wear the accelerometers. The sub-sample included 62 subjects, aged 25 to 69; 31 of whom were overweight with a BMI 25-29.9 or obese with a BMI ≥30 and 31 normal weight subjects with a BMI 18.5 - 24.9 matched for gender, height (± 1 inch), and age (± 1 year). Height, weight, age, BMI, body composition and reported physical activity were not different (P >.65) in the original 106 subjects and the sub-sample that wore accelerometers. No financial compensation was given. Subjects participated with the sole incentive of receiving their test results, and all participates completed the study. The subjects were provided the study protocol, approved by University Internal Review Board, before signing a consent form.

Anthropometrics, Body Composition, and Health History

Most data collection, other than accelerometry, took place in a laboratory on the university campus during a single 2-hour appointment. After subjects completed consent forms, height and weight were measured using a physician scale (Detecto, Webb City, MO) and stadiometer (Seca, Columbus, OH), with participants wearing light clothing and shoes removed. Subjects completed a short demographic and health history questionnaire that included questions about occupation and past medical history. Body composition was measured by licensed Medical Radiological Technologists, using the Prodigy Pro dual energy X-ray absorptiometry (DXA) (GE Medical Systems LUNAR, Madison WI, Encore 2002 software).

Physical Activity

Subjects completed a 40-item, investigator administered Yale Physical Activity Survey (179) to assess reported physical activity levels. Administration of this instrument required approximately 20 minutes during the 2-hour appointment at the campus laboratory. Each participant was asked to report the number of times and duration that specific activities, including spontaneous and planned, were performed over the past month. This monthly physical activity was then multiplied by a reported seasonal factor to account for seasonal differences in physical activity and reflect physical activity over an entire year. Surveys were completed over a 4-month period, from months January through April. Times and durations for each activity were multiplied by appropriate intensity codes and expressed in kilocalories per day and week. These intensity codes are obtained from the Compendium of Physical Activities, which is a compilation of studies that have determined the ratio of exercise metabolic rate to resting metabolic rate, also referred to as the metabolic cost or METs, for a variety of activities and sports using indirect calorimetry data (67). These intensity codes were independent of body weight.

Accelerometers were employed to measure physical activity. Participants wore the CSA ActiGraph (Computer Science and Applications, Inc., Shalimar, FL) around their waists during waking hours for seven consecutive days. Numerous validation studies have shown that the CSA ActiGraph, provides accurate and reliable data for assessing physical activity (58-61, 65, 66). Accelerometer data on the group were collected over a 6-month period, from months May through October. Matched pairs wore the accelerometers within the same month. Subjects were instructed to wear the ActiGraph in the same location on their waist every day. A protective pouch, elastic belt and clip were provided to each subject to aid in proper placement of the ActiGraph and to accommodate subject preference and comfort. Subjects were asked to complete a written log of any times and/or activities when the ActiGraph was not worn, e.g., swimming and water skiing. Energy expended from these additional activities was calculated using the Compendium of Physical Activities (67) .

Accelerometer data were recorded and stored on a minute-by-minute basis and later downloaded to a computer, via a Reader Interface Unit. Activity data were processed and analyzed with the use of a Microsoft ActiSoft program (ActiSoft version 3.2) (65) and expressed as total counts divided by registered time, i.e., $\text{counts}^{-1} \cdot \text{min}^{-1} \cdot \text{d}^{-1}$. Previous studies have employed regression equations, using CSA activity counts and indirect calorimetry data, to determine the metabolic cost, MET, corresponding to activity count data (65). Based on the MET system, the counts were converted into kilocalorie expenditure per day and week and into minutes spent in different intensity levels, i.e., light, moderate, hard and very hard.

Statistical Analyses

Data were analyzed using the Statistical Package for the Social Sciences (Version 11.0 for Mac OS X, Chicago, IL). Since the subjects were matched pairs, Pearson correlations assessed whether variables were correlated within pairs. If not correlated, data were analyzed with a typical between group analysis of variance (ANOVA). The effects of the fixed factors of gender and group (obese versus normal weight adults) on physical characteristics, activity-related energy expenditure, accelerometer counts, and minutes spent in various intensity levels were analyzed by ANOVA. If there were no significant gender by group interactions, only the main effects of group and gender were reported. Repeated measures ANOVA were employed to assess differences between physical activity derived from the Yale survey and accelerometers for each individual. For accelerometry data, if there was a significant group by time interaction, day-to-day differences for minutes spent in various intensity levels and physical activity-related energy expenditure between groups were reported. Repeated analyses were followed-up with Bonferonni adjusted paired comparisons. All data that were not normally distributed were log transformed. All assumptions for ANOVA and repeated measures ANOVA were fulfilled. Chi-square tests were employed to assess categorical accelerometer data, i.e., the number of subjects meeting 1995 CDC/ACSM and 2002 IOM physical activity recommendations, in relation to each group. Accepted statistical significance was $P < .05$.

RESULTS

Experimental and control subjects were matched for gender, age and height. Mean differences of 0.4 years and 2.0 centimeters were observed in age and height, respectively, between the overweight/obese and normal weight groups. On average, the group carrying excess weight was 28 kilograms heavier than their normal weight controls. Age, height, weight, BMI, and body composition of the study participants are presented in Table 3.1. We were initially concerned that the body fat percentages for our normal weight subjects were relatively high (24, 21, and 25% for total, males, and females). Gallagher et al. (180), who established new percentage body fat ranges based on DXA, densitometry and BMI measurements on over 1600 adults, recommended healthy body fat ranges for specific age categories, such as: 21-32% for females and 8-19% for males between 18-39 years of age; 23-33% for females and 11-21% for males between the ages 40-59 and 24-35% for females and 13-24% for males between the ages of 60-79 years of age. When we divided our sample into age categories, most of our normal weight subjects fell within their recommended body fat range for their age category. There were 3 males between the age of 40-59 who had slightly higher body fat percentages, but their BMI was <25 and therefore they were retained in the normal weight group.

Occupations reported by subjects on the health history form included homemakers, engineers, teachers, fitness instructors, students, nurses and pastors. The normal weight participants tended to report more active occupations, such as fitness professional and construction worker, and more of them were involved in recreational endurance sports in their spare time, e.g., long-distance running and cycling, than their overweight obese counterparts.

Participants wore an accelerometer for an average of 7.0 ±0.6 days, for 24 hours a day and removed it only for showering and water activities. Data showed that subjects in both groups rested or slept an average of 9 hours a night and were awake for approximately 15 hours a day. One subject wore the accelerometer for only 5 days and 4 subjects wore the accelerometer for 6 days. All other subjects wore them for the full week. Weekly and daily averages were adjusted for the number of days that each participant actually wore the accelerometer. When individual days were compared, only data from participants who wore the accelerometer on those days were included. For example, three subjects did not wear the accelerometer on Friday, so their data were excluded when assessing the Friday data sets, but their data were included for Saturday thru Thursday.

The mean weekly kilocalorie expenditure from the Yale survey and accelerometer measurements are summarized in Table 3.2. Repeated measures ANOVA revealed that mean kilocalorie expenditures reported on the Yale Survey were significantly higher than the energy expenditures measured by the accelerometers for both overweight/obese and normal weight groups. When survey and accelerometer data were compared, overweight/obese subjects appeared to overestimate their mean weekly and daily energy expenditure by about 60%, while normal weight subjects overestimated their mean weekly and daily energy expenditure to a larger extent, approximately 90%. Males who were overweight or obese overestimated their energy expenditure the least, 30% on average, while females of normal weight overestimated their energy use the most, an average of 130%.

Mean physical activity-related energy expenditure per week or per day did not differ between groups, whether estimated by the Yale survey or measured with accelerometers. However, weekly activity-related energy expenditure for both the survey and accelerometer methodology differed significantly when expressed as kcal/kg of body weight, as shown in Table 3.2. Weekly activity-related energy expenditures per kilogram of body weight as determined by Yale survey and accelerometer, respectively, were 30 and 50% lower for overweight/obese adults when compared to their normal weight counterparts ($P<.05$).

Large group differences also were observed in counts per day and minutes spent in various intensities as recorded by the accelerometers. These data are presented in Table 3.3. Overweight/obese subjects registered significantly lower mean 7-day, 2-day weekend and 5-day weekday counts when compared to their normal weight counterparts. Normal weight subjects spent significantly more time, 21 minutes per day on the average, engaged in moderate intensity or greater activities when compared to overweight/obese subjects. Overweight/obese participants spent significantly less time in moderate intensity activity or greater than their normal weight controls on weekdays, i.e., data summed from Monday thru Friday, 135 ±198 vs. 251 ±155 min; $P<.05$, and during the weekend, i.e., data summed from Saturday and Sunday, 64 ±65 vs. 95 ±61 min; $P<.02$.

There was not a significant group by time interaction for day-to-day analyses for total physical activity-related energy expenditure between groups. However, significant group by time interaction for daily minutes spent in moderate intensity or greater activity between groups allowed exploration of daily time spent in moderate activity. Mean minutes spent in moderate intensity or greater activity per day are summarized in Figure 3.1. Normal weight subjects spent significantly more time engaged in moderate intensity or greater activity throughout the week when compared to overweight/obese subjects ($P<.05$). Bonferroni adjusted paired comparisons determined that normal weight subjects spent more minutes in moderate intensity or greater activity for days Monday through Thursday when compared to overweight/obese subjects; however time in moderate or greater intensity activity did not differ on Friday, where values tended to converge, or on Saturday or Sunday.

The percentage of subjects meeting 1995 CDC/ACSM physical activity recommendations for 30 minutes of moderate intensity or greater activity 5 or more times a week, or ≥150 minutes a week, and the percentage of subjects meeting 2002 IOM physical activity recommendations for over 60 minutes a day of moderate intensity activity or greater, or ≥ 420 minutes a week, based on accelerometer data are summarized in Figure 3.2. Chi-square tests showed that normal weight subjects were significantly more likely to meet 1995 recommendations when compared to overweight/obese subjects, 94% vs. 71% (P<.05). Significantly more normal weight females met 1995 recommendations when compared to overweight/obese females, 95% vs. 53% (P<.001), whereas no differences between normal weight males and overweight/obese males meeting the 1995 recommendations were observed. Percentage of total groups and females and males in each group meeting the 2002 physical activity recommendations did not differ significantly. Only 13% of overweight/obese participants and 26% of normal weight participants met the more stringent recommendations made by the IOM in 2002.

DISCUSSION

In the past, investigators relied on subjective instruments, such as physical activity recall, records and questionnaires, to evaluate physical activity. Although reported measures are relatively inexpensive and easy to administer, subjects often over-report activity. Obese individuals are reported to overestimate physical activity by 30 to 50% (68, 69), compared to 8 to 30% for normal weight subjects (70). In contrast, our obese subjects overestimated physical activity levels by ~60% on the Yale survey when compared to accelerometer data, but our normal weight subjects overestimated their activity by 90%. Both overweight/obese and normal weight females overestimated their physical activity levels to a much larger extent when compared to the males. A possible explanation for the higher rate of overestimation by our normal weight subjects is that their occupations tended to be more active and some of them were training for an endurance sport, e.g., a long distance cycling or running event, when the Yale Survey was administered, but were in their off-season when the accelerometers were worn. The Yale survey uses a seasonal factor adjustment to account for difference in activity between seasons, but it is possible that all of the difference was not accounted for by simply applying this seasonal factor. However, when the analyses were run excluding these individuals (n=6) who had active occupations or were involved in recreational endurance activities, similar overestimations existed in the normal weight group.

Accelerometer data indicated that overweight/obese subjects in the present study were significantly less active than their matched counterparts. These differences occurred in recorded accelerometer counts throughout the week, the weekly and daily activity-related energy expenditure relative to body weight, and time spent in moderate intensity activity or greater, for the entire week and most individual days. Based on accelerometer counts per minute, overweight and obese individuals were less active on weekends and weekdays when compared to their normal weight matched pairs. These results were similar to studies conducted by Cooper et al. (19) and Rutter et al. (75) who reported that obese adults accumulated fewer activity counts than normal weight adults. In contrast, Meijer et al. (74) and Tyron et al. (76) found no difference in activity counts between obese and normal weight individuals. However, Meijer and Tyron employed different types and models of accelerometers from those used in our laboratory and none of the other studies employed matched overweight/obese and normal weight subjects.

Despite the deficits among overweight/obese subjects in time spent in moderate activity or greater, weekly and daily total energy expenditures did not differ significantly between subjects of excess and normal weight. Since the calculation used to convert accelerometer counts into energy expenditure takes into account the height and weight of each subject, the differences in physical activity levels, without similar differences in energy expenditure, can be explained in part by the increased energy cost of moving a larger body mass. When total energy expenditure was expressed in relation to body weight, activity expenditure was 2 kcal/kg on the average lower in overweight/obese subjects when compared to their normal weight match. Similar results were seen by Richards et al. (77) who compared the energy expenditure measured by accelerometers, for 134 severely obese adults and their normal weight siblings.

Few studies have compared time spent in different intensity levels, derived from accelerometers, in an obese/overweight and normal weight population. In the present study, overweight and obese participants spent significantly less time in moderate intensity activity or greater for the entire week, and during weekdays and weekends than their normal weight counterparts. Cooper et al. (19), who studied 72 normal weight and 12 obese adults, found that obese adults spent significantly less time in activity of at least moderate intensity than non-obese adults on weekends; however this difference was absent on weekdays among their subjects. Ekelund et al. (78) employed both accelerometers and DLW methods and found that obese adolescents spent significantly less accumulated time in moderate intensity physical activity when compared to normal weight subjects matched for height and age. All of these results indicate that if an overweight/obese individual spent more time in moderate intensity activity or greater they could considerably increase their daily energy expenditure, which would, in the absence of increased food intake, result in substantial weight loss.

Another phenomenon to consider is that when an individual increases their planned moderate intensity activity, their spontaneous activity, which includes fidgeting, sitting and standing, may subsequently decrease. Both Cooper et al. (19) and Hill et al. (50) suggest that on the days when individuals exercise, they are likely to decrease their spontaneous activity. Our results indicate increased total energy expenditure in association with planned exercise. On the days in which an individual spent at least 30 minutes in moderate intensity activity or greater, they expended an average of 410 kilocalories more a day in which they did not exercise. However, when an individual exercised for at least 60 minutes or more, they expended an average of 360 kilocalories more a day when compared to the energy expenditure on their more sedentary days. These results suggest that even if spontaneous activity does decrease on the days when an individual exercises, the energy expenditure is still substantially higher on those days. However, the energy expenditure difference was larger on days in which 30 minutes versus the days in which 60 minutes of exercise was performed. These results suggest that when individuals engage in long exercise bouts, e.g., 60 minutes or longer, their spontaneous activity decreases to a greater extent compared to days when they exercise only 30 minutes.

Only one other study has used accelerometers to assess how many adults met 1995 CDC recommendations for exercise. Cooper et al. (19) found that only 80% of non-obese participants and 60% of the obese accumulated at least 30 minutes of moderate intensity activity on five or more days of the week. Among subjects in the present study, over 70% of the overweight/obese subjects and over 90% of our normal weight subjects met 1995 CDC/ACSM recommendations, but only 13% of overweight/obese and 26% normal weight subjects met 2002 IOM recommendations for 420 minutes or more of moderate intensity exercise over the week.

It is likely that more of our participants met the 1995 recommendations because they volunteered for a study evaluating exercise and energy expenditure and probably were more active than the general population. Thus, among the general population, it is likely that larger percentages of both overweight/obese and normal weight adults do not meet either 1995 or 2002 national recommendations for exercise. It is possible that the increases in recommendations for longer and more frequent activity will encourage more of the adult population to strive to more closely meet the newer guidelines, but it also is entirely feasible that individuals will be discouraged by the lofty newer guidelines and possibly decrease their activity levels.

Although accelerometers provide investigators an accurate and reliable tool for measuring physical activity in free-living populations, these instruments are not without limitations. The waist-mounted accelerometers may not capture all of the energy expended in activities that require mostly arm movement, e.g., cooking, golf, deskwork, and weight training (59, 66). In addition, these accelerometers cannot be used for swimming or other water activities. However, our participants were asked to keep a log of all swimming and water activities and to record any activities performed that required excessive arm movement.

Fortunately very few of our participants (n=5) were swimmers, and their logs allowed us to account for the duration and frequency of the extra swimming activity.

Another concern is the effect that age has on physical activity levels. Literature suggests that physical activity declines with age (174, 181). In this study subjects were not divided into age categories for analyses, but our subjects were matched for age within 1 year between groups. Since subjects were matched for age, the effect of age on physical activity was not analyzed.

In conclusion, the present study found that even though there was no significant difference between energy expenditure between groups: 1) survey data tend to substantially overestimate physical activity among both normal weight individuals and those of excess weight; 2) obese and overweight adults were less physically active, on the basis of activity-related energy expenditure in relation to body weight, recorded accelerometer counts throughout the week, and on the amount of time spent engaged in moderate intensity activity or greater, than their normal weight counterparts matched for age, gender and height; and 3) over two thirds of both overweight/obese and normal weight subjects met 1995 CDC/ACSM national exercise recommendations while about one fourth or less of either group met 2002 IOM exercise recommendations. These results suggest that physical activity-related energy expenditure and the amount of time spent in moderate intensity activity or greater are associated with weight status. Weight loss/maintenance intervention should not only encourage individuals to increase moderate intensity or greater activity but also emphasize the importance of maintaining or even increasing spontaneous activity.

Table 3.1 Age, height, weight, BMI, and body composition of matched pairs of overweight/obese and normal weight adults [a]

	Overweight/Obese Group [b]			**Normal Weight Group** [c]		
	Total (n=31)	Men (n=12)	Women (n=19)	Total (n=31)	Men (n=12)	Women (n=19)
Age (y)	44.0 ±11.9	42.5 ±9.1	44.9 ±13.5	43.6 ±12.0	41.8 ±8.7	44.8 ±13.7
Height (cm)	169.1 ±9.1	178.3 ±6.4	163.2±4.4	171.0 ±9.0	180.5 ±5.4	165.0 ±4.3
Weight (kg) [d, e]	94.7 ±14.3	105.3 ±9.4	87.9 ±12.7	66.5 ±11.3	78.5 ±7.7	58.8 ±4.1
BMI [d, e]	33.0 ±3.3	33.1 ±1.7	32.9 ±4.1	22.5 ±1.6	24.1 ±1.3	21.6 ±0.9
Fat mass (kg) [d, e]	39.7 ±8.9	36.6 ±7.7	41.7 ±9.2	15.6 ±3.8	16.5 ±4.3	15.2 ±3.6
Fat mass (%) [d, e]	42.8 ±7.8	35.0 ±5.0	47.8 ±4.5	24.1 ±5.4	21.1 ±4.5	26.0 ±5.2

[a] Mean ±SD. There were no gender by group interactions (ANOVA).
[b] BMI ≥25 (182).
[c] BMI 18.5 - 24.9.
[d] Significant group effect (ANOVA), *P*<.001.
[e] Significant gender effect (ANOVA), *P*<.001.

Table 3.2 Weekly energy expenditure derived from voluntary activity (excluding basal metabolism) as reported on the Yale Physical Activity Survey and measured by accelerometers for matched pairs of overweight/obese and normal weight adults [a]

	Overweight/Obese Group [b]			Normal Weight Group [c]		
	Total (n=31)	Men (n=12)	Women (n=19)	Total (n=31)	Men (n=12)	Women (n=19)
Yale survey						
Weekly activity (kcal) [d]	6717 ±4380	7028 ±5301	6520 ±3834	7391 ±4319	7086 ±3759	7585 ±4729
Weekly activity (kcal/kg of body wt) [e]	75 ±54	70 ±58	78±53	115 ±30	91 ±48	130±85
Accelerometer Weekly activity (kcal) [d]	4216 ±2136	5410 ±2338	3462 ±1647	3855 ±1533	4704 ±1885	3318 ±982
Weekly activity (kcal/kg of body wt) [e]	45 ±20	51 ±19	41 ±20	58 ±21	61 ±27	56 ±16

[a] Mean ±SD. There were no gender by group interactions (ANOVA).
[b] BMI ≥25 (182).
[c] BMI 18.5 - 24.9.
[d] Significant group effect for reported (Yale) vs. measured (accelerometer) (Repeated measures ANOVA), *P*<.01.
[e] Significant group effect (ANOVA) between overweight/obese and normal weight subjects, *P*<.01.

Table 3.3 Counts and minutes spent in different intensity level activities as measured with accelerometers by matched pairs of overweight/obese and normal weight adults [a]

	Overweight/Obese Group [b]			**Normal Weight Group** [c]		
	Total (n=31)	Men (n=12)	Women (n=19)	Total (n=31)	Men (n=12)	Women (n=19)
Counts for 7 d ($cts^{-1} \cdot min^{-1} \cdot d^{-1}$) [d]	227 ±153	283 ±211	192 ±91	285 ±111	297 ±155	277 ±74
Light activity for 7 days (min/d)	1372 ±62	1374 ±67	1370 ±61	1361 ±85	1358 ±71	1364 ±94
Moderate activity or greater for 7 days (min/d) [d]	31 ±21	42 ±18	25 ±20	52 ±28	58 ±36	47 ±21
Weekday counts ($cts^{-1} \cdot min^{-1} \cdot d^{-1}$) [e]	237 ±195	306 ±288	193±88	295 ±115	310 ±134	285 ±105
Weekday moderate activity or greater (min/d) [e]	27 ±22	32 ±23	24 ±20	50 ±31	53 ±35	48 ±29
Weekend counts ($cts^{-1} \cdot min^{-1} \cdot d^{-1}$) [e]	216 ±113	232 ±120	205 ±111	293±161	285 ±219	298 ±116
Weekend moderate activity or greater (min/d) [d]	32 ±33	45 ±40	24 ±25	48 ±31	47 ±40	48 ±25

[a] Mean ±SD. There were no significant gender by group interactions (ANOVA).
[b] BMI ≥25 (182).
[c] BMI 18.5 - 24.9.
[d, e] Significant group effect (ANOVA), [d] $P<.01$; [e] $P<.05$.

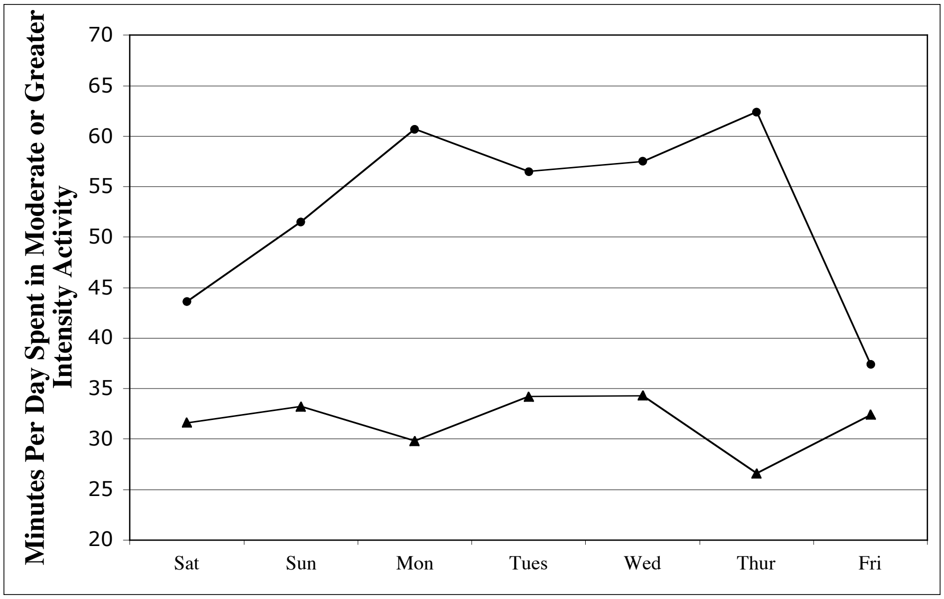


Figure 3.1. Minutes spent in moderate or greater intensity activity by overweight/obese subjects (▲) and normal weight subjects (●) as measured by accelerometry. Significant group by time effects (*P* <.05) were identified by repeated measures ANOVA. Bonferroni adjusted paired comparisons indicated significant differences in means for minutes spent in moderate intensity or greater activity between groups for days Monday through Thursday (*P*<.05).

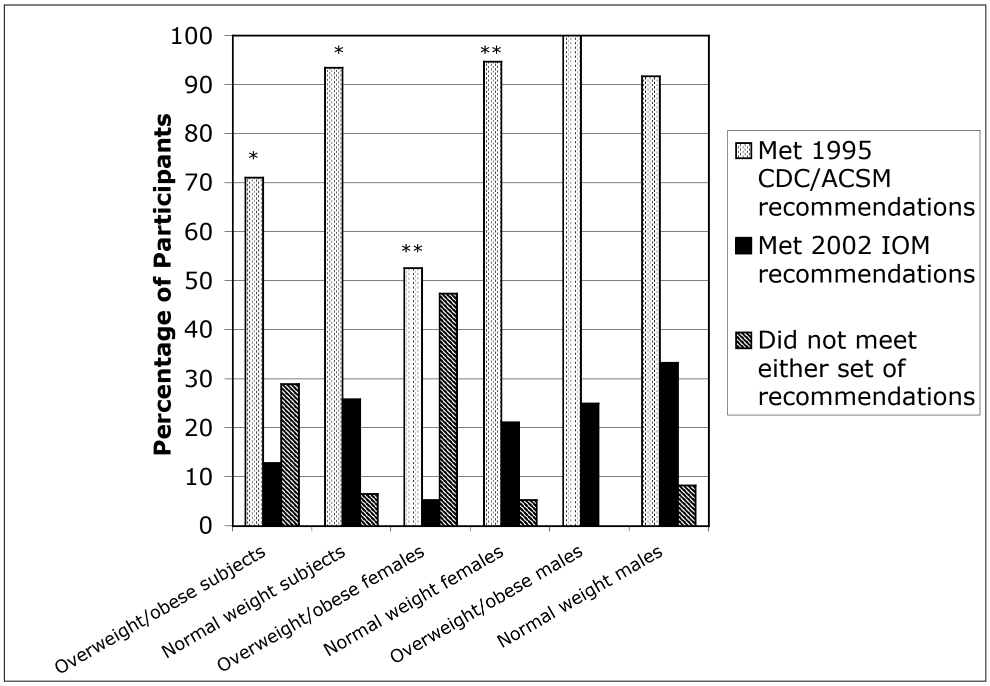


Figure 3.2. Percentage of overweight/obese and normal weight subjects, as measured by accelerometry, who met the 1995 CDC/ACSM recommendations (≥30 mins/day of moderate intensity or greater all days of the week) and the 2002 IOM recommendations (≥60 mins/day for 7 days). Chi-square tests showed that all overweight/obese subjects, and overweight/obese females as a group, were significantly less likely to meet the 1995 CDC/ACSM recommendations for exercise compared to their normal weight controls (*P<.05, **P<.001).

Chapter 4: Normal weight adults consume more fiber and fruit than their age and height matched overweight/obese counterparts

ABSTRACT

Objective To assess differences in dietary intake of overweight/obese subjects and their gender, age and height matched controls and to identify dietary components associated with increased deposition of body fat.

Design/Subjects A convenience sample of 52 overweight/obese and 52 normal weight adults matched for gender, age (±1 year) and height (±1 inch) were recruited from the local area. Dietary intake was assessed with the Block 60-item food frequency questionnaire; physical activity was measured by the Yale Physical Activity Survey; and percent body fat was measured via dual energy X-ray absorptiometry.

Statistical analyses performed Independent *t* tests compared consumption of various dietary components between groups. Multiple regression analyses determined the extent to which dietary components predicted percent body fat before and after controlling for age, gender, physical activity-related energy expenditure and other macronutrients. Spearman correlation coefficients examined relationships between nutrients and food guide pyramid servings and percent body fat.

Results Overweight/obese subjects consumed more total fat, saturated fat and cholesterol and less carbohydrate, complex carbohydrate and dietary fiber than controls. Reported intake of dietary fiber was inversely related to percent body

fat without (R^2=0.052, P=.02) and with (R^2=0.045, P=.013) control for potential confounding factors. Servings of fruit per day were negatively related to percent body fat (r = -0.40, P<.01).

Applications/Conclusions These findings suggest that the composition of the diet, especially low dietary fiber intake, plays a role in the etiology of obesity.

INTRODUCTION

Despite considerable attention to issues surrounding obesity and weight management, the prevalence of excess body weight and body fat in the population at large continues to increase. Although food intake is not solely responsible for this trend, it is indisputable that dietary habits play a key role. Although excess energy intake promotes weight gain, recent research indicates that specific dietary components appear to contribute to or inhibit the development of obesity. Results of animal and human studies indicate that dietary fat is associated with increased energy intake and promotes adiposity (26, 84, 88, 90). Other macronutrients, specifically complex carbohydrate and dietary fiber, have been extensively studied and found to be inversely related to body weight and body fat percentages (26, 107-109, 123, 183).

Several dietary components were either positively or negatively correlated with body weight and/or BMI status in various epidemiological studies (122, 124, 125, 182), but few investigators measured percent body fat (120, 123, 124, 146) and/or used multiple regression techniques, controlling for confounding variables, to identify the influence of dietary habits on adiposity (120, 146).

The purpose of our study is: 1) to assess differences in dietary intake between overweight/obese subjects and their normal weight controls matched for gender, age and height and 2) to use multiple regression techniques, controlling for confounding variables, to identify dietary component(s) that best predict body fat deposition.

METHODS

SUBJECTS

Subjects were recruited by posting flyers at local gyms, hospitals, sporting activities, and health centers and by sending out a campus wide e-mail to university faculty and staff. The initial sample included 138 subjects, 69 in each group, but 32 subjects were excluded because of the inability to find a matched control, and two subjects failed to provide adequate dietary data. The final sample included 104 adults (aged 19 to 69 years); 52 overweight or obese, and 52 normal weight subjects matched for gender, height (± 1 inch), and age (± 1 year). Based on the Hamwi equations, experimental subjects were >125% of their standard body weight for height and control subjects were ±10% of standard body weight for height (184). No monetary compensation was given, and subjects participated with the sole incentive of receiving their test results. Subjects read the experimental protocol, approved by the University Internal Review Board, before giving informed consent.

Anthropometrics, Body Composition, and Health History

Most data collection took place in a campus laboratory during a 2-hour appointment. After subjects completed consent forms, weight was measured with a physician scale (Detecto, Webb City, MO), and height was measured by a wall mounted stadiometer (Seca, Columbus, OH). Subjects completed a short demographic and health history questionnaire, which included questions about occupation and past medical history. Body composition was measured by a licensed Medical Radiological Technician using the dual energy X-ray absorptiometry (DXA; GE Medical Systems LUNAR, Madison, WI).

Physical Activity

Subjects completed a 40-item, investigator administered Yale Physical Activity Survey to assess reported physical activity levels (179). Administration of this instrument required approximately 20 minutes during the 2-hour appointment at the campus laboratory. Each participant reported the number of times and duration that certain activities, including spontaneous and planned, were performed over the past month. Times and durations for each activity were multiplied by appropriate intensity codes and expressed in kilocalories per week and day. The intensity codes are defined in terms of a resting metabolic rate and are independent of body weight.

Dietary Intake

All subjects completed the semi-quantitative 60-item Block food frequency questionnaire (FFQ) that has been validated for the estimation of individual dietary intake (153, 185). Participants reported how many times per week or month that they consumed specific food items and the approximate serving sizes of each food item. Verbal instruction from investigators, all Registered Dietitians, along with a handout with pictures depicting portions corresponding to FFQ options were given to each subject to aid in accurate estimation of portions sizes. Investigators were available for questions and/or clarification. The FFQ required around 20 minutes to complete. To eliminate skipped items and ambiguous answers, investigators checked each FFQ immediately after completion to insure each item was marked.

Completed FFQs were sent to the Berkley Nutrition Services for data scanning, via an Optical Mark Reader (OMR) scanner, and analysis. A standard computer algorithm was used to flag unusual or incomplete responses including: more than 15 foods skipped; too few foods eaten daily, the section on portion size entirely omitted or marked entirely "medium"; and more than two food items were reported with unreasonable frequencies. FFQ data was also excluded if daily energy intakes were <800 or >4,200 for men or <600 or >3,500 for women (156). A complete nutrient analysis, including macro- and micronutrients and

Food Guide Pyramid (FGP) servings per day (182) was provided by the Berkley Nutrition Services. The FGP does not specify what defines a serving of fat, oil, and sweet in the top category on the pyramid, so fat, oil and sweet servings were not reported in the present study. However, added sugar was defined by the USDA National Nutrient Database for Standard Reference (186) and was reported in the results.

Statistical Analyses

Variables that were not normally distributed were log transformed. Mean nutrient consumption and food guide pyramid servings between groups, and for each gender between groups were compared with independent t tests. Hierarchical multiple regression analyses were employed to examine the extent to which different dietary factors predicted percent body fat with and without statistical control for potential confounding factors such as age, gender, physical activity-related energy expenditure, energy intake, and other macronutrients. Spearman correlation coefficients were used to assess relationships between energy and nutrient intake, food guide pyramid servings and percent body fat. Accepted statistical significance was $P<.05$.

RESULTS

Age, height, weight, BMI, and percent body fat of the study participants are presented in Table 4.1. Among the 52 overweight/obese subjects (18 males and 34 females) and their normal weight controls matched for gender, age, and height, mean differences of 0.1 years and 1.8 centimeters were observed in age and height, respectively. On average, the overweight/obese group was 31 kilograms heavier and had 72% more body fat than their matched controls. According to BMI standards (182), BMIs for overweight/obese subjects were over 25.0 kg/m^2. Among the normal weight group, BMIs were between 18.5-24.9 kg/m^2, with the exception of 3 male subjects between 40 and 59 years of age who had BMIs of 25.1 to 25.4. However, these 3 subjects were under 108% of standard weight for height and had body fat percentages ranging between 11 - 21%, which were within the recommended healthy body fat ranges for men in this age category according to Gallagher et al. (180) and therefore remained in the normal weight group. In addition body fat percentages in 2 normal weight males were slightly higher than the recommended healthy body fat ranges; however, since BMIs for these men were under 25 kg/m^2 and they were under 107% of their standard body weight for height, they also were retained in the normal weight group.

The standard computer algorithm flagged 11 FFQs (10%) for possible response errors. Since investigators were present to double check FFQ responses, most of the FFQs were maintained for analysis. For example, the 3 FFQs flagged because more than 15 food items were skipped, were completed by vegetarians who eliminate many food items from their diets. Only one overweight female and subsequently her matched control, were excluded because her FFQ was flagged because too few foods eaten daily and her daily reported energy intake was below 600 kilocalories.

Table 4.2 provides mean intakes of energy and selected nutrients, expressed per 1,000 kilocalories. Independent *t* tests indicated that overweight/obese subjects consumed significantly more total fat, saturated fat, and cholesterol (P<.01) and significantly less carbohydrate, complex carbohydrate and dietary fiber per 1,000 kcals (P<.01) than their normal weight matched controls. Similar findings were seen for females between groups, but were absent for males. Total energy intake did not differ by group or gender. However, when energy and nutrient consumption was adjusted for body weight, some of the differences in nutrient intake disappeared while others became apparent. Energy intake per kilogram of body weight was approximately 5 kcal/kg of body weight less for overweight/obese subjects when compared to controls (P<.01). Group and female differences in consumption of total fat, saturated fat or cholesterol disappeared after adjustments were made for body weight. As a group, overweight/obese adults and overweight/obese females consumed less protein, carbohydrate, complex carbohydrate, dietary fiber, calcium and sodium per kilogram of body weight than their controls ($P<.05$). However, overweight/obese males and their normal weight controls differed only in the consumption of less complex carbohydrate and dietary fiber per kilogram of body weight by the overweight/obese group ($P<.05$).

Mean intake of food servings per day by group and by gender are presented in Table 4.3. Food servings per day as defined by the 1992 Food Guide Pyramid servings (187) and teaspoons of added sugar as defined by USDA National Nutrient Database for Standard Reference (182) were employed for these analyses. On average, overweight/obese subjects consumed about one more meat serving/day and one less fruit serving/day than their normal weight controls ($P<.01$). Similar results were observed for female subjects. Normal weight males also consumed more fruit servings per day than overweight/obese males. Surprisingly, consumption of added sugar did not differ between groups.

Spearman correlations were examined to show the interrelations between key dietary components and percent body fat. Correlation coefficients for fiber and complex carbohydrate, expressed in grams, percent of kilocalories, per 1,000 kilocalories and per kilogram of body weight, were negatively related to percent body fat ($r \geq -0.25$, $P<.01$). Fat, expressed in grams, percent of kilocalories, per 1,000 kilocalories, but not per kilogram of body weight, was positively related to percent body fat ($r \geq 0.26$, $P<.01$). Fruit servings per day, one of the two food groups that differed significantly between groups, was negatively related to percent body fat ($r = -0.40$, $P<.01$). Similar significant correlations between percent body fat and fiber and fruit servings/day ($r \geq -0.35$, $P<.05$) and fat ($r = 0.54$, $P<.01$) were found for females; however servings of fruit per day was the only significant dietary component related to percent body fat for males ($r = -0.44$, $P<.01$).

Table 4.4 presents regression analysis results for dietary fiber, total grams and per 1,000 kilocalories, as predictors of percent body fat with and without controlling for potential confounding factors. Before adjusting for differences in control variables, total dietary fiber in grams was a significant negative predictor of percent body fat, accounting for 5.2% of the variance. After controlling for age, physical activity-related energy expenditure, gender, total energy intake, and other macronutrients expressed in absolute weight, dietary fiber remained a significant contributor to percent body fat, accounting for 4.5% of the variance. Before adjusting for control variables, grams of dietary fiber per 1,000 kilocalories explained 6.7% of the variance in percent body fat. This parameter still explained 3.7% of the variance after controlling for confounding variables, i.e., age, physical activity-related energy expenditure, gender, total energy intake, and other macronutrients expressed per 1,000 kcal. Regression analyses of all other dietary components expressed in terms of absolute weight and as a percentage of kilocalories (e.g., fat, carbohydrate, protein) were examined, but none of these components were significant predictors of percent body fat or they were multi-collinear, i.e., inter-correlated between individual variables.

Also shown in Table 4.4, carbohydrate when expressed per kilogram of body weight was the only nutrient that significantly predicted percent body fat, accounting for 14.8% and 13.5% before and after controlling for confounding variables. Carbohydrate per body weight accounted for an even larger amount of the variance in percent body fat for females as a group, 21.4% ($F=18.02$, $P<.0001$) and 18.7% ($F=29.74$, $P<.0001$) before and after controlling for confounding variables.

DISCUSSION

A key finding of our study is that diet composition between overweight/obese adults and their normal weight counterparts is substantially different and may play a vital role in promoting or preventing obesity. Although total energy intake did not differ significantly between the groups, an absolute difference of about 200 kilocalories per day on the average in subjects matched for age and height would mediate toward weight gain of approximately 20 pounds per year in the overweight/obese group.

Overweight or obese adults consumed a larger portion of their energy from fat and a smaller portion from carbohydrate, specifically dietary fiber and complex carbohydrate, than their matched controls. Normal weight subjects received 33.5, 17.2, and 52.0% of energy from fat, protein, and carbohydrate, respectively; these values were similar to averages of US adults studied in the 1996 national consumption survey (188), of 32.7, 15.6, and 51.2% energy from fat, protein, and carbohydrate, respectively. Corresponding values for overweight/obese subjects in the present study were 38.7, 18.1, and 44.9% of total energy from fat, protein, and carbohydrate, respectively.

Most notable is the difference in dietary fiber and complex carbohydrate, which includes many high fiber foods, intake between the two groups and the possible effect that these dietary components have on weight status and adiposity. When dietary fiber and complex carbohydrate were expressed per 1,000 kilocalories, normal weight adults consumed an average of 33% more dietary fiber and 43% more complex carbohydrate daily than their overweight/obese counterparts. Several mechanisms by which dietary fiber may reduce risks for developing obesity are identified in the literature. The physical properties of dietary fiber, e.g., bulk/volume, viscosity, and water-holding capacity, enable it to slow digestion and absorption of nutrients, control rapid rises or falls in blood glucose, enhance satiety, and suppress energy intake (92, 94, 110, 167). Also foods high in dietary fiber are usually low in fat and energy. By increasing dietary fiber, one might subsequently decrease consumption of other energy/fat dense foods. The complete effects of dietary fiber on weight are not entirely clear, but many studies report that subjects found it easier to adhere to a weight loss diet when fiber was included in the dietary regimen (92, 111).

Dietary fiber was the only nutrient that when expressed by absolute weight accounted for a significant amount of the variance in percent body fat, both with and without controlling for other variables. Carbohydrate was the only nutrient, when expressed relative to body weight that significantly predicted body fat, before and after controlling for confounding variables. Although dietary fiber and carbohydrate appear to account for a rather small amount of the variance in body fat, 4-19%, the association provides useful information that could help bridge the gap between dietary components and adiposity and eventually aid in developing weight loss interventions.

The consumption of added sugar and fat has been identified as a primary culprit for increases in obesity (26, 127). Since the FGP does not specify what defines fat, oil, sweet or soda servings in the top category of the pyramid, often times investigators use the frequency of such items for analysis. Strangely enough, the frequency of added fats, oils, sweets, and sodas did not differ between groups. Nor were there differences evident between groups for percent of total energy from sweets or from added sugars in our sample. In addition, foods items higher in sugar content, such as cakes and cookies, were not significantly correlated to the weight parameters or to body fat percentage. However, possibly those foods higher in sugar and fat were under-reported more often than fruits, vegetables and lean meats. Our results indicate that diets low in fruit and high in meats, specifically high fat meats, exerted greater influence on weight and adiposity than added sugar or fat.

In order to apply these results to practice settings, e.g., weight loss interventions, one must look also at individual foods and food groups. Overweight subjects consumed approximately one less fruit serving daily when compared to their normal weight controls, which may partly explain differences in dietary fiber and carbohydrate between the two groups. Individual fruit items, e.g., fresh fruit and apples, were inversely related to weight, BMI and percent body fat for the entire group and for each gender ($r \geq -0.24$, $P<.01$). Surprisingly, fruit servings per day were positively correlated to teaspoons of added sugars ($r = 0.40$, $P<.01$). A possible explanation for the negative correlation of fruit with body fat, but positive correlation of fruit with added sugar content, might be that normal weight subjects added sugar to fruit sources, or ate fruits processed with more sugar (e.g., canned fruit in syrup), whereas overweight/obese subjects got their added sugars from baked products and other sweets. Subjects with excess weight also consumed an average of one meat serving more than their controls. Many of the high fat meats, e.g., breakfast sausage, hamburgers, and fried chicken and fish, were positively related to weight, BMI and percent body fat for the entire group and for females as a group ($r \geq 0.23$, $P<.05$).

Low vegetable consumption has been identified as a factor in the etiology of excessive weight gain (24, 127). Surprisingly, daily servings of vegetable were almost identical for both overweight/obese and normal weight groups, approximately 3.7 servings/day. To investigate further vegetable consumption was analyzed with and without both French fries and all potatoes. Daily servings of vegetables without French fries and all potatoes did not differ between the groups; 3.4 ±2.2 and 3.1 ±2.0 for overweight/obese versus 3.5 ±2.1 and 3.3 ±2.0 for normal weight subjects, respectively. In addition, vegetable servings a day, with and without including French fries and potatoes, were not significantly correlated to weight parameters or body composition. However, daily servings of French fries, were positively related to weight, BMI and body fat ($r \geq 0.25$, $P<.01$) for the entire group and for females.

Major advantages of the present study are that overweight/obese subjects were matched to normal weight adults for gender, age (±1 year) and height (±1 inch). This design allowed for direct comparisons of individuals, with theoretically similar energy needs, one group having maintained their weight within normal limits and another being overweight or obese. This matching more readily allocated differences in body weight and body fat to be attributed to dietary differences than is possible when unmatched groups are compared. To date, others have not reported the effect of nutrients on percent body fat and/or compared nutrient intake among overweight/obese adults and controls matched for gender, age and height. To our knowledge, only one other study compared dietary intakes between overweight/obese women and their normal weight controls, and in that investigation, subjects were matched for age only. Westerterp-Plantenga (126) reported that overweight women consumed a larger percentage of their total energy from fat and a lower percentage from carbohydrate when compared to their controls, but the effect that dietary components exerted on body fat was not explored.

Another advantage of the present study is that multiple regression techniques controlling for confounding variables were employed to assess the predictive power of dietary components on percent body fat. Few studies have looked at this phenomenon while controlling for other variables. Nelson et al. (120) who studied 203 adult men, found carbohydrate, complex carbohydrate and dietary fiber to be inversely associated with percent body fat after controlling for age, energy intake and fitness level. Tucker et al. (146) reporting on 205 females, showed that dietary fat, after controlling for confounding variables, accounted for 2.1% of the variance and was the only dietary component positively associated with percent body fat. Our regression analyses yielded similar results for dietary fiber and carbohydrate, but not for complex carbohydrate and dietary fat. Differences in population and methodology may account for differences in findings. In the current study, genders were analyzed together and separately, and percent body fat was measured with DXA, often regarded as a more sophisticated and accurate tool for body composition than skin-fold measures (35, 36) used by Nelson et al. (120) and Tucker et al. (146), each of whom studied only one gender.

A continual daunting task for investigators and an obvious limitation of the present study is the use of self-reported data to assess dietary intake. It has been well documented that all individuals under-report habitual dietary intake and there is a concern that overweight or obese subjects are even more likely to under-report dietary intake than those of normal weight. However, some investigators report that adults of normal and excess weight underestimate dietary intake to the same extent (166, 167). Although self reported instruments have limitations, easy administration and relatively low cost of these instruments allow more investigators to have access to habitual dietary intakes, especially for larger populations than would be possible with observation or measured methods of data collection.

APPLICATION

Despite the substantial evidence that diets high in fat, saturated fat, and cholesterol and low in carbohydrate, especially complex carbohydrate and dietary fiber, promote weight gain, both short-term and long-term (122, 189), the public is still attracted to popular weight loss strategies that emphasize decreasing carbohydrate and increasing fat and protein. Although, there is evidence that high protein, low carbohydrate diets produce substantial weight loss in the short term (122), to date, there are no long-term studies that examine the effects of these regimens. Obviously, no magic formula exists for weight loss, but our results indicate that a diet containing more than average amounts of fiber, complex carbohydrate and fruit is associated with normal body fat stores and standard weight for height. It appears that increasing dietary fiber, complex carbohydrate and fruit and vegetables in an individual's diet should be an important part of dietary intervention designed for weight management.

Table 4.1 Age, height, weight, BMI and percent body fat of matched pairs of overweight/obese and normal weight adults [a]

	Overweight/Obese Group [b]			**Normal Weight Group** [c]		
	Total (n=52)	Men (n=18)	Women (n=34)	Total (n=52)	Men (n=18)	Women (n=34)
Age (y)	39.7±12.3	39.9 ±10.5	39.5 ±13.4	39.8 ±12.2	39.8 ±10.1	39.7 ±13.3
Height (cm)	168.9 ±9.4	181.1 ±5.6	163.6 ±4.8	170.7 ±9.1	181.1 ±5.6	165.1 ±4.8
Weight (kg) [d, e, f]	96.4 ±14.7	106.7 ±9.4	90.9 ±14.1	65.4 ±11.7	79.5 ±7.0	57.9 ±4.5
Std wt. for ht (%) [d, e, f]	157.0 ±23.9	141.7 ±18.0	165.0 ±22.9	101.5±5.1	100.9 ±5.0	101.9 ±5.2
BMI [d, e, f]	33.7 ±4.0	33.1 ±1.8	34.0 ±4.8	22.2 ±1.8	24.2 ±1.2	21.2 ±1.0
Body fat (%) [d, e, f]	43.0 ±7.8	34.4 ±4.4	47.5 ±4.7	25.1 ±6.0	20.9 ±3.9	27.3 ±5.8

[a] Mean ±SD.
[b] >125% standard weight for height.
[c] 90-110% standard weight for height.
[d] Significant group effect (*t* test), $P<.01$.
[e] Significant female effect between groups (*t* test), $P<.01$.
[f] Significant male effect between groups (*t* test), $P<.01$.

Table 4.2 Energy and selected nutrient intake, expressed per 1,000 kilocalories, from the Block FFQ for overweight/obese subjects and their normal weight controls matched for gender, age and height [a]

Energy & Nutrients [d]	**Overweight/obese** [b] Total (n=52)	Men (n=18)	Women (n=34)	**Normal weight** [c] Total (n=52)	Men (n=18)	Women (n=34)
Calories	1806 ±723	2181 ±766	1607 ±623	1569 ±581	1909 ±678	1395 ±447
Total Fat (g) [e, f]	42 ±8	42 ±7	41 ±8	35 ±8	38 ±9	33 ±6
Saturated Fat (g) [e, f]	14 ±3	15 ±3	14 ±3	12 ±3	13 ±4	11 ±3
Cholesterol (mg) [e, f]	150 ±84	154 ±74	148 ±90	112 ±47	131 ±62	103 ±34
Protein (g)	44 ±10	42 ±8	44 ±11	41 ±8	40 ±10	41 ±7
Carbohydrate (g) [e, f]	111 ±23	107 ±18	114 ±26	127 ±26	121 ±32	130 ±23
Complex carbohydrate (g) [e, f, g]	43 ±23	33 ±17	49 ±24	62 ±34	51 ±27	68 ±36
Dietary fiber (g) [e, f]	9 ±3	9 ±3	10 ±4	12 ±5	11 ±5	13 ±5

[a] Mean ±SD.
[b] >125% standard weight for height.
[c] 90-110% standard weight for height.
[d] Nutrients expressed per 1,000 kilocalories.
[e] Significant group effect (*t* tests), *P*<.01.
[f] Significant female effect between groups (*t* tests), *P*<.01.
[g] Significant male effect between groups (*t* tests), *P*<.01.

Table 4.3 Food servings/day and added sugar content identified by the Block FFQ for overweight/obese subjects and their normal weight controls matched for gender, age and height [a]

Food Guide Pyramid Servings	Overweight/obese [b]			Normal weight [c]		
	Total (n=52)	Men (n=18)	Women (n=34)	Total (n=52)	Men (n=18)	Women (n=34)
Bread	4.2 ±2.6	5.4 ±2.9	3.6 ±2.3	4.1 ±2.3	4.7 ±1.9	3.8 ±2.5
Meat [d, e]	2.6 ±1.3	3.0 ±1.1	2.4 ±1.3	1.8 ±1.0	2.4 ±1.4	1.5 ±0.6
Dairy	1.3 ±1.2	1.5 ±1.3	1.3 ±1.1	1.3 ±1.0	1.3 ±1.2	1.3 ±0.9
Fruit [d, e, f]	0.9 ±0.9	0.9 ±0.9	0.9 ±0.9	1.6 ±1.0	1.5 ±0.9	1.7 ±1.0
Vegetable	3.7 ±2.2	3.2 ±2.1	3.9 ±2.3	3.7 ±2.1	3.5 ±1.6	3.7 ±2.3
Added sugar (tsp)	9.3 ±5.5	11.2 ±6.7	8.3 ±4.6	9.0 ±5.7	11.5 ±8.1	7.7 ±3.4

[a] Mean ±SD. Food servings per day were defined by the 1992 Food Guide Pyramid servings (182), and added sugar was defined by the USDA National Nutrient Database for Standard Reference (186).
[b] > 125% standard weight for height.
[c] 90-110% standard weight for height.
[d] Significant group effect (*t* tests), *P*<.01.
[e] Significant female effect between groups (*t* tests), *P*<.01.
[f] Significant male effect between groups (*t* tests), *P*<.05.

Table 4.4 Relationship between dietary fiber and carbohydrate intake to percent body fat without and with control for potential confounding factors for overweight/obese subjects and their normal weight controls matched for gender, age, and height [a]

	Criterion variable: percent body fat			
Predictor variable	**Variables controlled**	**F**	**R^2**	**P**
Dietary fiber (g)	None	5.59	0.052	0.020
	Age, physical activity-related energy expenditure, gender, total energy, protein, carbohydrate, and fat intake.	6.35	0.045	0.013
Dietary fiber grams per 1000 kcals	None	7.37	0.067	0.008
	Age, physical activity-related energy expenditure, gender, total energy, and protein, carbohydrate, and fat per 1000 kcals	5.59	0.037	0.020
Carbohydrate per kg of body weight	None	17.72	0.148	< 0.0001
	Age, physical activity-related energy expenditure, gender, total energy, protein, dietary fiber, and fat intake per kg of body weight.	34.01	0.135	<0.0001

[a] Values for F, R^2, and P do not represent the total regression model, but only the contributions of dietary fiber consumption before and after control for the other potential confounders.

Chapter 5: Commonly Used Activity Factors Fail to Assess Total Energy Expenditure Accurately

ABSTRACT

Objective To assess the accuracy of activity factors, i.e., values that represent energy expenditure in physical activity, as measured by accelerometers (AF_{ACC}), those determined by the World Health Organization (AF_{WHO}), which are commonly used in dietetic practice, and those published in the Dietary Reference Intakes (DRIs) for energy published in 2002 (AF_{DRI}) for overweight/obese subjects and their normal weight matched controls.

Subjects/Setting A convenience sample of 62 overweight/obese and normal weight adults were recruited from the local area to assess voluntary activity. Subjects were 31 overweight/obese adults, 12 males and 19 females, ages 25-69 years, and their normal weight controls matched for gender, age and height.

Design Resting energy expenditure (REE) was assessed with indirect calorimetry, and then a laboratory specific correction factor was applied to convert the REE values to basal energy expenditure. Physical activity was measured with accelerometers, worn by each participant during waking hours for 7 consecutive days. A panel of 8 Registered Dietitians (RDs) completed a questionnaire in which they assigned an AF_{WHO} to subject prototypes based on occupations and reported voluntary exercise. The AF_{WHO} most frequently assigned by the panel for each prototype was assigned to subjects that fit that prototype. An AF_{DRI} also was assigned to each subject based on age, BMI classification and

intensity level determined by the panel of RDs.

Statistical analyses performed Repeated measures analyses of variance were employed to compare activity factors within and between each group.

Results For the total sample, the mean AF_{ACC} was significantly lower than both the AFWHO and AF_{DRI}. When differences between activity factors within normal and overweight/obese groups were examined, the mean AF_{ACC} was significantly lower than activity factors derived from the WHO and DRI for normal weight adults, but the three activity factors did not differ among the overweight/obese group.

Applications/conclusions AFs determined by the WHO and DRI may overestimate energy needs for many adults, particularly those of normal weight. Dietetic practitioners should consider using more conservative activity factors for normal weight subjects or standardized activity factors from accelerometry data should be developed in order to improve practitioner's accuracy in estimating an individual's energy needs.

INTRODUCTION

Obesity has reached epidemic proportions for adults living in the United States. An alarming 64% of American adults are either overweight or obese by body mass index (BMI) standards of ≥25 or >30 kg/m^2, respectively (1). The rapid increase in the prevalence of obesity points to environmental and behavioral changes rather than genetic modifications as the primary causes. Weight gain ultimately results from a chronic modification of the energy balance equation, i.e., total energy intake continually exceeding total energy expenditure (10). Total energy expenditure (TEE) includes energy at rest, thermic effect of food, and physical activity. It is generally accepted that basal energy expenditure (BEE) is the largest component of TEE, accounting for >50% of the variance in TEE. Research also has consistently shown that the thermic effect of food accounts for 10% of the variance in TEE. The remaining component, physical activity, is the most variable component in the energy balance equation, accounting for anywhere from less than 5 to over 40% of TEE in humans (10). Physical activity includes exercise, activity performed for the purpose of improving fitness, and spontaneous activity, activity spent for the purpose of carrying out daily tasks. Because physical activity is the most variable component of TEE, it has the potential of being a key player in the etiology, prevention or treatment of obesity.

The imbalance in the energy equation that is promoting the epidemic obesity may be explained partly by individuals perceiving their energy needs to be higher than they actually are. For decades, clinicians have relied on predictive equations utilizing data, such as height, weight, age, and gender, to estimate energy needs. The two most popular protocols for estimating energy needs include equations such as the Harris Benedict Equation (HBE) (168), which estimates BEE, and the Dietary Reference Intakes (DRIs) (18), which estimate total energy expenditure (TEE). When an equation such as the HBE is used, the basal value is multiplied by an activity factor, established by the World Health Organization (WHO), and in some cases by a stress factor related to illness or injury, to determine TEE (170). The WHO activity factors (AF_{WHO}), based on many studies conducted in the early 1970s, were determined by the type and amount of time that young women and men throughout the world, ages 18-30 years, spent in occupational activities. A few years later the activity factors were expanded to include a wider range of occupations and leisure-time activities, AF_{WHO} ranges from very light to exceptional activity level (171). In 2002, the subcommittee for macronutrients updated the Dietary Reference Intakes (DRIs) for energy, citing doubly labeled water (DLW) studies that they believed to more accurately assess and determine total energy expenditure than the earlier work. DLW was employed to determine the ratio of total energy expenditure to basal energy expenditure (TEE/BEE), otherwise referred to as the physical activity level (PAL), for age and BMI status. The measured PALs were then assigned to various PAL intensity categories, e.g., sedentary, low active, active, and very active. Regression equations, using age, height and weight, and physical activity coefficients based on PAL intensity categories, determined the DRIs for energy. Either of these two methods, i.e., AF_{WHO} or AF_{DRI}, for predicting energy requirements require the dietetic practitioner to assign the AF to an individual, a decision generally based on that person's reported voluntary exercise level and occupation.

The purpose of this study was to assess and compare activity factors derived from accelerometers, WHO values and DRIs within and between a group of overweight/obese subjects and their normal weight counterparts matched for gender, age, and height. This matching design would allow direct comparisons of activity factors for individuals, with theoretically similar energy needs, one group having maintained their weight within normal limits and another being overweight or obese.

METHODS

Subjects

Subjects were recruited by posting flyers at local gyms, hospitals, sporting activities, and health centers and through a campus wide e-mail to faculty and staff. Out of the original 106 subjects recruited, a convenience sample was solicited to wear the accelerometers. The sub-sample included 62 willing subjects, aged 25 to 69; 31 of whom were overweight with a BMI 25.0-29.9 or obese with a BMI≥30 subjects and 31 normal weight subjects with a BMI 18.5-24.9 (182) matched for gender, age (± 1 year) and height (± 1 inch). Anthropometrics, body composition or physical activity levels did not differ significantly between the original group and the sub-sample. No monetary compensation was given, and subjects participated with the sole incentive of receiving their test results. All subjects completed the study; there were no missing data points. Before providing informed written consent, subjects were informed of the experimental protocol approved by the University Internal Review Board.

Anthropometrics, Body Composition, and Health History

Most of the data were collected in a campus laboratory. In a few cases, the indirect calorimetry was measured in the subject's or investigator's home. After subjects completed consent forms, height and weight were measured using a physician scale (Detecto, Webb City, MO) and stadiometer (SECA, Columbus, OH), with participants wearing light clothing and shoes removed. Subjects completed a short demographic and health history questionnaire, which included questions about occupation and past medical history.

Indirect Calorimetry

A portable Deltatrac Metabolic Monitor with an open circuit ventilated hood (serial number 65001, Sensor Medics Corporation, Yorba Linda, CA) was used to measure resting energy expenditure (REE). This instrument was calibrated according to manufacturer instructions before the first measurement of each testing day. Subjects were instructed to fast, except for plain water, and refrain from smoking cigarettes or taking any medication for at least three hours before being tested. In addition, participants were asked not to engage in any strenuous physical activity for at least twenty-four hours preceding the measurement. Participants were measured for a minimum of 15 minutes in a supine position in a semi-private comfortable room and were allowed to view non-stimulating National Geographic videos during the test. Results were calculated based on ten-minute average for minutes six through fifteen. For these minutes a "steady state" criterion of a coefficient of variation ≤10% for VO_2 was applied; for individuals who failed to meet the criterion, a mean of 5 consecutive minutes within the same time period with a coefficient of variation ≤5 % was accepted.

Additional data collected in our laboratory indicated that energy expenditure under resting conditions for minutes 6 through 15 was about 12%

higher than that measured for the same time period under basal conditions (190). Since we planned to compare our data with equations based on data collected under basal conditions, the resting values were reduced by 12% and will be referred to as basal energy expenditure (BEE).

Physical Activity

Physical activity was measured with accelerometers worn by subjects for 7 consecutive days. The CSA uniaxial accelerometer (Computer Science and Applications, Inc., Shalimar, FL), also called an ActiGraph, when worn on the waist enables conversion of accelerometer data into kilocalorie expenditure using a Microsoft ActiSoft program (ActiSoft version 3.2, 2003, Computer Science and Applications, Inc., Shalimar, FL) (65). Accelerometer readings were recorded and stored on a minute-by-minute basis and later downloaded to a computer, via a Reader Interface Unit. The activity data were expressed as total counts divided by registered time, i.e., $\text{counts}^{-1} \cdot \text{min}^{-1} \cdot \text{d}^{-1}$. Based on the ratio of exercise metabolic rate to resting metabolic rate for various activities, also known as the MET system, the counts were converted into kilocalorie expenditure and minutes spent in different intensity levels, i.e., light, moderate, hard and very hard were identified (65). Accelerometer data were collected over a 6-month time span, May to October. Subjects were instructed to wear the accelerometer in the same location on their waist every day. To aid in proper placement of the accelerometer and to accommodate subject preference and comfort, protective pouches, elastic belts and clips were provided. Subjects also were asked to complete a written log of times and/or activities when the accelerometer was not worn, e.g., swimming and water skiing. Energy expended from these additional activities was calculated using the Compendium of Physical Activities (67) .

Activity Factors

The daily kilocalorie expenditure from physical activity, determined from accelerometer data, was added to BEE and then divided by the BEE, to yield an objective activity factor (AF_{ACC}).

$$\text{AF as \% BEE} = \frac{\text{accelerometer physical activity (kcal/d)} + \text{BEE}}{\text{BEE}} * 100 = AF_{ACC}$$

As seen in the partial sample question provided in Figure 5.1, a panel of eight Registered Dietitians completed a questionnaire, where they were asked to assign an AF_{WHO} to subjects based on a prototype of occupations and reported activity levels. The prototypes of occupations were obtained from the demographic and health history form and the reported activity was obtained from a 40-item Yale Physical Activity Survey (179) that was administered to each subject during the initial campus visit. The intensity activity factor most often assigned by the panel was used (AF_{WHO}). The assigned activity factors for very light, light, moderate, heavy, and exceptional activity were 30, 50, 60, 90, and

120% of BEE, respectively, for women and 30, 60, 70, 110, and 140% of BEE, respectively, for men (171).

A physical activity level (PAL) from the 2002 DRIs (18) also was assigned to each subject based on each subject's activity level, determined from the prototype assignments by the expert panel, age and BMI. Since the PAL index is essentially the same concept as the AF, for simplicity the PAL values will be referred to as AF_{DRI}.

Statistical Analyses

Data were analyzed using the Statistical Package for the Social Sciences (SPSS 11.0, 2002, SPSS inc, Chicago, IL). All variables tested were normally distributed. Analyses of variance (ANOVA) were performed to assess differences in age, anthropometrics, and BMI between genders and groups. A repeated measures ANOVA, including the within subject variables of activity factors (as derived from accelerometers, WHO, and DRIs) and the between subject variable of group (overweight/obese and normal weight) was used to compare activity factor measures within each group and between each group. Repeated measures analyses were followed with Bonferonni adjusted paired comparisons. A *P* value of <.05 identified statistical significance.

RESULTS

The 62 subjects included 31 overweight/obese subjects, 12 males and 19 females, and 31 normal weight subjects matched for gender, height and age. Mean age, height, weight, BMI and BEE of the study participants are presented in Table 5.1. Mean differences of 2.0 centimeters and 0.4 years were observed in height and age, respectively, between the overweight/obese and normal weight groups. On average, the obese group was 28 kilograms heavier than their matched controls. Occupations reported by subjects on the health history form included homemakers, engineers, teachers, fitness instructors, and pastors. Six of the normal weight participants reported more active occupations than their overweight/obese counterpart, such as fitness instructors and construction workers. In addition, four of these same individuals were involved in recreational endurance sports, e.g., long distance running and cycling. On average, the BEE of the overweight/obese was 200 kcal/d more in overweight/obese subjects compared to their normal weight controls, a finding that would be expected due to their larger body masses.

Participants wore the accelerometer for an average of 7.0 ±0.6 days, for 24 hours a day and removed them only for showering and water activities. Data showed that subjects in both groups rested or slept an average of 9 hours a night and were awake for approximately 15 hours a day. One subject wore the accelerometer for only 5 days and 4 subjects wore the accelerometer for 6 days. All other subjects wore them for the full week. Daily physical activity-related energy expenditures were calculated using the number of days that each participant actually wore the accelerometer.

A repeated measure ANOVA was employed to assess differences between activity factors measures (derived from accelerometers, WHO, and DRI) within the total sample, within each group (overweight/obese and normal weight subjects), and between each group. Even though the subjects were matched pairs, age was entered as a covariate. Neither the main effect of age or interaction effect with age was significant; indicating the effect of age on the other variables was controlled for by matched pairs.

For comparisons between activity factors across the total sample, mean AF_{ACC} was significantly lower than both AF_{WHO} and AF_{DRI} (40 ±3 vs. 49 ±2 and 48 ±2%; P<.0001), while AF_{WHO} and AF_{DRI} were not different. On average, activity factors derived from accelerometers were about 10% lower than those determined by the WHO and DRIs.

Activity factor comparisons within and between each group are shown in Figure 5.2. AF_{ACC} were significantly lower than both AF_{WHO} and AF_{DRI} for normal weight subjects, while the latter two were not different. Activity factors generated by the three methods did not differ for overweight/obese subjects. When comparing activity factors between groups, AF_{DRI} and AF_{WHO} were significantly lower, approximately 15%, among the overweight/obese subjects compared to their normal weight controls. AF_{ACC} did not differ between groups.

DISCUSSION

A possible interpretation of the similarity of activity factors for the two groups derived from accelerometer data but differences seen in those factors derived from WHO or DRI methodology is that WHO and DRI activity factors overestimate energy expenditure in the normal weight subjects who were more active than their overweight/obese matches. The overestimation may occur because practitioners tended to place too much value on the exercise and/or occupation activity among those reporting an active lifestyle, more of whom were in the normal weight than the overweight/obese group.

Over the past decade, concerns have been raised regarding the accuracy of using WHO activity factors methodology for estimations of TEE (25, 31, 70, 172). Recently, investigators have found activity factors derived from DLW techniques, i.e. TEE/BEE, to be substantially higher than those proposed by the WHO. Many of these measured AF for sedentary to moderately active individuals ranged from 80 to 150% of BEE, which are considerably higher than the WHO activity factors of 30 to 70% of BEE for sedentary and moderately active individuals (25, 31, 174-177). In contrast, two groups found that TEE derived from WHO activity factor methodology and DLW were similar to one another (70, 172). Investigators who found high values for activity factors derived from DLW believed that a person's energy needs would be severely underestimated using the WHO activity factors (25, 31, 174-177). However, in our subjects the activity factors from DRI and WHO were comparable.

Based on these DLW studies, the 2002 DRIs for energy requirements were developed with the objective of more accurately estimating physical activity related energy expenditure and TEE. Although the DRIs are derived from DLW data, dietetic practitioners are still responsible for classifying the intensity level of a particular individual's activity, just as they are when using AF_{WHO}, before the energy calculation can be performed. A major concern with using either the WHO activity factors or the DRI methodology are that they both rely to a large extent on subjective measures.

Our findings suggest that practitioners overestimated the cost of reported physical activity for normal weight subjects and assigned activity factors that were too generous for the activity that was actually preformed. Although occupation played a part in the assignment of WHO and DRI activity factors, it appears that reported voluntary exercise was the primary influential factor for the Registered Dietitians on our panel. This phenomenon becomes more apparent when examining matched pairs who had similar occupations. For example, an overweight health care worker reported exercising 3-7 times a week and was assigned a light activity factor (50% BEE), while the normal weight health care worker reported exercising over 7 times a week and was assigned a moderate activity factor (60% BEE). For the overweight health care worker, the energy expenditure from the accelerometer and the energy expenditure that was applied using both WHO and DRI activity factors, was similar, providing an additional 700 kcal/day for physical activity. However, for the normal weight health care worker, the energy expenditure measured by the accelerometer was 430 kcal/day versus the 710 kcal/day that was applied by using the WHO activity factor and 980 kcal/day that was applied using the DRI activity factor. The high level of reported exercise by the normal weight subject apparently influenced the panel of dietitians to assign a moderate intensity activity factor, that essentially doubled the physical activity related energy expenditure as measured by accelerometry. It is documented (68, 69) that individuals tend to over report exercise, and this error may be compounded by dietetic practitioners who are quick to assign moderate intensity factors to their clients that report planned exercise, when in actuality these clients are more often sedentary and do not merit the higher activity classification. At most, the majority of individuals in the American population should probably be assigned a very light/sedentary or light/low active activity factor, i.e., 30 to 50% of BEE for females and 30 to 60% for males, regardless of reported exercise levels. Practitioners, however, may be hesitant to label their clients' activity as very light/sedentary or light/low active because of the negative connotations of the terms. Our data indicate that education of practitioners to assign more conservative activity factors to individuals is definitely warranted.

The only true way to accurately assess every individual's physical activity related energy expenditure is to directly measure it. Recent advances in accelerometer technology provide investigators with a relatively inexpensive and easy to administer instrument to measure free-living energy expenditure. Ideally if dietetic practitioners had their clients wear accelerometers for a prescribed period, accuracy of estimates of an individual's energy needs would be enhanced considerably. In some nutrition assessment settings, direct activity measurement might be possible, but cost and time preclude its implementation in every situation.

Results from the present study suggest that if activity factors were developed from accelerometer data, they would be lower than those activity factors derived from WHO and DRIs, at least for normal weight adults. Developing standardized activity factors from accelerometers might decrease the possibility of overestimating a person's energy requirements and allow practitioners to recommend energy intake with greater confidence. If a fairly large sample were to wear accelerometers for a prescribed period and record their daily physical activity levels, especially planned exercise, during that period then reported values could be matched to energy expenditure measured by the accelerometer data and later converted into the appropriate activity factor.

Nevertheless, practitioners would still be responsible for assigning these accelerometer activity factors, which means they would continue to rely to some extent on subjective measures. Thus education the practitioners should not be neglected.

Although, accelerometers provide researchers a more accurate and reliable tool for measuring physical activity in free-living populations, these instruments are not without limitations. Waist-mounted accelerometers are less accurate in measuring activities that require more arm movement, i.e., cooking, golf, deskwork, and weight training (59, 66). In addition accelerometers that are presently available cannot be used for swimming or other water activities. However, our participants were asked to keep a log of all swimming and water activities and to record any activities performed that required excessive arm movement. Fortunately very few of our participants (n=5) were swimmers, and their logs allowed us to account for the duration and frequency of the extra swimming activity.

Other limitations of the current study should be noted. All subjects in this study were volunteers who agreed to participate in a health study, and it is likely that they were more active than the general population. Thus, among the general population, larger differences in activity factors might have been apparent, e.g., activity from accelerometer would probably be lower and assuming exercise would still be over reported, the gap between measured and predicted activity factors would likely be wider. Another limitation is the relatively small sample size, especially for males.

APPLICATIONS

In most clinical and outpatient nutrition assessments, BEE prediction equations multiplied by WHO activity factors or PALs based on DRI methodology, to account for the physical activity component in the equation, are employed to estimate total energy needs. Our results suggest that activity factors determined by WHO and DRIs overestimate energy needs when compared to activity factors derived from accelerometers, at least among normal weight subjects. Dietetic practitioners should consider choosing a conservative activity factor, e.g., very light/sedentary or light/low active, for most individuals in the United States. Further research to establish standardized activity factors derived from accelerometer data from a large, appropriately selected population could provide practitioners with better tools for assessing energy needs also.

Occupation	Time Spent in Moderate Intensity Exercise	Activity Factor Very Light (30/30%)	 Light (60/50%)	 Moderate (70/60%)	 Heavy (110/90%)	 Exceptional (140/120%)
1. Homemaker	0-3 times/wk for 30-60 min/each	☐	☐	☐	☐	☐
	> 3- < 7 times/wk for 30-60 min/each	☐	☐	☐	☐	☐
	> 7 times/wk for > 60 min/each	☐	☐	☐	☐	☐
2. Teacher (all ages)	0-3 times/wk for 30-60 min/each	☐	☐	☐	☐	☐
	> 3- < 7 times/wk for 30-60 min/each	☐	☐	☐	☐	☐
	> 7 times/wk for > 60 min/each	☐	☐	☐	☐	☐
3. Registered Nurse	0-3 times/wk for 30-60 min/each	☐	☐	☐	☐	☐
	> 3- < 7 times/wk for 30-60 min/each	☐	☐	☐	☐	☐
	> 7 times/wk for > 60 min/each	☐	☐	☐	☐	☐

Figure 5.1. Sample questions from the expert panel questionnaire. Experts were asked to assign World Health Organization (WHO) activity factors (AF) based on a prototype of occupations and reported weekly voluntary exercise. The Health History Form was used to develop the prototype of occupations and the Yale Survey was used to establish the prototype of weekly exercise. Assigned WHO AF by gender, as a % of BEE are given with each description (male/female) (171). Each subject was assigned an AF on the decision of the expert panel, based on the subject's occupation and reported weekly exercise (AF_{WHO}). The AF most often selected by the panel was used.

Table 5.1 Age, height, weight, BMI, and BEE of matched pairs of overweight/obese and normal weight adults [a]

	Overweight/Obese Group[b]			**Normal Weight Group[c]**		
	Total (n=31)	Men (n=12)	Women (n=19)	Total (n=31)	Men (n=12)	Women (n=19)
Age (y)	44.0 ±11.9	42.5 ±9.1	44.9 ±13.5	43.6 ±12.0	41.8 ±8.7	44.8 ±13.7
Height (cm)	169.1 ±9.1	178.3 ±6.3	163.1 ±4.3	170.9 ±8.9	180.6 ±5.3	165.1 ±4.3
Weight (kg) [d, e, f]	94.7 ±14.3	105.3 ±9.4	87.9 ±12.7	66.5 ±11.3	78.5 ±7.7	58.8 ±4.1
BMI [d, e, f]	33.0 ±3.3	33.1 ±1.7	32.9 ±4.1	22.5 ±1.5	23.9 ±1.0	21.6 ±0.9
BEE (kcal/d) [d, e, f]	1575 ±299	1867 ±134	1390 ±212	1378 ±260	1660 ±148	1200 ±115

[a] Mean ±SD.
[b] Body Mass Index (BMI) ≥25.
[c] BMI 18.5 - 24.9.
[d] Significant group effect (ANOVA), *P*<.01.
[e] Significant female effect between groups (ANOVA), *P*<.01.
[f] Significant male effect between groups (ANOVA), *P*<.01.

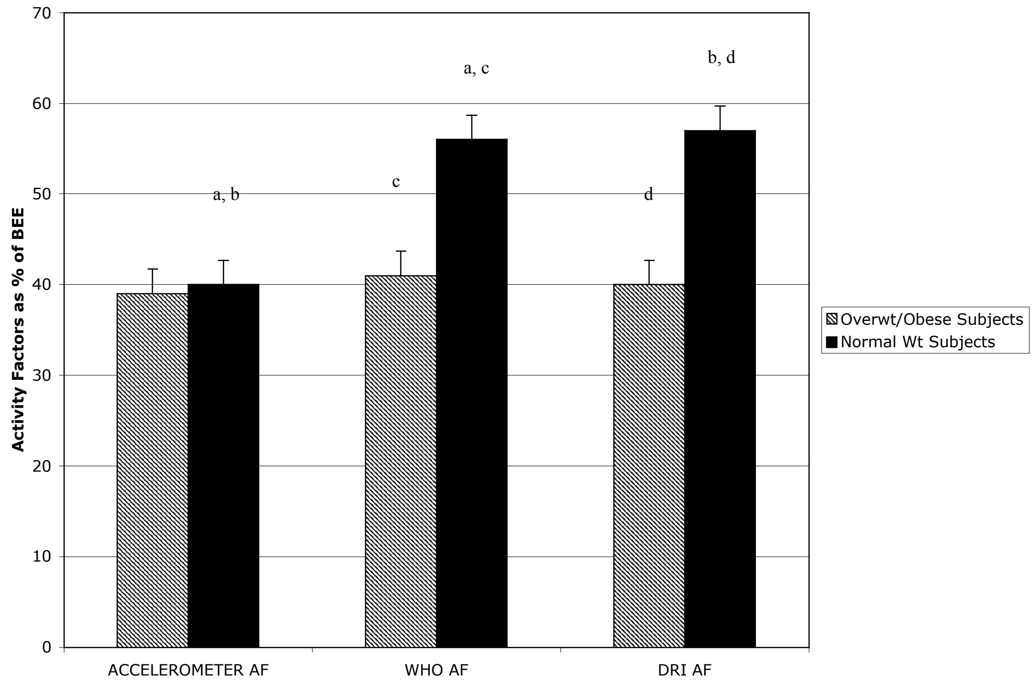


Figure 5.2 Means and standard errors of activity factors (AF) derived from the accelerometers, World Health Organization (WHO), and Dietary Reference Intakes (DRIs) for overweight/obese subjects (n=31) and their matched normal weight controls (n=31). Bars with the same letters differ from each other (*P*<.05).

Chapter 6: Conclusions and Recommendations

The objectives of this study were 1) to assess differences in voluntary physical activity between an overweight/obese population and their normal weight controls matched for gender, age and height; 2) to compare differences in dietary components between these two groups; and 3) to assess the accuracy of commonly used activity factors, i.e., indices used to represent physical activity related energy expenditure in predictive equations for energy, published by the World Health Organization (WHO) and in the Dietary Reference Intakes (DRIs). These results will facilitate the development and implementation of weight management programs.

The final sample size included 106 adults (aged 19 to 69 years); 53 overweight or obese subjects, and 53 normal weight subjects matched for gender, height (± 1 inch), and age (± 1 year). Based on the Hamwi equations (184), experimental subjects were >125% of their standard body weight for height and normal weight subjects were ±10% of standard body weight for height. Most data collection took place in a laboratory on the university campus during a 2-hour appointment. Height and weight were recorded, and subjects completed a short demographic and health history questionnaire. Body composition was measured by dual energy X-ray absorptiometry and resting energy expenditure was measured after a 3 hour fast using indirect calorimetry. A laboratory specific conversion factor of 12% was applied to REE values to yield basal energy expenditure. Subjects completed the Yale Physical Activity Survey and the Block Food Frequency questionnaire to assess reported physical activity and dietary intake. A sub-sample of 62 subjects, 31 overweight/obese subjects and their normal weight matched controls, wore an accelerometer, a portable instrument designed to detect acceleration and deceleration of human movement, around their waist for 7 consecutive days. Age, anthropometrics and body composition did not differ between participants from the initial sample and those from the sub-sample.

Accelerometer data indicated that overweight/obese subjects in the present study were significantly less active than their normal weight matched controls. Based on accelerometer counts per minute, overweight and obese individuals were less active on weekends and weekdays when compared to their controls. They spent significantly less time in moderate intensity activity or greater for the entire week and during weekdays and weekends evaluated separately than their normal weight counterparts. Normal weight subjects spent an average of 21 minutes more per day engaged in moderate intensity or greater activities compared to their overweight/obese matches. Even though total energy expenditure did not differ between groups, when energy expenditure was expressed in relation to body weight, it was lower in overweight/obese subjects than in their normal weight controls. These results indicate that if an individual with excess weight spent more time in moderate intensity activity or greater, they could increase their daily energy expenditure considerably, which would, in the absence of increased food intake, provide potential for weight loss.

In the absence of experimental data, some investigators suggest that when an individual increases their planned exercise, their spontaneous activity, e.g., fidgeting, sitting and standing, may subsequently decrease (19, 191). In contrast, our results indicate the addition of planned exercise into an individual's regimen results in increased total energy expenditure. On the days when our subjects spent at least 30 minutes in moderate intensity activity or greater, they expended an average of 410 kilocalories more a day compared to days in which they did not exercise for at least 30 minutes. In contrast, when our subjects exercised at least 60 minutes or more they expended an average of 360 kilocalories more a day compared to the energy expenditure on more sedentary days. These results suggest that even if spontaneous activity does decrease on the days when an individual exercises, total energy expenditure is still substantially higher than in days without exercise. However, this increased energy expenditure was larger on days where 30 to 59, as opposed to 60 or more minutes of moderate intensity exercise, was performed. It would appear that when individuals engage in long exercise bouts, e.g., over 60 minutes, their spontaneous activity decreases to a greater extent than on those days when only 30 minutes of exercise is performed. These findings suggest that weight management intervention should encourage individuals to spend 30 minutes or more a day engaged in moderate or greater activity but exercise exceeding 60 minutes a day may be counterproductive.

In addition, time spent in moderate intensity activity or greater for each subject was compared to the 1995 Centers for Disease Control and Prevention and American College of Sports Medicine (CDC/ACSM) recommendations (178) for at least 30 minutes of moderate intensity or greater activity 5 times or more a week and to the 2002 Institute of Medicine (IOM) recommendations (18) for over 60 minutes a day of moderate intensity activity or greater every day of the week. On average, 71% of the overweight/obese and 94% of the normal weight met 1995 exercise recommendations, but only 13% of overweight/obese subjects and 26% of normal weight participants met 2002 exercise recommendations. Once again, these results suggest that weight management interventions that encourage individuals to exercise for 30 minutes a day may be relatively successful in the general population, whereas exercise recommendations for 60 minutes or more a day may be unrealistic and discouraging for many individuals.

Weight management interventions should consider using objective instruments, such as accelerometers, to monitor and evaluate physical activity in their participants. By using these tools, the participant, along with the intervention coordinator, will have a more direct measurement of approximate daily energy expenditure and how many minutes a day are spent in activities of various intensity levels. Accelerometers will be useful tools for goal setting, monitoring and attainment and in program evaluation. There is also an accountability factor; if an individual is wearing an instrument that measures their physical activity level, they may be more likely to achieve their exercise goals. These small, portable instruments can store activity data for up to 22 consecutive days and are relatively inexpensive instruments, around $250 each. Despite the recent advances in accelerometry technology, these instruments are rarely used in the design and development of weight management programs. Further research using accelerometers in weight management programs is warranted.

Large differences in dietary habits appear to exist between an overweight/obese and normal weight population. It is generally accepted that excess energy intake promotes weight gain, but results from the present study, indicate that specific dietary components appear to contribute to the energy imbalance and development of obesity. Overweight/obese subjects consumed more total fat, saturated fat and cholesterol and less carbohydrate, complex carbohydrate and dietary fiber when compared to normal weight controls. When multiple regression techniques were employed, carbohydrate and dietary fiber were the only nutrients that accounted for a significant amount of the variance in percent body fat, both with and without controlling for other variables. After controlling for confounding variables, i.e., age, physical activity-related energy expenditure, total energy, and other macronutrients, carbohydrate, relative to body weight, still accounted for 13.5% of the variance and dietary fiber, as expressed in grams, still accounted for 4.5% of the variance in percent body fat. In addition dietary fiber and carbohydrate were negatively related to percent body fat and weight parameters. These findings, that carbohydrate and dietary fiber exert the largest effect on percent body fat, are consistent with the results from other investigations (107, 109, 120). When looking at individual food groups, overweight/obese subjects consumed one less fruit serving/day than their normal weight controls, and fruit servings/day were negatively related to percent body fat ($r = -0.40$, $P<.01$).

Despite the substantial and continual evidence that dietary fiber is beneficial for weight management, the public is still attracted to popular weight loss strategies that emphasize decreasing carbohydrate and increasing protein and fat. Although, there is evidence that high protein, low carbohydrate diets produce substantial weight loss in the short term (122), to date, there are no long-term studies that examine the effects of these regimens. Obviously, no magic formula exists for weight loss, but our results indicate that a diet containing more than average amounts of fiber, complex carbohydrate and fruit is associated with normal body fat stores and standard weight for height. It appears that increasing dietary fiber, complex carbohydrate, and fruit in an individual's diet should be an important part of dietary intervention designed for weight management.

Recently, "low-carbohydrate" foods have been introduced and are widely sold across the U.S. These food products labeled as "low-carbohydrate" are really foods that are high in dietary fiber and soy protein. To date, no research has been conducted using these "low-carbohydrate" foods in weight management programs. Further research should be conducted to compare a weight management program that increases dietary fiber in the form of fruits, vegetables and whole grains to one that increases fiber in the form of "low-carbohydrate" foods. It is unclear as to whether the source of dietary fiber affects the success of the weight management intervention and further research in this area is warranted also.

To date, activity factors derived from accelerometers and those published by WHO and as a part of DRIs for energy have not been compared. Our results from this comparison indicated that among normal weight subjects, activity factors derived from accelerometers were significantly lower than those determined from WHO and DRI protocols. In contrast, for the overweight/obese subjects, activity factors derived from the three methods were similar. These results suggest that for normal weight subjects: 1) activity factors determined from WHO and DRI protocols may overestimate energy needs, 2) practitioners need to assign more conservative or modest activity factors to most individuals, despite their reported activity levels, or 3) activity factors measured by accelerometers underestimate energy needs.

An expert panel, comprised of 8 Registered Dietitians (RDs), completed a questionnaire in which they assigned a WHO and DRI activity factors to subject prototypes based on occupations and reported voluntary exercise. Our findings indicate that practitioners tended to overestimate the cost of reported physical activity for normal weight subjects and assigned activity factors that were higher than the actual activity preformed. Although occupation played a role in the assignment of WHO and DRI activity factors, it appears that reported voluntary exercise was the more influential factor. This phenomenon was apparent when comparing matched subjects with similar occupations who varied in their reported weekly exercise. On average, normal weight subjects reported more weekly exercise and were almost always assigned a higher WHO and DRI activity factor than overweight/obese subjects, with the same occupation, who reported less weekly exercise. However, physical activity-related energy expenditure as measured with accelerometers was consistently around 40% of BEE for both groups. The WHO and DRI activity factors assigned to overweight/obese subjects allocated a similar physical activity-related energy expenditure of 40% of BEE, whereas assigned activity factors allocated over 55% of BEE to normal weight subjects. Dietetic practitioners may put too much emphasis on reported physical activity levels and assign moderate intensity factors to their clients, when in actuality their clients are more often sedentary and do not merit the higher activity classification. At most, the majority of individuals in the American population should probably be assigned a very light/sedentary or light/low active activity factor, i.e., 30 to 50% of BEE for females and 30 to 60% of BEE for males, regardless of reported exercise levels. Education of practitioners to assign more conservative activity factors to individuals definitely appears to be warranted.

Another option is for practitioners to consider using more objective measures, e.g., accelerometers, to estimate energy needs for their clients or patients. Since the feasibility of this is unlikely for many practice settings, future research should focus on developing standardized well-described activity factors derived from accelerometer data collected from a large sample. Although standardization of accelerometer activity factors would still require the practitioner to assign appropriate intensity levels to their clients/patients, our results indicate that the standardized values would be lower than WHO and DRI values frequently assigned at present for normal weight subjects. Standardizing accelerometer activity factors and educating practitioners to assign lower and more modest WHO or DRI activity factors should improve the accuracy in estimating energy needs.

Despite decade long controversies over what factors influence weight gain, research keeps returning to a discrepancy between energy intake and energy expenditure. Results of the current study with overweight/obese and normal weight subjects matched for gender, age and height indicate that limited physical activity-related energy expenditure, especially limited time spent in moderate or greater intensity, and dietary composition, especially low dietary fiber, complex carbohydrate, and fruit, play a role in the etiology of obesity. In addition, inaccurate estimations of energy needs by current prediction methodology fail to provide practitioners appropriate information for educating clients on balancing energy intake and output.

Appendix A

RECRUITMENT CAMPUS E-MAIL AND FLYER

Campus Wide Recruitment E-Mail

Would you like to know your % body fat and how many kilocalories you need to maintain or lose weight? Get this vital health information by volunteering to participate in a clinical nutrition research study. Testing will take approximately 1-2 hours and will be conducted on campus at Belmont Hall. If interested, and to see if you qualify, please respond to this e-mail with the following information: weight, height, and age.

Hope you will join us!

Thank You,
Project Staff
Human Ecology Department
The University of Texas at Austin

RECRUITMENT FLYER

IT'S ABOUT YOUR HEALTH.

UT Clinical Research Study

Seeking overweight adults (18 to 70)

to participate in a short study (1 day for ~ 2 hrs)

Receive a FREE body fat composition test and a calorie analysis

(valued at $250)

Please contact Jaimie Davis, R.D.

to see if you qualify.

phone: 512-694-4160

email: jaimiedavis@earthlink.net

Appendix B

CONSENT FORMS

CONSENT FORM - ORIGINAL SAMPLE

DEPARTMENT OF HUMAN ECOLOGY
THE UNIVERSITY OF TEXAS AT AUSTIN
Austin, Texas 78712-1097 · (512) 471-4287 · FAX (512) 471-5630

CONSENT FORM

For persons participating in the study called

Examination of a Commonly Used Adjustment Equation for Predicting Energy Needs

You are invited to participate in a study that investigates the amount of lean tissue included in total body mass. Our names are Jaimie Davis and Valerie Hodges and we are graduate students at The University of Texas at Austin in the Department of Human Ecology, working under the supervision of Beth Gillham, Ph.D. We hope to determine the amount of lean tissue that makes up total body weight, and use that information to predict how many calories someone needs in one day. You will be one of approximately 100 subjects chosen to participate in this study.

If you elect to participate, you will be asked to do the following. We will perform a calorimetry measurement to see how many calories you use while at rest. You will be asked to schedule your appointment at least two hours after your last meal or snack. This test will require that you relax in a lounge chair and breathe normally for approximately thirty minutes. After you relax, a large clear plastic dome will be placed over your head to measure oxygen intake and carbon dioxide output for 30 minutes. We will measure your height and weight also. You will then have your body composition measured by a Dual Energy X-ray Absorptiometry (DEXA) scan, a new technique that provides an accurate and precise measurement of body composition by passing two low dose x-rays across your reclining body. You will be asked to lie down on your back and remain motionless for 10 to 20 minutes. Both tests will be performed on the University of Texas campus by trained technicians. At the time of your appointment you will be asked to complete a diet history, physical activity, and general health questionnaire. This will take approximately 20 minutes of your time.

Possible risks to be expected from your participation in this study are minimal. There is the remote chance of discomfort if you will feel claustrophobic with a plastic dome over your shoulders and head or have difficulty lying still for up to 20 minutes. At no time will you be tested against your free will. Appropriate precautionary measures and supervision will protect against injury. If you are claustrophobic or experience anxiety in small places you may wish not to participate in this study.

You will be provided the results of these tests, which would cost you about $200 at a clinic or fitness program. The co-principal investigators for this study are Valerie Hodges and Jaimie Davis. If you have any further questions you may contact them at (512) 694-4160 and (512) 659-7779, respectively. In addition, if you have questions about your rights as a research participant, please contact Clarke A. Burnham, Ph.D., Chair, The University of Texas at Austin Institutional Review Board for the Protection of Human Subjects, 512/232-4383.

Data compiled from your performance will be kept in strict confidence at all times. Only Valerie, Jaimie, and their Supervising Professor, Beth Gillham, will have access to the information. Numbers rather than names will identify all information collected. The list that ties the study numbers to the individual subjects will be kept in a locked file in the researchers' office. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission.

Your decision whether or not to participate **will not affect** your future relations with The University of Texas at Austin. If you decide to participate, you are free to discontinue participation at any time without prejudice. A copy of this consent form will be given to you for your files.

You are making a decision whether or not to participate in the study called **"Examination of a Commonly Used Adjusted Equation for Predicting Energy Needs."** Your signature indicates that you have read the information provided on the previous page and have decided to participate. You agree to complete both DEXA scan and calorimetry techniques. **To the best of my knowledge I am not pregnant at the time of measurement.** You may **withdraw from the study at any time after signing this form**, should you choose to discontinue participation.

You may keep a copy of this form.

Signature of Participant	Signature of Investigator	Date

CONSENT FORM - SUB-SAMPLE

DEPARTMENT OF HUMAN ECOLOGY
THE UNIVERSITY OF TEXAS AT AUSTIN

Austin, Texas 78712-1097 · (512) 471-4287 · FAX (512) 471-5630

CONSENT FORM

For persons participating in the study called

Examination of a Commonly Used Adjustment Equation for Predicting Energy Needs

You are invited to participate in one or more additional activities a study that investigates basal and total energy expenditure, dietary intake and body composition. Our names are Jaimie Davis and Valerie Hodges and we are graduate students at The University of Texas at Austin in the Department of Human Ecology, working under the supervision of Beth Gillham, Ph.D. We hope to determine the amount of lean tissue that makes up total body weight, and use that information to predict how many calories someone needs in one day. We will validate that information by comparing the prediction with voluntary activity and typical dietary intake. You will be one of approximately 50 subjects chosen to participate in this part of the study.

If you elect to participate, you will be asked to do one or both of the following. Please check the activities that you will complete.

☐ Wear an actigraph for seven consecutive days. The actigraph, also known as an activity monitor, detects activity by sensing motion via an accelerometer. The actigraph is a small lightweight single axis activity-measuring instrument that can be worn on the waist to record physical activity. With each subject movement the actigraph produces a frequency response generated from 0.25-2.5 Hertz. This frequency is then expressed as "activity counts" and calories expended. The actigraph should be worn 24 hours a day in the same location on the waist and only removed when in contact with water. A protective pouch, waist-band, and clip will be issued to you to secure the actigraph to your waist.

☐ Complete an on-line interactive food recall and/or food record for three consecutive days, including one weekend day. You will need to log onto a specific web-site and complete the dietary recall program. Forms will be provided for the 3-day food record.

There are no possible risks to be expected from either of these activities.

You will be provided the results of these tests. The co-principal investigators for this study are Valerie Hodges and Jaimie Davis. If you have any further questions you may contact them at (512) 694-4160 and (512) 659-7779, respectively. In addition, if you have questions about your rights as a research participant, please contact Clarke A. Burnham, Ph.D., Chair, The University of Texas at Austin Institutional Review Board for the Protection of Human Subjects, 512/232-4383.

Data compiled from your performance will be kept in strict confidence at all times. Only Valerie, Jaimie, and their Supervising Professor, Beth Gillham, will have access to the information. Numbers rather than names will identify all information collected. The list that ties the study numbers to the individual subjects will be kept in a locked file in the researchers' office. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission.

Your decision whether or not to participate **will not affect** your future relations with The University of Texas at Austin. If you decide to participate, you are free to discontinue participation at any time without prejudice. A copy of this consent form will be given to you for your files.

You are making a decision whether or not to participate in the additional activities associated with the study called **"Examination of a Commonly Used Adjusted Equation for Predicting Energy Needs."** Your signature indicates that you have read the information provided on the previous page and have decided to participate. You agree to complete one or both of the designated activities as described above. You may **withdraw from the study at any time after signing this form**, should you choose to discontinue participation.

You may keep a copy of this form.

Signature of Participant	Signature of Investigator	Date

Appendix C

BLOCK BRIEF FOOD FREQUENCY QUESTIONNAIRE AND HANDOUT

BLOCK BRIEF FOOD FREQUENCY QUESTIONNAIRE

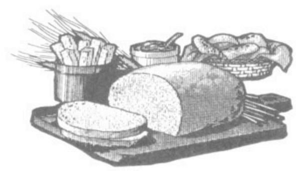
RESPONDENT ID NUMBER

0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9	9

TODAY'S DATE

	DAY		YEAR
Jan			
Feb			
Mar	0	0	2000
Apr	1	1	2001
May	2	2	2002
Jun	3	3	2003
Jul		4	2004
Aug		5	2005
Sep		6	2006
Oct		7	2007
Nov		8	2008
Dec		9	2009

BRIEF FOOD QUESTIONNAIRE



This form is about the foods you usually eat.
It will take about 15 - 25 minutes to complete.

- **Please answer each question as best you can. Estimate if you aren't sure.**
- **Use only a No. 2 pencil.**
- **Fill in the circles completely, and erase completely if you make any changes.**

Please print your name in this box.

SEX
- Male
- Female

If female, are you pregnant or breast feeding?
- No
- Yes
- Not female

AGE

0	0
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9

WEIGHT pounds

0	0	0
1	1	1
2	2	2
3	3	3
4	4	4
	5	5
	6	6
	7	7
	8	8
	9	9

HEIGHT ft. in.

ft.	in.
	00
	01
	02
3	03
4	04
5	05
6	06
	07
	08
	09
	10
	11

This form is about your usual eating habits in the past year or so. This includes all meals or snacks, at home or in a restaurant or carry-out. There are two kinds of questions for each food.

HOW OFTEN, on average, did you eat the food during the past year?
*Please DO NOT SKIP any foods. Mark "Never" if you didn't eat it.

HOW MUCH did you usually eat of the food?
*Sometimes we ask how <u>many</u> you eat, such as 1 egg, 2 eggs, etc., ON THE DAYS YOU EAT IT.
*Sometimes we ask "how much" as A, B, C or D. LOOK AT THE ENCLOSED PICTURES. For each food, pick the picture (bowls or plates) that looks the most like the serving size you usually eat. (If you don't have pictures: A=1/4 cup, B=1/2 cup, C=1 cup, D= 2 cups.)

EXAMPLE: This person drank apple juice twice a week, and had one glass each time. Once a week he ate a "C"-sized serving of rice (about 1 cup).

TYPE OF FOOD	HOW OFTEN IN THE PAST YEAR: NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH EACH TIME (SEE PORTION SIZE PICTURES FOR A-B-C-D)				
Apple juice	○	○	○	○	○	●	○	○	○	How many glasses each time	● 1	○ 2	○ 3	○ 4
Rice	○	○	○	○	●	○	○	○	○	How much each time	○ A	○ B	● C	○ D

TYPE OF FOOD	HOW OFTEN IN THE PAST YEAR: NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH EACH TIME SEE PORTION SIZE PICTURES FOR A-B-C-D				
How often do you eat each of the following foods all year round?														
Eggs, including egg biscuits or Egg McMuffins (Not egg substitutes)	○	○	○	○	○	○	○	○	○	How many eggs each time	○ 1	○ 2	○ 3	○ 4
Bacon or breakfast sausage, including sausage biscuit	○	○	○	○	○	○	○	○	○	How many pieces	○ 1	○ 2	○ 3	○ 4
Cooked cereals like oatmeal, cream of wheat or grits	○	○	○	○	○	○	○	○	○	Which bowl		○ B	○ C	○ D
Cold cereals like Corn Flakes, Cheerios, Special K, fiber cereals	○	○	○	○	○	○	○	○	○	Which bowl		○ B	○ C	○ D

Which cereal do you eat most often? **MARK ONLY ONE:**

○ Product 19, Just Right, Total

○ Bran Buds, Raisin Bran, Fruit-n-Fiber, other fiber cereals

○ Other cold cereal, like Corn Flakes, Cheerios, Special K

TYPE OF FOOD	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH EACH TIME				
Cheese, sliced cheese or cheese spread, including on sandwiches.	○	○	○	○	○	○	○	○	○	How many slices	○ 1	○ 2	○ 3	○ 4
Yogurt (not frozen yogurt)	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
How often do you eat each of the following fruits?														
Bananas	○	○	○	○	○	○	○	○	○	How many each time	○ 1/2	○ 1	○ 2	○ 3
Apples or pears	○	○	○	○	○	○	○	○	○	How many	○ 1/2	○ 1	○ 2	○ 3
Oranges, tangerines, not including juice	○	○	○	○	○	○	○	○	○	How many	○ 1/2	○ 1	○ 2	○ 3
Applesauce, fruit cocktail, or any canned fruit	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Any other fruit, like grapes, melon, strawberries, peaches, applesauce	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D

TYPE OF FOOD	HOW OFTEN IN THE PAST YEAR NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH EACH TIME SEE PORTION SIZE PICTURES FOR A-B-C-D				
How often do you eat each of the following vegetables, including fresh, frozen, canned or in stir fry, at home or in a restaurant?														
French fries, fried potatoes or hash browns										How much	A	B	C	D
White potatoes not fried, incl. boiled, baked, mashed & potato salad										How much	A	B	C	D
Sweet potatoes, yams, or sweet potato pie										How much	A	B	C	D
Rice, or dishes made with rice										How much	A	B	C	D
Baked beans, chili with beans, pintos, any other dried beans										How much	A	B	C	D
Refried beans										How much	A	B	C	D
Green beans or green peas										How much	A	B	C	D
Broccoli										How much	A	B	C	D
Carrots, or stews or mixed vegetables containing carrots										How much	A	B	C	D
Spinach, or greens like collards										How much	A	B	C	D
Cole slaw, cabbage										How much	A	B	C	D
Green salad										How much	A	B	C	D
Raw tomatoes, including in salad										How much	1/4	1/2	1	2
Catsup, salsa or chile peppers										How many TBSP.	1	2	3	4
Salad dressing or mayonnaise (Not lowfat)										How many TBSP.	1	2	3	4
Any other vegetable, like corn, squash, okra, cooked green peppers, cooked onions										How much	A	B	C	D
Vegetable soup, vegetable beef, chicken vegetable, or tomato soup										Which bowl		B	C	D

11120

PLEASE DO NOT WRITE IN THIS AREA

TYPE OF FOOD	HOW OFTEN IN THE PAST YEAR									HOW MUCH EACH TIME SEE PORTION SIZE PICTURES FOR A-B-C-D				
	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY					

MEATS

Do you ever eat chicken, meat or fish? ⬭ Yes ⬭ No IF NO, SKIP TO NEXT PAGE

TYPE OF FOOD	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH				
Hamburgers, cheeseburgers, meat loaf, at home or in a restaurant	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	How much meat	⬭ 1/8 lb.	⬭ 1/4 lb.	⬭ 1/2 lb.	⬭ 3/4 lb.
Tacos, burritos, enchiladas, tamales	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	How much	⬭ A	⬭ B	⬭ C	⬭ D
Beef steaks, roasts, pot roast, or in frozen dinners or sandwiches	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	How much	⬭ A	⬭ B	⬭ C	⬭ D
Pork, including chops, roasts, or dinner ham	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	How much	⬭ A	⬭ B	⬭ C	⬭ D

When you eat beef or pork, do you ⬭ Avoid eating the fat ⬭ Sometimes eat the fat ⬭ Often eat the fat ⬭ I don't eat meat

TYPE OF FOOD	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH				
Mixed dishes with meat or chicken, like stew, corned beef hash, chicken & dumplings, or in frozen meals	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	How much	⬭ A	⬭ B	⬭ C	⬭ D
Fried chicken, at home or in a restaurant	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	# medium pieces	⬭ 1	⬭ 2	⬭ 3	⬭ 4
Chicken or turkey not fried, such as baked, grilled, or on sandwiches	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	How much	⬭ A	⬭ B	⬭ C	⬭ D

When you eat chicken, do you ⬭ Avoid eating the skin ⬭ Sometimes eat the skin ⬭ Often eat the skin ⬭ N/A

TYPE OF FOOD	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH				
Fried fish or fish sandwich, at home or in a restaurant	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	How much	⬭ A	⬭ B	⬭ C	⬭ D
Any other fish or shellfish <u>not</u> fried, including tuna	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	How much	⬭ A	⬭ B	⬭ C	⬭ D
Hot dogs, or sausage like Polish, Italian or Chorizo	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	How many	⬭ 1	⬭ 2	⬭ 3	⬭ 4
Boloney, sliced ham, turkey lunch meat, other lunch meat	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	⬭	How many slices	⬭ 1	⬭ 2	⬭ 3	⬭ 4

When you eat lunch meats, are they ⬭ Usually low-fat ⬭ Sometimes ⬭ Rarely low-fat ⬭ N/A

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PLEASE DO NOT WRITE IN THIS AREA

TYPE OF FOOD	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH **EACH TIME** SEE PORTION SIZE PICTURES FOR A-B-C-D				
Pasta, breads, spreads, snacks														
Spaghetti, lasagna, or other pasta with tomato sauce	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Cheese dishes without tomato sauce, like macaroni and cheese	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Pizza, including carry-out	○	○	○	○	○	○	○	○	○	How many slices	○ 1	○ 2	○ 3	○ 4
Biscuits, muffins	○	○	○	○	○	○	○	○	○	How many each time	○ 1	○ 2	○ 3	○ 4
Rolls, hamburger buns, English muffins, bagels	○	○	○	○	○	○	○	○	○	How many each time	○ 1/2	○ 1	○ 2	○ 3
White bread or toast, including French, Italian, or in sandwiches	○	○	○	○	○	○	○	○	○	How many slices	○ 1	○ 2	○ 3	○ 4
Dark bread like rye or whole wheat, including in sandwiches	○	○	○	○	○	○	○	○	○	How many slices	○ 1	○ 2	○ 3	○ 4
Tortillas	○	○	○	○	○	○	○	○	○	How many each time	○ 1	○ 2	○ 3	○ 4
Margarine on bread, potatoes or vegetables	○	○	○	○	○	○	○	○	○	How many pats (Tsp.)	○ 1	○ 2	○ 3	○ 4
Butter on bread, potatoes or vegetables	○	○	○	○	○	○	○	○	○	How many pats (Tsp.)	○ 1	○ 2	○ 3	○ 4
Peanuts or peanut butter	○	○	○	○	○	○	○	○	○	How many TBSP.	○ 1	○ 2	○ 3	○ 4
Snacks like potato chips, corn chips, popcorn (Not pretzels)	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
Doughnuts, cake, pastry, pie	○	○	○	○	○	○	○	○	○	How many pieces	○ 1	○ 2	○ 3	○ 4
Cookies (Not lowfat)	○	○	○	○	○	○	○	○	○	How many	○ 1-2	○ 3-5	○ 6-7	○ 8+
Ice cream, frozen yogurt, ice cream bars	○	○	○	○	○	○	○	○	○	How much	○ A	○ B	○ C	○ D
When you eat ice cream or frozen yogurt, is it	○ Usually low-fat			○ Sometimes			○ Rarely low-fat			○ N/A				
Chocolate candy, candy bars	○	○	○	○	○	○	○	○	○	How many bars	① small	① medium	① large	② large

TYPE OF BEVERAGE	HOW OFTEN IN THE PAST YEAR									HOW MUCH EACH TIME SEE PORTION SIZE PICTURES FOR A-B-C-D				
	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY					
How often do you drink the following beverages?														
Real orange or grapefruit juice, Welch's grape juice, Minutemaid juices, Juicy Juice	○	○	○	○	○	○	○	○	○	How many glasses each time	○ 1	○ 2	○ 3	○ 4
Hawaiian Punch, Sunny Delight, Hi-C, Tang, or Ocean Spray juices	○	○	○	○	○	○	○	○	○	How many glasses each time	○ 1	○ 2	○ 3	○ 4
Kool Aid, Capri Sun or Knudsen juices	○	○	○	○	○	○	○	○	○	How many glasses each time	○ 1	○ 2	○ 3	○ 4
Instant breakfast milkshakes like Carnation, diet shakes like Slimfast, or liquid supplements like Ensure	○	○	○	○	○	○	○	○	○	How many glasses or cans	○ 1	○ 2	○ 3	○ 4
Glasses of milk (any kind)	○	○	○	○	○	○	○	○	○	How many glasses	○ 1	○ 2	○ 3	○ 4

When you drink glasses of milk what kind do you usually drink?
MARK ONLY ONE:

○ Whole milk
○ Reduced fat 2% milk
○ Low-fat 1% milk
○ Non-fat milk
○ Rice milk
○ Soy milk
○ I don't drink milk or soy milk

TYPE OF BEVERAGE	NEVER	A FEW TIMES per YEAR	ONCE per MONTH	2-3 TIMES per MONTH	ONCE per WEEK	TWICE per WEEK	3-4 TIMES per WEEK	5-6 TIMES per WEEK	EVERY DAY	HOW MUCH EACH TIME				
Cream, Half-and-Half or non-dairy creamer in coffee or tea	○	○	○	○	○	○	○	○	○	Total TBSP. on those days	○ 1	○ 2	○ 3-4	○ 5+
Regular soft drinks, or bottled drinks like Snapple (Not diet drinks)	○	○	○	○	○	○	○	○	○	How many bottles or cans	○ 1	○ 2	○ 3-4	○ 5+
Beer	○	○	○	○	○	○	○	○	○	How many bottles or cans	○ 1	○ 2	○ 3-4	○ 5+
Wine or wine coolers	○	○	○	○	○	○	○	○	○	How many glasses	○ 1	○ 2	○ 3-4	○ 5+
Liquor or mixed drinks	○	○	○	○	○	○	○	○	○	How many drinks	○ 1	○ 2	○ 3-4	○ 5+

During the past year, have you taken any vitamins or minerals regularly, at least once a month?

○ No, not regularly ○ Yes, fairly regularly

(IF YES) WHAT DID YOU TAKE FAIRLY REGULARLY?

VITAMIN TYPE	HOW OFTEN					FOR HOW MANY YEARS?					
	DIDN'T TAKE	A FEW DAYS per MONTH	1-3 DAYS per WEEK	4-6 DAYS per WEEK	EVERY DAY	LESS THAN 1 YR.	1 YEAR	2 YEARS	3-4 YEARS	5-9 YEARS	10+ YEARS
Multiple Vitamins. Did you take…											
Regular Once-A-Day, Centrum, or Thera type	○	○	○	○	○	○	○	○	○	○	○
Stress-tabs or B-Complex type	○	○	○	○	○	○	○	○	○	○	○
Antioxidant combination type	○	○	○	○	○	○	○	○	○	○	○
Single Vitamins (not part of multiple vitamins)											
Vitamin A (not beta-carotene)	○	○	○	○	○	○	○	○	○	○	○
Beta-carotene	○	○	○	○	○	○	○	○	○	○	○
Vitamin C	○	○	○	○	○	○	○	○	○	○	○
Vitamin E	○	○	○	○	○	○	○	○	○	○	○
Folic acid, folate	○	○	○	○	○	○	○	○	○	○	○
Calcium or Tums, alone or combined with vit. D or magnesium	○	○	○	○	○	○	○	○	○	○	○
Zinc	○	○	○	○	○	○	○	○	○	○	○
Iron	○	○	○	○	○	○	○	○	○	○	○
Selenium	○	○	○	○	○	○	○	○	○	○	○
Vitamin D, alone or combined with calcium	○	○	○	○	○	○	○	○	○	○	○

If you took vitamin C or vitamin E:

How many milligrams of **vitamin C** did you usually take, on the days you took it?

○ 100 ○ 250 ○ 500 ○ 750 ○ 1000 ○ 1500 ○ 2000 ○ 3000+ ○ don't know

How many IUs of **vitamin E** did you usually take, on the days you took it?

○ 100 ○ 200 ○ 300 ○ 400 ○ 600 ○ 800 ○ 1000 ○ 2000+ ○ don't know

How often do you use fat or oil in cooking?

○ Less than once per week ○ A few times per week ○ Once a day ○ Twice a day ○ 3+ per day

What kinds of fat or oil do you usually use in cooking? MARK ONLY ONE OR TWO

○ Don't know, or Pam
○ Stick margarine
○ Soft tub margarine
○ Butter
○ Butter/margarine blend
○ Low-fat margarine
○ Corn oil, vegetable oil
○ Olive oil or canola oil
○ Lard, fatback, bacon fat
○ Crisco

Did you ever drink more beer, wine or liquor than you do now? ○ Yes ○ No

Do you smoke cigarettes now? ○ Yes ○ No

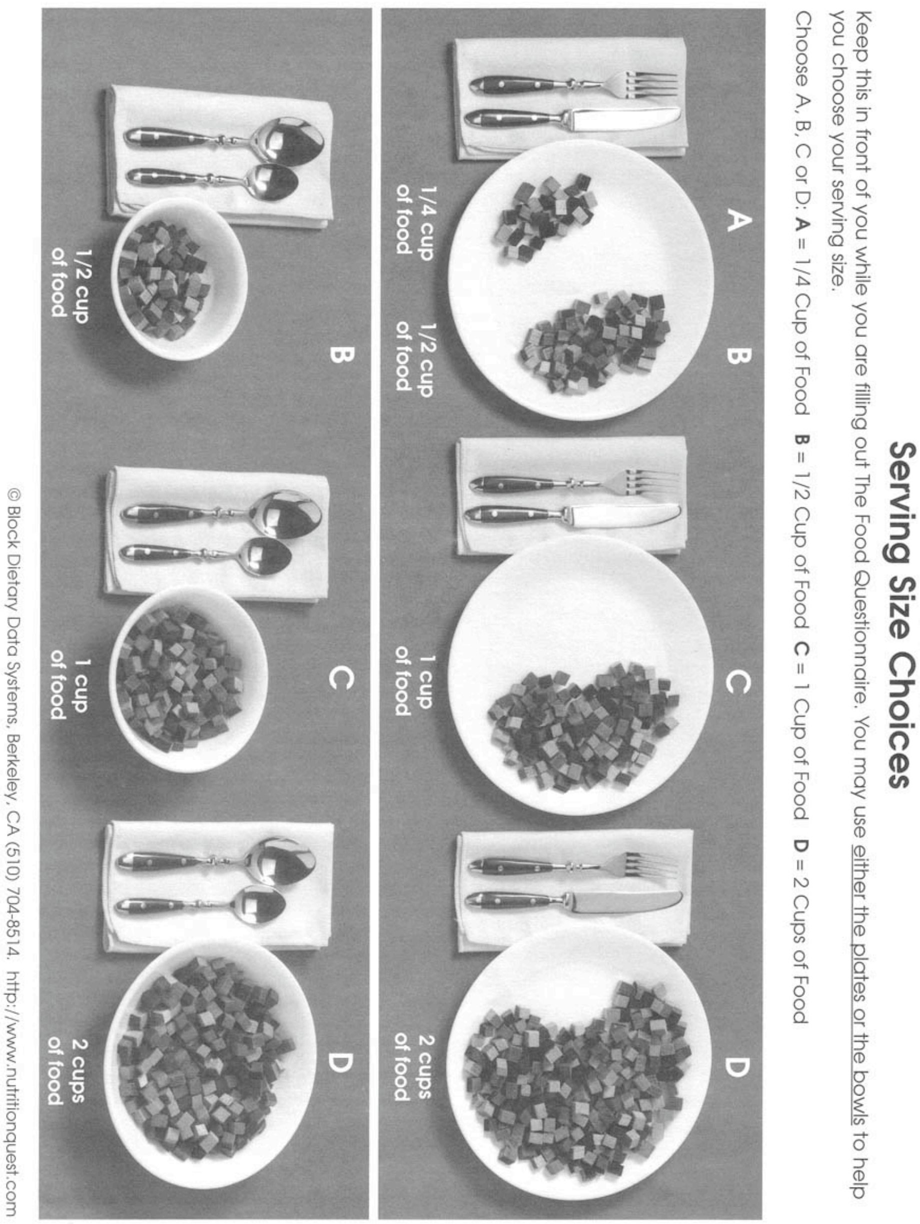
IF YES, On the average about how many cigarettes a day do you smoke now?

○ 1-5 ○ 6-14 ○ 15-24 ○ 25-34 ○ 35 or more

What is your ethnic group? (MARK ONE OR MORE)

○ Hispanic or Latino
○ White, not Hispanic
○ Black or African American
○ Asian
○ American Indian or Alaska Native
○ Native Hawaiian or Other Pacific Islander

SERVING SIZE CHOICES



BEVERAGE PORTION SIZES

Beverages	Portion Sizes
• Real orange, grapefruit juice, Welch's grape juice, Minutemaid juices, Juicy Juice	1= 1 c or 8 fl. Oz.
	2 = 2 c or 16 fl. Oz.
	3 = 3 c or 24 fl. Oz.
• Hawaiian Punch, Sunny Delight, Hi-C, Tang, or Ocean Spray juices	4 = 4 c or 32 fl. Oz.
• Kool Aid, Capri Sun, Knudsen juices	
• Instant breakfast milkshakes (Carnation, Slimfast, Ensure)	
• Glasses of Milk	
• Regular soft drinks Beer	Bottles/ Cans = 12 fl Oz.
• Wine	1 glass = 6 fl Oz
• Liquor or mixed drinks	1 drink = 5 fl Oz

FOOD FREQUENCY ANALYSIS PRINTOUT

Daily Nutrients from FOOD

34	CALORIES	(Kcal)
35	PROTEIN	(g)
36	TOTAL FAT	(g)
37	CARBOHYDRATE	(g)
38	CALCIUM	(mg)
39	PHOSPHORUS	(mg)
40	IRON	(mg)
41	SODIUM	(mg)
42	POTASSIUM	(mg)
43	VITAMIN A	(IU)
44	VITAMIN A	(RE)
45	THIAMIN (B1)	(mg)
46	RIBOFLAVIN (B2)	(mg)
47	NIACIN	(mg)
48	VITAMIN C	(mg)
49	SATURATED FAT	(g)
50	OLEIC ACID	(g)
51	LINOLEIC ACID	(g)
52	CHOLESTEROL	(mg)
53	FIBER	Total dietary fiber (g)
54	FOLATE	(mcg)
55	VITAMIN E	a-TE
56	ZINC	(mg)
57	ANIMAL ZINC	Zinc from animal sources (mg)

58	VITAMIN B6	(mg)
59	MAGNESIUM	(mg)
60	ALPHA-CAROTENE	(ug)
61	BETA-CAROTENE	(ug)
62	CRYPTOXANTHIN	(carotenoid) (ug)
63	LUTEIN	(carotenoid) (ug)
64	LYCOPENE	(carotenoid) (ug)
65	RETINOL	(preformed Vit. A, ug)
66	"CAROTENE"	Provitamin A carotenoids (ug)
67	GENISTEIN	Genistein (ug)
68	DAIDZEIN	Daidzein (ug)
69	VITAMIN D	(IU)
70	CAFFEINE	(mg)
71	VITAMIN K	(ug)
72	VITAMIN B12	(ug)
73	CYSTEINE	(mg)
74	METHIONINE	(mg)
75	GRAMSF	Grams of solid food (g)

Percents of Calories

76	PCTFAT	% of Kcal from fat
77	PCTPROT	% of Kcal from protein
78	PCTCARB	% of Kcal from carbohydrate
79	PCTSWEET	% of Kcal from sweets, desserts
80	PCTALch	% of Kcal from alcoholic beverages

Percents of Calories, calories from alcoholic beverages excluded from denominator

81	BA_PFAT	% fat cals, alcoholic beverages excluded from denominator
82	BA_PPROT	% prot cals, " " " " " "
83	BA_PCARB	% carb cals, " " " " " "

Fiber from different sources

84	FIBBEAN	Dietary fiber from beans (g)
85	FIBVEGFR	Dietary fiber from vegetables & fruits (g)
86	FIBGRAIN	Dietary fiber from grains (g)

Nutrients from vitamin supplements

87	SUP_VITA	Average daily Vit A from supplements (IU)
88	SUP_VITC	" " Vit C " " (mg)

Appendix D

YALE PHYSICAL ACTIVITY SURVEY

ID#_______________

The Yale Physical Activity Survey

Interviewer, please mark time: __ __ : __ __ : __ __
Hr Min Sec

Interviewer: (Please hand the subject the list of activities while reading this statement.) Here is a list of common types of physical activities. Please tell me which of them you did during a *typical week in the last month*. Our interest is learning about the types of physical activities that are a part of your *regular work and leisure routines*.

For each activity you do, please tell me how much time (in hours) you spent doing this activity during a typical week. (Hand subject card #1.)

	Time (hr/week)	Intensity code (kcal/min)
Work		
Shopping (e.g., grocery, clothes)	_____	3.5
Stair-climbing while carrying a load	_____	8.5
Laundry (time loading, unloading, hanging, folding only)	_____	3.0
Light housework: tidying, dusting, sweeping; collecting trash in home; polishing; indoor gardening; ironing	_____	3.0
Heavy housework: vacuuming, mopping; scrubbing floors and walls; moving furniture, boxes, or garbage cans	_____	4.5
Food preparation (10+ min in duration): chopping, stirring; moving about to get food items, pans	_____	2.5
Food service (10+ min in duration): setting table; carrying food; serving food	_____	2.5
Dishwashing (10+ min in duration): clearing table; washing/drying dishes; putting dishes away	_____	2.5
Light home repair: small appliance repair; light home maintenance/repair	_____	3.0
Heavy home repair: painting, carpentry, washing/polishing car	_____	5.5
Other: _______________	_____	_____
Yard work		
Gardening: planting, weeding, digging, hoeing	_____	4.5
Lawn mowing (walking only)	_____	4.5
Clearing walks/driveway: sweeping, shoveling, raking	_____	5.0
Other: _______________	_____	_____

Caretaking		
Older or disabled person (lifting, pushing wheelchair)	______	5.5
Childcare (lifting, carrying, pushing stroller)	______	4.0
Exercise		
Brisk walking (10+ min in duration)	______	6.0
Pool exercises, stretching, yoga	______	3.0
Vigorous calisthenics, aerobics	______	6.0
Cycling, exercycle	______	6.0
Swimming (laps only)	______	6.0
Other: ______________________	______	______
Recreational activities		
Leisurely walking (10+ min in duration)	______	3.5
Needlework: knitting, sewing, needlepoint	______	1.5
Dancing (moderate/fast): line, ballroom, tap, square	______	5.5
Bowling, bocci	______	3.0
Golf (walking to each hole only)	______	5.0
Racquet sports: tennis, racquetball	______	7.0
Billiards	______	2.5
Other: ______________________	______	______

> Interviewer: (Please read statement to subject.) I would now like to ask you about certain types of activities that you have done during *the past month.* I will ask you about how much vigorous activity, leisurely walking, sitting, standing, and other things that you usually do.

1. About how many times during the month did you participate in *vigorous* activities that lasted at least *10 minutes* and caused large increases in breathing, heart rate, or leg fatigue *or* caused you to perspire? (Hand subject card #2.)

Score: 0 = Not at all (go to Question 3)
1 = 1-3 times per month
2 = 1-2 times per week
3 = 3-4 times per week
4 = 5+ times per week
7 = Refused
8 = Don't know

Frequency score = ______________

2. About how long do you do this vigorous activity each time? (Hand subject card #3.)

Score: 0 = Not applicable
1 = 10-30 min
2 = 31-60 min
3 = 60+ min
7 = Refused
8 = Don't know

Duration score = ______________

Weight = 5

Vigorous activity index score:

Frequency score ____ × duration score ____ × weight ____ = ____________
(Responses of 7 or 8 are scored as missing.)

3. Think about the walks you have taken during the past month. About how many times per month did you walk for *at least 10 minutes* or more *without stopping* which *was not* strenuous enough to cause large increases in breathing, heart rate, or leg fatigue *or* cause you to perspire? (Hand subject card #2.)

   0 = Not at all (go to Question 5)
   1 = 1-3 times per month
   2 = 1-2 times per week
   3 = 3-4 times per week
   4 = 5+ times per week
   7 = Refused
   8 = Don't know

   Frequency score = ______________

4. When you did this walking, for how many minutes did you do it? (Hand subject card #3.)

   Score: 0 = Not applicable
   1 = 10-30 min
   2 = 31-60 min
   3 = 60+ min
   7 = Refused
   8 = Don't know

   Duration score = ______________

   Weight = 4

Leisurely walking index score:

Frequency score ____ × duration score ____ × weight ____ = ____________
(Responses of 7 or 8 are scored as missing.)

5. About how many hours a day do you spend moving around on your feet while doing things? Please report only the time that you are *actually moving*. (Hand subject card #4.)

   Score: 0 = Not at all
   1 = Less than 1 hr per day
   2 = 1 to less than 3 hr per day
   3 = 3 to less than 5 hr per day
   4 = 5 to less than 7 hr per day
   5 = 7+ hr per day
   7 = Refused
   8 = Don't know

   Moving score = ______________

   Weight = 3

Moving index score:

Moving score ____ × weight ____ = ____________
(Responses of 7 or 8 are scored as missing.)

6. Think about how much time you spend standing or moving around on your feet on an average day during the past month. About how many hours per day do you *stand*? (Hand subject card #4.)

   Score: 0 = Not at all
   1 = Less than 1 hr per day
   2 = 1 to less than 3 hr per day
   3 = 3 to less than 5 hr per day
   4 = 5 to less than 7 hr per day
   5 = 7+ hr per day
   7 = Refused

8 = DK

Standing score = ____________

Weight = 2

Standing index score:

Standing score ____ × weight ____ = ____________

(Responses of 7 or 8 are scored as missing.)

7. About how many hours did you spend sitting on an average day during the past month? (Hand subject card #5.)

Score: 0 = Not at all
1 = Less than 3 hr
2 = 3 hr to less than 6 hr
3 = 6 hr to less than 8 hr
4 = 8+ hr
7 = Refused
8 = DK

Sitting score = ____________

Weight = 1

Sitting index score:

Sitting score ____ × weight ____ = ____________

(Responses of 7 or 8 are scored as missing.)

8. About how many flights of stairs do you climb *up* each day? (Let 10 steps = 1 flight.) ____________

9. Please compare the amount of physical activity that you do during other seasons of the year with the amount of activity you just reported for a typical week in the past month. For example, in the summer, do you do more or less activity than what you reported doing in the past month?

(Interviewer, please circle the appropriate score for each season.)

	Lot more	Little more	Same	Little less	Lot less	Don't know
Spring	1.30	1.15	1.00	0.85	0.70	—
Summer	1.30	1.15	1.00	0.85	0.70	—
Fall	1.30	1.15	1.00	0.85	0.70	—
Winter	1.30	1.15	1.00	0.85	0.70	—

Seasonal adjustment score = sum over all seasons / 4 ____________ ____________

Interviewer, please mark time: __ __ : __ __ : __ __
Hr Min Sec

Appendix E

ACTIVITY FACTORS EXPERT PANEL QUESTIONNAIRE

ACTIVITY FACTOR QUESTIONNAIRE FOR EXPERTS

Dear Dietitians;

I was hoping that I could get your expert opinion on some research that I am conducting. Specifically, I am trying to test and evaluate the effectiveness of using activity factors proposed by the World Health Organization (WHO) for assessing energy needs. These popular activity factors are often multiplied by resting energy needs, determined from popular prediction equations (i.e., the Harris Benedict Equation), to yield a person's total energy needs. Many times dietitians use their own judgment to decide which activity factor to assign to an individual and often this decision is based on the person's occupation and voluntary exercise level. Please identify below what activity factor you would assign to various occupation and exercise levels. A brief description for each activity factor is provided.

Activity Level	Description of Level	Activity Factor (X BMR)
Very Light	Seated and standing activities, painting trades, driving, laboratory work, typing, sewing, ironing, cooking, playing cards, playing a musical instrument	1.3 (men) 1.3 (women)
Light	Walking on a level surface at 2.5 to 3 mph, garage work, electrical trades, carpentry, restaurant trades, housecleaning, child care, golf, sailing, table tennis	1.6 (men) 1.5 (women)
Moderate	Walking 3.5 to 4 mph, weeding, hoeing, carrying a load, cycling, skiing, tennis, dancing	1.7 (men) 1.6 (women)
Heavy	Walking with a load uphill, tree felling, heavy manual digging, basketball, climbing, football, soccer	2.1 (men) 1.9 (women)
Exceptional	Training in professional or world-class athletic events	2.4 (men) 2.2 (women)

Please mark the activity factor you would apply to each of the following occupations for each exercise level:

Occupation	Time Spent in Moderate Intensity Exercise	Activity Factor Very Light	Light	Mod.	Heavy	Except.
1. Homemaker	0-3 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 3- < 7 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 7 times/wk for > 60 min/ea	☐	☐	☐	☐	☐
2. Teacher (all ages)	0-3 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 3- < 7 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 7 times/wk for > 60 min/ea	☐	☐	☐	☐	☐
3. Registered Nurse	0-3 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 3- < 7 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 7 times/wk for > 60 min/ea	☐	☐	☐	☐	☐
4. Engineer	0-3 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 3- < 7 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 7 times/wk for > 60 min/ea	☐	☐	☐	☐	☐

		VL	light	Mod	Heavy	Except
5. Sales, Advertising, & Marketing	0-3 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 3- < 7 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 7 times/wk for > 60 min/ea	☐	☐	☐	☐	☐
6. Fitness Instructor	0-3 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 3- < 7 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 7 times/wk for > 60 min/ea	☐	☐	☐	☐	☐
7. Massage Therapist	0-3 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 3- < 7 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 7 times/wk for > 60 min/ea	☐	☐	☐	☐	☐
8. Construction Inspector/Manager	0-3 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 3- < 7 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 7 times/wk for > 60 min/ea	☐	☐	☐	☐	☐

		VL	light	Mod	Heavy	Except
9. Students	0-3 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 3- < 7 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 7 times/wk for > 60 min/ea	☐	☐	☐	☐	☐
10. Clerical, Administrative * any desk job	0-3 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 3- < 7 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 7 times/wk for > 60 min/ea	☐	☐	☐	☐	☐
11. Pastor	0-3 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 3- < 7 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 7 times/wk for > 60 min/ea	☐	☐	☐	☐	☐
12. Retired	0-3 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 3- < 7 times/wk for 30-60 min/ea	☐	☐	☐	☐	☐
	> 7 times/wk for > 60 min/ea	☐	☐	☐	☐	☐

Appendix F

DEMOGRAPHIC AND HEALTH HISTORY FORM

DEMOGRAPHICS AND HEALTH HISTORY FORM

ID#____________

Demographics and Health History Form

1. Name:____________________________ 2. Date:________________________

3. Address: __________________________ 4. Birthdate:______________________

5. Daytime phone:______________________ 6. Sex: _____Male _____Female
   Evening phone: ______________________

7. Occupation:________________________ 8. Ethnicity:______________________

9. Has your physician ever told you that you had any of the following? (Please check and give "Year of Onset", if applicable.)

Condition	**No**	**Yes**	**Year of Onset**	**Condition**	**No**	**Yes**	**Year of Onset**
Coronary Heart Disease				Arthritis:			
Angina Pectoris				Rheumatoid			
Myocardial Infarction				Degenerative			
Coronary Surgery				Gout			
Chronic Bronchitis				Other			
Emphysema				Cirrhosis			
High Blood Pressure				Prostate Disease			
Stroke				Multiple Sclerosis			
Thrombophlebitis				Parkinson's Disease			
Peptic Ulcer				Glaucoma			
Stomach Ulcer				Cataract			
Duodenum Ulcer				Osteoporosis			
Gall Bladder Disease				Nervous Breakdown			
Heartburn				Psychosis			
Appendicitis				Neurosis			
Ulcerative Colitis				Depression			
Diverticulitis				Alcoholism			
Diabetes				Cancer			
Gastroesophageal reflux disease (GERD)				Chronic Back Pain			
Other major disease							

Please specify other major disease ____

11. Have you dieted in the past year? ___Yes ___No
    Please list the type of diet(s) tried? ______________________________________

12. How many Calories do you think you need per day to maintain your current weight?__________________________

13. How many Calories do you think you need per day to lose weight?____________________

Appendix G

IMAGES OF MEASUREMENT TOOLS

DUAL ENERGY X-RAY ABSORPTIOMETRY (DXA) IMAGE

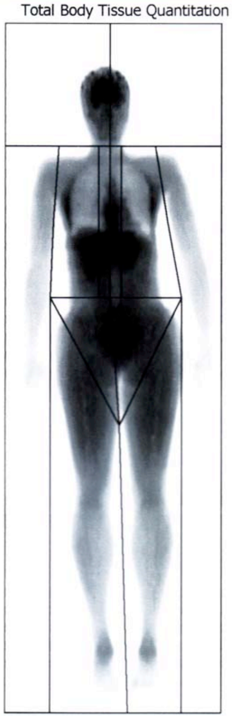
SAMPLE DXA SCAN PRINTOUT

Fitness Institute of Texas

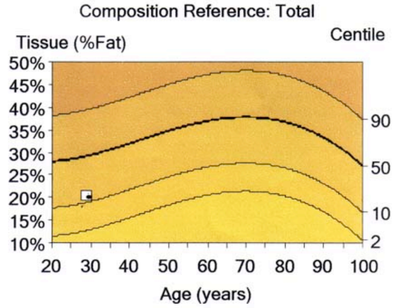
Dept. of Kinesiology & Health Education
University of Texas at Austin

Patient:	NAUERT, LISA	**Attendant:**	Sharon Beene
Birth Date:	4/19/1974 28.9 years		
Height / Weight:	64.0 in. 122.0 lbs.	**Measured:**	3/22/2003 10:26:22 AM (6.70)
Sex / Ethnic:	Female White	**Analyzed:**	3/22/2003 10:27:12 AM (6.70)

Total Body Tissue Quantitation



Composition Reference: Total



Region	Tissue (%Fat)	Centile	T.Mass (kg) [2,3]	Fat (g)	Lean (g)	BMC (g)
Arms	15.3	-	-	760	4,217	281
Legs	26.5	-	-	5,096	14,147	923
Trunk	17.9	-	-	4,310	19,758	626
Total	20.4	14	54.3	10,628	41,390	2,301

INDIRECT CALORIMETRY MACHINE IMAGE

ACTIGRAPH AND ACCESSORIES IMAGE

Appendix H

NUTRITION EDUCATION HANDOUT FOR PARTICIPANTS

NUTRITION EDUCATION FOR PARTICIPANTS

1. **Snacking:** Snacking is an excellent way to control your blood sugar. Many times when we only eat 2-3 times a day, we consume way too many Calories at one meal and our bodies are not able to break those Calories down efficiently. When you go long periods of time without eating (~6 hours), your blood sugar drops really low. When you finally get around to eating, you tend to make unhealthy choices, eat too fast, or too much. Sound familiar? Try to eat every 3-4 hours, this way you will consume fewer Calories at one time and be satisfied all day long.

    a. Combine a carbohydrate with a protein or a "good" fat
    b. Choose a high fiber carbohydrate
    c. Eat only 100-150 kcals for a snack

    Snack Ideas:

    - 1 T. peanut butter; 1 oz low-fat crackers; 1/2 cup skim milk
    - 2 cups light microwave popcorn; 1 oz low-fat cheese
    - 1/2 bagel; 2 T fat free or lite cream cheese
    - Nachos: 1 oz tortilla chips; 1/4 cup fat free refried beans; 1 oz light or fat free cheese
    - 1 cup yogurt; 1/4 cup high fiber dry cereal
    - 1/2 cup 1-2% cottage cheese; 1/2 cup fruit
    - 1 small (1 oz) bran muffin; 1/2 cup skim milk
    - 1-1/2 oz high fiber cereal with 1/2 cup milk
    - 1/2 English muffin; 1 oz Canadian bacon; 1 slice light cheese
    - 1 hard cooked egg (sliced or deviled with fat free dressing; 6 saltine type crackers or 1 oz of low fat crackers
    - 1 T peanut butter or 1 oz cheese; 1 medium apple
    - 1/2 cup trail mix: roasted soybeans, freeze dried veggies, sesame seeds, peanuts, pretzels, dried fruit
    - 1 string cheese; 6 crackers

2. **Portions:** Cut your portions in half. Try using a smaller plate. Split a meal with a friend or order an appetizer as your main course.

a. Carbohydrate portion sizes are usually the ones that are doubled or even tripled. Keep in mind that 1/2 cup of rice or noodles, 3/4 cup of cereal, and 1 small piece of bread are examples of 1 serving of bread. A bagel from a bagel shop can be 4-5 servings of carbohydrate, or a potato can be 5-6 servings of carbohydrate. Try to limit your carbohydrate servings to 1-2 servings at meals and 1 serving at snacks.

b. Meat servings also tend to be "super sized". One serving of meat is about 3 ounces or the size of your palm or a deck of playing cards.

c. If your still hungry, fill up on water rich vegetables (not potatoes or corn)

3. **Cut the fat:** Try to limit saturated fat intake.

   a. Limit your consumption of red meats to 2-3 times a week
   b. Use a larger variety of lean meat products. Fish, chicken and pork are
   lower in fat than red meat.
   c. Bake, grill or sauté the meat products
   d. Cook with plant oil (e.g., olive oil and walnut oil)
   e. Cut the amount of oil recommended in half
   f. Remove the butter from the table
   g. Use light or fat free products (avoid the ones with trans fat)

4. **Up your fiber:** Increase your dietary fiber to 25-30 grams a day. Not only does dietary fiber help prevent various types of cancer, it helps curb your appetite. It fills you up on smaller amount of food.

   a. Choose carbohydrate products (cereals, pasta, breads) with ≥ 4 grams of dietary fiber on the label (just because a product says whole wheat, does not mean it is a great source of fiber). Pay attention to the food labels!

   b. Increase your fruit and vegetable consumption

   c. Eat more beans, 1/2 cup of beans has around 7-8 grams of dietary fiber

GLOSSARY

The following abbreviations were used in the text of this document.

ACSM	American College of Sports Medicine
AF	Activity factor
BEE	Basal energy expenditure
BMI	Body Mass Index
CDC	Centers for Disease Control and Prevention
CSA	Computer Science and Applications, Inc.
CSFII	Continuing Survey of Food Intakes by Individuals
DLW	Doubly labeled water
DXA	Dual energy X-ray absorptiometry
FFM	Fat free mass
FFQ	Food frequency questionnaire
FM	Fat mass
GI	Glycemic index
MET	Metabolic equivalent
NHANESIII	National Health and Nutrition Examination Survey
IOM	Institute of Medicine
PAL	Physical activity level

RDA	Recommended Dietary Allowances
REE	Resting energy expenditure
TEE	Total energy expenditure
TEF	Thermic effect of food
WHO	World Health Organization
USDA	United States Department of Agriculture
YPAS	Yale Physical Activity Survey

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Vita

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