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# BODY COMPOSITION AND WAGES

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**ABSTRACT**

This paper examines the effect of body composition on wages. We develop measures of body composition – body fat (BF) and fat-free mass (FFM) – using data on bioelectrical impedance analysis (BIA) that are available in the National Health and Nutrition Examination Survey III and estimate wage models for respondents in the National Longitudinal Survey of Youth 1979. Our results indicate that increased body fat is unambiguously associated with decreased wages for both males and females. This result is in contrast to the mixed and sometimes inconsistent results from the previous research using body mass index (BMI). We also find new evidence indicating that a higher level of fat-free body mass is consistently associated with increased hourly wages. We present further evidence that these results are not the artifacts of unobserved heterogeneity. Our findings are robust to numerous specification checks and to a large number of alternative BIA prediction equations from which the body composition measures are derived.

Our work addresses an important limitation of the current literature on the economics of obesity. Previous research relied on body weight or BMI for measuring obesity despite the growing agreement in the medical literature that they represent misleading measures of obesity because of their inability to distinguish between body fat and fat-free body mass. Body composition measures used in this paper represent significant improvements over the previously used measures because they allow for the effects of fat and fat free components of body composition to be separately identified. Our work also contributes to the growing literature on the role of non-cognitive characteristics on wage determination.

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## I. Introduction

Obesity is defined as the presence of excessive body fat (Bjorntorp 2002, World Health Organization 1998). In the United States, the proportion of the adult population who is obese has risen from 15 percent in the mid-1970s to around 33 percent in the early 2000s (Centers for Disease Control and Prevention, 2007a). Today, well over half of the adult population is either obese or overweight. The dramatic increase in the prevalence of obesity has caused tremendous concern among public health officials because of the well-documented links between obesity and overweight and the risk of developing diseases and health problems such as hypertension, dyslipidemia, type 2 diabetes, coronary heart disease, strokes, and some cancers (Centers for Disease Control and Prevention, 2007b). Overweight and obesity are thought to be responsible for approximately 300,000 deaths a year in the United States (McGinnis and Foege, 1993; Allison et al., 1999; National Heart, Lung, and Blood Institute, 1998). Health problems associated with overweight and obesity also impose a substantial economic burden on the U.S. health care system, including both direct (e.g. preventive, diagnostic, and treatment services) and indirect costs (e.g. the value of earnings lost by individuals unable to work because of illness or disability and the value of future earnings lost by premature death). The total economic costs attributable to obesity have been estimated at about 99 billion dollars in 1995 (Wolf and Golditz, 1998) and about 117 billion dollars in 2000 (Centers for Disease Control and Prevention, 2007b).

While the prevalence of obesity has reached epidemic proportions, concerns about its consequences – both economic and social – have moved to the centre of public and policy discourse. "The Surgeon General's Call to Action to Prevent and Decrease

Overweight and Obesity" in 2001 calls for a unified national health policy for reducing the prevalence of obesity. Obesity and overweight are identified as one of the highest priority issues in public health and one of the ten leading health indicators in Healthy People 2010 – the health objectives for the first decade of the 21st century in the United States. Although one of the national health objectives for the year 2010 is to reduce the prevalence of obesity among adults to less than 15 percent, the current trend suggest that, if anything, the situation is getting worse rather than improving.

In addition to the well-documented adverse health consequences, obesity has also been shown to be associated with negative social and economic outcomes. For example, there is evidence documenting that obese individuals suffer from social stigmatization, discrimination, lowered self-esteem, and marriage problems (Gortmaker et al., 1993; Averett and Korenman, 1996; Averett and Korenman, 1999; Strauss, 2000). Recently, some of these social and health consequences have motivated economists to examine the potential relationship between obesity and overweight and labor market outcomes (Sargent and Blanchflower, 1995; Averett and Korenman, 1996; Behrman and Rosenzweig, 2001; Baum and Ford, 2004; Cawley, 2004; Averett and Korenman, 1999). The findings from these studies usually point to a negative association between obesity and wages for white females, but no clear evidence of a wage penalty exists for males or other female population groups and some studies even report a positive association between obesity and wages of black males.[2] These studies use either body weight or various indicators of body mass index (BMI) as a measure of obesity in their analyses. BMI, which is defined as the ratio of weight in kilograms and height in meters squared, is

[2] Baum and Ford (2004) report a weak penalty for male obesity, but the result becomes mixed when the sample is further divided by ethnicity, as reported by Averett and Korenman (1999) and Cawley (2004).

the most commonly used surrogate for obesity or excess body fat in social studies of obesity. The World Health Organization (WHO) sets the universally accepted cut-off points for classification of overweight and obesity as having a BMI over 25 and 30, respectively. The main reason for the wide use of BMI is its ease of calculation since most data sets used in socio-economic research contain the necessary information on height and weight to calculate it.

While BMI may be widely accepted by social scientists, it is well-known among the clinical researchers that it is at best an imperfect measure of excessive body fatness because it does not distinguish body fat from lean body mass (Smalley et al., 1990; Gallagher et al., 1996; Yusuf et al., 2004, 2005; Romero et al., 2006; Romero et al., 2007). In a recent study, Romero-Corral et al. (2006) conduct a systematic review of the medical literature on the association between BMI-based measures of obesity and total mortality for patients with coronary artery disease between 1996 and 2005. Their review of the literature suggests that overweight patients actually have a *better* survival rate and *lower* cardiovascular events than underweight or obese patients. Similar findings are also reported by several other studies that examine the association between BMI and mortality in patients without evidence of cardiovascular disease (Flegal et al., 2005; McGee, 2005).

Also referred to as obesity paradox, this lack of association (or an inverse association) between obesity and mortality has generated confusion among many medical researchers and doctors. Similar puzzling associations are also found between obesity and other types of health problems like chronic kidney disease (Kopple et al., 1999; Johnson et al., 2000; Kalantar-Zadeh, 2003). Romero-Corral et al. (2006) and Allison et al. (2002) point to the inability of BMI to properly distinguish between body fat and lean body mass as a possible explanation for the obesity paradox. Furthermore, Romero-Corral et al. (2006) stress the need for developing alternative measures of obesity by concluding that "rather than providing that obesity is harmless, our data suggest that alternative methods might be needed to better characterize individuals who truly have excess body fat, compared with those in whom BMI is raised because of preserved muscle mass" (page 676). This could cause BMI to be less sensitive to male obesity due to the relatively higher levels of lean body mass and lower levels of body fat in males.[3] Prentice and Jebb (2001) illustrate a wide a range of conditions in which BMI provides misleading information about body fat content. Gallager et al. (1996) further report that BMI alone explains only 26% of variations in body fat. A consensus report by WHO (1995) warns that BMI must be properly conditioned upon co-existing factors, such as muscularity, to avoid misidentification of a nutritional state. Furthermore, Rush et al. (2004) report that BMI cut-off points for overweight and obesity may not represent the same levels of body fat in various ethnic groups due to differences in body built, fat patterning, and muscularity that alters the relationship between BMI and body fat.[4] In a study that compares body fat measurements and BMI among 596 females and 294 males, De Lorenzo et al. (2001) find that a considerable number of both female and male subjects would not be classified as obese based on their BMI alone. The authors conclude that the reliability of BMI as a tool for measuring body fat is questionable, and

[3] A higher portion of women's body consists of body fat compared to men's due to demands of childbearing and other hormonal functions.

[4] In fact, a WHO expert consultation (2004) reports that the BMI cut-offs developed by WHO are not suitable for Asian populations and that there is no single cut-off point appropriate for defining obesity or overweight in all Asian groups.

that direct measurements of body fat would provide a significant improvement towards detecting and diagnosing obesity in individuals.[5]

These limitations of BMI have recently led many researchers to seek alternative measures of obesity that are based largely on anthropometric data such as body weight, stature, skinfold-thickness, waist-to-hip ratio, and waist circumference. These measures provide correlates of BMI or approximate estimates of body fatness, but they still suffer from the BMI's inability to differentiate various levels of fatness and leanness among different population groups (Lukaski, 1987; Gallagher et al., 1996; Chumlea et al., 2002; Sun et al., 2003).

A widely accepted method for detecting body fat is body composition. Although relatively unknown to economists, body composition has been used extensively by epidemiologists, nutritionists, and physiologists for studying nutritional health, physical growth, and physical performance (Forbes, 1987; Harris, 2002; Van Loan, 2003). Body composition describes human body as the sum of two or more components (Heyward and Wagner, 2004). The most prevalent model of body composition is the two-compartment models of Siri (1961) and Brozek et al. (1963) that divide body weight into body fat (BF) and fat-free mass (FFM). BF accounts for about 20 to 40 percent of body weight. It basically consists of adipose tissue whose main role is to store energy in the form of fat, while providing a measure of insulation. Sometimes referred to as lean body mass, FFM

[5] For more on the shortcomings of BMI as a measure of obesity, see Wada (2005, 2007) and Cawley and Burkhauser (2006).

is the larger component that includes everything else, including muscles and skeletons that make up to 2/3 of its weight.[6]

Models based on body composition have several advantages over models based on BMI or other indices of body size. First, body composition better reflects the biological condition of human body in which, as documented by the medical literature, BF is responsible for inferior health outcomes, while FFM is closely associated with improved health (Heitmann et al., 2000; Allison et al., 2002; Bigaard et al., 2004). Unlike BMI, whose marginal effect is not subject to direct interpretation, the marginal effect of BF or FFM has a biological meaning that can be traced to a physical increase in one of the body components. A marginal increase in BF is expected to be associated with a negative health outcome, while a marginal increase in FFM is expected to be associated with a positive health outcome.

Second, through their combined but opposite effects on health and physical performance, BF and FFM can exert a complex influence on the economic and social outcomes that cannot necessarily be captured by a measure that fails to distinguish one from the other. Because their expected effects are opposite from each other, there could be instances when they cancel each other out. Under such a scenario, a single index such as BMI will be subject to a type I error, i.e., the null hypothesis that obesity has no effect on wages would be falsely accepted. Models based on body composition, however,

[6] The terms lean body mass and FFM are often used interchangeably (Heyward and Wagner, 2004). Lean body mass contains a small amount of lipids, while FFM does not any lipids at all. In males, about 97 percent of lean body mass is FFM, while it is about 92 percent in females (Lohman, 1992).

would be robust to such error by preserving the interior variations the body instead of merging them together.[7]

Third, clinical studies by medical researchers and exercise physiologists have established that body composition is superior to body size at reducing unobserved variations in strength, health, and physical performance (Segal et al., 1987; Baumgartner, Heymsfield, and Roche, 1995; Bjorntorp, 2002). Differences in metabolic rates that cannot be explained by body weight can be attributed to body composition when incorporated into regression models (Institute of Medicine, 2005, p.113). We can control for some of the previously unaddressed differences in non-cognitive characteristics of human body by incorporating body composition into the wage models.

One drawback to using body composition in research is that it is considerably more difficult to obtain than BMI. To overcome this difficulty, physiologists and clinical investigators have developed bioelectrical impedance analysis (BIA) as a viable method for measuring body composition. BIA is increasingly used to measure body composition because it is precise, reliable, and easy to obtain (Kushner et al., 1990; Roubenoff et al., 1995; Sun et al., 2003; Chumlea et al., 2002).[8] In BIA, body composition is estimated by measuring the electrical resistance of a body to a weak electrical current (National Institutes of Health, 1994). The FFM registers a lower electrical resistance due to its high water content, whereas BF does not conduct electricity very well (Willett, 1998; Chumlea et al., 2002; Sun et al., 2003). The observed electrical resistance is then converted into

[7] It should be pointed out that the estimated coefficients are not additive because FFM and BF add up to body weight instead of a constant.

[8] Some of the other alternative methods of measuring body composition include skinfold thickness, underwater weighting, dual x-ray absorptiometry, magnetic resonance imaging (Caterson, 2002; Heshka, Buhl, and Heymsfield, 1994; Heymsfield et al., 1998). However, compared to BIA, these methods are prohibitively expensive or unreasonably intrusive (Caterson, 2002; Heshka, Buhl, and Heymsfield, 1994; Heymsfield et al., 1998) for use in large-scale epidemiological studies.

measures of BF and FFM by entering it into a predetermined prediction equation along with a set of easily acquired characteristics of individuals such as weight, height, age, and sex. A 1994 technology assessment conference sponsored by the National Institutes of Health (NIH) concludes that BIA is a useful technique for body composition analysis in healthy individuals and in those with a number of chronic conditions such as mild-to-moderate obesity, diabetes mellitus, and other medical conditions in which major disturbances of water distribution are not prominent (National Institutes of Health, 1994). The conference also stressed that the National Health and Nutrition Examination Survey (NHANES IIII), which contain measurements of BIA for a nationally representative population, could be extremely useful for examining the relationship between body composition and clinical risk factors such as blood pressure, blood lipids, and glucose intolerance.

Very recently, this increased interest in using bioelectric impedance analysis to construct body composition measures has caught the attention of several economists. In his dissertation research, Wada (2005, 2007) takes a departure from the other economic studies of obesity by using the method of BIA to estimate the effect of body composition on labor market outcomes. Cawley and Burkhauser (2006) also use conversion equations developed in NHANES III to study the effect of body composition on employment disability for respondents in the Panel Study of Income Dynamics (PSID). Both Wada (2005, 2007) and Cawley and Burkhauser (2006) use the prediction equations derived by Sun et al. (2003) to estimate conversion equations in NHANES III relating FFM and BF to self-reported height, weight, age, and the polynomials and interactions of these characteristics by gender, race, and ethnicity. Johansson et al. (2007) use data from a

Finnish sample to examine the relationship between obesity and wages. Their data set conveniently contains BIA information that allows them to calculate FFM and BF within the same data set. They find that BMI, weight, and BF are not significantly correlated with annual wages, while waist circumference is usually negatively correlated. But the effects of BF may not be properly distinguished from the opposing effects of FFM, because they do not control for FFM, which is highly correlated with body fat. It is possible that their results are also confounded by individual unobserved heterogeneity, since their data set is cross-sectional.

In this paper, we estimate the effect of body composition on wages in the United States. Our paper makes three main contributions to the literature. The first contribution is to the literature on the effect of obesity on wages. We argue that, compared to BMI, body fat is a more appropriate measure of obesity because it is the body fat that causes someone to become obese.[9] To capture the true effect of obesity on wages, the effects of FFM and BF should be identified separately. Using the newly derived measures of body composition, we show that increased body fat is unequivocally associated with decreased wages for both males and females. This result is in contrast to the mixed and somewhat less stable results obtained from BMI. Our results confirm the straightforward implications by models of health capital or labor market discrimination that obesity is associated with a wage penalty.

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[9] However, we would like to stress that it is not our goal or intention to dismiss the use of BMI as a measure of obesity completely. While there is a general consensus that BIA can be a valuable tool in measuring body composition, there is not a full agreement on the best prediction equation (Willett, 2006). Like every other method, the BIA is not without limitations. For example, the BIA makes the use of simplifying assumptions about body densities that may not always hold true. See Heyward and Wagner (2004) for detailed discussions of these issues.

The second contribution of this paper is providing insights into the effect of physical health on wages. The nutrition hypothesis from development economics states that increased body size should be associated with increased worker productivity.[10] This assumption of "bigger-is-better" has been questioned in light of the mixed evidence from the obesity literature.[11] In this paper, we present evidence that FFM has a positive effect on the wages of both male and female workers. This result is important because it demonstrates the beneficial effect of healthy growths on worker productivity. Since health is the conduit through which body size is thought to influence worker productivity, it should be the growth of healthy body component that should be associated with increased hourly wages. Our results show that the effect of healthy growth as represented by FFM is indeed positive and opposite to the effect of increased BF.

The third main contribution of this paper is to the growing literature on role of non-cognitive factors in wage determination. Our results indicate that the effects of body composition persist even after controlling for disability, sociability, teenage height, and occupational categories. A large body of research in the human capital literature has concluded that most of the variation in wages across individuals remains unexplained even after extensive controls of human capital investment (Keane, 1993; Bowles, Gintis, and Osborne, 2001). This has motivated many economists to focus on the potential role of non-cognitive factors on wage determination. For example, Hamermesh and Biddle (1994), Biddle and Hamermesh (1998), Harper (2000), Mocan and Tekin (2006), and Mobius, and Rosenblat (2006) find that beauty is positively related to wages. Kuhn and

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[10] See Fogel (1994) and Steckel (1995) for a summary of nutrition hypothesis.

[11] Behrman and Rozensweig (2001) explore the possibility that the negative effect of obesity is due to unobserved heterogeneity and not necessarily due to increased body size. Fogel (1994) presents his theory that the beneficial effect of body size is not properly captured by the observed relationship between BMI and mortality, which is U-shaped.

Weinberger (2005) document that leadership skills in high school generate positive wage effects later in life. Persico, Postlewaite and Silverman (2004) show that taller workers earn a wage premium, which can be traced back to their height in high school, and that this effect is mainly due to the impact of height on participation in high school sports and clubs. These findings are important because they highlight the significance of non-cognitive factors in wage determination. By examining the role of body composition on wages, this paper will expand this literature and contribute to the development of a better understanding of wage determination.

The remainder of this paper is organized as follows. Section II discusses the previous literature on the relationship between obesity and wages. Section III describes the BIA methodology and explains how the measures of body composition are constructed. This section also provides a discussion of the conceptual issues and the empirical model. Section IV describes the data sets used in the estimation. Section V discusses the results. Section VI provides the concluding remarks.

## II. Previous Literature on Obesity and Wages

As the proportion of population who is obese and overweight has increased substantially over the years, economists have become increasingly interested in examining the effects of obesity and overweight on labor market outcomes. The researchers have typically focused on wages, employed data from the National Longitudinal Survey of Youth 1979 (NLSY), and used body weight or BMI as the measure of obesity. While there appears to be some agreement in the literature on a negative effect of BMI on wages for white females, the evidence for males and other females is mixed. A few recent studies (e.g. Cawley, 2004; Baum and Ford, 2004) found negative correlations between overweight and obesity and wages, which tend to diminish once the unobserved heterogeneity is controlled for. Various empirical methods have been used to eliminate bias due to omitted variables and potential simultaneity between wages and obesity. These include instrumental variables (Pagan and Davila, 1997; Behrman and Rozensweig, 2001; Cawley, 2004), individual, sibling, or twin fixed effects (Averett and Korenman, 1996; Behrman and Rosenzweig, 2001; Baum and Ford, 2004; Cawley, 2004), and using lagged values of obesity or weight (Sargent and Blanchflower, 1994; Gortmaker et al., 1993; Averett and Korenman, 1996; Cawley, 2004).

Cawley (2004) is a recent and comprehensive study that reconciles the previous literature on the relationship between obesity and wages by using various empirical methods and measures of obesity. In addition to using BMI, he estimated models with weight in pounds and clinical classifications of underweight, overweight, and obese defined at various BMI cut-offs. He used data from 13 years of NLSY between 1981 and 2000 and limited his sample to individuals between 16 and 44. His findings from the OLS estimates indicate that heavier white females, black females, Hispanic females, and Hispanic males earn less, while heavier black males earn more than their lighter counterparts. The effects on white males are not statistically different from zero. These effects largely become weaker except for white females when individual fixed effects are controlled for. Also using data from the NLSY, Averett and Korenman (1996) find negative effects of obesity on wages among females while the effects on males are weak and mixed. The main sample used in Averett and Korenman (1996) is a single year data (1988) from the NLSY. Similar to Cawley (2004), they find some evidence to suggest that the effect of obesity on wages of males is nonlinear. When Averett and Korenman (1996) controlled for unobserved heterogeneity using sibling fixed effects, most of their estimates became statistically insignificant. Baum and Ford (2004) used various OLS and fixed effects models to examine the effect of obesity on wages using NLSY and found that the effect is negative and in the range of 0.7-6.1 percent for males and females. However, the fixed effects results for males are very small to have any meaningful implications and are not estimated with much precision. Pagan and Davila (1997) estimated cross-section models for the effect of obesity as measured by BMI on wages of males and females. They found negative effects on females but not on males. In a recent paper, Conley and Glauber (2005) focused on the effect of obesity on the earnings of older workers using data from the PSID. Consistent with the previous research using OLS, they found negative effects for females but not for males.

In summary, the existing evidence on the link between obesity and wages is based exclusively on external anthropometric measures like weight and BMI. The state of our current knowledge is such that obesity is usually associated with a wage penalty for the wages of white females, but the evidence on males is weak and mixed. Only Cawley (2004) and Averett and Korenman (1996) estimated their models separately by race and ethnicity. If in fact the effect of obesity on wages differs not only by gender but also by race and ethnicity, this may cast doubt on the findings of studies that combine whites, blacks, and Hispanics into a single group.

## III. Body Composition and Empirical Strategy

The BIA readings that we use to construct measures of body composition come from the NHANES III. The NHANES III is a nationally representative cross-sectional survey conducted between 1988 and 1994. It was designed to collect information on the health and nutritional status of the population through interviews and physical examinations. Using mobile laboratories, trained technicians obtained the necessary information to collect body composition for those over the age of 12 who were not known to be physically handicapped or pregnant at the time.[12] The total NHANES III sample consists of 31,311 examined participants. We use data from respondents with non-missing data on BIA readings.[13] These criteria result in a sample of 3,533 white females, 2,501 black females, 2,158 Hispanic females, 3,195 white males, 2,501 black males, and 2,158 Hispanic males. The use of NHANES III is central to our ability to construct measures of FFM and BF because it includes data on BIA readings as well as both self-reported and measured height and weight. However, the NHANES III does not allow for examining the effect of body composition on wages because it does not provide sufficient information to calculate hourly wages of the participants.

Many researchers have estimated prediction equations that relate FFM and BF to electrical resistance derived from the BIA methodology (Houtkooper et al., 1996; Ellis et al., 1999; Sun et al., 2003). In this study, we use the prediction equations derived by Sun et al. (2003). We do this for several reasons. The main reason is that the prediction equations derived by Sun et al. (2003) are particularly aimed at producing estimates of

[12] For more information on the sample design of the NHANES III, see U.S. Department of Health and Human Services (1996).

[13] The BIA readings are missing for many respondents due to reasons of pregnancies, underage, or incomplete examination.

body composition for the respondents in NHANES III (See Sun et al., 2003, p.332). Also, they are one of the most recently published prediction equations. Finally, these are the same equations used by Wada (2005, 2007) and Cawley and Burkhauser (2006).

Sun et al. (2003) used data from five research centers to establish the models that predict fat-free mass as a function of electrical resistance as well as height and weight. They obtain their measure of body fat by subtracting fat-free mass from total body weight. Fat-free mass is calculated from a deterministic formula based on bone mineral content, total body water, body volume, and body weight using a multicomponent molecular model derived particularly for body composition analysis (Heymsfield et al., 1996).[14] In this paper, we also examine a large number of alternative prediction equations derived by various other researchers. As discussed in detail in the results section, the findings presented in this paper are remarkably robust to a large number (47 of them) of alternative prediction equations. We believe that the reliability of our findings is strengthened overwhelmingly as a result of this robustness check.

Sun et al. (2003) provide broadly applicable prediction equations for fat-free mass for males and females samples using the BIA method.[15] They employ an all-possible-subsets regression analysis with variations of independent variables such as age, weight, BMI, stature, and resistance included in the analyses. The following equations were reported to provide the best fit for FFM:

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[14] This multicomponent molecular model is developed using superior clinical measurements by densitometry, isotope dilution or dual-energy X-ray absorptiometry (Heymsfield et al., 1996).

[15] As explained in Sun et al. (2003), the BIA data in NHANES III were obtained using a Valhalla type impedance analyzer (Valhalla Scientific, San Diego, CA, USA), while the conversion equations for the relationship between BIA and body mass are based on resistance obtained from an RJL model (RJL, Clinton Twp, MI, USA) device. Thus, before applying the prediction equations for the body composition, the Valhalla resistance value for each subject is converted to an equivalent RJL resistance value using conversion equations developed by Chumlea et al. (2002).These conversion equations are as follows: For males: RJL resistance = 2.5 + 0.98 Valhalla resistance; for females: RJL resistance = 9.6 + 0.96 Valhalla resistance.

For males:

$$\text{Fat - free mass} = -10.678 + 0.262\ \text{weight} + 0.652\ \frac{\text{stature}^2}{\text{resistance}} + 0.015\ \text{resistance} \qquad (1)$$

For females:

$$\text{Fat - free mass} = -9.529 + 0.168\ \text{weight} + 0.696\ \frac{\text{stature}^2}{\text{resistance}} + 0.016\ \text{resistance}, \qquad (2)$$

where weight is clinically measured weight in kilograms and stature is clinically measured height in centimeters. As emphasized in Sun et al. (2003), the predictive power of these equations is excellent with the R-squared values of 0.90 for males and 0.83 for females. They also tested and rejected the hypothesis that separate equations should be specified for blacks and whites.[16] They mentioned that their final equations tended to underpredict the FFMs for black males and females by 2.1 kilograms and 1.6 kilograms, respectively, while they tended to over-predict the FFM for white males by 0.4 kilogram and the FFM for white females by 0.3 kilogram. Our observations have been adjusted accordingly by adding or subtracting the average errors from each gender-ethnic group. Once the FFM is obtained from above equations, BF can easily be calculated as the difference between total weight and FFM.

Next, we run regressions that relate FFM and BF to observable characteristics of the individuals in the NHANES III. Since the coefficients from these regressions will later be used to construct measures of FFM and BF in the NLSY, it is important to make sure that these observable characteristics are available in both data sets. The FFM and the BF equations are estimated separately across gender, race, and ethnicity to account

[16] Sun et al. (2003) used a sample containing 1,474 whites and 355 blacks aged 12–94. Due to the differences in the sample representation, it would be reasonable to assume that the results would be more robust for whites than for blacks. Results for Hispanics should be viewed with caution since there was no Hispanics in the sample studied by Sun et al. (2003).

for the known differences between them. After experimenting with a large number of specifications, we chose the one with the largest explanatory power based on the R-squared values.[17] This specification includes the following self-reported covariates: age, $age^2$, $age^3$, weight, $weight^2$, $weight^3$, height, $height^2$, $height^3$, height*weight, age*height, a binary indicator for urban residence status, binary indicators for regions, and binary indicator for marital status.[18] The results from the prediction equations for FFM and BF are presented in Appendix Tables 1A and 1B, respectively. The adjusted R-squared values for the six groups are quite high between 0.78 and 0.83 for FFM and between 0.77 and 0.90 for BF. These high R-squared values imply that a very large proportion of the variation in the FFM and BF can be explained by the variations in the covariates included in these regressions. Therefore, we believe that these models do an excellent job explaining the variations in body composition components.

In the final step, the estimated coefficients from the FFM and BF regressions in the NHANES III are used to compute predicted FFM and BF values in the NLSY. We denote these values as $\hat{FFM}$ and $\hat{TBF}$. Given that the coefficients from FFM and BF regressions in the NHANES are consistent estimators and that the NHANES III and the NLSY are data sets that are independent of each other, the transferability of these coefficients between the two data sets is not problematic and $\hat{FFM}$ and $\hat{TBF}$ should serve as reliable and unbiased measures of the actual FFM and BF.

[17] Note that using specifications that are slightly different did not change any of the implications discussed in this paper.

[18] Note that Cawley and Burkhauser (2006) use a more parsimonious specification to predict BF and FFM in NHANES III than ours. However, in their paper they acknowledge the possibility of including a much broader set of variables in order to increase the predictive power of the models as long as these variables are available in both the NHANES III and the other data set in which the prediction will be made.

Once we construct the $\hat{FFM}$ and $\hat{TBF}$, we follow the previous literature in obesity to estimate the relationship between body composition and wages. Specifically, we specify a wage equation in the following form:

$$\text{Ln } W_{it} = X_{it}\,\beta + \alpha_1\,\hat{FFM}_{it} + \alpha_2\,\hat{TBF}_{it} + \varepsilon_{it}, \qquad (3)$$

where Ln $W_{it}$ is the logarithm of the hourly wage rate for individual i in year t; $X_{it}$ is a vector of the observed determinants of wages; β and α's are the parameters and $\varepsilon_{it}$ is the disturbance term.

As described above, we include various second and third order polynomials of height and weight along with their interactions in the prediction equations in the NHANES III, thus allowing the coefficients of body composition to be identified. Furthermore, we exclude height from the wage equations under the assumption that height influences wages only through its effect on body composition. However, taller individuals are thought to be endowed with more social capital through participating in social and sport clubs during high school as well as possibly more favorable treatment by their peers and this may generate an independent effect of an individual's height on his/her wage rate through its effect on the individual's sociability (Persico, Postlewaite and Silverman, 2004). Therefore, we will control for a set of variables that would serve as a proxy for the sociability of individuals, such as participation in high school sports and clubs, as measured in the NLSY. Alternatively, we will control for height during adolescence (prior to age 18) as a specification check. Also note that we include in our wage models variables like education, AFQT test scores, and parents' education which will also help control for the individual's social skills further.[19] Finally, we will also estimate all of our models with individual fixed effects that will account for all the time-invariant unobserved heterogeneity, including social skills developed during high school as well as height during adolescence.

**IV. Data**

The empirical analyses use data from two surveys – National Health and Nutrition Examination Survey 1988-94 (NHANES III) and National Longitudinal Survey of Youth (NLSY). The NHANES III, which is described in the previous section, is an ideal data set to study body composition because it provides information on self-reported height and weight, measured height and weight, measured waist circumference, measured waist-to-hip ratio, and more importantly, BIA readings. The availability of BIA readings in the NHANES III is crucial for the purpose of this paper because it enables us to construct measures of FFM and BF, which we later use in the wage regressions.

Our main data set is the NLSY, which is a nationally representative survey of the U.S. population. It started in 1979 with a cohort of males and females between ages 14 and 21. These individuals have been followed annually until 1993 and biannually thereafter. The NLSY provides detailed information on the labor market outcomes of respondents along with a rich set of personal and family characteristics. Although the NLSY does not provide a direct measure of body composition, it is one of the few economic surveys with longitudinal information on the body measurements, such as height and weight. We pooled all the NLSY between years 1981-2004 to create our

[19] Note that, despite concerns about the endogeneity of obesity, a Hausman test conducted by Cawley (2004) indicated that the hypothesis that OLS and IV coefficients are equal cannot be rejected for any of the six race-gender groups.

analysis sample because self-reported weight information is available in this period. Our NLSY sample for the wage models is between ages 18 and 49. We used the latest available height information as of age 20 or older as the respondent's adult height. To avoid changes in body composition during pregnancy, females who were determined to be pregnant at the time of an interview are dropped from our sample.[20] We also omit respondents who are in the armed forces (Baum and Ford, 2004). Finally, we omit the supplemental poor white sample. After applying these exclusion criteria, we have a pooled-sample of 73,397 observations.

The NLSY asks about the hourly wage of respondents at their primary jobs. We deflated the hourly wages to 1991 dollars using the Consumer Price Index.[21] The other variables included in the analyses are age, years of education, years of job tenure, an indicator for marital status, an indicator for urban residence, region indicators, the highest grade completed by the mother, the highest grade completed by the father, the score from Armed Forces Qualification Test (AFQT) as a proxy measure of intelligence, years of employment experience, and year dummies. We also include county unemployment rate as a control for labor demand conditions. A dummy variable indicating whether the individual has any health problems limiting the kind or amount of work one can perform is also included. Finally, we also constructed a binary indicator indicating blue-collar workers.

[20] Reports of current pregnancies and past pregnancies were not collected at every interview. To overcome this problem, a dataset was constructed from the birth dates of women's biological children and the interview dates. Women were identified as pregnant if the interview occurred between 9 months before or after the birth of a biological child.
[21] Following Cawley (2004), hourly wages were top- and bottom-coded to be between 1 and 500 in 1991 dollars.

The height and weight information provided in the NLSY is self-reported. Previous studies show evidence of reporting error in self-reports of weight and height (Rowland, 1989; Gorber et al., 2007). Gorber et al. (2007) conducted a review of existing empirical evidence to determine the degree of agreement between measured and self-reported measures of height, weight, and BMI. Their review of 64 studies suggested evidence for under-reporting for weight and BMI and over-reporting for height that varies between men and women. In order to avoid bias in their estimates, several studies utilized NHANES, which contains both measured and self-reported height and weight, to correct for reporting bias in the NLSY (Cawley, 2004, 2006; Lakdawalla and Philipson, 2002; and Chou, Grossman, and Saffer, 2004). Following the approach in these studies, we regressed measured weight on self-reported weight, its square and cube, age, age-squared, and age-cubed, separately by race and sex. Then we repeated this process for height. Finally, we used the coefficient estimates from the NHANES weight and height regressions to construct measures of weight and height in the NLSY that are corrected for reporting error.

Table 1 presents the descriptive statistics for the NLSY sample along with the definitions of the variables, including the predicted FFM and BF. The descriptive statistics is presented for the full sample as well as separately by gender, race, and ethnicity. As illustrated in Table 1, white males and white females are the tallest for their respective genders out of the three racial and ethnic groups. Black females and black males have the highest average FFM for their respective genders, even though they are slightly shorter than whites. Black females and Hispanic males possess the highest average BF. Females have higher BF than males regardless of race and ethnicity. These figures suggest that blacks and Hispanics on average are build more heavily than are whites. Although whites and blacks have almost the same average height, Hispanics are considerably shorter. This indicates that black males have a more solid body build due to the higher presence of FFM, while Hispanic males are less solidly built due to the disproportionately higher presence of BF. Hispanic males and black females have the highest BMI on average with values of 27.10 for Hispanic males and 27.22 for black females. The percentage of sample who is obese (BMI $\geq$ 30) is the highest for blacks among females with a percentage of 32.5 and for Hispanics among males with a percentage of 24.3.

The average hourly wage is highest among whites for both males and females. White males and females earn about 13.6 dollars and 10.4 dollars per hour, respectively. The proportion of sample having a health problem limiting work and other activities is highest among Hispanic males and black females while it is the lowest for black males and white females. The mother's and father's education are higher for whites than both blacks and Hispanics, indicating a higher level of socio-economic status for whites. Similarly, the AFQT test scores are the highest for white males and females while they are the lowest for black males and females. The proportion of sample working at blue collar occupations is highest for blacks among both males and females. Whites have more years of work experience than blacks and Hispanics regardless of gender. Finally, whites and Hispanics are more likely to be married than blacks among both males and females in our sample.

## V. Results

We first present the results for the prediction equations for FFM and BF from the NHANES III. To help account for differences across gender, races and ethnicity, these equations are estimated separately for males and females as well as whites, blacks, and Hispanics. Results from these models are displayed in Appendix Tables 1A and 1B, respectively. Weight and height as well as their polynomials and interactions with other variables appear to be important determinants of FFM for most males and females. The interaction between height and weight has a statistically significant coefficient for every group except for black males and white females. Age appears to have a significant and nonlinear effect for Hispanic men and white and black females while the other age coefficients are not statistically significant individually for other populations. Interestingly, being married has a negative association with the FFM of all males and a positive association with the FFM of all females. Another factor that contributes to FFM appears to be living in an urban area. We present the determinants of BF in Appendix Table 2B. Again, both height and weight appear to be important determinants of BF for each demographic group. Moreover, based on the coefficients on the second and third order polynomials as well as the interaction between height and weight, the relationships appear to be highly nonlinear. Being married is associated with an increase in BF among all three male groups while it has insignificant and much smaller coefficients for all three female groups. Urban residence is a negative determinant of BF for black and Hispanic males and black females, while it has a positive coefficient for white females. The R-squared values in these regressions are quite high, ranging from 0.77 to 0.90. Taken together, results in Appendix Tables 1A and 1B suggest that these models accurately predict the FFM and BF in NHANES III and that the estimated coefficients can reliably be used to construct FFM and BF in other data sets such as the NLSY.[22]

Next, we present results from wage models estimated using conventional measures of obesity in Table 2. The models are estimated separately by gender/race/ethnicity, using the NLSY. These measures include BMI, BMI and BMI-squared, weight (in kilograms), binary indicators of underweight, overweight, and obese (with healthy weight being the omitted category). We present these models before displaying the results from the models with body composition in order to re-establish what is already known in the economics of obesity literature. Since we use the predicted weight and height measures that are corrected for self-reporting error in the NLSY, the standard errors will be underestimated in the wage regressions using these predicted weight and height measures. Therefore, we report bootstrapped standard errors.[23]

We present these results in three different panels in Table 2. In panel A, we display the results from the OLS models using contemporaneous values of the obesity measures. The panel B uses lagged values of weight in order to guard against bias due to potential reverse causality from wages to weight, i.e., higher BMI may lead to lower wages because low wages contribute to obesity. Others in the literature who used this approach to eliminate bias from reverse causality used a lag of seven years in their weight measures (Gortmaker et al,. 1993; Sargent and Blanchflower, 1994; Averett and Korenman, 1996; and Cawley, 2004). We follow the same convention in this paper.

[22] The range of the R-squared values is consistent with those found in Cawley and Burhhauser (2006) who reported a range from 0.76 to 0.90 for body fat and 0.81 to 0.82 for fat-free mass. Note that the specifications used in that paper were more parsimonious than ours.
[23] The bootstrapping is implemented with 499 replications. The implications remained the same when we experimented with higher values of replications.

Finally, the third panel takes advantage of the longitudinal nature of the data set and controls for individual fixed effects in order to account for time-invariant heterogeneity.

The first row in the top panel suggests that higher BMI is negatively associated with wages of both males and females, though the effects are not statistically significant for white males and black males. Also the coefficients on white and black males are much smaller than those of other groups. These results are consistent with Cawley (2004) who found a statistically significant negative effect of BMI for all three groups of females.[24] Our effects for white and black males are much smaller compared to all other groups and they are not statistically significant. Although Cawley (2004) also found smaller coefficients for these two groups, he obtained a *positive* and statistically significant effect for black males.

However, imposing a linear association between BMI and the logarithm of wages may be restrictive. Therefore, we present results from the models that contain BMI and BMI squared in row two. To our knowledge, this is the first paper to include BMI and its square together in the wage regressions. As illustrated in the second row of Panel A in Table 2, when we allow for a non-linear relationship between BMI and wages, the coefficients on both BMI and $BMI^2$ become statistically significant for white and black men, while the effects for females become much less precisely estimated. For Hispanic males, only the coefficient on the squared term is statistically significant at the 10 percent level. Also the coefficients on $BMI^2$ are very small for all the female groups. Therefore, it appears that the relationship between BMI and the logarithm of wages appears to be

[24] The coefficients found by Cawley (2004) are strikingly similar to ours: -0.008 compared with our -0.009 for white females, -0.004 compared with our -0.003 for black females, and virtually identical coefficients for Hispanic females. For males, the effect of -0.006 found in this paper for Hispanic is also very close to -0.007 of Cawley (2004) and the effects are statistically significant in both papers.

negative and monotonically decreasing for females, while the males' wage profile appears to be nonlinear and follow an inverse U-shaped relationship, especially for white and black males. Using the coefficient estimates, the logarithm of wage rises until it peaks at a BMI of 28 for white males, 31 for black males and 24 for Hispanic males. These figures suggest that the wages of white and black males rise with BMI until they reaches a peak in the overweight region and then starts to fall thereafter.

Although the estimated BMI coefficients can be useful in providing insights into the shape of the relationship between obesity and wages, the size of the coefficients cannot be interpreted meaningfully. In row three, we include weight in kilograms in our regressions also controlling for height in meters. Consistent with row one, these results indicate a negative relationship between weight and wages for both females and males. The coefficients are statistically significant for all three female groups, while only the coefficient for Hispanics is statistically significant for males. The coefficients for white and black males are both much smaller in magnitude and statistically insignificant. The coefficient estimates indicate that a 1 kilogram (2.2 pounds) increase in weight is associated with about a 0.3 percent decrease in the wages of white and Hispanic females and about 0.1 percent decrease in the wages of black females. These coefficients are again consistent with those of Cawley (2004) who included his weight variable in pounds.

Finally, row 4 presents the OLS coefficients on the indicator variables for clinical weight classification. Among females, whites who are obese earn about 12.0 percent less than those of healthy BMI. Among black and Hispanic females, those who are obese earn about 5 and 9 percent less than those of healthy BMI, respectively. These coefficients exhibit striking similarities with those reported by Cawley (2004) and Averett and Korenman (1996).[25] Those who are overweight earn about 1.5 to 4.5 percent less than those who are healthy weight, though the coefficient is not estimated significantly for black females. Finally, being underweight is associated with about 5 percent decrease in wages relative to being of healthy BMI for black and Hispanic females, though coefficients are not statistically significant. These are close to -0.056 for black females and -0.071 Hispanic females reported by Cawley (2004). The coefficient of underweight is positive but very small and insignificant for white females.

For males, the coefficients are much less precisely estimated. There appears to be a gain of about 4.8 percent and a loss of 3.5 percent for white males who are overweight and obese, respectively, relative to those of healthy weight. White males who are underweight earn 14 percent less than those of healthy weight. It also appears that black males earn about 3.4 percent more if they are overweight compared to being in healthy BMI.[26] It is interesting to note that the coefficient estimates resemble an inverse U-shaped relationship for white and black males which peaks in the overweight region – a finding which is consistent with the results in row two.

The OLS results suggest that, in general, heavier females face a wage penalty regardless of their race and ethnicity and this penalty appears to be linear in weight. The magnitude of this penalty appears to be the largest for white females. For males, there appears to be an inverse U-shaped relationship between body weight and wages for white

[25] Specifically, Cawley (2004) documents a coefficient of -0.119 for white females, which is virtually identical to the one found in this paper. He also finds an effect of -0.061 for black females and an effect of -0.082 for Hispanic females, both of which are extremely close to those found in this paper. Averett and Korenman (1996) report a coefficient of -0.12, which is almost identical to the one found by Cawley (2004) and this paper.

[26] Again, the results for males are highly consistent with those of Cawley (2004). All nine coefficients have the same signs and the magnitudes on obese coefficients are very close to those of Cawley (2004).

and black males, although the magnitudes are weaker and the coefficients are less precisely estimated compared to females.

As explained earlier, the OLS estimates with contemporaneous weight may be subject to bias due to potential reverse causality. The results with lagged weight are presented in Panel B of Table 2. Despite the large reduction in sample size, the implications obtained in panel A remained the same when seven year lagged values of weight are used in the models.

Finally, we present the results from the fixed effects models that control for time-invariant unobserved heterogeneity in Panel C of Table 2. The inclusion of fixed effects changes the coefficients dramatically. For example, the BMI coefficients in the first two rows become smaller and imprecise for both white and Hispanic females. However, the BMI coefficient for black females switch signs and becomes positive. This finding is different from Cawley (2004) who found a very small and negative but insignificant coefficient for this group. This somewhat peculiar finding is explained by the results in the second row where both BMI and $BMI^2$ are entered into the models. The relationship between BMI and wages appear to be nonlinear and inverse U-shaped for black females, which reaches a peak well into the obese region. In fact, the wages go up until BMI reaches 41 and declines thereafter. Apparently, imposing a linear relationship as in the first row makes it appear like the effect of BMI on wages is positive for all levels of BMI for black females. When we use weight in the fixed effects models, the coefficients for white and Hispanics are no longer significant, while the coefficient for black females is again positive. These are consistent with the findings in the first two rows of Panel C. The positive effect of weight on wages for black females is again due to the non-linear relationship between weight and wages, which becomes obvious if we estimate models with weight and weight-squared for black females. The presence of a nonlinear relationship between wages and obesity for black females also finds support when we use indicator variables for clinical weight classification. Black females who are underweight earn about 14 percent less than those of healthy weight and those who are obese earn about 4.5 percent more than their counterparts who are of healthy weight. When we split the obese category into three indicators defined as obese ($30 \leq BMI < 40$), very obese ($40 \leq BMI < 45$), and super obese ($45 \leq BMI$), then the coefficients on obesity indicator variables turn out to be 0.384, 0.0694, and 0.0387, first two of which are statistically significant. This result confirms the previous finding that the relationship is inverse U-shaped for black females and it reaches a peak in the obese region. For white and Hispanic females, the coefficients become smaller and less precisely estimated when we use indicators for clinical weight classification. For white females, the effect of being overweight goes down to about 0.42 percent. This is smaller than 1.6 reported by Cawley (2004), but they are both insignificant.[27] For white females, only the obese coefficient is significant and it points to a 5.7 percent wage penalty for those who are obese. None of the coefficients for Hispanic females are significant.

For males, the inverse U-shaped relationship between BMI and wages obtained in the first two panels remained similar even after fixed effects are controlled for. Interestingly, the effect of BMI on wages for black males is positive and significant, a result also found in Cawley (2004). However, this somewhat surprising finding is

[27] The discrepancy can be explained by the fact that Cawley (2004) included observations for ages of 16-18. We obtain a very similar coefficient of -0.014 if we add them back to our sample. We exclude them, as did Baum (2004), out of the concern that teenage labor market is significantly different than those of adults.

explained by the second row when we include both BMI and $BMI^2$. Similar to black females, the relationship between BMI and wages is in fact nonlinear for black males. The wages increase with BMI until it reaches a peak at a BMI of 38 and decreases thereafter. For white and Hispanic males, the wages reach a maximum at a BMI of 27 and 31. These figures are also consistent with coefficients on the indicator variables for the clinical weight classifications. The wages reach a maximum at the overweight range for white males, while they continue rising into the obese range for black and Hispanic males. However, the coefficients are not estimated precisely for white and Hispanic males.

Taken together, the results from Panel C of Table 2 suggest that the relationship between obesity and wages is nonlinear and inverse U-shaped for white and black males as well as black females. There also appears to be a negative linear relationship for white females. The relationship for Hispanic females is likely to be driven by unobserved heterogeneity as the effects largely disappear when fixed effects are controlled for. There is some evidence for an inverse U-shaped relationship for Hispanic males though the coefficients are not estimated very precisely, possibly due to small sample size. Compared with the contemporaneous OLS results, the statistical significance and the magnitude of the effects somewhat diminish for all groups except for black males and females when we control for fixed effects. The effects usually reach a peak in the overweight or obese region for black females and black, white, and Hispanic males for whom the effects appear to follow an inverse U shape. In general, the relationship between BMI-based obesity and wages appears to be somewhat unstable and highly sensitive to the inclusion of non-linear obesity measures. As explained earlier, this may be due the effects of BF and FFM that are likely to be opposite to each other and the inability of BMI-based measures to appropriately sort out these two effects.

After establishing our baseline estimates with conventional measures of obesity and showing that they are mostly supportive of our current knowledge on the subject, we turn our attention to the main focus of the paper – the effect of body composition on wages. We estimate the wage models with two measures of body composition – FFM in kilograms and BF in kilograms. Similar to the models with conventional measures, we estimate three different sets of models. Table 3A presents the results from regressions with the contemporaneous measures of body composition. Table 3B displays the results from the lagged measures and Table 3C reports the fixed effects results.[28]

As we discussed in Section III, in order to account for the possibility that current height may serve as a proxy of the degree of the individual's social skills and that this may have an independent impact on wages, we also control for variables that would serve as a proxy for the sociability of the individual in some specifications. Specifically, the sociability variables that we include in the models are ten binary indicators for most active high school club participation, such as athletics or marching band.[29] To better assess the effect of these variables on the impact of body composition measures, we present results in Tables 3A and 3B with and without these indicators. The sociability

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[28] Note that, since these models use measures of body composition constructed from the regressions coefficients that are transferred from NHANES III to the NLSY, the standard errors will be underestimated. Therefore, we present bootstrapped standard errors in all these tables. We implemented bootstrapping with 499 replications. The implications of the results remained the same when we repeated higher values of replications.

[29] It is likely that the contemporaneous sociability variables are endogenous to wages because higher wages are likely to raise sociability. In order to avoid bias due to potential reverse causality from wages to sociability, we use sociability indicators from high school years rather than current indicators of sociability. Nevertheless, models that also included current indicators of sociability such as measures of self-assessed "shyness" did not change the results. These results are available from the authors upon request.

variables are not included in Table 3C because their effects are captured by the individual fixed effects.

In Table 3A, we find that the coefficients on the measures of body composition have the signs consistent with our expectations for all groups. That is, the FFM and the BF are associated with an increase and a decrease in wages, respectively, regardless of gender, race, and ethnicity. The effects are also significant for every group except for black males. In panel B, which includes sociability indicators, the results remained very similar to those in panel A. Including ten variables that capture the social skills of the individual do not cause appreciable changes to the coefficient estimates. Looking at the coefficients in Panel B of Table 3A, a one kilogram increase in the BF reduces wages by about 1 percent for Hispanic males and Hispanic females, and about 0.9-1.0 percent for white males and white females. The effects of BF on the wages of black males and females are smaller and only significant for females. The wages of black females go down by about 0.6 percent in response to a one kilogram increase in body fat.

When the FFM is raised by one kilogram, the wages increase by about 0.7 percent for white males and Hispanic males and about 1.3 percent for white and Hispanic females. Again, the effects on black males and females are smaller and both coefficients are insignificant. These results indicate that, while an increase in body size that is due to an increase in BF will hurt wages, FFM is actually beneficial. Interestingly, the sizes of the effects are very similar between whites and Hispanics for both males and females. In Table 3B, we present results with measures of BF and FFM with a lag of seven years. Despite the substantial decrease in the sample size for each group, the patterns obtained in Table 3A remained very similar.  Again, the effect of fat-free mass is positive for all groups and the effect of body fat is negative for all groups.

Table 3C presents the coefficients of FFM and BF from regressions with individual fixed effects.  These models account for all of the time-invariant unobserved factors, including sociability from high school.  Despite controlling for time-invariant heterogeneity, the results from Table 3C indicate that the effects of BF and FFM are still significant for white males and white females.  Another interesting finding is that the magnitudes of the FFM and BF effects for white males and white females approximately double between Tables 3A and 3C.  The coefficients are still with the expected sign for black and Hispanic males and females, though they are no longer significant individually.[30]

The persistent and significant effects of body composition even after controlling for individual fixed effects suggest that an increase in BF is indeed bad for the wages of not only white females as usually found in the studies using BMI, but it also reduces the wages of white males.  While BF reduces wages, we also find that individuals earn a wage premium for having an increase in their FFM.

[30] However, F-tests for the joint significance suggest FFM and BF coefficients are jointly significant at the six percent levels for both black males and black females.  Only the effects for Hispanic males and females are jointly not significant. The loss of statistical significance by Hispanic males and females could be due to a number of factors, including the fact that the original predictive equation provided by Sun et al. (2003) was developed from a sample containing white and black individuals but no Hispanics.  Also our results are based on FFM and BF measures that are derived from equations using BIA ratings and that the majority of these prediction equations are better suited for whites than blacks and Hispanics because of the significantly smaller sample sizes for the latter two groups. The current state of medial research is such that the availability of clinical data is much higher for whites than for minority groups.

*Alternative BIA Conversion Equations for FFM and BF*

It is possible that the findings that are discussed above are driven by the choice of a particular set of BIA conversion equations. Note that we chose the BIA conversion equations developed by Sun et al. (2003) primarily because the predictive equations derived by these authors are particularly intended for estimating body composition for the respondents in NHANES III. Sun et al. (2003) is also one of the most recently published studies on the subject and is also used by Wada (2005, 2007) and Cawley and Burkhauser (2006). Nevertheless, we believe that it is relevant to question whether our findings are sensitive to the choice of a particular set of prediction equations. In order to address this question, we gathered a comprehensive set of predictive equations estimated by other clinical researchers.

This set includes 47 BIA separate equations derived and published by various researchers at various times.[31] We believe that this set includes most of the well-known BIA prediction equations that exist in published sources. These equations are presented in Appendix Table 4. We estimated our models using each of these alternative equations. Note that we use the same set of repressors in these models and also include individual fixed effects. Remarkably, these estimations produced FFM and BF coefficients that are extremely consistent with those presented in this paper.

[31] This is the same list identified in a recent study by Willet et al. (2006), minus one redundant equation due to replication. We combine four equations in that list because they were body-fat specific equations of Segal et al. (1988) that were originally meant to be combined (see Heyward and Wagner, 2004) and should have been combined by Willet et al. (2006). All 4 equations based on percentage body fat (as opposed to level measures of FFM or body weight) are dropped from the list due to high degree of prediction errors stemming from a linear model being fitted to truncated values between 0 and 100. Many of the remaining prediction equations are actually less suitable for the purpose of this paper because they are derived for populations of different ages like children and older adults and some are derived only for whites or non-U.S. respondents. Nevertheless, they are retained in our analysis to show that the final result is largely robust to such built-in errors. To this list, we further add four equations from published resources.

In Table 4, we present the coefficients on the FFM and BF for each gender/race/ethnicity group for each of these 47 prediction equations. It is a very interesting that, in all 47 equations, all twelve FFM and BF coefficients – a total of 564 regression coefficients (47*12) – have the expected sign, that is, the effect of FFM is positive and the effect of BF is negative. In our opinion, it is a remarkable finding that not a single coefficient has a sign that contradicts with our expectations. As summarized in Table 5, for both white females and white males, the FFM coefficients are statistically significant in 46 out of 47 models and the BF coefficients are statistically significant in all 47 models. This is consistent with our results presented in Table 3C. For black females, the BF coefficients are significant in 44 models and the FFM coefficients are significant in 45 models. This suggests that the lack of statistical significance for black females in Table 3C is a rare exception than the rule. Hispanic females are a little bit less consistent with 35 FFM and 36 BF coefficients being statistically significant at conventional levels. We find less than half of the estimated coefficients are significantly different from zero for BF of Hispanic males and both BF and FFM of black males. Consistent with our findings in Table 3C, the FFM and BF coefficients for black males are small, and with the exception of just five FFM coefficients, none of the FFM and BF coefficients is statistically significant in any of the 47 equations. Given the overwhelming evidence of consistently insignificant effects for FFM and BF for black males as illustrated in Table 4, we conclude that body composition does not have a significant effect on the wages of this group.

Table 5 also presents the median of the 47 BF and 47 FFM coefficients for each group. The medians are generally larger in magnitude (44% on average) than the estimated coefficients using the prediction equations of Sun et al. (2003). The fact that the median values move away from zero give support to our claim that our main result was not driven by the choice of a particular prediction equation. We believe that this analysis provides convincing and clear evidence that the results presented in Table 3 are not driven by the choice of a particular set of prediction equations.

The persistent and significant effects of body composition even after controlling for individual fixed effects suggest that an increase in BF is indeed bad for the wages of not only white females as usually found in the studies using BMI, but it also reduces the wages of both white males as well as black females. Also FFM is consistently associated with increased hourly wages for these three groups. Although the BF and FFM coefficients for Hispanics males and females are in the expected direction in all specifications, the evidence is somewhat less clear for this group than whites and blacks dues to a fewer number of statistically significant effects. This is likely due to the small sample sizes for Hispanics and the fact that the majority of the prediction equations used in Table 4 are better suited for whites and blacks. We find that Black males are the only group for whom effects are small and almost never significant. The findings of consistent effects of body composition across different gender, race, and ethnic groups are in contrast to the mixed results usually found by the studies using BMI as the measure of obesity.

*Discussion and Robustness*

Several potential explanations can be offered for the negative effect of body fat on wages. One of these explanations is that body fat lowers an individual's productivity through adversely affecting health. Fixed effects would capture any time-invariant health problems or limitations that would be correlated with body fat. However, this explanation is still plausible if the health limitations or problems are time-variant. Note that all of our wage models include a binary variable indicating any health limitation in the kind or amount of work one can perform while on the job. This variable is included in the fixed effects models since it is available in every year and can be time-variant. The effect of this variable is negative in every model and it remains mostly statistically significant even in the fixed effects models. Furthermore, the coefficients on body composition variables remain essentially the same when the health limitation variable is excluded from the models.[32]

Customer discrimination may be another explanation for the negative effect of body fat if customers in certain occupations have negative preferences against employees with higher levels of body fat. Note that we include a binary indicator for the individual's blue-collar occupation in our models. The exclusion of the blue-collar occupation indicator did not cause any appreciable chance in the coefficients of body composition variables in Table 3C. As a further test of customer discrimination explanation, we also constructed ten binary occupational indicators and included them in the fixed effects models instead of a single indicator for blue-collar occupation. The fixed effects results with occupation dummies are presented in Appendix Table 2. As illustrated in the table, the estimates remained almost identical when we controlled for

[32] Another possible explanation is that health limitations due to high levels of body fat adversely affecting the ability of individuals to work rather than their wages (Baum and Ford, 2004).

occupation indicators in the models. These results suggest that the opposing effects of body fat and fat-free mass are independent of customer discrimination.[33]

Another explanation would be that individuals with excess body fat may be less concerned about their future and thus invest less in accumulating human capital (Baum and Ford, 2004). However, our models include education, tenure, experience, and current school attendance, which should control for investments in human capital. Thus, this hypothesis is unlikely to explain why body fat lowers wages in our analysis.

Another possibility is the likely negative correlation between self-esteem of an individual and fatness. Cawley (2004) offers this as an explanation as to why obesity has a negative effect on the wages of white females. In order to support his argument, he cites evidence indicating that obesity has a more adverse effect on the self-esteem of white females than it does on the self-esteem of black and Hispanic females. Averett and Korenman (1999) find that obesity is associated with low self-esteem among white females, but not among black females. If increased body fat is indeed negatively correlated with self-esteem, this may be an explanation for the negative effects of BF that we find in this paper. Furthermore, if in fact obesity has a more negative effect on the self-esteem of whites than blacks and Hispanics, this would support our finding that the BF effects are the largest for white males and females. Note that we control for a large number of variables that proxy sociability of the individual. For example, we control in some of our models participation in high school clubs and sports as well as self-assessed indicators of shyness. If these variables capture the self-esteem of the individuals, then this explanation is unlikely to be responsible for the effects obtained in this paper.

[33] Note that we cannot rule out the possibility of employer discrimination.

Another potential explanation is that stigma of obesity may be less severe among blacks and Hispanics because overweight and obesity is observed at higher rates among blacks and Hispanics than among whites in the United States. According to data from the Centers for Disease Control and Prevention, approximately 30 percent of non-Hispanic white adults were obese in 2003-2004, while the percentage of obese adults among Mexican Americans and non-Hispanic blacks were 36.8 percent and 45 percent, respectively. This may again explain why the effects are much stronger and more precisely estimated for whites than they are for blacks and whites.

The sociability indicators, which are included in the models to control for any direct effect that height can have on wages through impacting an individual's social capital, do not cause any appreciable change to the coefficients. In order to guard against the possibility that sociability indicators do not fully capture this channel, we experimented with models controlling for height during adolescence. Specifically, we estimated models with earliest available height before age 18 in addition to the sociability indicators. In order to implement this, we had to restrict our sample such that earliest available height of an individual is from a point in life before age 18. As a result of this, our sample sizes went down to less than 1/4$^{th}$ of original sizes. These results are presented in Appendix Table 3. Despite dramatic reductions in the sample sizes, all of the FFM and BF coefficients are in the expected sign and the effects are largely consistent with those in previous tables. Note that sociability indicators are also controlled for in these models. Results remained very similar when we controlled only for height before age 18.[34]

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[34] Note that fixed effects cannot be controlled for in these models as sociability and height before age 18 are time invariant characteristics.

## VI. Conclusion

In this paper, we estimate the effect of body composition on wages by gender and ethnicity. Our main contributions are three-fold. First, we expand the literature on the economics of obesity by introducing a new measure of obesity and the one that is also consistent with the definition of obesity. Previous studies on this subject exclusively relied on BMI and body weight to measure obesity. However, there is ample evidence to suggest that these are not good surrogates of obesity because of their inability to distinguish between fat body mass and fat-free mass. Since it is the body fat that classifies an individual as obese, the effects obtained in previous studies may be confounded by the impact of fat-free component of body composition. Our study is the first to examine the relationship between body composition and wages. We measure body composition by body fat and fat-free mass.

Second, this paper is also the first study to investigate the effect of fat-free mass on wages. Because FFM consists mostly of muscles and skeletons, FFM presents a plausible proxy for estimating the effect of physical health on worker earnings. Because it is health through which body size or nutritional status is thought to influence worker productivity, it should be the healthy growth that should be associated with increased hourly earnings. The body composition measures allow us to distinguish between the effects of healthy physical growth (represented by an increase in FFM) and an unhealthy physical growth (represented by an increase in BF) on wages. Our results are consistent with the theoretical implication that FFM is associated with increased hourly wages, while BF is associated with decreased hourly wages. These findings imply that public health officials should pay particular attention to the opposing effects of body composition components on health and labor market outcomes when designing nutrition intervention programs aimed at reducing the incidence of obesity.

Third, this paper contributes to the growing literature on the role of non-cognitive factors on wage determination. Recently, researchers found that non-cognitive characteristics such as beauty, leadership, and tallness are all positively related to earnings. We expand this literature by examining the role of another potentially important non-cognitive characteristic of the individuals in body composition. Our results show that the positive and the negative effects of FFM and BF are independent of adolescent height or other factors capturing sociability of individuals.

Our findings indicate that increased body fat decreases the wages of both males and females. The effects are very clear for white males, white females, black females, and to a lesser extent for Hispanic males and females. The effects of body composition on the wages of black males are found to be much smaller and statistically insignificant. These findings are in contrast to the previous studies that found strong evidence of a negative effect on white females but for other population groups. These studies largely missed the effect on other groups, possibly due to the problems associated with their measures that are discussed in this paper. Given that a higher proportion of women's body consists of fat than men due to demands for childbearing and other hormonal functions, BMI may serve as a better measure of excessive fatness for women than men. Such gender-dependent correlation could particularly explain the previously mixed and unstable findings for men. Our results also indicate that individuals with high levels of fat-free mass or lean body mass earn a wage premium. We also present evidence that these results are not artifacts of other characteristics of the individuals that are correlated with obesity. Finally, we show evidence that our findings are robust to the choice of prediction equation based on which the body composition measures are derived.

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## Table 1
## Descriptive Statistics (Mean and Standard Error) of NLSY 1979

| Variables | Definitions | Full Sample | White Males | Black Males | Hispanic Males | White Females | Black Females | Hispanic Females |
|---|---|---|---|---|---|---|---|---|
| Hourly Wage | Hourly wage rate in 1991 dollars (adjusted by CPI) | 11.28 | 13.59 | 10.31 | 11.95 | 10.39 | 8.753 | 9.816 |
| | | (16.42) | (18.00) | (15.43) | (18.42) | (16.49) | (10.02) | (15.30) |
| FFM | Estimated Fat-free Mass in kilograms | 54.50 | 63.34 | 65.00 | 60.47 | 43.73 | 47.74 | 41.90 |
| | | (12.12) | (8.477) | (8.860) | (8.777) | (5.578) | (6.714) | (5.584) |
| BF | Estimated Body Fat in kilograms | 22.07 | 20.49 | 18.08 | 21.27 | 23.00 | 27.16 | 24.97 |
| | | (9.676) | (7.593) | (8.097) | (7.946) | (10.30) | (12.14) | (10.36) |
| BMI | Weight/Height$^2$ | 25.79 | 26.05 | 26.41 | 27.10 | 24.13 | 27.22 | 25.68 |
| | | (5.169) | (4.300) | (4.449) | (4.737) | (5.285) | (6.493) | (5.735) |
| Underweight | Dummy variable = 1 if BMI<18.5 | 0.0153 | 0.00661 | 0.00715 | 0.00562 | 0.0341 | 0.0143 | 0.0129 |
| | | (0.123) | (0.0811) | (0.0843) | (0.0748) | (0.182) | (0.119) | (0.113) |
| Healthy | Dummy variable = 1 if 18.5≤BMI<25 | 0.473 | 0.443 | 0.445 | 0.345 | 0.612 | 0.378 | 0.466 |
| | | (0.499) | (0.497) | (0.497) | (0.475) | (0.487) | (0.485) | (0.499) |
| Overweight | Dummy variable = 1 if 25≤BMI<30 | 0.314 | 0.379 | 0.352 | 0.407 | 0.208 | 0.283 | 0.288 |
| | | (0.464) | (0.485) | (0.478) | (0.491) | (0.406) | (0.450) | (0.453) |
| Obese | Dummy variable = 1 if 30≤BMI | 0.198 | 0.172 | 0.195 | 0.243 | 0.147 | 0.325 | 0.233 |
| | | (0.398) | (0.377) | (0.396) | (0.429) | (0.354) | (0.468) | (0.423) |
| Weight [b] | Kilograms | 76.68 | 83.72 | 83.08 | 81.77 | 67.04 | 75.19 | 67.13 |
| | | (17.78) | (15.91) | (16.48) | (15.97) | (15.29) | (18.62) | (15.53) |
| Height [b] | Meters | 1.707 | 1.784 | 1.773 | 1.728 | 1.646 | 1.635 | 1.586 |
| | | (0.0925) | (0.0625) | (0.0614) | (0.0541) | (0.0563) | (0.0523) | (0.0480) |
| Health Limitation | Dummy variable = 1 if Health limits kind or amount of work | 0.0401 | 0.0343 | 0.0325 | 0.0358 | 0.0484 | 0.0503 | 0.0372 |
| | | (0.196) | (0.182) | (0.177) | (0.186) | (0.215) | (0.218) | (0.189) |
| AFQT 1980 | Armed Forces Qualification Test from 1980-1981 | 43.71 | 54.88 | 24.39 | 33.22 | 54.94 | 26.26 | 32.76 |
| | | (28.46) | (27.94) | (22.68) | (25.76) | (25.36) | (19.89) | (23.18) |
| Mother's Education | Years of education completed by mother | 11.11 | 12.07 | 11.08 | 8.150 | 11.97 | 11.02 | 8.233 |
| | | (3.143) | (2.346) | (2.523) | (4.337) | (2.363) | (2.604) | (4.022) |
| Father's Education | Years of education completed by father | 11.10 | 12.33 | 10.22 | 8.393 | 12.23 | 10.25 | 8.447 |
| | | (3.904) | (3.322) | (3.399) | (4.791) | (3.164) | (3.608) | (4.569) |
| Children | # of biological/step/adopted children in | 0.944 | 0.823 | 0.653 | 1.021 | 0.974 | 1.240 | 1.251 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | the household | (1.173) | (1.119) | (1.081) | (1.279) | (1.130) | (1.223) | (1.262) |
| Attend | Dummy variable =1 if currently attending school | 0.0856 | 0.0824 | 0.0609 | 0.0685 | 0.101 | 0.0887 | 0.101 |
| | | (0.280) | (0.275) | (0.239) | (0.253) | (0.302) | (0.284) | (0.301) |
| Married | Dummy variable =1 if married | 0.479 | 0.541 | 0.321 | 0.488 | 0.550 | 0.310 | 0.505 |
| | | (0.500) | (0.498) | (0.467) | (0.500) | (0.498) | (0.463) | (0.500) |
| Education | Years of education | 13.16 | 13.37 | 12.70 | 12.36 | 13.50 | 13.31 | 12.68 |
| | | (2.309) | (2.413) | (2.083) | (2.473) | (2.198) | (1.978) | (2.441) |
| Age | Age in years (to the closest month) | 31.52 | 31.31 | 31.38 | 31.09 | 31.65 | 32.11 | 31.85 |
| | | (6.924) | (6.836) | (6.778) | (6.777) | (7.107) | (6.876) | (7.045) |
| Tenure | Years of tenure (50 weeks/year) | 4.200 | 4.705 | 3.557 | 4.213 | 4.059 | 4.132 | 3.837 |
| | | (4.781) | (5.100) | (4.288) | (4.775) | (4.630) | (4.870) | (4.415) |
| Experience | Years of work experience (50 weeks/year) | 11.24 | 12.15 | 10.51 | 11.44 | 11.28 | 10.00 | 10.41 |
| | | (6.643) | (6.760) | (6.438) | (6.577) | (6.587) | (6.450) | (6.529) |
| Low unemployment [a] | Dummy variable =1 if unemployment rate is less than 5.9% | 0.465 | 0.462 | 0.520 | 0.376 | 0.467 | 0.545 | 0.370 |
| | | (0.499) | (0.499) | (0.500) | (0.484) | (0.499) | (0.498) | (0.483) |
| Medium unemployment | Dummy variable =1 if unemployment rate is between 6% and 8.9% | 0.347 | 0.356 | 0.354 | 0.326 | 0.352 | 0.335 | 0.323 |
| | | (0.476) | (0.479) | (0.478) | (0.469) | (0.478) | (0.472) | (0.468) |
| High unemployment | Dummy variable =1 if unemployment rate is between 9% and 11.9% | 0.121 | 0.118 | 0.0964 | 0.170 | 0.117 | 0.0871 | 0.174 |
| | | (0.326) | (0.323) | (0.295) | (0.376) | (0.322) | (0.282) | (0.379) |
| Very high unemployment | Dummy variable =1 if unemployment rate is higher than 12% | 0.0671 | 0.0640 | 0.0294 | 0.128 | 0.0632 | 0.0325 | 0.133 |
| | | (0.250) | (0.245) | (0.169) | (0.334) | (0.243) | (0.177) | (0.340) |
| Urban | Dummy variable =1 if urban | 0.790 | 0.728 | 0.841 | 0.916 | 0.724 | 0.862 | 0.912 |
| | | (0.407) | (0.445) | (0.366) | (0.277) | (0.447) | (0.345) | (0.284) |
| Northeast | Dummy variable =1 if Northeast region | 0.172 | 0.188 | 0.170 | 0.157 | 0.186 | 0.139 | 0.135 |
| | | (0.377) | (0.390) | (0.375) | (0.363) | (0.389) | (0.345) | (0.341) |
| West | Dummy variable =1 if West region | 0.195 | 0.165 | 0.0840 | 0.468 | 0.168 | 0.0714 | 0.440 |
| | | (0.396) | (0.371) | (0.277) | (0.499) | (0.374) | (0.257) | (0.496) |
| Midwest | Dummy variable =1 if Midwest region | 0.255 | 0.360 | 0.181 | 0.0669 | 0.325 | 0.172 | 0.0843 |
| | | (0.436) | (0.480) | (0.385) | (0.250) | (0.468) | (0.377) | (0.278) |
| South [a] | Dummy variable =1 if South region | 0.378 | 0.287 | 0.566 | 0.309 | 0.322 | 0.618 | 0.341 |
| | | (0.485) | (0.453) | (0.496) | (0.462) | (0.467) | (0.486) | (0.474) |
| Blue-collar | Dummy variable =1 if blue-collar occupation [b] | 0.475 | 0.554 | 0.692 | 0.636 | 0.297 | 0.413 | 0.307 |
| | | (0.499) | (0.497) | (0.462) | (0.481) | (0.457) | (0.492) | (0.461) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year 1981 | Dummy variable =1 if year=1981 | 0.0437 | 0.0443 | 0.0400 | 0.0441 | 0.0480 | 0.0368 | 0.0427 |
| | | (0.204) | (0.206) | (0.196) | (0.205) | (0.214) | (0.188) | (0.202) |
| Year 1982 | Dummy variable =1 if year=1982 | 0.0670 | 0.0693 | 0.0640 | 0.0681 | 0.0716 | 0.0557 | 0.0633 |
| | | (0.250) | (0.254) | (0.245) | (0.252) | (0.258) | (0.229) | (0.243) |
| Year 1985 | Dummy variable =1 if year=1985 | 0.0673 | 0.0685 | 0.0689 | 0.0706 | 0.0678 | 0.0612 | 0.0634 |
| | | (0.250) | (0.253) | (0.253) | (0.256) | (0.251) | (0.240) | (0.244) |
| Year 1986 | Dummy variable =1 if year=1986 | 0.0672 | 0.0671 | 0.0706 | 0.0704 | 0.0671 | 0.0654 | 0.0611 |
| | | (0.250) | (0.250) | (0.256) | (0.256) | (0.250) | (0.247) | (0.239) |
| Year 1988 | Dummy variable =1 if year=1988 | 0.0707 | 0.0724 | 0.0739 | 0.0725 | 0.0682 | 0.0708 | 0.0643 |
| | | (0.256) | (0.259) | (0.262) | (0.259) | (0.252) | (0.257) | (0.245) |
| Year 1989 | Dummy variable =1 if year=1989 | 0.0718 | 0.0733 | 0.0746 | 0.0758 | 0.0685 | 0.0713 | 0.0682 |
| | | (0.258) | (0.261) | (0.263) | (0.265) | (0.253) | (0.257) | (0.252) |
| Year 1990 | Dummy variable =1 if year=1990 | 0.0694 | 0.0705 | 0.0715 | 0.0730 | 0.0649 | 0.0718 | 0.0694 |
| | | (0.254) | (0.256) | (0.258) | (0.260) | (0.246) | (0.258) | (0.254) |
| Year 1992 | Dummy variable =1 if year=1992 | 0.0694 | 0.0703 | 0.0711 | 0.0719 | 0.0669 | 0.0690 | 0.0687 |
| | | (0.254) | (0.256) | (0.257) | (0.258) | (0.250) | (0.253) | (0.253) |
| Year 1993 | Dummy variable =1 if year=1993 | 0.0700 | 0.0718 | 0.0714 | 0.0717 | 0.0675 | 0.0681 | 0.0701 |
| | | (0.255) | (0.258) | (0.258) | (0.258) | (0.251) | (0.252) | (0.255) |
| Year 1994 | Dummy variable =1 if year=1994 | 0.0674 | 0.0692 | 0.0683 | 0.0663 | 0.0655 | 0.0654 | 0.0690 |
| | | (0.251) | (0.254) | (0.252) | (0.249) | (0.247) | (0.247) | (0.254) |
| Year 1996 | Dummy variable =1 if year=1996 | 0.0719 | 0.0709 | 0.0732 | 0.0696 | 0.0713 | 0.0746 | 0.0741 |
| | | (0.258) | (0.257) | (0.260) | (0.255) | (0.257) | (0.263) | (0.262) |
| Year 1998 | Dummy variable =1 if year=1998 | 0.0699 | 0.0685 | 0.0677 | 0.0673 | 0.0700 | 0.0748 | 0.0746 |
| | | (0.255) | (0.253) | (0.251) | (0.251) | (0.255) | (0.263) | (0.263) |
| Year 2000 [a] | Dummy variable =1 if year=2000 | 0.0679 | 0.0646 | 0.0655 | 0.0634 | 0.0706 | 0.0730 | 0.0735 |
| | | (0.252) | (0.246) | (0.247) | (0.244) | (0.256) | (0.260) | (0.261) |
| Year 2002 | Dummy variable =1 if year=2002 | 0.0641 | 0.0603 | 0.0622 | 0.0581 | 0.0668 | 0.0718 | 0.0689 |
| | | (0.245) | (0.238) | (0.241) | (0.234) | (0.250) | (0.258) | (0.253) |
| Year 2004 | Dummy variable =1 if year=2004 | 0.0624 | 0.0590 | 0.0572 | 0.0571 | 0.0653 | 0.0702 | 0.0687 |
| | | (0.242) | (0.236) | (0.232) | (0.232) | (0.247) | (0.256) | (0.253) |
| Observations | | 73,397 | 22,833 | 9,509 | 6,936 | 19,468 | 8,756 | 5,895 |

Notes: Standard deviations are in parentheses. [a] Omitted category. [b] Adjusted height and weight. (See the text for explanations).

## Table 2
## Results from the Log Wage Models

### *Panel A* - Contemporaneous OLS Results

| Variable | White Males | Black Males | Hispanic Males | White Females | Black Females | Hispanic Females |
|---|---|---|---|---|---|---|
| BMI | -0.00163 | 0.00153 | -0.00571** | -0.00865*** | -0.00289** | -0.00629*** |
| | (0.00175) | (0.00203) | (0.00240) | (0.00129) | (0.00138) | (0.00179) |
| BMI | 0.0521*** | 0.0396*** | 0.0242 | -0.00981 | -0.00746 | -0.00657 |
| | (0.0102) | (0.0129) | (0.0174) | (0.00751) | (0.00719) | (0.00972) |
| $BMI^2$ | -0.000918*** | -0.000646*** | -0.000502* | 0.0000199 | 0.0000715 | 0.0000044 |
| | (0.000171) | (0.000220) | (0.000275) | (0.000123) | (0.000108) | (0.000149) |
| Weight | -0.000623 | 0.000511 | -0.00217*** | -0.00316*** | -0.00105** | -0.0026*** |
| | (0.000550) | (0.000643) | (0.000803) | (0.000476) | (0.000514) | (0.000717) |
| Underweight | -0.141** | -0.0805 | -0.0442 | 0.0187 | -0.0504 | -0.0521 |
| | (0.0602) | (0.0579) | (0.0875) | (0.0249) | (0.0429) | (0.0699) |
| Overweight | 0.0475*** | 0.0336* | -0.0102 | -0.0456*** | -0.0147 | -0.0364* |
| | (0.0138) | (0.0176) | (0.0240) | (0.0141) | (0.0175) | (0.0221) |
| Obese | -0.0349* | 0.0216 | -0.0437 | -0.119*** | -0.0509** | -0.0896*** |
| | (0.0203) | (0.0246) | (0.0326) | (0.0195) | (0.0216) | (0.0264) |
| Observations | 22,833 | 9,509 | 6,936 | 19,468 | 8,756 | 5,895 |

### *Panel B* - Lagged OLS Results

| | | | | | | |
|---|---|---|---|---|---|---|
| BMI | -0.00207 | 0.00268 | -0.00721** | -0.00977*** | -0.00578*** | -0.00761*** |
| | (0.00219) | (0.00284) | (0.00325) | (0.00185) | (0.00205) | (0.00256) |
| BMI | 0.0728*** | 0.0326* | 0.0137 | -0.0222** | -0.00404 | 0.00257 |
| | (0.0146) | (0.0181) | (0.0209) | (0.00978) | (0.0115) | (0.0165) |
| $BMI^2$ | -0.00137*** | -0.000546* | -0.000369 | 0.000227 | -0.0000297 | -0.000177 |
| | (0.000264) | (0.000318) | (0.000352) | (0.000176) | (0.000192) | (0.000265) |
| Weight | -0.000790 | 0.000878 | -0.00246** | -0.00363*** | -0.00209*** | -0.00317*** |
| | (0.000697) | (0.000879) | (0.00108) | (0.000683) | (0.000753) | (0.00103) |
| Underweight | -0.0241 | -0.0273 | -0.0336 | 0.0578* | 0.0388 | -0.0720 |
| | (0.0616) | (0.0785) | (0.131) | (0.0320) | (0.0417) | (0.0843) |
| Overweight | 0.0333** | 0.00540 | -0.0173 | -0.0776*** | -0.0137 | -0.0465* |
| | (0.0165) | (0.0237) | (0.0281) | (0.0182) | (0.0214) | (0.0257) |
| Obese | -0.0816*** | -0.00220 | -0.0646 | -0.0894*** | -0.0814*** | -0.0919*** |
| | (0.0258) | (0.0351) | (0.0408) | (0.0280) | (0.0295) | (0.0349) |
| Observations | 9,466 | 3,982 | 2,864 | 7,896 | 3,646 | 2,403 |

### *Panel C* - Fixed Effects Results

| | | | | | | |
|---|---|---|---|---|---|---|
| BMI | -0.00269 | 0.00578** | 0.000848 | -0.00324* | 0.00406* | -0.00176 |
| | (0.00214) | (0.00265) | (0.00309) | (0.00181) | (0.00227) | (0.00299) |
| BMI | 0.0194** | 0.0294** | 0.0394** | -0.00347 | 0.0221*** | 0.0119 |
| | (0.00820) | (0.0123) | (0.0177) | (0.00881) | (0.00804) | (0.0122) |
| $BMI^2$ | -0.00036*** | -0.000386* | -0.000639** | 0.00000369 | -0.000268** | -0.000210 |
| | (0.000132) | (0.000199) | (0.000284) | (0.000138) | (0.000116) | (0.000187) |
| Weight | -0.000763 | 0.00199** | 0.000411 | -0.00108 | 0.00158* | -0.000760 |
| | (0.000677) | (0.000845) | (0.00102) | (0.000674) | (0.000835) | (0.00117) |
| Underweight | -0.00451 | -0.0728 | -0.00190 | -0.0404 | -0.141*** | 0.00764 |
| | (0.0473) | (0.0788) | (0.0857) | (0.0264) | (0.0476) | (0.0503) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Overweight | 0.0162 | 0.0323* | 0.0101 | -0.00420 | 0.0247 | 0.0131 |
| | (0.0119) | (0.0174) | (0.0198) | (0.0142) | (0.0169) | (0.0232) |
| Obese | -0.0140 | 0.0561** | 0.0374 | -0.0574*** | 0.0456* | -0.00612 |
| | (0.0199) | (0.0265) | (0.0314) | (0.0217) | (0.0243) | (0.0358) |
| Observations | 22,833 | 9,509 | 6,936 | 19,468 | 8,756 | 5,895 |

Notes: Bootstrapped, robust standard errors clustered around individuals are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

**Table 3A**
**OLS Results from the Models using Contemporaneous Fat-Free Mass and Body-Fat**

**Panel A**

| Variable | White Males | Black Males | Hispanic Males | White Females | Black Females | Hispanic Females |
|---|---|---|---|---|---|---|
| Fat-Free Mass | 0.00752*** | 0.00457 | 0.00842** | 0.0129*** | 0.00835* | 0.0145* |
| | (0.00225) | (0.00286) | (0.00410) | (0.00339) | (0.00499) | (0.00796) |
| Body Fat | -0.00884*** | -0.00355 | -0.0122*** | -0.0107*** | -0.00584** | -0.0108** |
| | (0.00259) | (0.00322) | (0.00421) | (0.00185) | (0.00278) | (0.00432) |
| Sociability indicators | No | No | No | No | No | No |
| Observations | 22,833 | 9,509 | 6,936 | 19,468 | 8,756 | 5,895 |

**Panel B**

| Variable | White Males | Black Males | Hispanic Males | White Females | Black Females | Hispanic Females |
|---|---|---|---|---|---|---|
| Fat-Free Mass | 0.00705*** | 0.00345 | 0.00742* | 0.0126*** | 0.00813 | 0.0133* |
| | (0.00228) | (0.00287) | (0.00419) | (0.00340) | (0.00500) | (0.00806) |
| Body Fat | -0.00878*** | -0.00289 | -0.0110** | -0.0104*** | -0.00567** | -0.00979** |
| | (0.00260) | (0.00324) | (0.00430) | (0.00186) | (0.00278) | (0.00436) |
| Sociability indicators | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 22,833 | 9,509 | 6,936 | 19,468 | 8,756 | 5,895 |

Notes: Bootstrapped, robust standard errors clustered around individuals are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

**Table 3B**
**OLS Results from the Models using Lagged Fat-Free Mass and Body-Fat**

**Panel A**

| Variable | White Males | Black Males | Hispanic Males | White Females | Black Females | Hispanic Females |
|---|---|---|---|---|---|---|
| Fat-Free Mass | 0.00795*** | 0.00385 | 0.00623 | 0.0147*** | 0.0123** | 0.0246** |
| | (0.00269) | (0.00311) | (0.00507) | (0.00423) | (0.00611) | (0.0100) |
| Body Fat | -0.00971*** | -0.00144 | -0.0107* | -0.0118*** | -0.00955*** | -0.0169*** |
| | (0.00335) | (0.00329) | (0.00551) | (0.00231) | (0.00341) | (0.00556) |
| Sociability indicators | No | No | No | No | No | No |
| Observations | 8,989 | 3,715 | 2,706 | 7,668 | 3,536 | 2,325 |

**Panel B**

| Variable | White Males | Black Males | Hispanic Males | White Females | Black Females | Hispanic Females |
|---|---|---|---|---|---|---|
| Fat-Free Mass | 0.00750*** | 0.00262 | 0.00480 | 0.0147*** | 0.0120* | 0.0226** |
| | (0.00274) | (0.00315) | (0.00512) | (0.00426) | (0.00615) | (0.0102) |
| Body Fat | -0.00994*** | -0.00120 | -0.00937* | -0.0116*** | -0.00932*** | -0.0152*** |
| | (0.00339) | (0.00331) | (0.00561) | (0.00233) | (0.00344) | (0.00568) |
| Sociability indicators | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 8,989 | 3,715 | 2,706 | 7,668 | 3,536 | 2,325 |

Notes: Bootstrapped, robust standard errors clustered around individuals are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

**Table 3C**
**Fixed Effects Results from the Models using Fat-Free Mass and Body-Fat**

| Variable | White Males | Black Males | Hispanic Males | White Females | Black Females | Hispanic Females |
|---|---|---|---|---|---|---|
| Fat-Free Mass | 0.0154** | 0.00557 | 0.0128 | 0.0302** | 0.0231 | 0.0236 |
| | (0.00643) | (0.00669) | (0.00777) | (0.0146) | (0.0193) | (0.0199) |
| Body Fat | -0.0160*** | -0.00144 | -0.0114 | -0.0162** | -0.00931 | -0.0126 |
| | (0.00618) | (0.00626) | (0.00712) | (0.00706) | (0.0100) | (0.00997) |
| Observations | 22,833 | 9,509 | 6,936 | 19,468 | 8,756 | 5,895 |

Notes: Bootstrapped, robust standard errors clustered around individuals are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

**Table 4**
**Fixed-Effects Estimation with Supplementary BIA Equations with FFM and BF**

| Prediction Equation | Variable | White Males | Black Males | Hispanic Males | White Females | Black Females | Hispanic Females |
|---|---|---|---|---|---|---|---|
| Boulier | FFM | 0.00942*** | 0.00489 | 0.00760* | 0.0306** | 0.0296** | 0.0161 |
| | | (0.00364) | (0.00421) | (0.00460) | (0.0122) | (0.0119) | (0.00977) |
| | BF | -0.0410*** | -0.00953 | -0.0284* | -0.101*** | -0.0899** | -0.0543* |
| | | (0.0145) | (0.0161) | (0.0171) | (0.0382) | (0.0393) | (0.0316) |
| Cordain | FFM | 0.0162*** | 0.00681 | 0.0125* | 0.0479** | 0.0455** | 0.0255* |
| | | (0.00604) | (0.00688) | (0.00743) | (0.0189) | (0.0188) | (0.0153) |
| | BF | -0.00875*** | -0.000302 | -0.00541 | -0.0166*** | -0.0134** | -0.00927* |
| | | (0.00301) | (0.00327) | (0.00339) | (0.00599) | (0.00660) | (0.00528) |
| Danford2 | FFM | 0.0191*** | 0.00764 | 0.0145* | 0.0557** | 0.0525** | 0.0295* |
| | | (0.00707) | (0.00803) | (0.00867) | (0.0218) | (0.0217) | (0.0176) |
| | BF | -0.0137*** | -0.00171 | -0.00887 | -0.0296*** | -0.0251** | -0.0162* |
| | | (0.00475) | (0.00520) | (0.00545) | (0.0109) | (0.0116) | (0.00926) |
| Danfordl | FFM | 0.0139*** | 0.00617 | 0.0109* | 0.0421** | 0.0402** | 0.0223* |
| | | (0.00523) | (0.00599) | (0.00648) | (0.0166) | (0.0165) | (0.0134) |
| | BF | -0.00875*** | -0.000302 | -0.00541 | -0.0167*** | -0.0134** | -0.00927* |
| | | (0.00301) | (0.00327) | (0.00339) | (0.00599) | (0.00660) | (0.00528) |
| Davies | FFM | 0.0158*** | 0.00671 | 0.0123* | 0.0470** | 0.0446** | 0.0250* |
| | | (0.00591) | (0.00674) | (0.00728) | (0.0185) | (0.0184) | (0.0150) |
| | BF | -0.00875*** | -0.000302 | -0.00541 | -0.0166*** | -0.0134** | -0.00927* |
| | | (0.00301) | (0.00327) | (0.00339) | (0.00599) | (0.00660) | (0.00528) |
| Deurenberg1 | FFM | 0.0177*** | 0.00726 | 0.0137* | 0.0520** | 0.0492** | 0.0277* |
| | | (0.00659) | (0.00751) | (0.00809) | (0.0204) | (0.0204) | (0.0165) |
| | BF | -0.00875*** | -0.000302 | -0.00541 | -0.0166*** | -0.0134** | -0.00927* |
| | | (0.00301) | (0.00327) | (0.00339) | (0.00599) | (0.00660) | (0.00528) |
| Deurenberg2 | FFM | 0.0213*** | 0.00827 | 0.0163* | 0.0611** | 0.0576** | 0.0326* |
| | | (0.00786) | (0.00892) | (0.00960) | (0.0239) | (0.0240) | (0.0194) |
| | BF | -0.00875*** | -0.000302 | -0.00542 | -0.0166*** | -0.0134** | -0.00927* |
| | | (0.00301) | (0.00327) | (0.00339) | (0.00599) | (0.00660) | (0.00528) |
| Deurenberg3 | FFM | 0.0180** | 0.00811 | 0.0153 | 0.0480** | 0.0431** | 0.0270 |
| | | (0.00731) | (0.00818) | (0.00936) | (0.0189) | (0.0205) | (0.0191) |
| | BF | -0.0211*** | -0.00471 | -0.0161 | -0.0464*** | -0.0380* | -0.0268 |
| | | (0.00808) | (0.00882) | (0.00999) | (0.0174) | (0.0198) | (0.0183) |
| Deurenberg4 | FFM | 0.0159** | 0.00891 | 0.0169 | 0.0375** | 0.0326* | 0.0195 |
| | | (0.00788) | (0.00872) | (0.0111) | (0.0160) | (0.0193) | (0.0214) |
| | BF | -0.0122** | -0.00285 | -0.0114 | -0.0240** | -0.0175 | -0.0132 |
| | | (0.00555) | (0.00601) | (0.00779) | (0.00944) | (0.0122) | (0.0135) |
| Deurenberg5 | FFM | 0.0222*** | 0.00853 | 0.0169* | 0.0635** | 0.0597** | 0.0339* |
| | | (0.00819) | (0.00929) | (0.00999) | (0.0249) | (0.0249) | (0.0202) |
| | BF | -0.00875*** | -0.000301 | -0.00542 | -0.0166*** | -0.0134** | -0.00927* |
| | | (0.00301) | (0.00327) | (0.00339) | (0.00599) | (0.00660) | (0.00528) |
| Estonl | FFM | 0.0192*** | 0.00768 | 0.0146* | 0.0560** | 0.0528** | 0.0297* |
| | | (0.00712) | (0.00809) | (0.00873) | (0.0219) | (0.0218) | (0.0177) |
| | BF | -0.0196*** | -0.00341 | -0.0131* | -0.0450*** | -0.0392** | -0.0244* |
| | | (0.00686) | (0.00756) | (0.00795) | (0.0168) | (0.0176) | (0.0141) |
| Fjeld2 | FFM | 0.0294*** | 0.0106 | 0.0218* | 0.0825** | 0.0769** | 0.0439* |
| | | (0.0108) | (0.0121) | (0.0131) | (0.0321) | (0.0321) | (0.0260) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | BF | -0.0525*** | -0.0128 | -0.0365* | -0.131*** | -0.117** | -0.0703* |
| | | (0.0186) | (0.0207) | (0.0219) | (0.0496) | (0.0509) | (0.0409) |
| Fjeldl | FFM | 0.0133*** | 0.00597 | 0.0104* | 0.0403** | 0.0386** | 0.0214* |
| | | (0.00499) | (0.00572) | (0.00620) | (0.0160) | (0.0158) | (0.0129) |
| | BF | -0.00875*** | -0.000302 | -0.00541 | -0.0167*** | -0.0134** | -0.00927* |
| | | (0.00301) | (0.00327) | (0.00339) | (0.00599) | (0.00660) | (0.00528) |
| Gray1 | FFM | 0.0104* | 0.0114 | 0.0137 | 0.0185* | 0.0247** | 0.0105 |
| | | (0.00623) | (0.00775) | (0.0106) | (0.0102) | (0.0102) | (0.0138) |
| | BF | -0.00398** | -0.000892 | -0.00411 | -0.00754** | -0.00633* | -0.00493 |
| | | (0.00201) | (0.00241) | (0.00362) | (0.00333) | (0.00377) | (0.00557) |
| Gray2 | FFM | 0.00835** | 0.00971* | 0.00879 | 0.00777 | 0.0142*** | 0.00797 |
| | | (0.00382) | (0.00576) | (0.00626) | (0.00576) | (0.00454) | (0.00583) |
| | BF | -0.00648** | -0.00294 | -0.00548 | -0.00815* | -0.00862** | -0.00861 |
| | | (0.00260) | (0.00365) | (0.00418) | (0.00451) | (0.00388) | (0.00557) |
| Heitmann3 | FFM | 0.0115* | 0.00778 | 0.0140 | 0.0294** | 0.0254 | 0.0124 |
| | | (0.00653) | (0.00723) | (0.00978) | (0.0133) | (0.0166) | (0.0194) |
| | BF | -0.00963** | -0.00232 | -0.0100 | -0.0162** | -0.0107 | -0.00756 |
| | | (0.00486) | (0.00528) | (0.00734) | (0.00655) | (0.00886) | (0.0104) |
| Heitmannl | FFM | 0.0135* | 0.00919 | 0.0173 | 0.0366** | 0.0307 | 0.0133 |
| | | (0.00807) | (0.00892) | (0.0124) | (0.0168) | (0.0214) | (0.0254) |
| | BF | -0.00825* | -0.00190 | -0.00899 | -0.0130** | -0.00803 | -0.00541 |
| | | (0.00437) | (0.00476) | (0.00684) | (0.00533) | (0.00735) | (0.00880) |
| Houtkooper1 | FFM | 0.0177*** | 0.00725 | 0.0135* | 0.0521** | 0.0492** | 0.0276* |
| | | (0.00658) | (0.00749) | (0.00809) | (0.0204) | (0.0203) | (0.0165) |
| | BF | -0.0171*** | -0.00269 | -0.0113 | -0.0385*** | -0.0332** | -0.0209* |
| | | (0.00596) | (0.00656) | (0.00689) | (0.0143) | (0.0150) | (0.0120) |
| Houtkooper2 | FFM | 0.0161*** | 0.00679 | 0.0123* | 0.0479** | 0.0454** | 0.0253* |
| | | (0.00600) | (0.00684) | (0.00740) | (0.0188) | (0.0186) | (0.0152) |
| | BF | -0.0170*** | -0.00267 | -0.0113 | -0.0383*** | -0.0330** | -0.0208* |
| | | (0.00594) | (0.00653) | (0.00685) | (0.0142) | (0.0149) | (0.0120) |
| Jebb | FFM | 0.0394*** | 0.0134 | 0.0290* | 0.109*** | 0.101** | 0.0578* |
| | | (0.0143) | (0.0161) | (0.0173) | (0.0420) | (0.0422) | (0.0342) |
| | BF | -0.0185*** | -0.00310 | -0.0123* | -0.0422*** | -0.0366** | -0.0229* |
| | | (0.00647) | (0.00713) | (0.00749) | (0.0157) | (0.0165) | (0.0132) |
| Kushner_Schoeller1 | FFM | 0.0143*** | 0.00628 | 0.0111* | 0.0432** | 0.0411** | 0.0228* |
| | | (0.00536) | (0.00613) | (0.00665) | (0.0170) | (0.0168) | (0.0137) |
| | BF | -0.0122*** | -0.00129 | -0.00782 | -0.0258*** | -0.0216** | -0.0141* |
| | | (0.00423) | (0.00462) | (0.00483) | (0.00945) | (0.0101) | (0.00807) |
| Kushner_Schoeller2 | FFM | 0.0243*** | 0.00913 | 0.0182* | 0.0692** | 0.0648** | 0.0368* |
| | | (0.00893) | (0.0101) | (0.0109) | (0.0270) | (0.0269) | (0.0219) |
| | BF | -0.0143*** | -0.00189 | -0.00931 | -0.0312*** | -0.0266** | -0.0170* |
| | | (0.00497) | (0.00545) | (0.00570) | (0.0115) | (0.0122) | (0.00975) |
| Kushner_Schoeller3 | FFM | 0.0212*** | 0.00824 | 0.0160* | 0.0612** | 0.0575** | 0.0324* |
| | | (0.00782) | (0.00887) | (0.00957) | (0.0239) | (0.0238) | (0.0193) |
| | BF | -0.0160*** | -0.00239 | -0.0106 | -0.0357*** | -0.0307** | -0.0194* |
| | | (0.00559) | (0.00614) | (0.00644) | (0.0133) | (0.0139) | (0.0112) |
| Kushner1 | FFM | 0.0139*** | 0.00616 | 0.0108* | 0.0422** | 0.0402** | 0.0223* |
| | | (0.00522) | (0.00597) | (0.00648) | (0.0166) | (0.0164) | (0.0134) |
| | BF | -0.0110*** | -0.000937 | -0.00693 | -0.0225*** | -0.0187** | -0.0124* |
| | | (0.00378) | (0.00413) | (0.00431) | (0.00820) | (0.00882) | (0.00705) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Kyle | FFM | 0.0266*** | 0.0174* | 0.0293** | 0.0760*** | 0.0625*** | 0.0419* |
| | | (0.00782) | (0.00905) | (0.0120) | (0.0221) | (0.0217) | (0.0240) |
| | BF | -0.0183*** | -0.00785 | -0.0183** | -0.0400*** | -0.0294*** | -0.0219* |
| | | (0.00515) | (0.00575) | (0.00753) | (0.0111) | (0.0113) | (0.0122) |
| Lohman2 | FFM | 0.0188*** | 0.00757 | 0.0143* | 0.0550** | 0.0518** | 0.0291* |
| | | (0.00697) | (0.00793) | (0.00856) | (0.0215) | (0.0214) | (0.0174) |
| | BF | -0.0228*** | -0.00432 | -0.0154* | -0.0534*** | -0.0467** | -0.0289* |
| | | (0.00800) | (0.00883) | (0.00931) | (0.0200) | (0.0208) | (0.0167) |
| Lohman3 | FFM | 0.0204*** | 0.0120 | 0.0198** | 0.0611*** | 0.0518*** | 0.0325* |
| | | (0.00639) | (0.00740) | (0.00907) | (0.0192) | (0.0185) | (0.0186) |
| | BF | -0.0161*** | -0.00525 | -0.0139** | -0.0355*** | -0.0268** | -0.0190* |
| | | (0.00478) | (0.00532) | (0.00640) | (0.0106) | (0.0107) | (0.0105) |
| Lohmanl | FFM | 0.0212*** | 0.00826 | 0.0160* | 0.0613** | 0.0576** | 0.0325* |
| | | (0.00783) | (0.00889) | (0.00958) | (0.0239) | (0.0238) | (0.0194) |
| | BF | -0.0213*** | -0.00389 | -0.0143* | -0.0494*** | -0.0431** | -0.0268* |
| | | (0.00746) | (0.00822) | (0.00866) | (0.0185) | (0.0193) | (0.0154) |
| Lukaski_Bolonchuk2 | FFM | 0.0225*** | 0.00862 | 0.0169* | 0.0646** | 0.0606** | 0.0343* |
| | | (0.00829) | (0.00940) | (0.0101) | (0.0252) | (0.0251) | (0.0204) |
| | BF | -0.0169*** | -0.00263 | -0.0112 | -0.0380*** | -0.0327** | -0.0206* |
| | | (0.00589) | (0.00648) | (0.00680) | (0.0141) | (0.0148) | (0.0119) |
| Lukaski_Bolonchukl | FFM | 0.0232*** | 0.00881 | 0.0174* | 0.0663** | 0.0622** | 0.0352* |
| | | (0.00853) | (0.00966) | (0.0104) | (0.0259) | (0.0258) | (0.0210) |
| | BF | -0.0165*** | -0.00251 | -0.0108 | -0.0368*** | -0.0317** | -0.0200* |
| | | (0.00573) | (0.00630) | (0.00661) | (0.0137) | (0.0144) | (0.0115) |
| Lukaski1 | FFM | 0.0158*** | 0.00671 | 0.0123* | 0.0470** | 0.0447** | 0.0250* |
| | | (0.00592) | (0.00675) | (0.00729) | (0.0185) | (0.0184) | (0.0150) |
| | BF | -0.00875*** | -0.000302 | -0.00541 | -0.0166*** | -0.0134** | -0.00927* |
| | | (0.00301) | (0.00327) | (0.00339) | (0.00599) | (0.00660) | (0.00528) |
| Lukaski2 | FFM | 0.0157*** | 0.00666 | 0.0122* | 0.0466** | 0.0443** | 0.0248* |
| | | (0.00585) | (0.00668) | (0.00721) | (0.0184) | (0.0183) | (0.0148) |
| | BF | -0.00875*** | -0.000302 | -0.00541 | -0.0167*** | -0.0134** | -0.00927* |
| | | (0.00301) | (0.00327) | (0.00339) | (0.00599) | (0.00660) | (0.00528) |
| Lukaski3 | FFM | 0.0179*** | 0.0104 | 0.0170** | 0.0545*** | 0.0468*** | 0.0288* |
| | | (0.00571) | (0.00663) | (0.00800) | (0.0175) | (0.0168) | (0.0165) |
| | BF | -0.0118*** | -0.00297 | -0.00954** | -0.0242*** | -0.0179** | -0.0130* |
| | | (0.00353) | (0.00391) | (0.00459) | (0.00728) | (0.00746) | (0.00717) |
| Lukaski4 | FFM | 0.0183*** | 0.0104 | 0.0171** | 0.0556*** | 0.0479*** | 0.0293* |
| | | (0.00589) | (0.00683) | (0.00817) | (0.0181) | (0.0174) | (0.0168) |
| | BF | -0.0121*** | -0.00297 | -0.00964** | -0.0251*** | -0.0187** | -0.0134* |
| | | (0.00365) | (0.00405) | (0.00471) | (0.00765) | (0.00783) | (0.00743) |
| Macias | FFM | 0.0169*** | 0.0103* | 0.0166** | 0.0517*** | 0.0441*** | 0.0275* |
| | | (0.00531) | (0.00619) | (0.00760) | (0.0163) | (0.0157) | (0.0158) |
| | BF | -0.0139*** | -0.00420 | -0.0118** | -0.0295*** | -0.0219** | -0.0158* |
| | | (0.00410) | (0.00455) | (0.00546) | (0.00874) | (0.00889) | (0.00874) |
| Rising | FFM | 0.0310*** | 0.0111 | 0.0230* | 0.0868** | 0.0808** | 0.0462* |
| | | (0.0113) | (0.0128) | (0.0138) | (0.0337) | (0.0338) | (0.0274) |
| | BF | -0.0283*** | -0.00590 | -0.0193* | -0.0677*** | -0.0598** | -0.0366* |
| | | (0.00998) | (0.0110) | (0.0117) | (0.0255) | (0.0264) | (0.0212) |
| Roubenoff | FFM | 0.0183*** | 0.0104 | 0.0171** | 0.0556*** | 0.0479*** | 0.0293* |
| | | (0.00589) | (0.00683) | (0.00817) | (0.0181) | (0.0174) | (0.0168) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | BF | -0.0121*** | -0.00297 | -0.00964** | -0.0251*** | -0.0187** | -0.0134* |
| | | (0.00365) | (0.00405) | (0.00471) | (0.00765) | (0.00783) | (0.00743) |
| Segal1 | FFM | 0.0134 | 0.0143 | 0.0186 | 0.0281* | 0.0353** | 0.0133 |
| | | (0.00855) | (0.0104) | (0.0150) | (0.0150) | (0.0160) | (0.0217) |
| | BF | -0.00613* | -0.00283 | -0.00721 | -0.0121** | -0.0114* | -0.00641 |
| | | (0.00340) | (0.00406) | (0.00623) | (0.00560) | (0.00643) | (0.00918) |
| Segal2 | FFM | 0.0101* | 0.0110 | 0.0118 | 0.0159* | 0.0227*** | 0.0122 |
| | | (0.00523) | (0.00693) | (0.00858) | (0.00931) | (0.00814) | (0.0111) |
| | BF | -0.00807** | -0.00423 | -0.00802 | -0.0129** | -0.0134** | -0.0105 |
| | | (0.00368) | (0.00470) | (0.00621) | (0.00636) | (0.00601) | (0.00876) |
| Segal3 | FFM | 0.00827** | 0.0110** | 0.00804 | 0.0294* | 0.0365** | 0.0129 |
| | | (0.00400) | (0.00557) | (0.00747) | (0.0157) | (0.0170) | (0.0230) |
| | BF | -0.00840** | -0.00576 | -0.00675 | -0.0218** | -0.0226* | -0.0105 |
| | | (0.00359) | (0.00460) | (0.00681) | (0.0106) | (0.0120) | (0.0169) |
| Stolarczyk | FFM | 0.0164*** | 0.0184** | 0.0213* | 0.0196** | 0.0268*** | 0.0147 |
| | | (0.00621) | (0.00843) | (0.0114) | (0.00971) | (0.00846) | (0.0127) |
| | BF | -0.00585*** | -0.00300 | -0.00661* | -0.00827** | -0.00706** | -0.00657 |
| | | (0.00205) | (0.00257) | (0.00384) | (0.00334) | (0.00317) | (0.00517) |
| VanLoan_Maychn | FFM | 0.0126* | 0.0133 | 0.0162 | 0.0242* | 0.0317** | 0.0147 |
| | | (0.00731) | (0.00915) | (0.0124) | (0.0132) | (0.0129) | (0.0178) |
| | BF | -0.0104* | -0.00637 | -0.0119 | -0.0188** | -0.0199** | -0.0122 |
| | | (0.00544) | (0.00666) | (0.00955) | (0.00914) | (0.00952) | (0.0136) |
| VanLoan2 | FFM | 0.0178*** | 0.00727 | 0.0136* | 0.0523** | 0.0494** | 0.0277* |
| | | (0.00660) | (0.00752) | (0.00812) | (0.0205) | (0.0204) | (0.0166) |
| | BF | -0.0218*** | -0.00404 | -0.0147* | -0.0507*** | -0.0443** | -0.0275* |
| | | (0.00764) | (0.00843) | (0.00888) | (0.0190) | (0.0198) | (0.0159) |
| VanLoan3 | FFM | 0.0183*** | 0.00742 | 0.0139* | 0.0537** | 0.0506** | 0.0284* |
| | | (0.00679) | (0.00772) | (0.00834) | (0.0210) | (0.0209) | (0.0170) |
| | BF | -0.0198*** | -0.00346 | -0.0132* | -0.0455*** | -0.0396** | -0.0247* |
| | | (0.00692) | (0.00763) | (0.00803) | (0.0170) | (0.0177) | (0.0142) |
| VanLoanl | FFM | 0.0167*** | 0.00696 | 0.0128* | 0.0495** | 0.0468** | 0.0262* |
| | | (0.00622) | (0.00708) | (0.00766) | (0.0194) | (0.0193) | (0.0157) |
| | BF | -0.0237*** | -0.00457 | -0.0160* | -0.0556*** | -0.0488** | -0.0301* |
| | | (0.00831) | (0.00918) | (0.00968) | (0.0209) | (0.0217) | (0.0174) |
| Wattanapenpaiboon2 | FFM | 0.0171*** | 0.00708 | 0.0131* | 0.0506** | 0.0478** | 0.0268* |
| | | (0.00637) | (0.00725) | (0.00784) | (0.0198) | (0.0197) | (0.0160) |
| | BF | -0.0140*** | -0.00182 | -0.00913 | -0.0305*** | -0.0259** | -0.0166* |
| | | (0.00487) | (0.00534) | (0.00560) | (0.0113) | (0.0119) | (0.00954) |
| Wattanapenpaiboonl | FFM | 0.0186*** | 0.00750 | 0.0141* | 0.0544** | 0.0513** | 0.0288* |
| | | (0.00689) | (0.00783) | (0.00846) | (0.0213) | (0.0212) | (0.0172) |
| | BF | -0.0223*** | -0.00418 | -0.0150* | -0.0521*** | -0.0456** | -0.0282* |
| | | (0.00783) | (0.00864) | (0.00910) | (0.0195) | (0.0203) | (0.0163) |

Notes: Bootstrapped, robust standard errors clustered around individuals are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

**Table 5**
**Summary Statistics for Supplemental BIA Equations with FFM and BF**

| Statistics | Variable | White Males | Black Males | Hispanic Males | White Females | Black Females | Hispanic Females |
|---|---|---|---|---|---|---|---|
| # of equations with | FFM | 46 | 5 | 37 | 46 | 45 | 35 |
| significant coefficients | BF | 47 | 0 | 18 | 47 | 44 | 36 |
| Median coefficient | FFM | 0.0177 | 0.0083 | 0.0145 | 0.0517 | 0.0468 | 0.0275 |
| | BF | -0.0122 | -0.0029 | -0.0096 | -0.0258 | -0.0219 | -0.0141 |

## Appendix Table 1A
## Determinants of Fat-free Mass (FFM) from NHANES III

| Variable | White Males | Black Males | Hispanic Males | White Females | Black Females | Hispanic Females |
|---|---|---|---|---|---|---|
| Age | 0.0150 | 0.217 | -0.0860 | 0.170** | 0.173 | -0.181* |
| | (0.118) | (0.156) | (0.131) | (0.0775) | (0.115) | (0.106) |
| $Age^2$ (/100) | -0.197 | 0.122 | 0.445** | -0.525*** | -0.543*** | 0.00905 |
| | (0.170) | (0.227) | (0.200) | (0.0817) | (0.154) | (0.145) |
| $Age^3$ (/100) | 0.00103 | -0.000703 | -0.00352** | 0.00324*** | 0.00343*** | -0.000452 |
| | (0.00109) | (0.00163) | (0.00144) | (0.000534) | (0.00109) | (0.00106) |
| Height | 302.6 | -234.8 | -253.0*** | -158.0 | -93.96 | -282.5*** |
| | (238.9) | (221.2) | (55.69) | (121.2) | (97.22) | (83.07) |
| $Height^2$ (/100) | -180.2 | 148.3 | 156.7*** | 93.45 | 56.65 | 173.3*** |
| | (144.9) | (131.1) | (33.98) | (83.71) | (66.97) | (48.50) |
| $Height^3$ (/100) | 35.38 | -29.09 | -32.49*** | -15.77 | -11.24 | -35.71*** |
| | (29.32) | (25.80) | (7.001) | (19.13) | (15.28) | (9.035) |
| Weight | 0.223 | -0.253 | -0.330 | 0.222* | -0.298 | -0.236 |
| | (0.180) | (0.183) | (0.211) | (0.128) | (0.216) | (0.150) |
| $Weigh^2$ (/100) | -0.175 | 0.526*** | 0.360 | 0.143 | 0.373 | 0.357*** |
| | (0.116) | (0.127) | (0.264) | (0.0985) | (0.229) | (0.116) |
| $Weight^3$ (/100) | 0.000332 | -0.00200*** | -0.00170* | -0.000582 | -0.00173* | -0.00180*** |
| | (0.000337) | (0.000369) | (0.000997) | (0.000366) | (0.000918) | (0.000417) |
| Height*Weight | 0.272** | 0.156 | 0.332*** | -0.00646 | 0.241*** | 0.234*** |
| | (0.112) | (0.109) | (0.0820) | (0.0800) | (0.0745) | (0.0899) |
| Age*Height (/100) | -0.672 | -25.74*** | -11.03 | 1.282 | 1.621 | 12.47** |
| | (5.527) | (7.656) | (7.026) | (4.222) | (5.965) | (5.646) |
| Age*Weight (/100) | 0.0871** | 0.171*** | 0.103** | 0.0527** | 0.0410 | -0.0307 |
| | (0.0386) | (0.0485) | (0.0443) | (0.0225) | (0.0367) | (0.0355) |
| Urban | 0.376** | 0.639*** | 0.170 | -0.193* | 0.275* | 0.327*** |
| | (0.163) | (0.223) | (0.171) | (0.105) | (0.155) | (0.126) |
| Northeast | 0.934*** | 0.376 | 0.695 | 0.344*** | 0.241 | 0.0717 |
| | (0.217) | (0.303) | (0.484) | (0.132) | (0.203) | (0.262) |
| West | 0.511** | 0.249 | -0.287 | 0.701*** | 0.149 | -0.395*** |
| | (0.245) | (0.370) | (0.183) | (0.148) | (0.264) | (0.135) |
| Midwest | 0.793*** | 0.476* | 0.375 | 0.901*** | 0.300* | 0.263 |
| | (0.184) | (0.279) | (0.289) | (0.117) | (0.181) | (0.234) |
| Married | -0.0299*** | -0.0392*** | -0.0328*** | 0.0288*** | 0.0328*** | 0.0232*** |
| | (0.0112) | (0.0117) | (0.0108) | (0.00627) | (0.00708) | (0.00713) |
| Constant | -154.7 | 151.2 | 164.8*** | 99.52* | 75.81 | 176.9*** |
| | (131.8) | (124.3) | (31.78) | (58.35) | (47.55) | (46.50) |
| Observations | 3,195 | 2,276 | 2,400 | 3,533 | 2,501 | 2,158 |
| R-squared | 0.827 | 0.824 | 0.816 | 0.820 | 0.810 | 0.778 |

Notes: Robust standard errors are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

## Appendix Table 1B
## Determinants of Body Fat (BF) from NHANES III

| Variable | White Males | Black Males | Hispanic Males | White Females | Black Females | Hispanic Females |
|---|---|---|---|---|---|---|
| Age | -0.0482 | -0.264* | -0.209 | -0.280*** | 0.212 | 0.0792 |
| | (0.127) | (0.152) | (0.137) | (0.0965) | (0.204) | (0.133) |
| $Age^2$ (/100) | 0.0953 | 0.466** | 0.268 | 0.533*** | -0.0430 | 0.323 |
| | (0.190) | (0.219) | (0.207) | (0.107) | (0.299) | (0.216) |
| $Age^3$ (/100) | -0.000752 | -0.00354** | -0.00187 | -0.00339*** | -0.0000070 | -0.00268* |
| | (0.00120) | (0.00152) | (0.00147) | (0.000689) | (0.00204) | (0.00161) |
| Height | -116.2 | 960.7* | 220.3*** | 579.9*** | 383.8** | 313.3*** |
| | (253.8) | (570.8) | (61.71) | (134.7) | (162.5) | (53.26) |
| $Height^2$ (/100) | 70.07 | -575.7* | -139.0*** | -397.2*** | -247.2** | -203.6*** |
| | (153.8) | (345.1) | (39.99) | (95.35) | (104.8) | (31.95) |
| $Height^3$ (/100) | -14.98 | 113.7 | 27.52*** | 86.01*** | 49.99** | 41.59*** |
| | (31.08) | (69.44) | (8.758) | (22.20) | (22.33) | (5.964) |
| Weight | 0.440** | 0.786*** | 0.846*** | 0.846*** | 0.279 | 0.750*** |
| | (0.192) | (0.213) | (0.221) | (0.141) | (0.524) | (0.199) |
| $Weigh^2$ (/100) | 0.356*** | 0.199* | -0.183 | -0.0713 | 0.441 | -0.0935 |
| | (0.123) | (0.117) | (0.286) | (0.132) | (0.505) | (0.159) |
| $Weight^3$ (/100) | -0.00082** | -0.0000817 | 0.00117 | -0.0000488 | -0.00220 | 0.000192 |
| | (0.000377) | (0.000338) | (0.00111) | (0.000468) | (0.00208) | (0.000590) |
| Height*Weight | -0.195 | -0.275** | -0.133 | 0.0303 | 0.106 | 0.0724 |
| | (0.119) | (0.119) | (0.0869) | (0.102) | (0.116) | (0.117) |
| Age*Height (/100) | 3.592 | 17.02** | 13.57* | 8.822* | -10.11 | -4.053 |
| | (5.696) | (7.599) | (7.233) | (5.157) | (9.693) | (7.096) |
| Age*Weight (/100) | -0.0107 | -0.254*** | -0.156*** | -0.167*** | -0.0208 | -0.190*** |
| | (0.0454) | (0.0488) | (0.0460) | (0.0277) | (0.0817) | (0.0670) |
| Urban | 0.0460 | -0.511** | -0.385** | 0.215* | -0.382* | -0.189 |
| | (0.163) | (0.225) | (0.170) | (0.125) | (0.227) | (0.172) |
| Northeast | -0.566*** | -0.409 | -0.975** | -0.184 | -0.433* | -1.048*** |
| | (0.207) | (0.302) | (0.413) | (0.164) | (0.263) | (0.313) |
| West | -0.179 | -0.217 | 0.507*** | -0.542*** | -0.736* | 0.155 |
| | (0.260) | (0.382) | (0.180) | (0.172) | (0.385) | (0.182) |
| Midwest | -0.769*** | -0.0672 | -0.168 | -0.833*** | -0.169 | -0.347 |
| | (0.184) | (0.286) | (0.295) | (0.148) | (0.262) | (0.402) |
| Married | 0.0430*** | 0.0481*** | 0.0376*** | 0.00623 | -0.00956 | 0.00320 |
| | (0.0122) | (0.0132) | (0.0107) | (0.0111) | (0.0123) | (0.0100) |
| Constant | 61.42 | -546.0* | -129.7*** | -290.5*** | -205.7** | -177.4*** |
| | (140.1) | (315.0) | (32.60) | (62.70) | (86.55) | (29.49) |
| Observations | 3,195 | 2,276 | 2,400 | 3,533 | 2,501 | 2,158 |
| R-squared | 0.765 | 0.776 | 0.761 | 0.899 | 0.872 | 0.865 |

Notes: Robust standard errors are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

## Appendix Table 2

**Fixed Effects Results from the Models using Fat-Free Mass and Body-Fat with Occupational Dummies**

| Variable | White Males | Black Males | Hispanic Males | White Females | Black Females | Hispanic Females |
|---|---|---|---|---|---|---|
| Fat-Free Mass | 0.0143** | 0.00595 | 0.0118 | 0.0284** | 0.0196 | 0.0210 |
| | (0.00641) | (0.00647) | (0.00778) | (0.0143) | (0.0185) | (0.0199) |
| Body Fat | -0.0155** | -0.00195 | -0.0105 | -0.0148** | -0.00765 | -0.0109 |
| | (0.00616) | (0.00600) | (0.00715) | (0.00692) | (0.00964) | (0.00995) |
| Observations | 22,833 | 9,509 | 6,936 | 19,468 | 8,756 | 5,895 |

Notes: Bootstrapped, robust standard errors clustered around individuals are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

## Appendix Table 3

**OLS Results from the Models using Contemporaneous Fat-Free Mass and Body-Fat (Restricted to Earliest Available Height at Age before 18)**

| Variable | White Males | Black Males | Hispanic Males | White Females | Black Females | Hispanic Females |
|---|---|---|---|---|---|---|
| Fat-Free Mass | 0.0151*** | 0.0302*** | 0.0179 | 0.0369** | 0.000194 | 0.00370 |
| | (0.00573) | (0.00907) | (0.0123) | (0.0183) | (0.0198) | (0.0184) |
| Body Fat | -0.0118** | -0.0287*** | -0.0176 | -0.0191** | -0.00268 | -0.00323 |
| | (0.00574) | (0.00997) | (0.0123) | (0.00889) | (0.0102) | (0.00954) |
| Sociability indicators | Yes | Yes | Yes | Yes | Yes | Yes |
| Earliest available Height | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 5,110 | 2,055 | 1,624 | 3,877 | 1,712 | 1,285 |

Notes: Bootstrapped, robust standard errors clustered around individuals are in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

## Appendix Table 4
## BIA Prediction Equations

| | |
|---|---|
| For Lean Body Mass [a] | |
| Heitmann1 | $0.279Ht^2/R + 0.181Wt + 0.231Ht + 0.064(Sex + Wt) - 0.077Age - 14.94$; M = 1, F = 0 |
| Segal 1 | $0.00108Ht^2 - 0.02090R + 0.23199Wt - 0.06777Age + 14.59453$ |
| Segal 2 | $0.00132Ht^2 - 0.04394R + 0.30520Wt - 0.16760Age + 22.66827$ |
| Segal 3 | Segal 3a-3d combined together. See Heyward and Wagner (2004, p.140) |
| Segal 3a | $0.00066360Ht^2 - 0.02117R + 0.62854Wt - 0.12380Age + 9.33285$ |
| Segal 3b | $0.00088580Ht^2 - 0.02999R + 0.42688Wt - 0.07002Age + 14.52435$ |
| Segal 3c | $0.00064602Ht^2 - 0.01397R + 0.42087Wt + 10.43485$ |
| Segal 3d | $0.00091186Ht^2 - 0.01466R + 0.29990Wt - 0.07012Age + 9.37938$ |
| Van Loan and Mayclin | $0.000985Ht^2 + 0.3736Wt - 0.0238R - 4.2921Sex - 0.1531Age + 17.7868$; M = 0, F = 1 |
| For FFM | |
| Boulier | $0.40Ht^2/R + 0.64Wt - 0.16Age + 6.37 - 2.71Sex$; M = 1, F = 2 |
| Cordain | $0.81Ht^2/R + 6.86$ |
| Chumlea | $-10.678 + 0.262Wt + 0.652Ht^2/R + 0.015R$ (M) and $-9.529 + 0.168Wt + 0.696Ht^2/R + 0.016R$ (F) |
| Deurenberg1 | $0.762Ht^2/R + 4.20$ |
| Deurenberg2 | $0.672 \times Ht^2/R + 3.1Sex + 3.9$; M = 1, F = 0 |
| Deurenberg3 | $0.406 \times Ht^2/R + 0.360Wt + 5.58Ht + 0.56Sex - 6.48$ |
| Deurenberg4 | $0.340 \times Ht^2/R + 15.34Ht + 0.273Wt - 0.127Age + 4.56Sex - 12.44$ |
| Deurenberg5 | $0.652 \text{ x } Ht^2/R + 3.8Sex+10.9$ |
| Eston1 | $0.52Ht^2/R + 0.28Wt + 3.25$ |
| Gray1 | $0.00151Ht^2 - 0.0344R + 0.140Wt - 0.158Age + 20.387$ |
| Gray2 | $0.00139Ht^2 - 0.0801R + 0.187Wt + 39.830$ |
| Houtkooper1 | $0.58Ht^2/R + 0.24Wt + 2.69$ |
| Houtkooper2 | $0.61Ht^2/R + 0.25Wt + 1.31$ |
| Jebb | $0.348613Ht^2/R + 0.168998Wt + 13.96674$ |
| Lohman1 | $0.475Ht^2/R + 0.295Wt + 5.49$ |
| Lohman2 | $0.485Ht^2/R + 0.338Wt + 5.32$ |
| Lohman3 | $0.62Ht^2/R + 0.21Wt + 0.10X_c + 4.2$ |
| Lukaski1 | $0.821Ht^2/R + 4.917$ |
| Lukaski2 | $0.827Ht^2/R + 5.21$ |
| Lukaski3 | $0.756Ht^2/R + 0.110Wt + 0.107X_c - 5.463$ |
| Lukaski4 | $0.734 Ht^2/R + 0.096Xc + 0.116Wt + 0.878Sex - 4.033$ |
| Macias | $0.7374Ht^2/R + 0.1763Wt - 0.1773Age + 0.1198*Xc - 2.4658$ |
| Rising | $0.34Ht^2/R + 0.33Wt - 0.14Age + 6.18Sex + 13.74$ |
| Roubenoff | $0.734Ht^2/R + 0.116Wt + 0.096X_c + 0.984Sex - 4.03$; M = 1, F = 0 |
| Stolarczyk | $0.001254Ht^2 - 0.04904R + 0.1555Wt + 0.1417X_c - 0.0833Age + 20.05$ |
| Van Loan1 | $0.50Ht^2/R + 0.37Wt + 1.93Sex + 3.12$; M = 1, F = −1 |
| Van Loan2 | $0.51Ht^2/R + 0.33Wt + 1.69Sex + 3.66$; M = 1, F = −1 |
| Van Loan3 | $0.53Ht^2/R + 0.29Wt + 1.38Sex + 4.40$; M = 1, F = −1 |
| Wattanapenpaiboon1 | $0.4936Ht^2/R + 0.332Wt + 6.493$ |
| Wattanapenpaiboon2 | $0.6483Ht^2/R + 0.1699Wt + 5.091$ |

| | |
|---|---|
| For Total Body Weight [a] | |
| Danford1 | $0.65Ht^2/R + 0.71$ |
| Danford2 | $0.45Ht^2/R + 0.11Wt + 1.84$ |
| Davies | $0.60Ht^2/R + 0.50$ |
| Fjeld1 | $0.67Ht^2/R + 0.48$ |
| Fjeld2 | $0.18Ht^2/R + 0.39Wt + 0.76$ |
| Heitmann3 | $0.240Ht^2/R + 0.172Wt + 0.040(Sex \times Wt) + 0.165Ht - 17.58$ |
| Kushner1 | $0.593Ht^2/R + 0.065Wt + 0.04$ |
| Kushner and Schoeller1 | $0.5561Ht^2/R + 0.0955Wt + 1.726$ |
| Kushner and Schoeller2 | $0.382Ht^2/R + 0.105Wt + 8.315$ |
| Kushner and Schoeller3 | $0.396Ht^2/R + 0.143Wt + 8.399$ |
| Lukaski and Bolonchuk1 | $0.372Ht^2/R + 3.05Sex + 0.142Wt - 0.069Age + 4.98$; M = 1, F = 0 |
| Lukaski and Bolonchuk2 | $0.374Ht^2/R + 0.151Wt - 0.083Age + 2.94Sex + 4.65$; M = 1, F = 0 |

Ht is height in centimeters, Wt is weight in kilograms, R is resistance in ohms, Xc is reactance in ohms (reactance is a different type of resistance sometimes used in BIA). Source: Willett et al. (2006), supplemented by Heyward and Wagner (2004), Deurenberg et al (1989), Kyle, et al (2001), Lukaski (1985), and Macias (2007).[a] Lean body mass (LBM) is converted to FFM by the equation FFM = 0.97*LBM for males and FFM = 0.92*LBM for females (Willett, 2006; Lohman, 1992). Total body weight (TBW) is converted to FFM by FFM = TBW/0.73 (Willett, 2006; Houtkooper, et al., 1996).