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The Impact of Self-Reported Physical Activity Levels on the Prediction of Body Fatness from BMI in White and Black College Students

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THE IMPACT OF SELF-REPORTED PHYSICAL ACTIVITY LEVELS ON THE PREDICTION OF BODY FATNESS FROM BMI IN WHITE AND BLACK COLLEGE STUDENTS

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DEDICATION

This work is dedicated to the three most important people in my life, namely my wife, my daughter, and my dad. To my amazing wife, Jamie, you are my rock and none of this would have been possible without your patience and understanding during the countless hours spent studying for school, writing this thesis, and working full-time from dusk till dawn every day for three years. To my new baby girl, Stella Grace, born in December of 2007, may you learn to love life, to never be afraid to fail, and to have the courage to pursue your ambitions with passion, an open heart, and especially an open mind. Last but certainly not least, to my dad, you have always been my greatest fan, from the time I was born. In a way, I have you to thank for all of this, because you were the one that taught me about the importance of exercise and nutrition long before college when I was just a kid. You also instilled in me the belief that anything could be achieved through hard work and dedication. I hope you will consider my graduation as a tribute to you.

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LIST OF ABBREVIATIONS

BMI = body mass index

BMC = bone mineral content

CVD = cardiovascular disease

DXA = dual-energy X-ray absorptiometry

FM = fat mass

FFM = fat-free mass

HD = hydrodensitometry

IPAQ = International Physical Activity Questionnaire

LTM = lean-tissue mass

MET = metabolic equivalent

MET-hrs·wk^{-1} = metabolic equivalent hours per week

NHANES = National Health and Nutrition Examination Survey

PA = physical activity

%BF = percent body fat

PRESS = prediction sum of squares

RMSE = root mean square error

SD = standard deviation

SEE = standard error of estimate

STM = soft tissue mass

TBW = total body water

TE = total error

ABSTRACT

The purpose of this study was to test the hypothesis that self-reported physical activity (PA) levels quantified from the International Physical Activity Questionnaire (IPAQ) could be used to improve the prediction of percent body fat (%BF) measured by dual-energy X-ray absorptiometry (DXA) from body mass index (BMI), gender, and race in White and Black college students.

A total of 278 students, aged 18 – 24 yr, volunteered to participate. There were 133 males (85 White and 48 Black) and 145 females (77 White and 68 Black). Total activity levels were quantified in MET-hours per week (MET-hrs·wk^{-1}) using the IPAQ short form. Height and weight were measured and BMI values calculated (kg·m^{-2}). Percent fat was assessed using DXA. Regression analysis was used to determine the impact of MET-hrs·wk^{-1} on the relationship between %BF and BMI, taking gender and race into account. The prediction sum of squares (PRESS) statistic was used to cross-validate the models.

Mean (± SD) values were as follows: MET-hrs·wk^{-1} 37.4 ± 21.9, %BF 24.5 ± 9.3%, and BMI 24.4 ± 4.1 kg·m^{-2}. Percent body fat was significantly correlated with MET-hrs·wk^{-1} (r = -0.44, $p < 0.0001$) and BMI ($r = 0.38$, $p < 0.0001$). Stepwise regression analysis of a reduced model with BMI, gender and race produced an R^2 value of 0.81 (root mean square error [RMSE] = 4.07). A full model with the additional variable MET-hrs·wk^{-1} marginally improved the prediction of %BF ($R^2 = 0.83$, RMSE = 3.87). When cross-validated, the corresponding PRESS statistic for the reduced and full model was 4.10 and 3.90, respectively.

These results suggest that %BF can be predicted with greater precision and accuracy in a college-aged population when MET-hrs·wk^{-1} are included in addition to BMI, gender, and race.

CHAPTER 1
INTRODUCTION

Accurate measures of body composition are important in many areas of health-related research including formulating dietary recommendations and exercise prescriptions, estimating a healthy body weight for clients and athletes, and promoting an understanding of health risks associated with too much fat (Heyward & Wagner, 2004). The two major components of body composition are fat mass (FM) and fat-free mass (FFM), the former of which is the most variable among individuals. In fact, relative body fatness, or percent body fat (%BF), varies considerably based on biological factors including age, gender, and race (Heymsfield, Lohman, Wang, & Going, 2005; Heyward & Wagner, 2004). In addition, lifestyle behaviors such as physical activity (PA) and dietary habits may contribute to differences in body composition among individuals within certain population subgroups (Deurenberg, Deurenberg-Yap, Wang, Lin, & Schmidt, 1999; Guo, Zeller, Chumlea, & Siervogel, 1999; Horber, Kohler, Lippuner, & Jaeger, 1996; Kohrt, Malley, Dalsky, & Holloszy, 1992; Lahti-Koski, Pietinen, Heliovaara, & Vartiainen, 2002; Mattila, Tallroth, Marttinen, & Pihlajamaki, 2007; Ode, Pivarnik, Reeves, & Knous, 2007). In order to examine the relationship between these variables, accurate and precise measurements are necessary.

Direct measures of body composition including %BF, can be easily obtained in clinical and laboratory settings using techniques such as dual-energy X-ray absorptiometry (DXA) (Heyward & Wagner, 2004). However, in epidemiological studies, weight adjusted for height, or the body mass index (BMI, in $kg \cdot m^{-2}$), is used as a surrogate measure of obesity (U.S. Department of Health and Human Services, 1998). However, the use of BMI assumes that after adjusting weight for height, all individuals have the same relative fatness independent of age, gender, and race (Gallagher et al., 1996), and therefore a BMI value of 30 is considered obese in

all adults aged 20 to 74 (U.S. Department of Health and Human Services, 1998). Therefore, the main limitation of BMI as an index of obesity is that it fails to account for the composition of body weight (Heyward & Wagner, 2004), which is comprised mainly of fat, lean-tissue, and bone mineral (World Health Organization, 2000).

Despite its limitations, a number of studies have found that BMI provides a reasonable estimate of adiposity, as long as gender, age, and race are taken into account (Deurenberg, Yap, & van Staveren, 1998; Gallagher et al., 2000; Gallagher et al., 1996). However, the influence of additional factors such as PA on the relationship between %BF and BMI has not been extensively reviewed. The inclusion of PA may need to be taken into consideration when developing body fat prediction equations in order to help partially explain the variation between BMI and %BF in certain population subgroups. For instance, in young adult college populations, those with a higher activity level may have a greater proportion of body weight as lean-tissue mass (LTM) compared to sedentary counterparts at the same weight. This would result in an overestimation of %BF from BMI when using prediction equations that were developed in a less active population (Ode et al., 2007).

Regular physical activity (PA) has been shown to greatly reduce the risk of developing chronic diseases (U.S. Department of Health and Human Services, 1996). Despite well-documented evidence regarding the negative consequences of physical inactivity, participation in exercise decreases significantly between adolescence and adulthood, the age range of most university students (Irwin, 2004). The transition from high school to college is considered a critical period for development of obesity due to lifestyle changes such as poor dietary habits (Anderson, Shapiro, & Lundgren, 2003) and decreased PA (World Health Organization, 2000) that can lead to weight gain. A cross-sectional study conducted by Leslie et al. (2001) on physical activity levels of young adults in Australia indicated that the reported "sedentariness" of

those aged 12-24 years was 14% versus 24% for those aged 25-39 (Leslie, Fotheringham, Owen, & Bauman, 2001). There is also evidence suggesting that "diseases of inactivity" such as atherosclerosis may begin in the second and third decades of life (Strong et al., 1999).

Given the rising prevalence of obesity and physical inactivity in the young adult population, it is important to develop and evaluate methods of estimating or predicting %BF in this population (Arroyo et al., 2004), particularly since health complications associated with being overweight or obese are related to increased levels of body fat rather than body weight alone (World Health Organization, 2000). Since body composition has been shown to vary between sedentary and trained young and older males and females (Kohrt et al., 1992), the aim of the present study was to examine differences in self-reported PA and body composition in White and Black college students aged 18-24, and to determine the impact of PA on the relationship between BMI and %BF in this population, taking gender and race into account. To our knowledge, no study has assessed the ability of self-reported PA to improve the prediction of %BF in a biracial group of college students. It was hypothesized that PA would help to explain some of the variation in %BF between subjects even after accounting for BMI, gender, and race.

Justification

Physical inactivity is considered a global health concern and long-term insufficient PA is a prevalent and preventable leading risk factor for chronic disease and death (World Health Organization, 2004). Public health officials have identified college-age individuals as a neglected but important population for initiatives addressing lifestyle changes to decrease health risks. In fact, increasing PA and prevention of obesity are listed as the top two priority health indicators of the Healthy Campus 2010 initiative, a national campaign established in 2000 by the USDHHS which parallels the objectives of the Healthy People 2010 agenda (American College Health Association, 2006).

Based on a systematic review of university students' participation in adequate amounts of PA, approximately half or more of university students in the U.S., Canada, and China were categorized as insufficiently active. However, due to differences in measurement tools, comparing PA prevalence rates across studies is a major challenge. A specific recommendation of the WHO's "Global Strategy on Diet, Physical Activity and Health" is that more attention be given to conducting and promoting national and international monitoring and surveillance of physical activity. The lack of a standardized instrument to measure the prevalence of PA poses limitations when requiring comparative inferences across the different samples. The International Physical Activity Questionnaire (IPAQ) was designed specifically for use by public health officials to monitor entire populations and to allow for international comparisons. This questionnaire allows for cross-national surveillance and has reasonable measurement properties for monitoring population levels of PA among 15- to 65-yr.-olds (Craig et al., 2003). Therefore, access to modern DXA equipment along with an opportunity to examine the influence of self-reported PA levels from the IPAQ on body composition in a biracial cohort of healthy university students was the impetus for conducting this study.

Objectives

The objectives of this study were as follows:

1. To develop a %BF prediction model for use with White and Black university students aged 18-24 using DXA as the criterion measure and BMI, gender, race, and MET-hrs·wk^{-1} as predictor variables.
2. To determine the impact of MET-hrs·wk^{-1} on the prediction of %BF by comparing the developed model to a three-variable reduced model containing BMI, gender and race.
3. To investigate gender and racial differences in PA and body composition in a young-adult college population.

Hypotheses

1. In young adult college students, BMI, gender, and race will explain at least 75% of the variance in %BF estimated from DXA.
2. The addition of MET-hrs·wk^{-1} will significantly improve the prediction of %BF in this study sample compared with a model containing only BMI, gender, and race.

Assumptions

- The sample size is adequate to develop an accurate body fat prediction model applicable to the study population.
- The International Physical Activity Questionnaire (IPAQ) used to collect data on self-reported PA levels is a valid and reliable measurement instrument.
- The participants understood the survey questions and comprehended how to correctly complete them.
- The participants were truthful in their responses.
- Dual-energy X-ray absorptiometry is a valid and reliable instrument for measuring total percent body fat in all subjects regardless of body thickness or hydration status.

Limitations

- Since the majority of participants were recruited from kinesiology and nutrition classes, the self-reported values of PA obtained may not be representative of an average or typical university student.
- The results of the present study are applicable only to subjects of similar age, race, BMI and self-reported PA levels obtained using the IPAQ short form.

Definitions

- Anthropometry: measurement of body size and proportions including body weight, stature, circumferences, skinfold thicknesses, and bony widths and lengths (Heyward & Wagner, 2004).
- Body composition: the ratio of lean body mass (structural and functional elements in cells, body water, muscle, bone, heart, liver, kidneys, etc.) to body fat (essential and storage) mass (U.S. Department of Health and Human Services, 1998).
- Body Mass Index (BMI): body weight (in kg) divided by height (in m^2) used as a practical marker to assess obesity; often referred to as the Quetelet Index. An indicator of optimal weight for health and different from lean mass or percent body fat calculations because it only considers height and weight (U.S. Department of Health and Human Services, 1998).
- Obesity: a condition of abnormal or excessive fat accumulation in adipose tissue, to the extent that health may be impaired (World Health Organization, 2000). Defined as a body mass index (BMI) of greater than or equal to 30 $kg \cdot m^{-2}$ (U.S. Department of Health and Human Services, 1998).
- Overweight: an excess of body weight but not necessarily body fat. Defined as a body mass index of 25 to 29.9 $kg \cdot m^{-2}$ (U.S. Department of Health and Human Services, 1998).
- Metabolic Equivalent (MET): a unit used to estimate the metabolic cost (oxygen consumption) of physical activity. One MET equals the resting metabolic rate of approximately 3.5 ml O_2 per kilogram of body weight per minute (U.S. Department of Health and Human Services, 1996).
- Dual-energy X-ray absorptiometry (DXA): body composition method used in clinical and research settings to measure total percent body fat (%BF), fat mass (FM), bone-free lean-

tissue mass (LTM), bone mineral content (BMC), and bone mineral density (BMD), from X-ray attenuation (Heyward & Wagner, 2004).

- Physical activity: any bodily movement produced by skeletal muscles that result in an expenditure of energy (U.S. Department of Health and Human Services, 1996).

CHAPTER 2
REVIEW OF LITERATURE

Introduction

Measuring body composition is important for many areas of health-related research. There are known differences in body composition based on many factors including age, gender, race, and level of PA. The relationship between PA and body composition is not fully understood, partially due to differences in assessment methodology. Self-reports of PA are widely used to monitor population trends in PA levels. However, differences in survey instruments have made cross-national comparisons difficult. The IPAQ was developed to provide a standardized instrument for estimating PA across populations. College students are an excellent group to study these relationships due to a wide variation in demographics, racial/ethnic identities, and lifestyle behaviors.

Body Composition Reference Methods

Several reference methods are available and widely used today to assess body composition in humans. The human body is composed primarily of water, protein, minerals, and fat. A 2-C model of body composition divides the body into fat-mass (FM) and fat-free mass (FFM). Body fat is the most variable component among individuals, whereas the FFM has a relatively constant composition (Deurenberg & Deurenberg-Yap, 2001). Reference data for the development of body composition models was originally based on the chemical analysis of organs and a limited number of human cadaver analyses that quantified the fat and fat-free (water, protein, and mineral) content of the human body (Heyward & Wagner, 2004).

Three commonly used reference methods include hydrodensitometry (HD), hydrometry (i.e., doubly labeled water), and dual-energy X-ray absorptiometry (DXA). A multi-component (4-C) model which includes all three methods is currently recommended as the most accurate

criterion method for estimating body composition (Heymsfield et al., 2005; Heyward & Wagner, 2004). This model measures four quantities: body volume, total body water, bone mineral, and body mass (Heymsfield et al., 2005).

Hydrodensitometry (HD) is perhaps the oldest and most widely used reference method for determining body composition. Behnke and colleagues proposed this model in 1942. This method uses a mathematical function derived from body mass and body volume to determine fat-mass (FM). This technique is considered a two-component (2-C) model for assessing body composition, as it partitions the body into fat mass (FM) and fat-free mass (FFM; i.e., water, protein, and mineral) (Heyward & Wagner, 2004). Using Archimedes principle, Behnke et al. established an inverse relationship between body density (Db) and FM. Based on this model, body mass (BM) is considered the sum of FM and FFM. Body volume, determined from underwater weighing, is based on two assumptions, specifically that the density of fat (0.900 g/cm^3 at 36°C) and the density of the FFM (1.100 g/cm^3 at 36°C) are constant for all individuals (Heyward & Wagner, 2004).

Several equations for estimating %BF have been developed using HD as the reference. The two most common equations were developed by Siri (1956) and Brozek et al. (1963) (Heymsfield et al., 2005). Siri calculated a total error (TE) of 3.9% BF for the general population (Heyward & Wagner, 2004). Generally, these 2-C model equations provide reasonable estimates of %BF. However, age, gender, race, level of body fatness, and physical activity all affect the relative proportion of water, mineral, and protein in the FFM and therefore the overall density of the FFM (Heyward & Wagner, 2004; Wagner & Heyward, 2000, 2001). For example, the average density of the FFM of African American females and males (1.106 g/cm^3) is greater than 1.10 g/cm^3 because of their higher bone mineral content and body protein (Heyward & Wagner, 2004). Therefore, the major limitation of using these 2-C model equations is that they use

assumed values for the relative composition of the FFM and the densities of each constituent. Specifically, the densities and proportions of water, protein, and mineral are assumed to be constant within and between subjects and the individual being measured differs from the reference body only in the amount of fat tissue (Heyward & Wagner, 2004).

Hydrometry is the measurement of total body water (TBW). Since water comprises over 60% of body weight and approximately 73% of the FFM, determining TBW is central to measuring body composition (Heymsfield et al., 2005). The reference method for measuring TBW is based on the dilution principle (Heyward & Wagner, 2004). With this method, the concentration of hydrogen or oxygen isotopes in biological fluids (e.g., saliva, plasma, and urine) following equilibration is measured and compared to baseline. The amount of FFM can then be calculated using a 2-C or 3-C model. However, this method is based on several assumptions which, if violated, introduce a source of measurement error. For instance, this model assumes that the hydration factor of the FFM is 73%. A study by Lohman, Harris et al. (2000) reported that even with no technical error, biological variability in the water content of the FFM (~2%) corresponds to a 3.6% error in body fat (Lohman, Harris, Teixeira, & Weiss, 2000).

Dual-energy X-ray absorptiometry (DXA) involves the attenuation of a dual-energy X-ray beam as it passes through a subject. The amount of beam attenuation (reduction in intensity) depends on the amount and the composition of the material within the subject. For DXA scans, part of the attenuation is due to bone and part is due to soft tissue. An X-ray beam with two energies is therefore necessary to distinguish between the two types of soft tissue, fat mass (FM) and bone-free lean-tissue mass (LTM). The difference in attenuation of the two energies allows the determination of the amount of bone and the amount of soft tissue present in the scan region. DXA exposes subjects to an extremely small amount of ionizing radiation, in the order of 0.06 mrem for a total body scan. This amount of radiation is nearly 250 times less than a typical

dental X-ray and is considered low enough that no shielding of the room or health technicians are required.

The basic principle underlying DXA is that the attenuation of X-rays with high- and low-intensity photons is measurable and dependent on the thickness, density, and chemical composition of the underlying tissue (Pietrobelli, Formica, Wang, & Heymsfield, 1996). The attenuation of X-ray beams through fat, lean tissue, and bone varies due to differences in the densities and chemical composition of these tissues. The major assumptions of DXA focus on the estimation of the soft-tissue composition using this technology (Heyward & Wagner, 2004). In theory, the attenuation of a given substance is a constant. However, these values may change with variations in thickness (Pietrobelli et al., 1996). Manufacturers of DXA have attempted to correct this limitation using calibration phantoms that contain substances of known quantity and density that simulate fat, soft tissue, and bone (Heyward & Wagner, 2004).

Although the DXA method assumes a constant hydration of 0.73 for lean-tissue mass, several investigators have found that DXA measurements are relatively unaffected by fluctuations in total body water (± 2%) in normal healthy adults (Heymsfield et al., 2005; Mazess, Barden, & Hanson, 1990; Z. M. Wang et al., 1998). Lohman and colleagues theorized that a 5% change in the water content of the FFM would be likely to affect DXA %BF estimates by only 1% to 2.5% BF (Lohman et al., 2000). In a review of studies using DXA, Lohman (1996) determined the precision of $\%BF_{DXA}$ to be around 1% BF (Heyward & Wagner, 2004). Moreover, when compared to a 6-C chemical model, the prediction error of the DXA method for estimating fat-mass ranges between 1.7 – 2.0 kg (Z. M. Wang et al., 1998).

Comparison studies between DXA and a multi-component (4-C) model have shown that DXA performs equally well for estimating total body composition in young adults (Prior et al., 1997), and individuals varying widely in age (Boileau et al., 1994; Friedl, DeLuca, Marchitelli,

& Vogel, 1992; Lohman et al., 2000; Z. M. Wang et al., 1998). Prior and colleagues (1997) conducted a study to determine whether the accuracy of DXA was affected by gender, race, athletic status, or musculoskeletal development in young adults (Prior et al., 1997). The investigators hypothesized that the agreement between the 4-C model and DXA would be better than the agreement between DXA and HD in terms of percent body fat. The major finding of this study was that $\%BF_{DXA}$ (17.5 ± 8.5%) agreed well with $\%BF_{4\text{-}C}$ (17.1 ± 8.3%) in young White and Black males (21.2 ± 2.1 y) and females (20.7 ± 2.6 y) over a wide range of BMI values (17.1 to 41.2 $kg \cdot m^{-2}$), musculoskeletal development (mesomorphy 1.6 to 9.6), and %BF (3 to 50%). Moreover, mean $\%BF_{DXA}$ was not significantly different from ($\bar{x}_{diff} \pm SD_{diff} = 0.4 \pm 2.9\%$; P = 0.10) and highly related (r = .94, SEE = 2.8%) to percent body fat from the 4-C model. According to Lohman (1992), the accuracy of a new method to predict %BF as compared to a reference method should be evaluated based on the standard error of the estimate (SEE), with values < 3.0% considered very good (Lohman, 1992). Based on the results from Prior et al., DXA exhibited very good accuracy as indicated by a SEE of 2.8% and very little systematic error in the prediction based on the total error (TE) of 2.9%.

Boileau et al. (1994) conducted a study using a group of males and females (N = 308) ranging in age from 8 to 75 years old and found reasonably good agreement between $\%BF_{DXA}$ and $\%BF_{4\text{-}C}$ (SEE = 3.1%) (Boileau et al., 1994). Friedl and colleagues (1992) investigated the reliability of fat estimates from a 4-C model in ten soldiers who were each tested three times (Friedl et al., 1992). These investigators found that the greatest source of error in the 4-C model equation was from HD (~ 1%) followed by TBW estimates (~ 0.5 L). Prior et al. (1997) examined this data to compare $\%BF_{4\text{-}C}$ to $\%BF_{DXA}$ and found that the two methods agreed very well ($\bar{x}_{diff} \pm SD_{diff} = 0.4 \pm 2.5\%$) (Prior et al., 1997).

Defining Obesity

Obesity is a global problem (Popkin & Doak, 1998; World Health Organization, 2000) characterized by an increased amount of body fat to the extent that health may be impaired. From a physiological perspective, the benchmark of obesity is excess body fat to the extent that health is impaired (Ogden, Yanovski, Carroll, & Flegal, 2007; World Health Organization, 2000). However, the amount of body fat considered to be excess is not clear-cut or defined, as it depends on age, gender, race, and health status (Ogden et al., 2007). Direct measures of body fat are difficult to obtain and are not practical for large-scale population studies. Consequently, most current clinical and epidemiological studies rely on measurement of body weight and height to screen for overweight and obese individuals (National Center for Health Statistics, 2004a; Ogden et al., 2007).

The most widely used proxy to define obesity is the body mass index (BMI; in $kg \cdot m^{-2}$). In 1998, the World Health Organization (WHO) declared obesity an epidemic (Drewnowski & Popkin, 1997; Popkin & Doak, 1998; World Health Organization, 2000) and developed a classification scheme based on BMI values to operationally define overweight and obesity (U.S. Department of Health and Human Services, 1998; World Health Organization, 1995, 2000). As such, adult cut-points of 25 and 30 $kg \cdot m^{-2}$ are used to identify individuals as overweight and obese, respectively.

The WHO classification of weight status is based primarily on the association between BMI and mortality (World Health Organization, 2000). A BMI of 30 and above is associated with a modest increase in risk of mortality (Ogden et al., 2007). The exact shape of the BMI-mortality relation is debatable, although a number of studies have suggested a U- or J-shaped curve with the nadir of the curve occurring around a BMI of 25 $kg \cdot m^{-2}$ (Engeland, Bjorge, Selmer, & Tverdal, 2003; Ogden et al., 2007; Troiano, Frongillo, Sobal, & Levitsky, 1996).

Despite controversy regarding the magnitude of relationship between obesity and mortality (World Health Organization, 2000), current evidence suggests that mortality rates are 50 to 100 percent greater in persons with a BMI of 30 $kg \cdot m^{-2}$ compared to those with a BMI in the healthy range (U.S. Department of Health and Human Services, 1998). As weight increases, so does the prevalence of health risks, particularly for cardiovascular disease (CVD) and type 2 diabetes (Centers for Disease Control and Prevention, 2007a; U.S. Department of Health and Human Services, 1998). In fact, the primary cause of excess obesity-related mortality is from CVD (Dorn, Schisterman, Winkelstein, & Trevisan, 1997; Ogden et al., 2007). In terms of morbidity, it has been suggested that the relationship between BMI and type 2 diabetes is perhaps stronger than for any other comorbidity (Ogden et al., 2007), as several cross-sectional and prospective studies have repeatedly observed a positive association between BMI values and an increase in risk for developing type 2 diabetes (Janssen, Katzmarzyk, & Ross, 2002; U.S. Department of Health and Human Services, 1998).

Many studies have shown that BMI is a reasonable measure of adiposity in healthy adults (Deurenberg, Weststrate, & Seidell, 1991; Deurenberg & Yap, 1999; Gallagher et al., 1996; Garrow & Webster, 1985; U.S. Department of Health and Human Services, 1998). However, the use of BMI assumes that after adjusting weight for height, all individuals have the same relative fatness independent of age, gender, and race (Gallagher et al., 1996), and therefore a BMI value of 30 is considered obese in all adults aged 20 to 74 (U.S. Department of Health and Human Services, 1998). For instance, percent body fat (%BF) increases with age and is higher in females than males, but these differences may not be detected by BMI (Baumgartner, Heymsfield, & Roche, 1995; World Health Organization, 1995). Furthermore, factors such as body build (Deurenberg et al., 1999; Rush et al., 2004) and level of PA have also been shown to affect the relationship between BMI and percent body fat (Heyward & Wagner, 2004). Consequently,

athletes are often misclassified as obese based on their BMI even though their %BF may be well within a healthy range (Heyward & Wagner, 2004). Therefore, the main limitation of BMI as an index of obesity is that it fails to account for the composition of body weight (Heyward & Wagner, 2004), which is comprised mainly of fat, lean-tissue, and bone mineral (World Health Organization, 2000). Besides, the WHO defines obesity in terms of excess body fatness, rather than excess body weight (Deurenberg et al., 1998; Heyward & Wagner, 2004; World Health Organization, 2000).

National Trends in Obesity

Data from nationally representative samples indicate that the prevalence of obesity has increased dramatically over the past three decades in Americans of all ages (Flegal & Troiano, 2000; National Center for Health Statistics, 2003; Ogden et al., 2006; Ogden, Fryar, Carroll, & Flegal, 2004; Ogden et al., 2007), with nearly one-third of adults classified as obese and 17% of children and adolescents classified as overweight (Ogden et al., 2006). These trends are paralleled on college campuses with approximately one-third of university students categorized as overweight or obese (The American College Health Association, 2007).

The principal source of national data on healthy weight, overweight, and obesity is obtained from the National Health and Nutrition Examination Survey (NHANES) (Flegal, Carroll, Kuczmarski, & Johnson, 1998; Ogden et al., 2006; Ogden et al., 2004). Since 1960, the NHANES program of the National Center for Health Statistics, Centers for Disease Control and Prevention (CDC) has conducted cross-sectional health examination surveys from a nationally representative sample of the United States population (Ogden et al., 2004). Data collected from each NHANES survey provide current estimates and secular trends for overweight and obesity for the United States population (Flegal et al., 1998; Flegal & Troiano, 2000; Ogden et al., 2006; Ogden et al., 2007).

From 1960 to 2004, the prevalence of obesity in males and females combined increased by nearly 60% from 13.3 to 32.9 percent (Ogden et al., 2007), with the majority of this increase observed within the last two decades. Moreover, it has been suggested that these trends will continue to increase. A recent systematic review and meta-regression analysis conducted by Wang & Beydoun (2007) concluded that approximately 41% of Americans are projected to be obese by the year 2015 (Y. Wang & Beydoun, 2007). Similar patterns have been observed in children and adolescents 6-19 years old with an approximate three-fold increase in the prevalence of overweight within the last twenty-five years (5.5% to 17.1%) (Ogden et al., 2007).

Results from several large-scale population-based and cross-sectional studies suggest that the prevalence of obesity increases with age. A breakdown of the most recent NHANES data (2003-2004) by age group indicates that the percentage of individuals considered obese was 18.8% for 6-11 year olds, 28.5% for 20-39 year olds, and 36.8% for 40-59 year olds (Ogden et al., 2006). These data represent a nationally representative sample of people in the United States that were actually measured for height and weight.

Two other national surveys based on self-reported data confirm results from the NHANES data. The Youth Risk Behavior Survey (YBRS) is a national survey that has been conducted by the Centers for Disease Control (CDC) every two years since 1990 to monitor health risk behaviors of high school students in grades 9-12 (Centers for Disease Control and Prevention, 2006). Self-reported data from 2005 indicate that 31.5% of high school students described themselves as overweight, and the percentage of students that described themselves as overweight was lowest among 9th graders and highest among 12th graders (Centers for Disease Control and Prevention, 2006). Similar trends have been observed in college students. Since 1998, the American College Health Association (ACHA) has conducted surveys on college campuses to document the health status of university students and to provide baseline data to

support national objectives such as Healthy Campus 2010. Based on reference group data from 2006, 36.4% (N = 33,866) of college students described themselves as being either slightly or very overweight (American College Health Association, 2007).

The Relationship between BMI and Body Composition

Reference methods for estimating %BF are typically available only in research or clinical settings (Heyward & Wagner, 2004). These methods generally provide greater accuracy in the assessment of body composition; however, each one is not without inherent assumptions and limitations. Moreover, at the population level, reference methods are simply not feasible. Therefore, prediction equations which rely on statistical relationships between easily measurable body parameters and a reference method have been developed (Deurenberg & Deurenberg-Yap, 2001).

The most practical and widely used field methods to estimate %BF at the population level are BMI, bioelectrical impedance analysis (BIA), and skinfold thickness measurements (Deurenberg et al., 2001; Heymsfield & Baumgartner, 2006). The accuracy of the latter two methods to estimate body fat is described elsewhere and is beyond the scope of this review. For the assessment of obesity in epidemiological studies, BMI is the preferred method. Minimal equipment is needed and errors in measurement due to intra- or inter-observer variation are small (Deurenberg et al., 1991). From BMI, %BF can be predicted, using age- and gender-specific equations (Deurenberg et al., 2001; Deurenberg et al., 1991; Gallagher et al., 2000; Gallagher et al., 1996; Garrow & Webster, 1985) as well as ethnic-specific equations (Deurenberg et al., 1998; Gallagher et al., 1996).

In a landmark study which ultimately lead to the widespread use of the body mass index as a screening tool for obesity, Garrow and Webster (1985) found that the regression of fat·height^{-2} on weight·height^{-2} was 0.943 for males and 0.955 for females (Garrow & Webster,

1985). Based on these findings, these authors developed gender-specific prediction equations to estimate fat mass in kilograms based solely on weight (W) and height (H).

$$\textbf{For males: Fat (kg)} = (.715\ W/H^2 - 12.1)\ H^2$$

$$\textbf{For females: Fat (kg)} = (.713\ W/H^2 - 9.74)\ H^2$$

The authors reported errors of approximately 4.2 kg and 5.8 kg of fat for males and females, respectively. This error is of similar magnitude to that found with HD, hydrometry, and total body potassium counting. However, it was recognized in the original publication that this formula was not suitable for athletes or the elderly where there would be significant variations in lean body mass.

One of the first studies to develop and cross-validate a body fat prediction equation based on BMI was conducted by Deurenberg et al. in 1991 (Deurenberg et al., 1991). These investigators developed a multiple regression model using a sample of 1,229 subjects (57.6% female) with HD as the reference method. Subjects represented a wide range of age (7-83 y) and BMIs (13.9-40.9 $kg \cdot m^{-2}$). The total group of subjects was randomly divided into two groups, one group to develop the model (group A) and another group to cross-validate the prediction equation (group B). For subjects older than 18 years, %BF was predicted using the Siri (1961) equation. Corrections were made for age and level of body fatness based on previously published articles by the investigator. Differences between observed %BF and predicted %BF in groups A and B were small (< 0.5%) but significant ($p < .05$). However, the authors chose to combine the two groups to develop a model based on the entire sample of adults (defined as ≥ 16 y). The combined group equation had an R^2 value of .79 and a SEE of 4.1 %BF.

%BF = 1.2 BMI + .23 age – 10.8 gender – 5.4

Where gender = 0 for females, 1 for males.

When mean observed differences were examined by age group, the 16-20 year old group (*n* = 170) and the 21-25 year old group (*n* = 304) exhibited the lowest difference with predicted percent body fat.

In 1996, Gallagher and colleagues developed a %BF prediction equation to test the hypothesis that BMI is representative of body fatness independent of age, gender, and ethnicity (Gallagher et al., 1996). The investigators used a 4-C model to assess the %BF of 504 White and 202 Black males and females between the ages of 20-94. Statistically significant age ($p < .05$ - .001) and gender ($p < .001$) effects were observed among the groups, with higher %BF noted in older subjects compared to younger persons and greater amounts of body fat found in females than in males throughout the entire adult life span. After controlling for age and gender, ethnicity did not significantly influence the %BF – BMI relationship. In that study, BMI accounted for 25% of the variance in percent body fat. The addition of age and gender resulted in an R^2 value of .67 and a SEE of 5.68% body fat.

%BF = 1.47 BMI + .12 age – 11.61 gender - .22 race – 10.13

Where gender = 0 for females, 1 for males; race = 0 for White, 1 for Black.

In 1998, Deurenberg and colleagues conducted a meta-analysis of 32 studies to examine the relationship between BMI and %BF in different ethnic groups to evaluate the validity of BMI cut points for obesity (Deurenberg et al., 1998). Subjects included 11,924 adult males and females, 4,492 of which were Caucasian and 1,958 Black. The remaining 5,474 subjects represented Ethiopians, Chinese, Thai, Indonesians, and Polynesians. For twenty-eight data points, %BF was determined by HD, in 26 studies by DXA, in 13 studies by hydrometry, in 13 studies by a 3-C or multi-component model, and in 14 studies using bioelectrical impedance or skinfold thickness measurements. A stepwise multiple linear regression analysis was conducted with Caucasians as the reference group to develop a prediction equation of %BF from BMI. The

model was applied to different ethnic population groups and the residuals were calculated and tested for significance from zero. The resultant prediction equation had an R^2 value of .88 and a SEE of 2.5%.

%BF = 1.294 BMI + .20 age – 11.4 gender – 8.0

Where gender = 0 for females, 1 for males.

Mean residuals for the American Black females was -1.9 (SEM 0.8; $p < .05$) and males was -1.9 (SEM 1.0; *NS*). The investigators concluded that the prediction equation based on Caucasian subjects overestimated the %BF of the American Blacks, suggesting that a 1.3 unit increase in BMI values would be necessary in order to reflect equal levels of body fat.

In response to the international criteria proposed for defining obesity based on BMI values, Gallagher et al. (2000) conducted a multi-site study to develop %BF ranges that corresponded to BMI guidelines (Gallagher et al., 2000). The study design included three groups of subjects (White, African American, and Asian) evaluated at three different sites (United States, United Kingdom, and Japan). White subjects were evaluated at the US and the UK site, African Americans were evaluated in the US only, and Asian subjects were evaluated in Japan only. Body fat was measured by DXA at all three sites, and a 4-C model was additionally applied at the US and UK sites. The total sample consisted of 1,626 subjects (613 males and 1,013 females) including 417 Whites, 254 African Americans, and 955 Asians, with a mean age range from 39.3 y in Asian females to 56.2 in African American females. Asian subjects had the lowest BMI values, whereas African American females had the highest values. The investigators noted a curvilinear relationship between %BF and BMI within all groups, and therefore used 1/BMI (BMI^{-1}) in the regression analysis to linearize the data. There was a high correlation between $\%BF_{4\text{-}C}$ and $\%BF_{DXA}$ ($R = .95$; SEE = 3.2; $P < .001$). The stepwise multiple regression equation for the entire group using the $\%BF_{4\text{-}C}$ model produced an R^2 value of .79 and SEE of 3.97%.

Another equation was presented for the Whites and African Americans together with ethnicity removed that produced an R^2 value of .74 and SEE 4.98%.

$$\%\textbf{BF} = \mathbf{64.5 - 848\ (BMI^{-1}) + .079\ age - 16.4\ gender}$$

$$\mathbf{+\ .05\ (gender\ x\ age) + 39.0\ (gender\ x\ BMI^{-1})}$$

Where gender = 0 for females, 1 for males.

Based on their observations, Gallagher et al. determined the predicted %BF for three separate age groups (20-39, 40-59, and 60-79 y) corresponding to a BMI of 30 kg·m^{-2}. The values for the 20-39 y White and African American males and females were 25% and 39%, respectively (Gallagher et al., 2000).

Very few studies have developed population-specific body fat prediction models for university students. Moreover, even fewer have used DXA as the criterion measure. In one study, Rush et al. (2004) examined the relationship between body size, body composition, and fat distribution in 114 healthy males (64 European, 31 Pacific Island, 19 Asian Indian) aged 17-30 years (Rush et al., 2004). The authors of this study noted a curvilinear relationship between $\%BF_{DXA}$ and BMI, and therefore applied a log transformation to make the data linear. The regression model developed had an R^2 value of .72 and SEE 4.89%.

$$\mathbf{\%BF = 105.79 + log_{10}\ (BMI) - 128.42 - (3.77\ x\ group1) + (7.60\ x\ group2)}$$

Where group1 = 0 for Europeans or Asian Indians, 1 for Pacific Islanders

Group2 = 0 for Europeans or Pacific Islanders, 1 for Asian Indians.

Arroyo et al. (2004) compared %BF predicted from HD using the Siri (1961) equation as the reference to four other published equations in 653 (190 male and 463 female) university students aged 18-30 years in Spain (Arroyo et al., 2004). Comparisons were based on two other HD equations (Brozek, 1963; Lean, 1996), one equation based on bioelectrical impedance (Lohman, 1992) and one equation based on BMI (Deurenberg et al., 1991). The investigators determined

that the two other equations based on HD had the highest agreement with the reference, followed by the BMI-based equation and the impedance-based equation, thereby concluding that BMI is a poor predictor of %BF body fatness in university students. However, the purpose of that study was to compare previously published equations for predicting body fat in college students rather than developing a new prediction model. Furthermore, it is reasonable to assume that equations based on the same reference method will perform better than ones developed using other reference methods.

The Relationship between Physical Activity and Body Composition

Total energy expenditure represents the sum of three primary components: resting energy expenditure (~60%), the thermic effect of food (~10%), and non-resting energy expenditure, primarily in the form of physical activity (~30%) (U.S. Department of Health and Human Services, 1996). The third component is the most variable among individuals. In addition to excess body weight, physical inactivity has been identified as an independent risk factor for CVD in the 1996 Surgeon General's Report (U.S. Department of Health and Human Services, 1996).

Many of the protective effects of PA against CVD are related to its positive impact on obesity. Several comprehensive reviews have consistently concluded that PA generally affects body composition and weight favorably by promoting fat loss while maintaining or increasing lean mass (Toth, Beckett, & Poehlman, 1999; U.S. Department of Health and Human Services, 1996). Cross-sectional studies have also demonstrated a negative relationship between level of PA and BMI (World Health Organization, 2000). Physical activity has also been shown to play a role in the prevention and treatment of obesity (Kriketos, Sharp, Seagle, Peters, & Hill, 2000). In a longitudinal study conducted in Finland among 25-64 year old adults over a fifteen year period, an inverse association was found between BMI and self-reported PA, and this association

strengthened over time (Lahti-Koski et al., 2002). Furthermore, a systematic review conducted in 2000 found that most, but not all prospective observational studies have shown that PA helps attenuate increases in fat mass (Fogelholm & Kukkonen-Harjula, 2000).

There are several potential explanations for inconsistent findings, including differences in study design, instrumentation, sample size and characteristics, and outcome measures. For example, some studies have failed to find an association between PA and BMI, but have observed relationships between PA and percent body fat. A recent prospective study conducted with 140 young adult male conscripts found only DXA-measured %BF to be significantly related to running in a stepwise regression analysis including BMI, %BF, and FM (Mattila et al., 2007). In fact, %BF was the strongest predictor of physical fitness, not BMI.

Another reason for inconclusive data may be due to the method used to describe PA levels. Physical activity is difficult to assess accurately in large-scale studies. Gold standard methods of measurement such as indirect calorimetry and doubly labeled water require expensive equipment and trained personnel. Accelerometers are another option, but the data can be extremely difficult to interpret. Recently, Lohman et al. (2006) examined whether body composition measured from DXA was associated with PA derived from accelerometry in a multi-ethnic group of 1,553 girls (Lohman et al., 2006). They found that body fat and fat mass index (fat mass$\cdot m^{-2}$) were most negatively associated with PA (r = -0.17 and r = -0.16, respectively for MET-weighted moderate-to-vigorous physical activity [MVPA]; $p \leq 0.002$).

Although the use of objectively-measured PA may be considered preferable, self-reports are still the most practical for assessing PA levels at the population level (Sarkin, Nichols, Sallis, & Calfas, 2000). However, many self-reported PA questionnaires have been developed for large-scale epidemiological studies (Pereira et al., 1997; Sarkin et al., 2000), making comparisons of

results difficult to interpret. Consequently, there is a need for accurate self-reports that can be administered to large groups of people both cheaply and easily.

National Trends in Physical Activity

The American College of Sports Medicine (ACSM) and the American Heart Association (AHA) currently recommend that all adults aged 18-65 accumulate a minimum of thirty minutes of moderate-intensity aerobic PA on five days per week or twenty minutes of vigorous-intensity aerobic PA on three days per week (Haskell et al., 2007). A shorthand method for categorizing the intensity of specific activities is the MET, or metabolic equivalent (Ainsworth et al., 2000), with one MET representing an individual's energy expenditure while sitting quietly (Haskell et al., 2007). Based on a compendium of activities created by Ainsworth and colleagues, 3-6 METs is considered moderate-intensity, and anything over 6 METS is considered vigorous. When combining moderate and vigorous intensity activity to meet the current recommendations, the minimum goal is to engage in 450-750 $MET\text{-}min \cdot wk^{-1}$ (9.5 to 12.5 $MET\text{-}hrs \cdot wk^{-1}$) (Haskell et al., 2007).

Current national data indicate that 68% of US males and 71% of females fail to meet the current recommendations for PA; and 39% of males and 42% of females engage in no leisure-time PA (Bassuk & Manson, 2005; Centers for Disease Control and Prevention, 2007b). Additionally, PA levels decline with age (Toth et al., 1999). These age-related trends in PA are associated with increased body weight and body fatness (Guo et al., 1999; Kohrt et al., 1992). Young people are at particular risk for becoming sedentary as they grow older (National Center for Health Statistics, 2004b). Many adult behaviors are established during late adolescence and early adulthood (Buckworth & Nigg, 2004; National Center for Health Statistics, 2004a; Ogden et al., 2007). Nationwide in 2005, only 35.8% of high school students reported being physically active for at least 60 minutes/day on at least five of the previous days (i.e., met currently

recommended levels of PA) and 9.6% had not participated in any moderate or vigorous PA during the preceding seven days (Centers for Disease Control and Prevention, 2006).

Among college-aged students, a systematic review conducted in 2004 of 19 studies representing 35,747 university students concluded that over 50% of American and Canadian university students are insufficiently active and do not meet the CDC/ACSM minimum guidelines for physical activity (Irwin, 2004). Similarly, results from the 2006 ACHA National College Health Survey indicated that only 44.2% (*N* = 41,221) of U.S. college students reported exercising for at least 20 minutes vigorously or 30 minutes moderately on at least three of preceding seven days (The American College Health Association, 2007).

Buckworth & Nigg (2004) reported PA levels and sedentary behaviors among a cohort of 490 college students (73.8% White & 16.2% Black) with a mean age of 21 ± 4.0 years and 90.8% were between 18 and 24 years (Buckworth & Nigg, 2004). They found that 73.1% of students reported having participated in moderate or vigorous exercise at least three times in the past seven days. In addition, more students in that sample engaged in moderate activities on at least five of previous seven days (30.6% vs. 19.5%), and vigorous activity on at least three days (53.2% vs. 37.6%) than those students sampled in the 1995 NCHRBS (Douglas et al., 1997).

Gaps in the Literature

The current international recommendations for health-enhancing PA (HEPA) call for 30-minutes of moderate-intensity activity at least five days per week or 20-minutes of vigorous-intensity activity at least three days per week (Haskell et al., 2007). The International Physical Activity Questionnaire (IPAQ) was developed by a global working group of PA researchers from the WHO, the CDC, and other partners in response to the demand for a comparable and valid instrument for assessing PA levels across populations and countries (International Physical Activity Questionnaire, 2002). The questionnaire has been tested worldwide and is now

recommended for use in national population-based prevalence studies (Craig et al., 2003). It assesses the total amount of vigorous and moderate-intensity PA covering all major domains, for example work/education, transport, chores, recreation/exercise, and walking undertaken within the previous seven days.

The Eurobarometer study conducted in 2002 provided prevalence data using the IPAQ across fifteen European Union countries (Sjostrom, Oja, Hagstromer, Smith, & Bauman, 2006). They found that Sweden was the least active (23%) and that the Netherlands was the most active (44%) country. However, this study was conducted across a wide age range (15-55+ years). As Leslie et al. (2001) pointed out, “the broader age group categories (often 10 or more yr) that have generally been reported for population surveys do not provide a perspective on age-specific prevalences and trends within the early years of adulthood” (Leslie et al., 2001). To my knowledge, only one study has investigated PA levels in college students using the IPAQ. Patterson et al. (2006) examined 201 Irish college students and found that the proportion of students considered “sufficiently active” ranged from 21.4% in females to 44.7% in males (Patterson et al., 2006). However, they used the long-format which has been found to give different results than the short form.

Therefore, the current investigation seeks to develop a body fat prediction equation that takes into consideration two standardized measurements (i.e. BMI and IPAQ scores) in a young adult college population. The purpose was to test the hypothesis that IPAQ scores could be used to improve the prediction of body fatness. In addition, this study will contribute baseline PA data from the IPAQ combined with its relationship with body composition variables in White and Black university students.

CHAPTER 3
SUBJECTS AND METHODS

Study Sample

A total of 278 healthy university students aged 18-24 were included in the present study. There were 133 males (85 White and 48 Black) and 145 females (77 White and 68 Black). All subjects participated voluntarily and were recruited from undergraduate kinesiology and nutrition classes, fraternities and sororities, and flyers posted on-campus. Females that were pregnant or thought they might be pregnant and individuals weighing over 250 pounds (due to weight limit requirements of the DXA device) were excluded from participating. The research protocol was approved by the Louisiana State University Institutional Review Board (approval number: 2657) and all subjects provided written informed consent.

Measured Variables

Body Composition

Standing height was measured with a stadiometer (Shorr Productions; Olney, MD, 2004) and body weight with a digital scale (SECA 880; SECA Corporation Weighing and Measuring Systems; Hanover, MD, 2004). Body mass index (BMI) values were calculated as weight in kilograms divided by height in meters squared ($kg \cdot m^{-2}$). BMI is a reasonable measure of obesity at the population-level (Garrow & Webster, 1985) but should not be the only measurement used to estimate %BF due to a ± 5% standard error (American College of Sports Medicine, 2006).

Dual-energy X-ray absorptiometry (DXA) was used to measure body composition. Specifically, a full-size Prodigy Pro (GE Lunar Corporation, Madison, WI) total body scanner in conjunction with Encore 2004 software (version 8.10.027) was used to obtain estimates of total percent body fat (%BF). The Prodigy Pro is a narrow-angle fan-beam densitometer that uses a CZT (Cadmium-Zinc-Telluride) detector to directly convert X-rays into an electronic signal. The

X-ray source is self-contained and mounted within the table, while the CZT detector is mounted within the scan arm located directly above the table. Controlled by a computer, the source and detector move in tandem across the subject, producing a transverse scan of the area of interest.

The DXA method is considered a 3-C tissue-level model of body composition, as a total body scan provides information regarding fat-mass (FM), bone-free lean-tissue mass (LTM), and bone mineral content (BMC) (Heyward & Wagner, 2004). In order to obtain %BF, the DXA model uses proprietary algorithms which essentially uses two separate sets of 2-C model equations (Ellis, 2000). The first set of equations is used to partition the body into bone and soft-tissue mass (STM) (STM = fat + LTM), and the second set of equations divides the STM into fat and lean-tissue (Heyward & Wagner, 2004). Percent body fat by DXA ($\%BF_{DXA}$) for the total body is obtained from the output using the following formula:

$$\mathbf{\%BF_{DXA} = FM / (FM + LTM + BMC)}$$

The *in-vivo* precision error for the Prodigy Pro given by the manufacturer is less than 1%. The *in-vitro* precision error of the phantom measurements used to calibrate the machine daily is 0.23%. In several reviews of studies comparing DXA estimates of %BF to estimates obtained using a multi-component molecular model, Lohman determined the precision of $\%BF_{DXA}$ to be within 1-3% BF (Heyward & Wagner, 2004; Lohman, 1996; Lohman et al., 2000).

Physical Activity and Demographic Data

Demographic information including age, gender, race, and self-reported height and weight were obtained from survey questions (Appendix B).

The IPAQ short form (Appendix C) was administered to assess the frequency and duration of vigorous- and moderate-intensity activity, walking, and sedentary activity performed during the previous week. The IPAQ was developed in 1998 by an international group of PA assessment experts in an effort to provide a valid instrument suitable for surveillance of PA

within and between countries (International Physical Activity Questionnaire, 2002). Between 1997 and 1998, four long and four short forms of the IPAQ were designed (administered by telephone interview or self-administered, with two alternate reference periods, either the "last 7 days" or a "usual week" of recalled PA) (Craig et al., 2003). Following the development process, extensive reliability and validity testing were conducted in 2000 across twelve countries (14 sites). Fourteen centers from twelve countries collected reliability and/or validity data on at least two of the eight IPAQ instruments.

Test-retest reliability coefficients for the self-administered short form ranged from 0.66 to 0.88 (N = 292, ρ = 0.75) (Craig et al., 2003). The observed concurrent validity between the different short forms showed reasonable agreement (pooled ρ = 0.58, 95% CI 0.51 – 0.64). The criterion validity of the self-report long and short forms was assessed against CSA (Computer Science and Applications, Inc., Shalimar, FL) accelerometers over a seven day period. Fair to moderate agreement between measures was observed with the short form (N = 781, pooled ρ = 0.30, 95% CI 0.23 – 0.36). The overall process evaluation indicated that the short form using the "last 7 d" was the version most sites preferred and the consensus panel therefore recommended using this version for national and regional prevalence studies (Craig et al., 2003).

Ekelund and colleagues (2000) examined the criterion-related validity of the IPAQ short form in a sample of 198 subjects aged 20-69 years (Ekelund et al., 2006). Subjects wore an MTI Actigraph activity monitor around their waist for seven consecutive days and then completed the IPAQ short form. The investigators reported that the total activity from the objective PA data (average counts min^{-1}) and the IPAQ data ($MET\text{-}min \cdot day^{-1}$) were significantly and positively correlated (N = 185, r = .34, $p < .001$).

Procedures

Data were collected from each participant during one session lasting approximately forty-five minutes in the Louisiana State University Nutrition and Health Assessment Laboratory. Appointments were scheduled through e-mail and subjects were informed to wear lightweight, loose fitting clothing with no metal attached and to not exercise or drink more than one cup (8 oz.) of any caffeine-containing beverages on the day of testing.

Upon arrival, the primary investigator (MZ) explained the experimental protocol and participants were asked to read and sign the Subject Consent Form (Appendix A) and a short demographic survey (Appendix B). Next, subjects were given the IPAQ (Appendix C) to assess total health-enhancing physical activity (HEPA) and sedentary activity. Participants completed the short (last 7 days) self-administered IPAQ (IPAQ-S7S) version using an interview probe-type format directed by the researcher (MZ). A probe protocol similar to the one used by Rzewnicki et al. (2002) was used to minimize the potential for over-reporting (Rzewnicki, Auweele, & De Bourdeaudhuij, 2002). Participants were asked to recall the frequency (days per week), duration (minutes) and level of intensity (vigorous, moderate, walking or sitting) of PA undertaken within four domains: leisure-time PA, work-related PA, transport-related PA, and domestic and gardening (yard) activities. During the interview, respondents were asked to explain their responses, and give more exact, more complete, and more detailed reports for the last seven days. A sample question included: ‘You said that you were vigorously active three days last week for an average of thirty minutes each day. Can you please tell me about that activity’. Probe questions included: ‘Were these activities performed for at least 10 minutes consecutively?’ and ‘How was your breathing affected?’ Subjects were told to think of vigorous activities as those where they probably wouldn’t be able to sustain a conversation with someone. Attention was given to the explicit criteria used by the IPAQ such as the minimum duration of 10

minutes for individual bouts of physical activity. The IPAQ includes an additional question which asks about time spent sitting during a weekday; however, this question was not included in the analysis.

Based on the responses, each subject's PA level was computed and recorded in MET-minutes per week (MET-min·wk^{-1}) according to the IPAQ scoring protocol (International Physical Activity Questionnaire, 2005). The IPAQ assigns MET levels of 8.0, 4.0, and 3.3 to vigorous-, moderate-intensity, and walking activities, respectively. MET-min·wk^{-1} is calculated as: MET level x minutes of activity/day x days per week. Total PA values were re-coded into MET-hours per week (MET-hrs·wk^{-1}) by dividing MET-min·wk^{-1} by sixty.

Subjects were grouped into three categories (high, moderate, low) according to the IPAQ scoring protocol. The "high" IPAQ category is meant to reflect "total sufficient activity," consistent with current recommendations for health-enhancing physical activity (HEPA) (Sjostrom et al., 2006) and students were classified as such if they accumulated at least 3,000 MET-min·wk^{-1} of total activity, or 1,500 MET-minutes of vigorous activity on at least three of the previous seven days. A more detailed description of the scoring protocol is available on-line (International Physical Activity Questionnaire, 2005).

Standing height (inches) and weight (pounds) were measured twice without shoes by a trained technician (MZ). A third measure was taken if height differed by more than 0.5 inches or weight by more than 0.5 pounds. The digital scale was calibrated prior to each session using two 5 lb. weights.

Total percent body fat (%BF) was estimated using a Prodigy Pro whole-body scanner (GE Medical Systems, Madison, WI). The DXA machine was calibrated daily against the standard calibration block supplied by the manufacturer. The instrument automatically altered scan depth (standard or thick) based on the thickness of the subject as estimated from age, height,

and weight. All subjects were scanned in a supine position with the midline of the body centered on the table using the longitudinal centerline as a guide. Approximate scan times for standard and thick modes were six and ten minutes, respectively. All scans were performed and analyzed by one trained operator (MZ).

DXA exposes subjects to an extremely small amount of ionizing radiation, in the order of 0.06 mrem for a total body scan. This amount of radiation is nearly 250 times less than a typical dental X-ray and is considered low enough so that no shielding of the room or health technicians are required. Despite the low dosage of radiation, female subjects were not scanned if they were pregnant. Additionally, individuals receiving DXA scans were advised not to wear clothing with any metal attached (i.e., zippers, buttons, wire-bra), as these items cause the X-ray beams to scatter, thus decreasing the precision of the scan.

Statistical Methods

Descriptive Statistics

Descriptive statistics including means (*M*), standard deviations (*SD*), and ranges were calculated for age, height, weight, BMI, %BF, fat mass (FM), lean-tissue mass (LTM), bone mineral content (BMC), and MET-hrs·wk^{-1} for each gender and racial group using SAS (v. 9.1.3; SAS Institute, Inc., Cary, NC). Comparisons of the means between gender and among racial/ethnic groups within each gender were tested using Student's *t* test. The proportion of males and females considered overweight (BMI between 25 and 29.9 kg·m^{-2}) and obese (BMI ≥ 30 kg·m^{-2}) was tabulated, as well as the number of students considered "sufficiently active" based on total PA levels and according to the IPAQ scoring protocol. Pearson's correlation coefficients were calculated by gender to investigate the relations between MET-hrs·wk^{-1} or %BF on age and body composition. Simple linear regression plots of the response variable

(%BF) versus BMI and MET-hrs·wk^{-1} were constructed to determine the strength of relationship. Two-sided *p*-values were considered significant at $p < .05$.

Variable Selection and Preliminary Model Development

Multiple stepwise linear regression analyses were used to investigate the influence of MET-hrs·wk^{-1} and to determine the most appropriate weight-height index (BMI, BMI^2, or BMI^{-1}) on percent body fat. Potential first order interaction terms were considered during model development, and all potential models were checked for normality and homogeneity of variance. Gender and race were both coded as dummy variables.

There were two stages involved in the preliminary model development process. Gender-specific models were constructed for the first stage, whereas regression analyses were conducted on the total dataset for the second stage. The preliminary equations were selected by measures of goodness-of-fit statistics, including R^2 values and the root mean square error (RMSE). The coefficient of determination (R^2) is the proportion of total variance in the response variable that is accounted for by the predictor variables in the model. Increasing the number of predictor variables in a model will always result in larger R^2 values. High R^2 values are an indication that the equation fits the data. A high R^2 value and a low RMSE are indicators of explained variability and good precision. The RMSE is a measure of lack of precision of a prediction model, as it is technically considered extraneous variability unexplained by the model. The square root of the sum of squares of the deviations of the predicted values from the observed values, divided by the total number of observations minus the number of parameters, is the RMSE. That is,

$$\text{RMSE} = \sqrt{\frac{\sum(\text{observed} - \text{predicted})^2}{(n-p-1)}}$$

where n is the number of observations and p is the number of predictor variables. The RMSE is used as a measure of goodness of fit. When comparing models, the one with the smallest RMSE has the highest precision (Roche, Heymsfield, & Lohman, 1996). The RMSE value can be standardized for the mean value of the response variable to create a coefficient of variation (CV). The CV is useful in comparing equations with different response variables.

Cross-validation is the application of a prediction model to a sample independent from the one used to construct the equation (Myers, 1990). The total error (TE) is used to measure the performance of a predictive equation on cross-validation (Heyward & Wagner, 2004). The TE represents the average deviation of individual scores from the line of identity, where the slope is equal to one and the y-intercept is equal to zero (Heyward & Wagner, 2004). Total error is calculated as the square root of the sum of squared differences between the observed and the predicted values divided by the number of subjects in the cross-validation sample (Sun et al., 2003). A general rule is that the value of the TE should be similar to the RMSE of the same equation for the sample used in its development (Roche et al., 1996). The closer the TE is to the RMSE, the greater the accuracy of an equation when applied to an independent sample.

Final Model Selection

The accuracy of each candidate model was evaluated by using the PRESS (prediction sum of squares) statistic. The PRESS is an external cross-validation technique used to determine the TE or true prediction error of a regression model (Myers, 1990). For this procedure, each subject in the sample is excluded one at a time and regression analysis is performed on the remaining *n*-1 subjects. The value for each omitted data point is predicted, and a PRESS residual score (Y – Y') is calculated. The true prediction error of the model is determined by measuring and averaging the sum of squares of all PRESS residuals (Heyward & Wagner, 2004). The PRESS was calculated using the following formula:

$$\text{PRESS} = \sqrt{\frac{\sum(\text{observed} - \text{predicted})^2}{n}}$$

where n is the number of observations in the cross-validation sample. The final models were selected based on the smallest difference between the PRESS and the RMSE.

CHAPTER 4
RESULTS

Descriptive Statistics

In total 278 subjects participated in the study. There were 133 males (85 White and 48 Black) and 145 females (77 White and 68 Black). The ages, physical characteristics, and DXA-measured body compositions for the study sample are shown in **Table 1**.

TABLE 1. Descriptive statistics for the study sample of White and Black males and females (N = 278)

Variable	White males	Black males	White females	Black females
n	85	48	77	68
Age (y)	20.6 ± 1.7[1] (18-24)[2]	20.5 ± 1.5 (18-24)	20.3 ± 1.5 (18-24)	20.2 ± 1.3 (18-23)
Height (m)	1.77 ± 0.66 (1.62-1.98)	1.77 ± 0.76 (1.64-1.97)	1.64 ± 0.71 (1.47-1.82)	1.65 ± 0.75 (1.51-1.84)
Weight (kg)	79.5 ± 11.3 (51.6-108.2)	84.1 ± 15.1 (57.7-112.9)	59.3 ± 9.4[3] (42.5-86.1)	65.6 ± 11.8 (45-95)
BMI ($kg \cdot m^{-2}$)	25.3 ± 3.3 (18.5-35.3)	26.8 ± 4.5 (18.8-36.4)	22.1 ± 2.9[3] (17.5-32.6)	24.3 ± 4.6 (17.4-36.9)
%BF	17.7 ± 6.3 (6.9-34.4)	19.3 ± 8.1 (5.0-37.4)	29.2 ± 6.2 (15.6-42.7)	31.5 ± 8.2 (16.2-49.0)
FM (kg)	14.6 ± 6.7 (4.3-33.6)	17.2 ± 9.5 (3.2-41.7)	17.6 ± 5.9[4] (6.8-32.8)	21.3 ± 8.9 (8.7-46.0)
LTM (kg)	62.2 ± 7.2 (41.3-81.9)	63.7 ± 7.9 (49.2-87.7)	39.0 ± 4.7[4] (30.1-53.1)	41.3 ± 4.9 (32.7-55.0)
BMC (kg)	3.4 ± 0.5 (2.0-4.5)	3.6 ± 0.6 (2.2-4.9)	2.4 ± 0.4[3] (1.7-3.7)	2.8 ± 0.5 (2.0-3.9)
MET-hrs·wk^{-1}	45.3 ± 23.8 (6.8-103.4)	45.2 ± 23.1 (14.9-107.3)	32.6 ± 16.3 (2.5-73.7)	27.4 ± 18.4 (0-81.3)

[1] $\bar{x} \pm SD$
[2] Range
[3] Significantly different from Black females, $P < 0.001$
[4] Significantly different from Black females, $P < 0.01$
Note. BMI = body mass index; %BF = percent body fat from DXA; FM = fat mass; LTM = lean-tissue mass; BMC = bone mineral content; MET-hrs·wk^{-1} = calculated physical activity level from the IPAQ.

Age was similar for the entire group. Compared with the females, the males were taller, heavier, had higher BMIs, lean-tissue masses (LTM), bone mineral contents (BMC), and self-reported PA levels (MET-hrs·wk^{-1}), whereas females had higher absolute and %BF ($p < 0.0001$ for all; data not shown). As shown in **Table 1,** age, height, %BF, and MET-hrs·wk^{-1} were similar across White and Black subjects within each gender. No significant differences were observed in the physical characteristics of males, although differences in weight, BMI and BMC approached

significance (p = .07, p = .05 and p = .06, respectively). In females, body weight, BMI, FM, LTM, and BMC were all significantly greater ($p < .01$) in Black compared with White subjects, with differences in %BF approaching significance (p = .06). White females reported higher mean values of self-reported PA in MET-hrs·wk^{-1}, although this difference was also not statistically significant (p = .07).

Based on currently established cut-points for BMI established by the U.S. Department of Health and Human Services (U.S. Department of Health and Human Services, 1998), the percentage of males and females considered overweight (25 to 29.9 kg·m^{-2}) was 43% and 17%, and the percentage considered obese (≥ 30 kg·m^{-2}) was 15% and 6%, respectively. In terms of the number of students considered "sufficiently active" based on total PA levels using the IPAQ scoring protocol, 84 (63%) males and 52 (36%) females accumulated at least 3,000 MET-min·wk^{-1} or 1,500 MET-minutes of vigorous-intensity activity on at least three of the previous seven days. When separated by race, the proportions were 65% and 60% for White and Black males, respectively, and 43% and 28% for White and Black females.

The Relationship between Physical Activity and Body Composition Variables

Simple linear regression plots of the response variable (%BF) versus BMI (**Figure 1**) and MET-hrs·wk^{-1} (**Figure 2**) were constructed for the entire sample delineated by gender. A significant linear relationship was observed between %BF and both BMI (r^2 = .14, $p < .0001$) and MET-hrs·wk^{-1} (r^2 = .19, $p < .0001$). As shown in **Figure 1**, males had less %BF than females across all levels of BMI values. In contrast, the relationship between %BF and MET-hrs·wk^{-1} depicted in **Figure 2** appeared to be more random and evenly scattered among the entire group, with a slight tendency for males to report higher levels of PA than females.

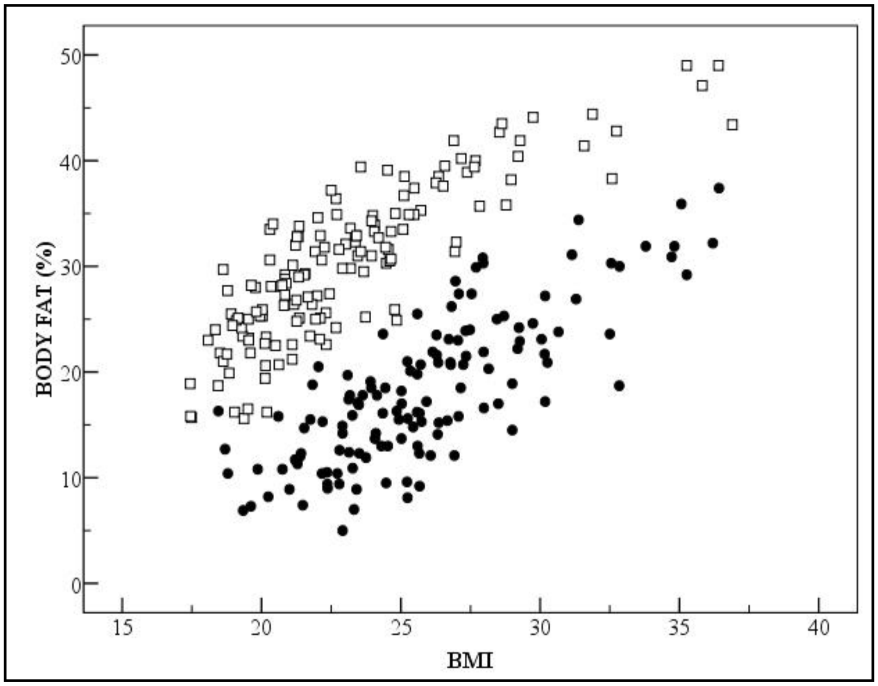

Figure 1. The relation between body fat percentage and body mass index (BMI, in kg·m^{-2}) in males (●) and females (□).

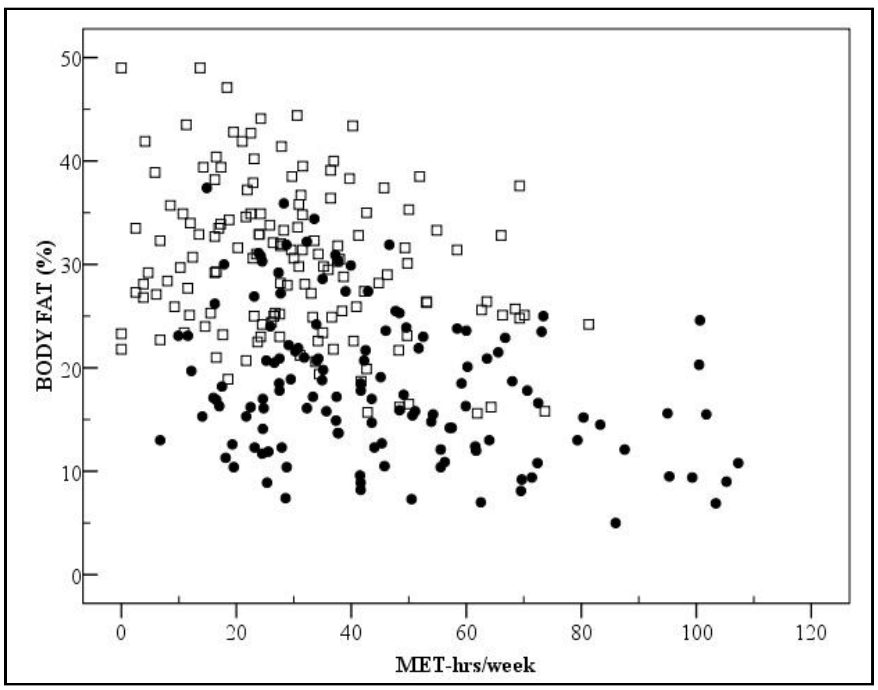

Figure 2. The relation between body fat percentage and MET-hrs·wk^{-1} in males (●) and females (□).

The correlation coefficients for %BF and MET-hrs·wk^{-1} versus age and body composition variables in males and females are shown in **Table 2**. Percent body fat was highly related to weight, BMI, and FM in both groups ($p < .001$), and significantly associated with BMC in males ($p < .05$) and females ($p < .01$). Physical activity in MET-hrs·wk^{-1} was significantly negatively correlated with FM and %BF in males and females ($p < .001$), and positively related with LTM in males ($p < .05$). There were no significant relationships observed between MET-hrs·wk^{-1} and weight or BMI.

TABLE 2. Pearson correlations (*r*) in males and females for percent body fat (%BF) or MET-hrs·wk^{-1} with age and body composition variables

	%BF		**MET-hrs·wk^{-1}**	
	Males	Females	Males	Females
Age (y)	.07	-.07	.06	.13
Height (cm)	-.08	-.14	.12	.10
Weight (kg)	**.68*****	**.73*****	-.07	-.10
BMI (kg·m^{-2})	**.79*****	**.85*****	-.14	-.16
FM (kg)	**.97*****	**.94*****	**-.27****	**-.21****
LTM (kg)	.11	.10	**.17***	.13
BMC (kg)	**.21***	**.27****	.09	.03
%BF	--	--	**-.32*****	**-.28*****

Note. %BF = percent body fat from DXA; MET-hrs·wk^{-1} = calculated physical activity level from the IPAQ; BMI = body mass index; FM = fat mass; LTM = lean-tissue mass; BMC = bone mineral content.
* $p < .05$; ** $p < .01$; *** $p < .001$.

Preliminary Model Development

Stage 1

Multiple stepwise regression analyses were conducted for males and females separately to determine which weight-height index (BMI, BMI^2, BMI^{-1}) produced the "best" equation for predicting %BF when combined with MET-hrs·wk^{-1} and race. In males, BMI was the most appropriate index, and race was not a significant predictor. The two-predictor variable equation with BMI and MET-hrs·wk^{-1} resulted in a model with an R^2 value of 0.67 and RMSE of 4.07. In

females, BMI^{-1} produced a better fit than BMI, and race was a significant predictor. The three-predictor variable model (BMI^{-1}, MET-hrs·wk^{-1}, and race) produced an R^2 of 0.78 and a RMSE value of 3.48. A summary of the stepwise procedure along with the parameter estimates is shown in **Table 3a**.

TABLE 3a. Summary of the stepwise selection procedure and parameter estimates of percent body fat in males and females separately

Group	Step	Variable Entered	Parameter Estimate	Standard Error	Partial R-Square	Model R-Square	*P*
Males	0	Intercept	-14.814	2.63	--	--	<.0001
	1	BMI	1.394	0.09	0.622	0.622	<.0001
	2	MET-hrs·wk^{-1}	-0.065	0.02	0.047	0.669	<.0001
Females	0	Intercept	75.368	2.16	--	--	<.0001
	1	BMI^{-1}	-954.979	45.89	0.745	0.745	<.0001
	2	MET-hrs·wk^{-1}	-0.067	0.02	0.022	0.766	0.0001
	3	Race[§]	-1.529	0.61	0.010	0.776	0.0127

Note. BMI = body mass index; MET-hrs·wk^{-1} = calculated physical activity level from the IPAQ; BMI^{-1} = body mass index inverse.
[§] 0 = White, 1 = Black.

When cross-validated, both models exhibited high accuracy as indicated by the PRESS statistic. In males, the PRESS was 4.13. In females, the PRESS was 3.52. A comparison of goodness of fit and PRESS statistics along with the equations that resulted in the highest R^2 values and lowest RMSE is provided in **Table 3b**.

TABLE 3b. Best prediction equations for estimating percent body fat for males and females

		Goodness of fit		
Group	Equation	R^2	RMSE	PRESS
Males	%BF = 1.39 BMI – 0.07 MET-hrs·wk^{-1} – 14.81	0.67	4.07	4.13
Females	%BF = – 954.98 BMI^{-1} – 0.07 MET-hrs·wk^{-1} – 1.53 race + 75.37	0.78	3.48	3.52

Note. RMSE = root mean square error; PRESS = prediction sum of squares; BMI = body mass index; MET-hrs·wk^{-1} = calculated physical activity level from the IPAQ; BMI^{-1} = body mass index inverse. For race: 0 = White, 1 = Black.

Stage 2

Multiple stepwise regression analyses were performed on the total combined dataset to determine the influence MET-hrs·wk^{-1} on the prediction of percent body fat from BMI, gender, and race. First, a reduced model was constructed without the MET-hrs·wk^{-1} variable. Next, a full model was developed which contained BMI, MET-hrs·wk^{-1}, gender, and race as predictor variables. Finally, the reduced model was compared with the full model to determine the contribution of the self-reported PA variable on percent body fat.

As shown in **Table 4**, the reduced model with gender, BMI, and race explained 81% of the variance in percent body fat. Gender and BMI contributed 41% and 40%, respectively to the model. The addition of race marginally improved the equation, but explained less than 1% of the variance (P = 0.06). Overall, the three-variable reduced model resulted in an adjusted R^2 value of 0.81 and a RMSE of 4.07.

TABLE 4. Summary of the stepwise selection procedure and parameter estimates for the reduced model of percent body fat versus gender, body mass index, and race for the total study sample (N = 278)

Regression coefficients					
Gender[‡] $\hat{\beta} \pm$ SE	BMI $\hat{\beta} \pm$ SE	Race[§] $\hat{\beta} \pm$ SE	Intercept $\hat{\beta} \pm$ SE	RMSE	R^2_{adj}[†]
-11.96 ± 0.86***			30.25 ± 0.59***	7.16	.410
-16.16 ± 0.52***	1.51 ± 0.06***		-4.71 ± 1.50**	4.09	.808
-16.35 ± 0.53***	1.54 ± 0.06***	-0.99 ± 0.51	-4.94 ± 1.53*	4.07	.809

Note. $\hat{\beta} \pm SE$ = parameter estimate ± standard error; RMSE = root mean squared error; BMI = body mass index.
[‡] 0 = female, 1 = male.
[§] 0 = White, 1 = Black.
[†] R^2_{adj} = explained variance of the model adjusted for the degrees of freedom.
[*] $p < .05$; [**] $p < .01$; [***] $p < .0001$.

The results for the full model with MET-hrs·wk^{-1} are shown in **Table 5**. Gender emerged as the most influential variable (partial r^2 = .411, $p < .0001$), followed by BMI (partial r^2 = .397, $p < .0001$), MET-hrs·wk^{-1} (partial r^2 = .018, $p < .0001$), and race (partial r^2 = .002, p = .027). As

shown in **Table 5**, self-reported PA in MET-hrs·wk^{-1} contributed an additional 2% to the model, increasing the adjusted R^2 value to 0.825 and reducing the RMSE from 4.09 to 3.89. The final addition of race improved the prediction model marginally (p = .027) resulting in a multiple adjusted R^2 value of .829 and a RMSE of 3.87.

TABLE 5. Summary of the stepwise selection procedure and parameter estimates for the full model of percent body fat versus gender, body mass index, self-reported physical activity (MET-hrs·wk^{-1}), and race for the total study sample (N = 278)

Regression coefficients						
Gender‡	BMI	MET-hrs·wk^{-1}	Race§	Intercept	RMSE	R^2_{adj}†
$\hat{\beta} \pm$ SE	$\hat{\beta} \pm$ SE	$\hat{\beta} \pm$ SE	$\hat{\beta} \pm$ SE	$\hat{\beta} \pm$ SE		
-11.96 ± 0.86***				30.25 ± 0.59***	7.16	.411
-16.16 ± 0.52***	1.51 ± 0.06***			-4.71 ± 1.50**	4.09	.808
-15.08 ± 0.54***	1.46 ± 0.06***	-0.06 ± 0.01***		-1.69 ± 1.53	3.89	.825
-15.27 ± 0.54***	1.50 ± 0.06***	-0.06 ± 0.01***	-1.08 ± 0.49*	-1.90 ± 1.53	3.87	.829

Note. $\hat{\beta} \pm SE$ = parameter estimate ± standard error; RMSE = root mean squared error; BMI = body mass index; MET-hrs wk^{-1} = calculated physical activity level from the IPAQ.
‡ 0 = female, 1 = male.
§ 0 = White, 1 = Black.
† R^2_{adj} = explained variance of the model adjusted for the degrees of freedom.
* $p < .05$; ** $p < .01$; *** $p < .0001$.

Alternative Model Testing and Final Model Selection

From the preliminary gender-specific models, the relationship between BMI and %BF appeared to be linear for the males and curvilinear for the females. Therefore, alternative models were explored using the various indices (BMI, BMI^2 and BMI^{-1}) to determine the best index to include in the pooled study sample. The candidate models, including the full and reduced equations, were also cross-validated using the PRESS statistic to determine the most accurate model.

A comparison of goodness-of-fit and cross-validation statistics for four models is shown in **Table 6.** A quadratic model consisting of gender, BMI, MET-hrs·wk^{-1}, BMI^2, and race resulted in the highest adjusted R^2 value (0.832) and the lowest RMSE (3.823). The full model

came in second with an adjusted R^2 value of 0.828 and a RMSE of 3.865. A model with BMI^{-1} was the third most accurate (R^2_{adj} = 0.826, RMSE = 3.884), and the reduced model without MET-hrs·wk^{-1} came in last (R^2_{adj} = 0.809, RMSE = 4.077).

TABLE 6. Comparison of goodness-of-fit and PRESS statistics for the full and reduced models and two alternative models

		Goodness of fit		
Model	Equation	R^2_{adj}	RMSE	PRESS
Full	%BF = 1.50 BMI – 15.27 gender – 1.08 race – 0.06 MET-hrs·wk^{-1} – 1.90	0.828	3.865	3.899
Reduced	%BF = 1.54 BMI – 16.35 gender – 0.99 race – 4.94	0.809	4.077	4.099
BMI^2	%BF = 2.85 BMI – 0.03 BMI^2 – 15.51 gender – 1.02 race – 0.07 MET-hrs·wk^{-1} – 19.01	0.832	3.823	3.868
BMI^{-1}	%BF = – 934.41 BMI^{-1} – 15.63 gender – 0.90 race – 0.07 MET-hrs·wk^{-1} + 74.21	0.826	3.884	3.919

Note. R^2_{adj} = explained variance of the model adjusted for the degrees of freedom; RMSE = root mean square error; PRESS = prediction sum of squares cross-validation statistic; BMI = body mass index; MET-hrs·wk^{-1} = calculated physical activity level from the IPAQ; BMI^{-1} = body mass index inverse; BMI^2 = body mass index squared.
For gender: 0 = female, 1 = male.
For race: 0 = White, 1 = Black.

Overall, all four models performed well, with relatively small differences in goodness-of-fit statistics (R^2_{adj} 0.81 to 0.83, RMSE 3.82 to 4.10). When cross-validated, the model with the smallest difference between the PRESS and RMSE was the reduced model (0.022). The PRESS statistic and difference between the RMSE for the full model was 3.899 and 0.034, respectively. The BMI-1 model was almost identical to the full model, with a PRESS of 3.919 and a difference of 0.035. Finally, the quadratic model, which produced the highest adjusted R^2 value and the lowest RMSE, resulted in the largest difference in error when cross-validated (0.045).

Therefore, while the alternative models compared equally well or better with the full and reduced models, the full model containing the predictor variables BMI, MET-hrs·wk^{-1}, gender, and race appeared to be the most parsimonious, meaning that the difference in total error of

precision (e.g., PRESS – RMSE) obtained by the alternative models was higher than the full model, thereby justifying the use of the full model as a simpler field method for predicting percent body fat. The reduced model without MET-hrs·wk^{-1} performed fairly well as an alternative to the full model, compared to other published prediction equations with BMI, gender, and race as predictor variables.

CHAPTER 5
DISCUSSION

Major Findings

The aim of this study was to examine the influence of self-reported PA levels quantified from the IPAQ on the relationship between DXA-measured %BF and BMI in White and Black college students, and to test the hypothesis that IPAQ scores could be used to improve the prediction of %BF from body mass index (BMI), gender, and race in a young adult college population.

The results were in support of the hypothesis. The variable of MET-hrs·wk^{-1} obtained from the IPAQ was found to be significantly related to %BF independent of BMI, gender, and race and improved the predictability of %BF from self-reported information by two-percent. The results are strengthened by the use of a standardized instrument to measure PA, and the fact that its use in college-aged populations has been limited and its application as an independent predictor of %BF has not been previously tested. Furthermore, since BMI is a simple, easy-to-use field method that is used to estimate the prevalence of obesity in large-scale epidemiological studies, a prediction equation that utilizes BMI and predicts body fatness with greater precision and accuracy should provide an alternative to health professionals, universities, and sports and fitness facilities to assess health risk. Several investigators have used BMI in combination with age, gender, and race to predict body fat in children and adults. However, to my knowledge, this study is the first to use the IPAQ in addition to BMI to predict %BF in a biracial group of university students. Field methods for estimating %BF provide an opportunity for examining the relationship between BMI and body fat, provided that the equations are valid and have been rigorously tested. Several equations have been developed for children and adults; however, very few have been developed specifically for university students of different races. The results of the

present study are further strengthened by use of DXA to measure %BF and the application of the PRESS statistic to cross-validate the developed prediction models to determine the total error or true prediction error.

The Relationship between Physical Activity and Body Composition

Self-reported PA levels were found to be significantly and inversely related to %BF, but not with BMI, weight, or height, irrespective of gender and race. This is in agreement with a recent prospective study conducted with 140 young adult males which found that %BF from DXA, but not BMI, was the strongest predictor of physical fitness (Mattila et al., 2007). Similarly in a study by Lohman et al. (2006), body fat was found to be the variable most negatively associated with MVPA derived from accelerometry in adolescent girls (Lohman et al., 2006). Physical activity has been shown to favorably influence body composition, primarily due to its attenuating effect on age-related decreases in lean-tissue mass and increases in fat-mass (Guo et al., 1999). It is plausible that physically active young adults may experience changes in body composition without actually decreasing body weight. Therefore, the sole use of BMI as a measure of adiposity is limited because it is simply an index of body weight (not body fat) adjusted for height.

It was hypothesized that the addition of IPAQ scores would significantly improve the prediction of body fatness in this study sample compared to a model without MET-hrs wk^{-1} based on BMI, gender, and race. The IPAQ was developed and validated across twelve countries in an effort to provide a standard instrument for estimating PA levels internationally in adults aged 15 to 65. The short form is recommended for population-based surveillance. In essence, nationwide acceptance of the IPAQ could lead to more accurate and meaningful comparison studies of PA, just like the international use of BMI values to estimate obesity.

Physical Activity Levels of College Students

In this study, there appeared to be gender- and race-specific differences in IPAQ scores with White males describing the highest mean levels and Black females reporting the lowest mean levels of participation. Based on the IPAQ scoring protocol, 65% and 60% of White and Black males and 43% and 28% of White and Black females were considered "sufficiently active." Overall, 63% of males and 36% of females accumulated at least 3,000 MET-min·wk^{-1} or 1,500 MET-minutes of vigorous-intensity activity on at least three of the previous seven days. However, any differences between races within gender should be interpreted cautiously due to unequal representation of groups and the possibility of sampling bias. These results are consistent with the one previous study which utilized the IPAQ in college students. Using the IPAQ long format, Patterson et al. (2006) found that males were significantly more active than females, with 44.7% vs. 21.4% in the highest tertile (Patterson et al., 2006). Furthermore, Irwin (2004) found that university females, and especially Black females, were more likely to be insufficiently active than university males (Irwin, 2004).

However, Sarkin et al. (1998) demonstrated the challenge in comparing PA prevalence rates across studies using dissimilar measurement tools (Sarkin et al., 2000). For example, based on a systematic review of university students' sufficient PA, approximately half or more of university students in the U.S., Canada, and China were categorized as insufficiently active (Irwin, 2004). In Australia, 40% of students were insufficiently active; in Europe, 67% were inactive; and in Nigeria virtually no students engaged in any PA. Similarly, results from the 2006 ACHA National College Health Survey indicated that only 44.2% (N = 41,221) of U.S. college students reported exercising for at least 20 minutes vigorously or 30 minutes moderately on at least three of preceding seven days (The American College Health Association, 2007). Buckworth & Nigg (2004) reported PA levels and sedentary behaviors among a cohort of 490

college students (73.8% White & 16.2% Black) with a mean age of 21 ± 4.0 years and 90.8% were between 18 and 24 years (Buckworth & Nigg, 2004). They found that 73.1% of students reported having participated in moderate or vigorous exercise at least three times in the past seven days. In addition, more students in this sample engaged in moderate activities on at least five of previous seven days (30.6% vs. 19.5%), and vigorous activity on at least three days (53.2% vs. 37.6%) than those students sampled in the 1995 NCHRBS (Douglas et al., 1997). Nonetheless, Sarkin, et al.'s findings from each of the questionnaires used, together with all of the other studies' findings, indicated that regardless of the measure, university students were not sufficiently active to achieve health benefits.

Despite differences observed between gender and racial groups in this study, IPAQ scores still contributed significantly to the prediction of %BF, whether the data were split by gender, gender and race, or pooled. To my knowledge, this is the first study to consider the influence of self-reported PA levels on the prediction of body fatness. Future studies could examine whether additional self-reported variables improve the prediction of body fatness.

The Relationship between BMI and Body Composition

Body mass index has been shown to be a reasonable measure of adiposity in adults, although the strength of association varies across gender and racial/ethnic groups. In this study, correlations between %BF and BMI ranged from 0.79 in males to 0.85 in females. This is consistent with previous literature. In a recent comparison study conducted with group of male and female college athletes and non-athletes, Ode et al. (2006) found correlations ranging from 0.53 to 0.70 in males and from 0.58 to 0.90 in females. Others have generally found correlations from 0.5 to 0.8 between BMI and %BF (Lohman, 1992, Garrow & Webster, 1985). In Mattila et al.'s study of young adult male conscripts, the correlation between DXA-measured %BF and BMI was 0.82.

When separated by race, correlations were lower in White subjects (r = 0.71 in White males and 0.77 in White females) compared to Black subjects (r = 0.88 for Black males and 0.90 for Black females). This finding is in contrast with Gallagher et al.'s (1996) study which found that the correlations were stronger in White subjects compared to Blacks, with observed correlation coefficients ranging from 0.58 in Black males to 0.75 in White females (pooled r = 0.67). However, that study was conducted mainly with middle-aged adults with higher levels of body fat than subjects in the present study.

Body Fat Prediction Equations Using BMI

Other studies that have developed body fat prediction equations using BMI have been conducted across wide age ranges. These studies have consistently found age-related differences in %BF after controlling for BMI, gender, and race (Deurenberg et al. 1991; Gallagher et al. 1996; Deurenberg et al. 1998; Gallagher et al. 2000). For example, Gallagher et al. (1996) found that BMI, gender, age, and race/ethnicity explained 67% of the variance in %BF in White and Black males and females aged 20 to 94 years. Once more, in 2000, Gallagher and colleagues developed a prediction equation using BMI, age, gender and race/ethnicity that explained 79% of the variance in %BF from a 4-C model. In this study, gender, BMI, and race produced a population-specific equation that explained 81% of the variance in %BF from DXA, and the model was more precise in terms of the standard error. Furthermore, the investigators of the previous studies did not cross-validate their models. Therefore, their equations could also be considered population-specific.

Due to differences observed in body composition between males and females of different races, some suggest that universal cutoff values for defining obesity based on BMI may be inappropriate (Deurenberg, 2001; Gallagher et al., 2000). For instance, at any given level of %BF, age- and gender-matched Caucasians have a lower BMI than Blacks and Polynesians, and

a higher BMI than Asians (Deurenberg et al., 1998). Based on currently established cut-points for BMI established by the U.S. Department of Health and Human Services (U.S. Department of Health and Human Services, 1998), the percentage of males and females in this study considered overweight (25 to 29.9 $kg \cdot m^{-2}$) was 43% and 17%, and the percentage considered obese (≥ 30 $kg \cdot m^{-2}$) was 15% and 6%, respectively. In contrast, when using the %BF cut-points established by Gallagher et al. (2000) which correspond to overweight and obese BMI values for White and Black adults aged 20-39, the proportion of overly fat males (≥ 20% BF) and females (≥ 33% BF) in this study sample was 38.3% and 27.6%, respectively. Furthermore, the proportion of obese males (≥ 25% BF) and females (≥ 39% BF) corresponding with a BMI value greater than or equal to 30 $kg \cdot m^{-2}$ was 15% and 11%, respectively.

The present study found a significant relationship between BMI, gender, race, and self-reported PA in young adult White and Black males and females. Similar findings have been reported for BMI, gender, and race in adults with a broad range in ages. However, given that %BF increases with age and is at least partially attributed to a decrease in PA levels, it is important to develop population-specific equations that include a measure of PA. Knowledge of typical levels of PA obtained from an instrument such as the IPAQ can contribute to the estimation of body composition for specific critical periods of weight gain, such as young adulthood.

Limitations

It is important to note that results from this study were obtained using a convenience sample of students responding to a flyer offering a free body composition assessment. Therefore, these results are only generalizable to 18-24 year old college students of similar body composition. In addition, while every effort was made to ensure that the respondents understood how to complete the IPAQ, there is always the possibility of sampling bias, particularly when

collecting self-reported measurements. Furthermore, the IPAQ self-administered short version was administered to participants using an interview format to minimize the potential for over-reporting of PA levels. Consequently, the true effect of obtaining self-reported PA levels using the IPAQ short form in the manner in which it was intended cannot be determined from this study.

Implications for Future Research

As the prevalence of obesity continues to escalate, especially among the young population, it is important to document and report acceptable ranges of relative body fat for specific age and racial groups. Obesity is widely recognized as a major public health initiative in America, as reports from government and private entities such as the Surgeon General's Call to Action to Prevent and Decrease Overweight and Obesity and Healthy Campus 2010 have emerged. Causes of obesity are multi-factorial and include a combination of genetic, metabolic, socioeconomic, and cultural influences. However, behavioral and environmental factors are most likely the greatest contributors of obesity and therefore deserve the greatest attention(U.S. Department of Health and Human Services, 2001). Poor dietary habits combined with physical inactivity account for approximately 300,000 deaths every year.

Since body composition is known to vary according to age, gender, race, and level of PA, it is important to develop accurate equations for estimating %BF specifically for target groups of individuals such as college students. Since the measurement of %BF can be accurately and easily obtained by reference methods such as DXA in a laboratory setting but not in the field, statistical methods can be applied to develop and validate regression models. This study will provide an additional tool for health professionals to use to assess the current health status of individuals based on predicted body fat from BMI plus PA rather than basing the degree of health risk on BMI alone.

Conclusion

In order to improve the predictability of equations to estimate percent body fat, the results from this investigation support the notion that total physical activity levels should be considered. When compared with a prediction model that included BMI, gender, and race as predictor variables, the addition of IPAQ scores increased the explained variance by 2% and reduced the error term, resulting in a more accurate equation in this sample. In addition, the current findings demonstrate the importance of examining or predicting body fatness rather than relying on body mass index alone to determine excess health risk in young adults. The prediction models developed from this study were derived with the use of data from 278 participants representing a wide range of body sizes and total levels of PA from a large public university in Louisiana. The results suggest that self-reported PA levels quantified from the IPAQ can be used as an independent predictor of body fatness in university students when combined with gender BMI, and race.

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APPENDIX A
INFORMED CONSENT

LOUISIANA STATE UNIVERSITY AND A&M COLLEGE
INFORMED CONSENT FORM

Study Title: Investigating Relationships between the Built Environment, Health Behaviors, and Body Composition in University Students.

Performance Site: Nutrition and Health Assessment Laboratory, 252 Knapp Hall, Louisiana State University, Baton Rouge, LA.

Contacts: The following investigators are available to answer questions about this project:
Dr. Georgianna Tuuri, 225-578-1722
Mr. Michael Zanovec, 225-578-0797
Dr. Lisa Johnson, 225-578-3552
Dr. Melinda A. Solmon, 225-578-2639

Purpose of the Study: The purpose of the study is to examine the relationship between characteristics of your physical environment and your physical activity, eating habits and body composition.

Subjects: In order to participate in this research study you must be between 18 and 22 years of age, a registered LSU student, and in good health. If you are on medication, please share this information with the principal investigator. If you are pregnant or think that you might be pregnant or weigh more than 250 pounds you are not eligible to participate.

Study Procedures: Please come to the Nutrition and Health Assessment Laboratory in 252 Knapp Hall which is on the LSU campus. On the day of testing, please don't exercise and don't drink more than one cup (8 oz.) of any caffeine-containing beverages. Wear lightweight, loose fitting clothes that don't have any metal on them (short sleeve cotton shirts and jogging shorts preferred). You will have to remove your jewelry for some of the tests. It will take about 45 minutes to complete all of the measurements. The time for you to come in for testing will be arranged between you and the researchers.

On the day of testing:

1. You will be asked to read and sign the Subject Informed Consent and complete some brief questionnaires.
2. Your height and weight will be measured, and we will calculate your body mass index (BMI).
3. We will take seven skinfold thickness measurements. Each will take about two to four seconds. It doesn't hurt and you will only feel a slight pinch.
4. You will also take a dual-energy X-ray absorptiometry (DXA) test. This DXA test is called a total body scan. It will tell us about your bone mineral content and density, your lean tissue mass, and your total and percent body fat. You will not have to change your clothes as long as they are loose fitting and do not contain any metal. You will be asked to remove all your jewelry and to lie quietly on your back on the DXA table while the machine scans.

The DXA scan will take about 5 minutes. There are no side effects of having a DXA test, it will cause no discomfort, and it is totally non-invasive. You will be given a copy of your DXA report after the scan is completed.

Benefits: As a participant in this study you will have the opportunity to learn about your own body composition and bone mineral density. You will receive a free bone density test (DXA) and printouts which will show you your estimated percent body fat, and grams of lean, fat, and bone tissue.

Risks/Discomforts/ Measures Taken to Reduce Risk: You should experience no discomfort when answering the questions about yourself. If you do not want to answer a question, you may skip that question.

For the DXA test you will have to remove your jewelry, and if you have metal on your clothing you will have to wear a hospital gown. None of the measurements will hurt. The only risk is that during the DXA test you will be exposed to a very small level of ionizing radiation. The X-ray dose for a total body DXA scan is 250 times less than a dental X-ray and 2500 times less than the yearly dose considered safe by The Louisiana Department of Environmental Quality Regulatory Code. In addition, all personnel operating the standard DXA and the peripheral DXA machines have been properly trained and are licensed to safely perform DXA scans. You should not participate in a total body DXA scan any more frequently than once every 6 months. You must be 18 years of age or older and you cannot be pregnant to participate in these tests.

If you wish to discuss these risks or any other possible discomforts you might experience you may call the Project Director listed on this form.

Right to Refuse/ Withdrawal: Your participation in this study is entirely voluntary.

You may change your mind and withdraw from the study at any time without penalty or loss of any benefit to which your may otherwise be entitled. Should you not finish all the procedures, you will be given information about all the measurements that you have completed.

Privacy: All records and information you give us permission to keep will be filed in the office of the investigator and kept confidential. However, the LSU Institutional Review Board (who oversees university research with human participants) may inspect and/or copy the study records. Your results may be published, but your name or any other identifying information will be not included in the publication. This will be possible because participants will be assigned a code so they cannot be personally identified during the analyses. Other than as set forth above, your identity will remain confidential unless disclosure is legally compelled.

Financial Information: There is no cost to you for participating, nor will you be paid for participating in the study.

Withdrawal: You may choose to withdraw from the study at any time without prejudicing your standing with LSU, penalty or loss. Should you not finish all the procedures, you will be given information about all the measurements that you have completed.

Removal: The project director reserves the right to remove a subject from the research if he/she fails to meet the requirements of the study protocol.

Signatures:

The study has been discussed with me and all my questions have been answered. I may direct additional questions regarding study specifics to the investigators. If I have questions about participants' rights or other concerns, I can contact Robert C. Matthews, Chairman, LSU Institutional Review Board, 225-578-8692. I agree to participate in the study described above and acknowledge the researchers' obligation to provide me with a copy of this consent form if signed by me.

Participant Signature ____ Date ____________________

Witness ____ Date ____________________

APPENDIX B
DEMOGRAPHIC SURVEY

SECTION A: Demographics

Name: ______________________________ Date: ________________

Address: ______________________________

____

E-mail address: ______________________________ Date of birth: ________________

Telephone number: ______________________________ Age: ________________

Please tell us about yourself:

1. Gender:	① Female ② Male
2. What is your height <u>without</u> shoes? *(5 ft. = 60 in.; 6ft. = 72 in.)*	____________ inches
3. How much do you weigh <u>without</u> shoes? *(1 kg = 2.2 lbs.)*	____________ pounds
4. What is your <u>current</u> student status?	① Part-time ② Full-time
5. What is your <u>current</u> living arrangement?	① On-campus (dorm/residential hall, fraternity/sorority housing, or on-campus apartments ② Off-campus (apartment, house, etc.) ③ Off-campus (home w/ parents/guardian
6. What is your <u>primary</u> mode of transportation to and from campus?	① Automobile ④ Bicycle ② Bus ⑤ Walk ③ Motorcycle ⑥ I live on campus
7. What is your <u>primary</u> mode of transportation around and across campus (i.e., to classes, meetings, etc.)?	① Automobile ④ Bicycle ② Bus ⑤ Walk ③ Motorcycle

8. On average, how many hours per week (7 days) do you typically work a semester?	① ≤ 10 hrs. ② 11-20 hrs. ③ 21-30 hrs.	④ 31-40 hrs. ⑤ > 40 hrs. ⑥ I do not work during the semester
9. What is your current marital status?	① Single (never married) ② Engaged/committed dating relationship	③ Married ④ Divorced or widowed
10. What is your racial/ethnic background?	① White, Caucasian, Non-Hispanic ② Black, African American, Non-Hispanic	③ Asian ④ Hispanic ⑤ Other
11. What is the estimated annual income of your family?	① < $20,000 ② $20,001-$40,000 ③ $40,001-$60,000	④ $60,001-$80,000 ⑤ $80,001-$100,000 ⑥ > $100,000
12. Do you have a physical disability or chronic disease that keeps you from being able to participate in regular physical activities?	① Yes ② No	

APPENDIX C
INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE (IPAQ)
(www.ipaq.ki.se)

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

   _____ **days per week**

   ☐ No vigorous physical activities → ***Skip to question 3***

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

   _____ **hours per day**
   _____ **minutes per day**

   ☐ Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

   _____ **days per week**

   ☐ No moderate physical activities → ***Skip to question 5***

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

_____ hours per day
_____ minutes per day

☐ Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

_____ days per week

☐ No walking → ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

_____ hours per day
_____ minutes per day

☐ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

_____ hours per day
_____ minutes per day

☐ Don't know/Not sure

This is the end of the questionnaire, thank you for participating.

VITA

Michael Zanovec was born in May, 1979, in Baton Rouge, Louisiana. He received his Bachelor of Science degree in kinesiology in December 2004 from Louisiana State University (LSU). In February of 2005, Michael was hired as a research associate by the LSU AgCenter to assist in a two-year formal investigation of a childhood obesity prevention initiative called Smart Bodies. During this time he began his coursework in pursuit of a master's degree in human nutrition and food within the School of Human Ecology at LSU. Michael is a current member of several professional organizations, including the American College of Sports Medicine (ACSM), the Obesity Society, American Society for Nutrition (ASN), and is currently the Chair-Elect of the Exercise Science division of the Louisiana Association for Health, Physical Education, Recreation, and Dance (LAHPERD). He is also a member of the International Society for Clinical Densitometry (ISCD) and is a Certified Densitometry Technologist (CDT). Michael is a May 2008 candidate for a Master of Science in the human nutrition and food division within the School of Human Ecology, and would like to pursue a doctoral program in kinesiology in the near future.