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Obesity and Physical Fitness in the Labor Market

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OBESITY AND PHYSICAL FITNESS IN THE LABOR MARKET

BY

ROY WADA

A Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree
of
Doctor of Philosophy
in the
Department of Economics
Andrew Young School of Policy Studies
Of
Georgia State University

GEORGIA STATE UNIVERSITY
2007

ACCEPTANCE

This dissertation was prepared under the direction of the candidate's Dissertation Committee. It has been approved and accepted by all members of that committee, and it has been accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Economics in the Andrew Young School of Policy Studies of Georgia State University.

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ABSTRACT

OBESITY AND PHYSICAL FITNESS IN THE LABOR MARKET

By

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May 2007

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Mixed results have been reported when body size is used to estimate the effect of health and nutritional status on worker productivity. This dissertation offers an alternative hypothesis that body composition rather than body size is responsible for the effects of health and nutritional status on worker productivity. Body fat is responsible for the poor health associated with obesity. Lean body mass is responsible for the superior performance associated with physical fitness. Studies using body size alone cannot distinguish the combined, but opposite effects, of body fat and lean body mass.

A method is provided here that overcomes the lack of data for body composition. The clinical information available in the Third National Health and Nutrition Examination Survey 1988-94 (NHANES III) is used to estimate body composition for the survey participants in the National Longitudinal Survey of Youth (NLSY 1979). The inclusion of estimated body composition in the estimated wage equation shows that the effect of lean body mass on the wage rate is positive while the effect of body fat is negative.

Estimated body composition is then used to examine the role of physical differences in the gender wage gap. The decomposition of the gender wage gap shows that most of the previously unexplained differences in wages between men and women can be attributed to the gender differences in body composition. The explanatory power of estimated body composition rises significantly with occupational physical strength requirements. This result suggests that estimated body composition is capturing occupational requirements previously omitted from the past studies.

The findings presented in this dissertation indicate that body composition plays an important, though previously unidentified, role on wage determination. It is clear that capital investments in body composition yield economic dividends by impacting hourly wages of workers. Empirical studies that do not address differences in body composition risk obtaining biased results. Future public health policies should take into consideration the combined but opposite effects of body fat and lean body mass. It is not body size alone, but the compositional makeup of the human body, that public health policies may need to address.

CHAPTER 1

On the Size and Composition of the Human Body

Health affects worker productivity, but health itself is difficult to measure. The lack of reliable measurements of health makes it difficult to quantify the relationship between health and worker productivity. The lack of reliable measurements also confounds possible implementations of productivity-related health policies. A public policy cannot be appropriately implemented if the desired outcome cannot be properly identified and evaluated.

In the absence of reliable measurements of health, economists studying the effects of health on worker productivity have often used body size as a convenient indicator of health and nutritional status (see Currie and Madrian 1999; Dasgupta 1993). Body size may be non-causally related to productivity (e.g., Steckel 1995) or may contribute directly to productivity as a form of human capital (see e.g., Fogel 1994; Schultz 2002). Either way, nutrition-based models of health assume a positive relationship between body size and worker productivity.[1] Economic historians have made the use of this assumption by using population height as a proxy for the standard of living (Steckel 1995; Strauss and Thomas 1998).

Nutrition-based models using body size, however, are mainly concerned with the problems of hunger. They preclude the harmful effects of obesity.[2] The recent problems

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[1] Prominent examples of nutrition-based models would be nutrition models of the efficiency wages (see, for example, Dasgupta 1997; Leibenstein 1957).

[2] A large number of recent studies have documented the detrimental effect of obesity on health and income. Fontaine et al. (2003) estimate that about 10 years of life are lost due to obesity. Mokdad et al. (2004) attribute 400,000 annual deaths to poor diet and physical inactivity. Averett and Korenman (1996) and Cawley (2004) document that the obesity penalty is higher for women than men. See also Behrman and Rosenzweig (2001). For older studies on the ill effects of obesity, see Taylor (1931) and Pauling (1958).

of obesity may pose a challenge to the existing models based on nutrition because obesity is increasingly found among low-income populations with traditionally higher rates of hunger and unemployment.[3] Yet while this may still be the case in developing countries, the opposite is true for developed countries. The coexistence of obesity with poverty is contrary to the main assumption behind the nutrition-based models based on the assumption that body size helps increase worker productivity.

Moreover, body size may not be a reliable indicator of health or nutritional status. The human body is not homogenous, as its biological makeup cannot be adequately tracked by body size alone. The combined effects of various body components can give rise to the mixed effects of nutrition on worker health and productivity.

This dissertation presents the idea that body composition offers a superior method for properly identifying physical endowments within a human body for the purpose of studying the effects of nutritional status on worker health and productivity. Although relatively unknown to economists, body composition is the preferred method used by nutritionists and physiologists for studying the human body.

Because body fat is markedly different from the rest of body, a two-component model established by Siri (1961) and Brozek (1963) separates the human body into body fat (BF) and lean body mass (LBM). The two-component model has been successfully applied in studies of health, growth, nutrition status, and physical performance (see Forbes 1987; Harris 2002; Van Loan 2003). The main insight behind body composition is that not all body components are healthy or desirable. Based on their effects on health

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[3] See Sarlio-Lahteenkorva and Lahelma (1999), Jeffery et al. (1989), Sobal and Stunkard (1989), Dallongeville et al. (2005), and Thurston et al. (2005).

and physical work performance, it is easy to hypothesize that LBM is positively correlated with hourly earnings while BF is negatively correlated with them.

Models based on body composition have several advantages over models based on body size alone. First, various aspects of health can be simultaneously addressed by multiple components.[4] When a single index such as body size is used to describe health, an index number problem causes a loss of information. By directly addressing the underlying components, body composition does a better job of reducing the biological variations in strength, health, or metabolic rate (see Baumgartner, Heymsfield, and Roche 1995; Bjorntorp 2002; 2005, p.113; Segal et al. 1987) Second, models based on body composition are biologically sound, meaning that the assigned properties are biologically justified instead of arbitrarily determined. While the health-nutrition-productivity nexus has been the subject of discussion (see Currie and Madrian 1999; Fogel 1994; Strauss and Thomas 1998), the biologically justified mechanism has not been fully developed in previous studies.

The main conclusions found by the body composition model of productivity can be summarized as follows: (1) returns to size vary considerably by body components; (2) mixed empirical results can be produced by various mixes of body components; and (3) longitudinal changes in body composition represent capital investments in the human body.

The remainder of this chapter will review the existing literature on body size and body composition, motivate the link between body composition and economic outcomes, and present clinical evidence for long-term investments in body composition.

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[4] Strauss and Thomas (1998) indicates that health is a multi-dimensional phenomena.

Empirical Literature and Possible Explanations

Despite a considerable amount of literature, the empirical evidence for the link between body size and worker productivity has been mixed. The direction of estimated returns to body size has remained sensitive to the method used to measure body size and to the demographic sample used in the analysis (see e.g., Cawley 2004; Fogel 1994). When height is used to measure body size, taller workers appear to earn more income than their shorter counterparts (Loh 1993; Persico, Postlewaite, and Silverman 2004; Sargent and Blanchflower 1994; Schultz 2002). Strauss and Thomas (1998) report that the elasticity of wages with respect to height is about one in the U.S. and three to four times higher in Brazil. The proposed link between height and earnings includes physical appearance (Sargent and Blanchflower 1994), discrimination (Loh 1993), sociability (Persico, Postlewaite, and Silverman 2004), and human capital (Schultz 2002).

Many studies have used body mass index (BMI) to better reduce the variation in body weight due to height. BMI is calculated by dividing weight by the square of height.[5] Individuals with BMI greater than 30 kilograms/meters^2 are considered obese. Despite its wide use in the literature, highly mixed results are associated with BMI. Obese white women as measured by BMI earn less income, while similar effects are not observed for black women or men of any ethnicity (Averett and Korenman 1996; Cawley 2004; Gortmaker et al. 1993; Loh 1993; Pagan and Davila 1997; Register and Williams 1990; Sargent and Blanchflower 1994). Furthermore, mixed results have been reported in mortality studies using BMI. The effect of BMI on mortality is affected by gender, ethnicity, and cause of death. The relationship between BMI and mortality can be J, U, or

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[5] BMI is customarily calculated using the metric units: meters and kilograms. Higher BMI is supposed to indicate obesity.

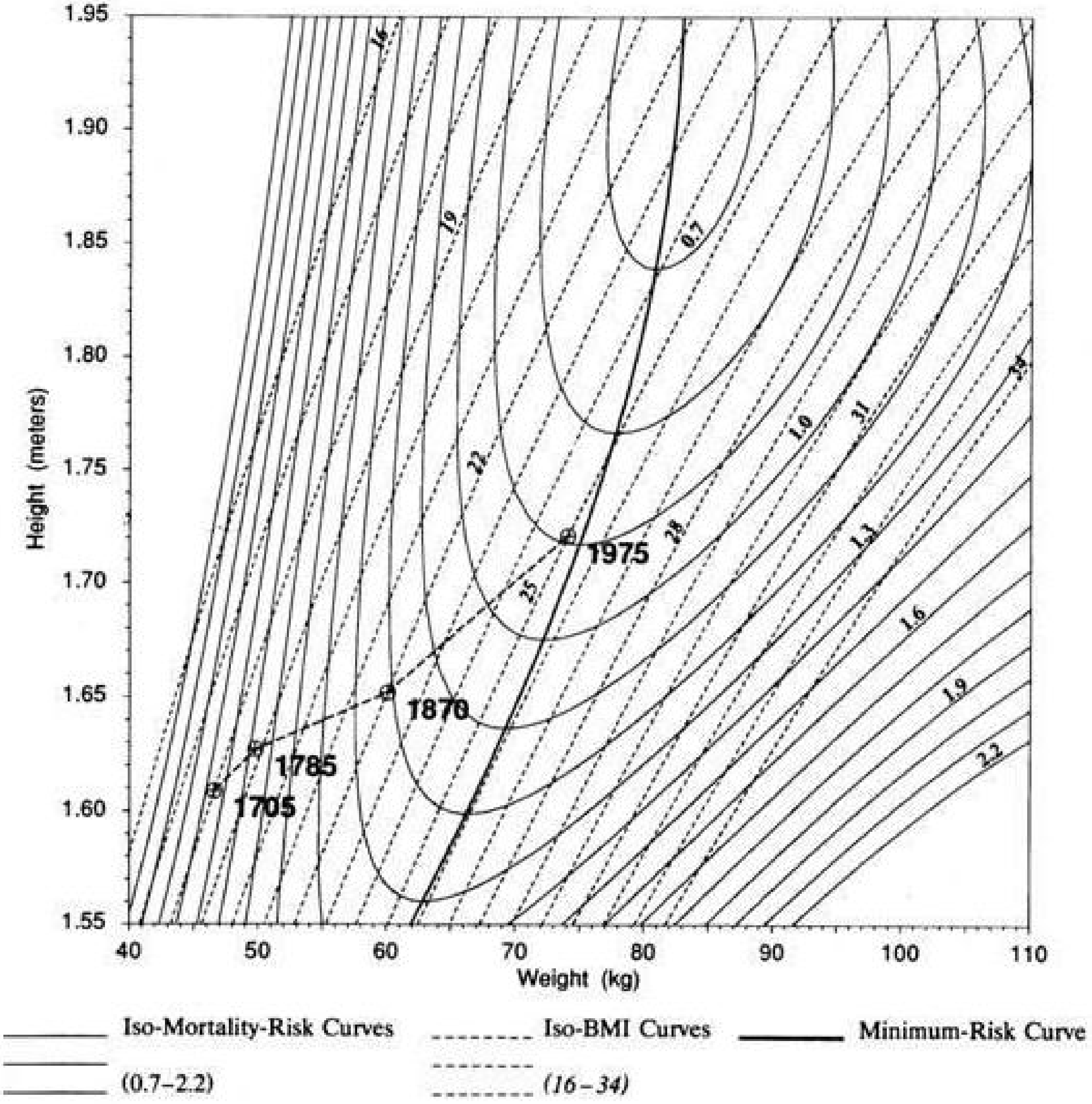
L-shaped (see Bender et al. 1998; Dorn et al. 1997; Durazo-Arvizu et al. 1998; Durazo-Arvizu et al. 1997; Dyer et al. 2004; Hayashi et al. 2005).

The standard response to these empirical difficulties is to suspect the presence of unobserved heterogeneity. Much effort has been expended toward correcting this problem, including the application of sophisticated methods such as twin or sibling differencing, individual fixed-effects, or instrumental variables analysis (see e.g., Averett and Korenman 1996; Behrman and Rosenzweig 2001; Cawley 2004; Costa 1996; Thomas and Frankenberg 2002). The attempts to control for unobserved heterogeneity have not proven effective in reconciling the mixed empirical results. The directions of the estimated effects still vary widely between height, weight, and BMI, as well as across demographic samples and by the method used to control for unobserved heterogeneity.

In an effort to reconcile empirical difficulties, Fogel (1994) offered the observation that mortality-minimizing BMI increases with height. Fogel’s (1994) BMI and mortality curves are reproduced here to illustrate the difficulty associated with reconciling the apparently inconsistent effects of body size on health. Figure 1 indicates that the marginal effect of height on mortality is a function of body weight with its effect changing from negative to positive. This means that height is detrimental to health when body weight is too low. On the other hand, the marginal effect of body weight on mortality is also a function of body weight. It changes from positive to negative. This means that too much or too little body weight is harmful to health.

Figure 1

BMI and Mortality Curves



From Figure 3 in Fogel (1994, p.376). Reprinted by permission.

Based on this evidence, it would be difficult to argue that height or weight consistently represents capital investments in the human body. Capital-based arguments are based on positive returns to a capital stock. While the returns to human capital may be nonlinear, non-positive returns would violate the basic tenets of capital investment. The non-monotonic marginal effects of height and weight indicate that they may not be the best method for measuring capital investment in human body size.

Body Composition Model of Human Capital

Given that body size has yielded mixed results, perhaps body size is not the best method for studying capital investments in the human body. This dissertation takes a departure from the existing approaches by focusing on the composition of the human body.

Two-Compartment Model of Body Composition

The main finding in the body composition literature is that not all body components are healthy. The simplest and the most popular model of body composition is the model by Siri (1961) and Brozek (1963) that partitions the human body into two components: body fat (BF) and lean body mass (LBM). LBM and BF can exert influence on the economic outcomes through their combined but opposite effects on health and physical performance.

The medical literature suggests that LBM is associated with improved health, while BF is associated with decreased health (Allison et al. 2002; Bigaard et al. 2004; Heitmann et al. 2000). Lung capacity, which helps determine physical performance, is positively associated with LBM and negatively associated with BF (Wannamethee, Shaper, and Whincup 2005). LBM and BF affect work performance, especially for workers in job categories with physical requirements such as soldiers in the military or professional athletes (Kusano, Vanderburgh, and Bishop 1997; Marriott and Grumstrup-Scott 1992).

Body fat (BF) is a relatively homogeneous body component responsible for poor health associated with obesity and cardiovascular diseases (Ramsay et al. 2006). Clinical studies conclude that obese individuals expend more effort while walking (Chen et al. 2004). Since obesity is defined as the presence of excessive body fat (Bjorntorp 2002; Bouchard and Shephard 1994; McArdle, Katch, and Katch 1996; WHO Expert Committee 1995; Wilmore and Costill 1999; World Health Organization 1998), body composition is an ideal method for studying the ill effects of obesity.[6]

LBM includes all body components other than body fat.[7] In particular, it includes digestive, cardiopulmonary, and musculoskeletal systems that make it possible to eat, walk, lift, or fight off disease.[8] Incapacities are associated with partial failures of these systems, as evidenced by musculoskeletal disorders. LBM also represents a biological store of useful energy. The body preferably uses glycogen (carbohydrate) stored in muscle tissues for fuel during physical exertions (Billeter and Hoppeler 2003; Jackson 1998; Sharkey 1975). BF contains more energy, but BF is a poor fuel source for short-term bursts of physical effort, which explains why obese individuals with a large store of

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[6] It should be noted here that not all body fat is unhealthy. A minimum of body fat is deemed essential for physiological functions (International Commission on Radiological Protection 1975; Rodahl and Issekutz 1964).

[7] LBM actually contains 3-6 percent body fat. For technical purposes, LBM without any body fat is called fat-free mass (FFM). LBM and FFM are used here interchangeably unless FFM is used for its precise medical definition.

[8] The non-fat components are lumped together as lean body mass as a matter of convenience. Body fat is easily identifiable from the rest of body components.

BF display inferior physical performance.[9] The glycogen content of muscle responds to the long-term demand and increases up to 50 percent in strength-trained individuals (Tesch and Alkner 2003).[10] During life-threatening emergencies such as severe burns, physical injuries, or serious illness, LBM is broken down for its energy and protein contents (Beisel 1983; Herndon et al. 2001; Wolfe et al. 1987), which helps to explain the higher survival rates among men and larger individuals compared to women, children, and stunted individuals.[11]

Differential Association between Body Size and Composition

The difficulty of distinguishing LBM and BF using aggregated measurements such as height and weight is illustrated in Fig. 2.15 in Forbes (1987, p.63), which shows cross-sectional CAT scans of arms belonging to thin and obese individuals.[12] The obese arm looks similar to the thin arm except for the thick layer of body fat lying under the skin. External measurements of height and weight will likely fail to capture such differences because they cannot reliably distinguish a pound of body fat from a pound of muscle tissues.

The previously reported difficulties of estimating the effect of body size on earnings or mortality can be attributed to the arbitrary association between body size and

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[9] The body apparently engages in a tradeoff between the need for storage and energy-generation. Its high energy density makes BF an ideal form for storage, but it also slows the rate at which BF can be burned as a fuel. Glycogen, on the other hand, releases energy readily, but its bulkiness (as it contains water) makes it a poor form of energy storage. BF is predominantly utilized during rest and lighter physical movements and for restoring glycogen and other forms of short-term fuels.

[10] Glycogen is a limiting factor on the duration of exercise, and its depletion in skeletal muscle causes exhaustion and fatigue during prolonged exercise and activity (Hultman and Sjoholm 1986; Nieman 2003, p.306-9). The maximum amount of energy available from muscle glycogen is about 2000 kcal (Brooks, Fahey, and Baldwin 2005, p.36), which incidentally is slightly less than a day’s requirement, thus explaining the exhaustion at the end of the day.

[11] Muscle tissues hurt during short episodes of fever due to energy-providing catabolism (break down).

[12] CAT scan is an imaging technique not unlike x-ray photography, except it also detects soft tissues.

body composition. Height is more strongly correlated with LBM, while body weight is more strongly correlated with BF (Forbes 1987; Sjostrom 1993). It is therefore not surprising that the effect of height on wages tends to be positive, which reflects the beneficial effects of LBM, while the effect of body weight tends to be negative, which reflects the harmful effects of BF.

Clinical evidence shows the presence of LBM and BF to be non-uniform functions of body size. Forbes (2003, p.239) indicates that LBM constitutes higher portions of body weight in smaller individuals (Forbes 2003; Mingrone et al. 2001).[13] On average, about 2/3 to 3/4 of excess body weight consists of body fat (Forbes 2003; Heymsfield et al. 1997a). Such portions of body fat are gender specific (see Mingrone et al. 2001), which would cause gender-specific outcomes with respect to body size. Consistent with this interpretation, a clinical study shows that a woman loses higher portions of BF when she loses body weight, while a man loses equal portions of BF and FFM (Sartorio et al. 2005). The gender differences in desires for weight loss are apparently due to this gender difference in the composition of weight loss. It is hypothesized here that the gender-specific outcomes reported by many researchers (Averett and Korenman 1996; Cawley 2004; Gortmaker et al. 1993; Loh 1993; Pagan and Davila 1997; Register and Williams 1990) can be attributed to these underlying differences in body composition. This possibility is explored in detail in Chapter 2.

Body indices such as BMI will complicate the analyses, since BMI is calculated as a changing ratio between body weight and the square of height. BMI does not necessarily reflect the changing ratio between LBM and BF. Since BMI is known to

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[13] The proportions of BF in the excess body mass usually peaks at about 75 % (Thomas et al. 1998; Webster, Hesp, and Garrow 1984).

increase with height in men but decrease with height in women (Mandel et al. 2004), biased results may be obtained when using BMI.

Figure 5.5 in Institute of Medicine (2005, p.129) shows the endowments of FFM and BF plotted against height. We can see that for the same level of BMI, men possess more FFM and slightly less BF than women. For BMI of 35, we see that women possess significantly higher levels of BF, while men possess much higher levels of FFM. The steeper slope for FFM also indicates that height is more correlated with FFM than it is correlated with BF. The slope of FFM is steeper for men than for women, which means that the correlation between height and FFM is stronger in men than in women. Given such underlying differences, it is clear that sophisticated econometric analysis attempting to control for potential heterogeneity is unlikely to be able to fix the inherent biases associated with the estimation strategies using BMI.

A number of recent studies have already suggested that the combined but opposite effects of FFM and BF could be responsible for the non-monotonic effect of BMI on mortality (Allison et al. 2002; Bigaard et al. 2004; Heitmann et al. 2000). The healthy effect of FFM dominates at the low end of BMI, while the harmful effect of BF dominates at the high end of BMI. Their combined effects could therefore trace a U-shaped curve as FFM reduces mortality at the low end of BMI, while BF increases mortality at the high end of BMI.[14] It is hypothesized here that a similar relationship exists for hourly wages. This possibility is also explored in Chapter 2.

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[14] This issue is explored in Chapter 2.

Body Composition Model of Obesity and Physical Fitness

Because LBM containing digestive, skeletal, and muscular systems is directly related to the respective metabolic functions of these systems, we can view LBM as an indicator of physical fitness (Fontaine and Allison 2004). Physical fitness is a measure of one’s ability to engage in physical activity. Physical activity has been defined as bodily movement produced by muscular contraction (U.S. Public Health Service 1996). Such a view is consistent with Currie and Madrian’s (1999) proposed definition of health as a measurement of one’s work capacity, which is one’s ability to work usefully.

By providing its service over extended periods of time, physical fitness as measured by LBM can be thought of as a capital good. On the other hand, BF is clearly related to obesity (Fontaine and Allison 2004). Thus, obesity with its inherent future health risks can be interpreted as a capital bad. Like most investments in health, investments in body composition are not job-specific because the worker can make use of them at other jobs. Thus, we can interpret the capital investment in LBM and BF as a general form of human capital investment.

If health is a form of human capital, as originally proposed by Schultz (1961) and further developed by Grossman (1972), then the levels of LBM and BF should follow a time-pathway consistent with the capital theories of investment. Mincer (1974) has previously suggested that the concave shape of the age-earnings profile is the result of on-the-job training and human capital depreciation. There is strong evidence indicating that physical fitness develops in response to short-term and long-term demand for physical performance. During basic training in the military, for example, men and women gain about 2.5 kilograms of FFM (Harman and Frykman 1992). Men lose some BF during this period, while the evidence for women is mixed (Harman and Frykman 1992). The responsiveness of obesity and physical fitness to training and their deterioration (depreciation) in the absence of sustained training makes BF and FFM ideal candidates for measuring capital investments in human body with upfront costs and delayed rewards.

A simple model of health based on body composition might take the following form:

$$\max\ K = \sum_{t=0}^{T} \frac{h_t(LBM\ \ , BF_t)}{(1+r)^t} \text{ s.t. } (LBM_t, BF_t) = \eta_t(LBM_{t-1}, BF_{t-1}, C_{t-1}, I_{t-1}) \in \aleph \qquad (1.1)$$

where K is the stock of health capital, T is the time horizon, r is the discount rate, h is the additive function of health due to body composition, the pair of LBM and BF are determined by consumption C and investment I during the previous time period, and the biologically feasible sets $\aleph$ excludes biologically impossible levels of LBM and BF. For our purposes, we assume $\frac{\partial h}{\partial LBM} > 0$ and $\frac{\partial h}{\partial BF} < 0$. In this model, depreciation occurs from consumption activity alone.

As Mincer (1974, p.85) explains, the economic theory provides no guidance for the specific forms of the consumption and investment functions. In our case, the functional forms are biologically determined and currently unknown to us.[15] It was argued, however, by Mincer (1974), and generally accepted, that the optimal time-pathway entails an early buildup of capital endowment followed by a gradual decline over the lifecycle. An initial buildup of LBM takes advantages of its future expected benefits while its gradual decline anticipates the end of the lifespan at which LBM loses all its utility. Because the marginal impact of BF is the opposite of LBM, we can expect

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[15] Mincer gets around this problem by assuming a mathematically tractable “experience functions” containing exponential rate of decline.

BF to increase at an increasing rate through the lifespan, subject to the biological limitation. A rational individual would delay the buildup of BF towards the end of the lifespan, due to the extended disutility associated with excessive presence of BF.

Our assumption about the increasing presence of BF with age is important for three reasons. First, it precludes the possibility of reverse causality in which the increased income during the middle portion of the lifespan might be responsible for a temporary increase in FFM and BF. Our model assumes that BF will continue to increase well after the income has fallen. Only FFM is expected to change in tandem with the income. Second, differential profiles between FFM and BF are contrary to the predictions made by the nutrition models of body size in which physical growth is a direct outcome of nutritional consumption. Our model assumes that the timing of the lifecycle is more important, as it affects the growth cycle of body components within the human body. Third, while obesity and bodily growth have been previously thought to be a direct function of nutrient intake, our lifecycle model makes a counter-assumption that FFM should decrease with age, while BF should increase at an increasing rate over a lifetime.

It is important to note here that the body composition model does not depend on taste differences. Like other models of human capital investment, only the differential endowments are required to generate the assumed outcome. Because the health effect of LBM is positive and that of BF is negative, the rational solution is to build up LBM early in the lifecycle and let it depreciate later in life, while allowing BF to accumulate towards the end of the lifecycle.

Ideally, our model should be verified using longitudinal observations of body composition. Long-term longitudinal observations, however, are very rare due to the previous lack of simple and inexpensive methods for measuring body composition.

A review of short-term clinical studies suggests that men and women will begin to lose LBM after middle-age and gain BF in place of it (Going et al. 1994). A graph composed by Forbes (1999, p.799) from a variety of short-term longitudinal observations clearly demonstrates the peaking of FFM during the early 20s for men and women. The timing of the peak clearly differs from the known peaks in income during middle-age. The graph also shows BF to continually increase throughout the lifespan, although not always at an increasing pace. Such longitudinal changes in body composition have been previously explained as a decline in energy expenditure, lack of exercise, or malfunction of oxidative capacity (see e.g., Schwartz 2004). A simple explanation can be offered by our lifecycle model that the opposing properties of FFM and BF contribute to their lifetime profile.

A mismatch in the exact timing of peaks exists between FFM and the known peaks in income. FFM peaks during the early 20s, while income peaks during the 40s. The apparent mismatch may be explained by the fact that income in today’s economy is more strongly explained by cognitive forms of human capital as the recent technological changes have favored white-collar workers (Berman, Bound, and Griliches 1994). Increasing computerization has deemphasized the role of physical strength on the job (Weinberg 2000). If this is the case, earnings should have peaked at earlier age during the earlier part of the last century. According to the figures published by the Bureau of Census, this is indeed the case. Peak earnings have shifted from the age range of 25-34 during the middle 20th century to the age range of 45-54 today.[16] This finding is consistent with the view that pecuniary rewards attributable to physical strength have decreased in the recent years. If this is the case, then today's workers face decreased incentives for investing in physical fitness and increased incentives for investing in non-physical skills in the form of education and experience.

Cross-sectional studies are more readily available than longitudinal studies. Kyle et al. (2001) used a cross-sectional sample. Three things are noteworthy. First, levels of FFM follow a concave profile as predicted by the human capital theory of body composition. FFM rises rapidly during childhood (which is not shown in the graph) and continue rising during teenage years (which is shown). After reaching a peak during middle age, FFM declines at a declining rate as it appears in the graphs. Second, BF increases with an increasing rate until suddenly decreasing at the end of lifespan.

The sudden decrease in BF at the end of lifespan is not unexpected considering the cross-sectional nature of the data. The observed levels of BF would be downwardly biased for two reasons. First, the selection is imposed on the cross-sectional data in the form of non-random death: obese individuals die out of the sample. FFM would be upwardly biased (stunted individuals die out) while BF would be downwardly biased (obese individuals die out). A longitudinal study shows that obese women and men were 115 percent and 81 percent more likely to die before the age of 70, respectively (Peeters et al. 2003). Both the FFM and the BF curves in the graph clearly display a discontinuity after the age of 65, at which point the rate of mortality is known to rise sharply. *U.S. Decennial Life Tables for 1989-91* shows that the rate of mortality sharply increases from

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[16] The trend is found using the data from Series P60, which is maintained by the Bureau of Census. It contains the historical records for the distribution of income. See P60-01, P60-53, P60-107, P60-159, P60-197, and P60-229. Series P60 is available at http://www.census.gov/prod/www/abs/income.html.

about 3 percent between the ages of 45 and 65 to about 50 percent between the ages of 65 and 85.

Second, the cohort effect places an increasingly large downward bias on both BF and FFM due to the size differences between generations. Examining such a cohort effect in a clinical sample, Borkan (1983) concludes that, of the average height loss of 7.3 centimeters between the ages of 22 to 82, only 4.3 can be attributed to longitudinal changes.[17] The remaining 3.0 centimeters are due to the cohort effect in which the elder cohorts were physically smaller even when they were young. This means that FFM, which is more strongly correlated with height, would be downwardly biased by the cohort effect. The effect on BF is unclear.

The existing clinical evidence discussed above supports the notion that lean body mass acts as a capital good while body fat a capital bad. Costly investments in lean body mass would be made earlier in lifetime and allowed to depreciate. Negative impacts of body fat, on the other hand, would be avoided until the end of the lifecycle.

This chapter presented the existing literature and the basic theory behind the effect of body composition on worker productivity. Chapter 2 proposes a method for estimating body composition. The effect of the estimated body composition on hourly wages is estimated. Chapter 3 explores the effect of body composition in the gender wage gap. Chapter 4 concludes.

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[17] Borkan (1983) refers to cohort effect as “secular effect.”

CHAPTER 2

Obesity Wage Penalty and Omitted Muscularity

Introduction

Previous studies on the effect of obesity on hourly wage have reported mixed results for six gender-ethnic/racial groups (Averett and Korenman 1996; Cawley 2004).[18] In these studies, obesity is measured using body mass index (BMI), which is calculated as body weight in kilograms divided by the square of height in meters.[19] Higher BMI is thought to indicate the presence of obesity. Obesity is defined as the presence of excessive body fat (Bjorntorp 2002; Bouchard and Shephard 1994; McArdle, Katch, and Katch 1996; WHO Expert Committee 1995; Wilmore and Costill 1999; World Health Organization 1998).[20] Typical wage-BMI profiles found in previous studies are illustrated in Figure 2 by gender. The women's wage profile is linear and monotonically decreasing in BMI, while the men's wage profile is highly non-linear and non-monotonic. The men's wage profile rises until it peaks in the overweight region of BMI and then subsequently decreases.

The striking disparity between men and women is the puzzle of the gender-specific obesity penalty that has perplexed researchers during the last two decades. For women, the negative effect of BMI on hourly wage is consistent with the common beliefs about the harmful effects of obesity. For men, however, it appears as if a moderate

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[18] The six groups are white men, white women, black men, black women, Hispanic men, and Hispanic women.

[19] BMI is intended to reduce variability in body weight with respect to height.

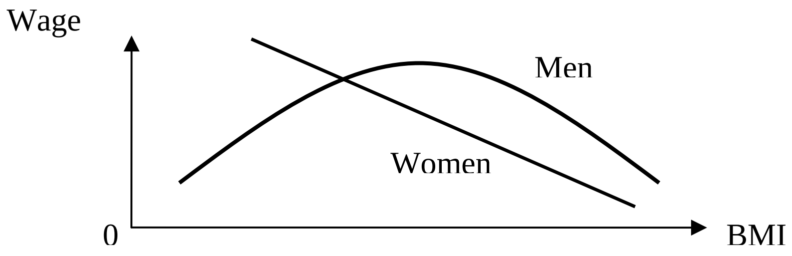
[20] Excessive body fat is usually defined as the level of fatness detrimental to the health outcome (Antipatis and Gill 2001; Caterson 2002; Metropolitan Life Insurance Company 1959, 1983). An alternative is to define it as excessive body fat for a given body weight (Scott 1997), which can be interpreted as percentage body fat, or for a given height or frame size (Wilmore and Costill 2004), which is what BMI is intended to show.

amount of obesity might be desirable. It is not exactly clear why the men's wage profile peaks in the overweight region of BMI while the women's wage profile does not. The obesity literature also shows that the risk of becoming obese is higher for women of lower income but not for men of similar backgrounds across industrialized nations (Jeffery et al. 1989; Sarlio-Lahteenkorva and Lahelma 1999; Sobal and Stunkard 1989). Similarly, the development of diseases associated with obesity also correlate with lower income or lower education for women, though not as much for men (Dallongeville et al. 2005; Thurston et al. 2005).

These mixed results suggest that we do not have a sound understanding of the impact of obesity on the labor market outcomes. Given the current interest in obesity following the rapid rise in its incidence coupled with the subsequent debate on policy intervention, it is important that we provide further insights into the effect of obesity on worker productivity.

Figure 2

Wage-BMI Profiles for Men and Women



Source: Based on findings by Averett and Korenman (1996) and Cawley (2004)

The puzzle of the obesity penalty is not limited to the dimension of gender, but also exists across the three ethnic and racial groups (white, black, Hispanics). Among the six gender-ethnic/racial groups, white women appear to bear the highest burden of obesity penalty, followed by white men (Gortmaker et al. 1993; Register and Williams 1990). In an OLS analysis, black women appear to suffer about the half of the obesity penalty of white women (Averett and Korenman 1996; Cawley 2004).

Black men appear to suffer a slight obesity penalty when BMI is used as a measure of obesity, but they appear to enjoy an obesity premium (positive return) when body weight is used to measure obesity (Cawley 2004). The results for Hispanics generally lie between the results for blacks and whites.

Because the wage-BMI profiles of Hispanics generally lie between the results for blacks and whites, it might be reasonable to speculate that racial discrimination and cultural norms are attenuating the impact of the obesity penalty for the minority groups. Race-specific preferences for obesity, however, cannot explain the highly non-monotonic wage profile for men.

Rather than looking to the inexplicable differences in preference for explaining the observed differences in the obesity penalty, this dissertation instead examines the possibility that obesity has been systematically mismeasured in previous studies by using BMI to indicate obesity. The gender-specific bias can be introduced into the wage equation if BMI inadequately and unequally identifies obesity.

Behrman and Rosenzweig (2001) have suggested that unobserved heterogeneity may be responsible for the negative effect of obesity on earnings. Cawley (2004) makes a similar argument. This paper differs from the previous interpretations of unobserved heterogeneity by hypothesizing that the possible effect of the unobserved component is *positive*, which could be attenuating the *negative* effect of obesity and thus producing the previously reported mixed results.

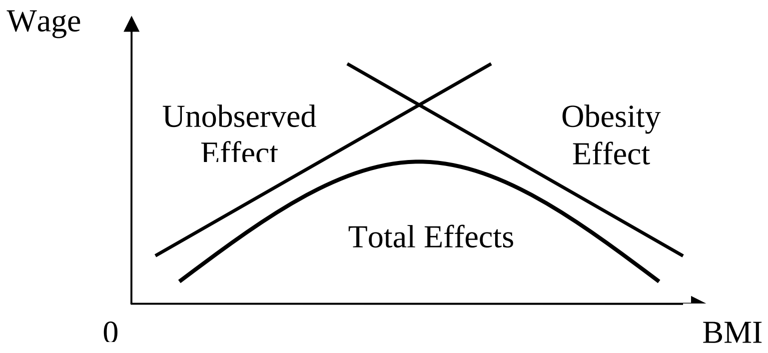
A possible solution to the problem appears in the concavity of the men's wage profile. The curiously non-monotonic behavior of the men's wage profile suggests the possible existence of multiple components within BMI. Assuming obesity increases with BMI and its effect on wage is monotonically negative, the construction of the concave wage profile must also require the existence of a second component with three necessary characteristics. First, in order to counteract the negative effect of obesity, the effect of the second component must positive. Second, in order for the negative effect of obesity to emerge at the higher BMI, the total effect of the second component must decrease with the increasing BMI. Third, in order to explain the gender specific obesity penalty, the second component should be more strongly associated with men than with women.

One such candidate for this component is the musculoskeletal system, which is the combination of skeletal and muscular tissues responsible for creating physical force during physical activity. The musculoskeletal system has all of the necessary characteristics detailed above: The expected marginal effect of the musculoskeletal system is the opposite of obesity, its existence appears to decrease with BMI, and it appears to exist in larger quantities in men than in women. Assuming the effect of skeletal-muscularity is positive and more prevalent at the lower BMI, its effect would dominate the negative effect of obesity at the lower extremes of BMI.

In Figure 3, the concave curve of the men's profile reflects the non-monotonic effect of BMI on hourly wage. The two component curves with opposite slopes reflect the marginal contributions of the musculoskeletal system and obesity as separate functions of BMI. In the middle-region of BMI, the positive effect of muscularity is increasingly canceled out by the negative effect of increasing obesity. In the upper extremes of BMI, where obesity is more prevalent for each unit of BMI, the negative effect of obesity would completely dominate the positive effect of muscularity. Such changes in underlying composition might be absent from the women's wage profile if the average woman is less muscular than the average man.

Figure 3

Men's Wage-BMI Profile and Two Underlying Components



Body Composition and Obesity

The available evidence on the reliability of BMI supports the composite-curve theory. The medical literature suggests the following when BMI is used to indicate obesity: (1) significant mismeasurement of obesity is likely for some segment of the population, (2) muscles can be misidentified as body fat, (3) men are more likely to be misidentified as obese than are women, (4) BMI is not very reliable in its mid-ranges, and (5) the relationship between BMI and body fatness is dependent on age, gender, and ethnicity. The clinical evidence is discussed in more detail below.

Health experts have long been aware that BMI measures obesity with a significant error. Gallagher et al. (1996) report that BMI alone explains only 26% of variations in human body fat. Adding coexisting factors such as age and sex raises the explanatory power to 76%. The prediction of body fatness using BMI is not very precise (Roubenoff, Dallal, and Wilson 1995; Smalley et al. 1990). Since BMI can not reliably separate obesity from muscularity or frame size (Garn, Leonard, and Hawthorne 1986), McLaren (1987) thus suggests that one should use caution using a measurement as crude as BMI in studying obesity.

The Expert Committee at the World Health Organization (1995) strictly warns that BMI must be properly conditioned with the coexisting factors, such as muscularity, to avoid misidentification of a nutritional state.[21] BMI has a different significance for both the overnutritioned and the undernutritioned population because it reflects both lean body mass and body fatness at the different ranges of BMI (Malina, Katmarzyk, and Siegel 1998). BMI detects the presence of obesity in the upper range of BMI as well as the presence of starvation in the lower range of BMI (WHO Expert Committee 1995). Not surprisingly, misidentifications often occur in the mid-region of BMI where lean body mass might be mistaken for body fat (Kuczmarski and Flegal 2000).

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[21] For example, a low income can indicate poverty in a large household but not in a small household. Likewise, a low birth weight of an infant can indicate maternal malnutrition in underweight mothers but not in overweight mothers. In this sense, BMI can indicate obesity in a sedentary population but not in an athletic one (WHO Expert Committee 1995).

Coexisting factors that can influence the relationship between BMI and body fatness include age and sex (Gallagher et al. 1996). Since the average man is more muscular than the average woman, the mismeasurement caused by omitted muscularity is likely to be associated with gender. Women with the same BMI as men possess significantly more body fat and less lean body mass (Chumlea et al. 2002; Gallagher et al. 1996). Hence, BMI is observed to misidentify obesity more frequently in men than in women (Kuczmarski and Flegal 2000). Health researchers have also reported that a gender variable appears to lose its significance in the mortality equation when BMI in the is replaced with estimated levels of lean body mass and body fat tissues (Sjostrom 1993).

The evidence concerning BMI and ethnicity/race is more complex. Norgan (1994) rejects the hypothesis that there are no inter-ethnic differences in BMI, while Gallagher, et al (1996) fail to reject it. A meta-analysis using existing studies shows that blacks have 1.3 times higher BMI than whites for the same level of body fatness after controlling for age and gender (Deurenberg, Yap, and van Staveren 1998).[22] Several other studies find evidence that the relationships between BMI and body fatness differ among ethnicities for women but not for men (Fernandez et al. 2003; Jackson et al. 2002).

The overall clinical evidence thus suggests four main problems with using BMI in the wage equation. First, BMI has a positive covariance with both muscularity and obesity. A strong correlation with the object of measurement is not enough; an ideal index should be uncorrelated with the omitted variables of interest. Second, the covariance between BMI and muscularity and between BMI and obesity are likely to be non-linear functions of BMI. This means that one of them is likely to be more strongly

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[22] The ethnic differential worsens when compared across transcontinental nationalities such as Chinese, Ethiopians, Indonesians, Thais, and Polynesians.

associated at one range of BMI than the other. Third, such non-linearity in the covariance is likely to be dependent on gender and ethnicity. The previously reported gender and ethnic differences in the obesity penalty may be a statistical artifact. Fourth, muscularity and obesity are correlated with each other. The collinearity between the two components aggravates the potential omitted variable bias.

Because one index such as BMI cannot simultaneously control for the two correlated variables, previous studies using BMI appear to have underidentified obesity in the wage equation. This index number problem has likely led to the introduction of a systematic measurement error. Because this dissertation is concerned with obesity as the subject of study, and BMI is more strongly correlated with obesity at higher BMIs (Fernandez et al., 2003), measurement error is treated here as a case of omitted variable bias with muscularity being omitted from the wage equation. The clinical evidence suggests that approximately 35-50 percent of total body weight is muscle (International Commission on Radiological Protection 1975). In comparison, the typical range of body fat for men is about 15-30 percent of total body weight. We cannot reasonably expect to obtain an unbiased estimate of the effect of body size by focusing on the smaller body fat component of the human body to the neglect of the larger muscular component.

Suppose muscularity is the omitted variable whose correlation with BMI is conditioned on BMI as well as on gender.[23] The log-linear wage equation, while controlling for other covariates z_i , might look like this:

$$\log w_i = \gamma_1 BMI_i + \beta z_i + u_i \tag{2.1}$$

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[23] We have assumed earlier, for the sake of discussion, that BMI is used to measure obesity while muscularity is omitted from the equation.

Individual muscularity M_i is hiding in the error term, $u_i = M_i + e_i$. The marginal effect of BMI on wage w_i would be biased.

$$\frac{\partial \log w_i}{\partial BMI_i} = \gamma_1 + \gamma_2 \frac{\text{cov}(BMI_i, M)}{\text{var}(BMI_i)} \tag{2.2}$$

γ_1 and γ_2 are the marginal effects of *BMI* and *M*, respectively. We assume the following three conditional covariances expressing the gender-specific covariance between BMI and muscularity. *Gender_i* is 1 for men and 0 for women.

Men: $$[\lim_{BMI \to 0} \text{cov}(BMI_i, M) > 0 \mid gender = 1] \tag{2.3}$$

$$[\lim_{BMI \to \infty} \text{cov}(BMI_i, M) = 0 \mid gender = 1] \tag{2.4}$$

Women: $$[\text{cov}(BMI_i, M) = 0 \mid gender = 0]\ \forall BMI \in [0, \infty] \tag{2.5}$$

The above assumptions for men state that as BMI approaches 0, the covariance between BMI and muscularity is positive, and as men's BMI goes to infinite, the link between BMI and muscularity becomes attenuated. Assuming $\gamma_1 < 0$ and $\gamma_2 > 0$, the marginal effect of BMI could be positive for men when BMI is low, zero when BMI is in the middle, and negative when BMI is high. Therefore, the men's wage equation suffers from a conditionally expressed omitted variable bias that is expressed strongly at low BMI but weakly at high BMI. For women, the covariance is 0 or negligibly small through all relevant ranges of BMI. The marginal effect of BMI will approach the true value for women as it increases in our simplified model.

To avoid the potential measurement errors associated with BMI, this paper proposes to use body composition as a clinically-justified indicator of obesity. Body composition is the most common method for assessing body fatness (Heymsfield et al.

1996). The two-compartment method of body composition, attributed to Siri (1961) and Brozek (1963), is well suited for assessing body fatness by separating the human body into body fat (BF) and fat-free mass (FFM). FFM consists of lean tissues such as bones, muscles, and water.[24]

The body composition approach to obesity adopted in this paper is consistent with the conceptual definition of obesity as the presence of excessive body fat discussed earlier. A comparison to mortality would be useful in understanding the two different approaches to obesity represented by BMI and body composition. It is commonly accepted among health experts that the source of excess mortality associated with high BMI is body fatness (Prentice and Jebb 2001). A number of recent works have demonstrated that the association between mortality, body fatness, and BMI are non-monotonic for men but not for women (Allison et al. 2002; Zhu et al. 2003). Figure 4 displays the well-known u-shaped mortality risk as a function of BMI that exists for men but not for women (Allison et al. 2002). Allison, et al. (2002) argue that the u-shaped mortality risk is due to the combined but opposite effect of body fat and lean body mass. Figure 4 is remarkably similar to Figure 3, except for the inversion of the concavity. In particular, the unobserved effect is represented by the fat-free mass index and the obesity effect is represented by the fat-mass index. The impact of BMI on mortality is the opposite of its effect on productivity, as measured by the wage. The two figures tell the same story; more than one body component may be responsible for the observed effect of obesity on earnings.

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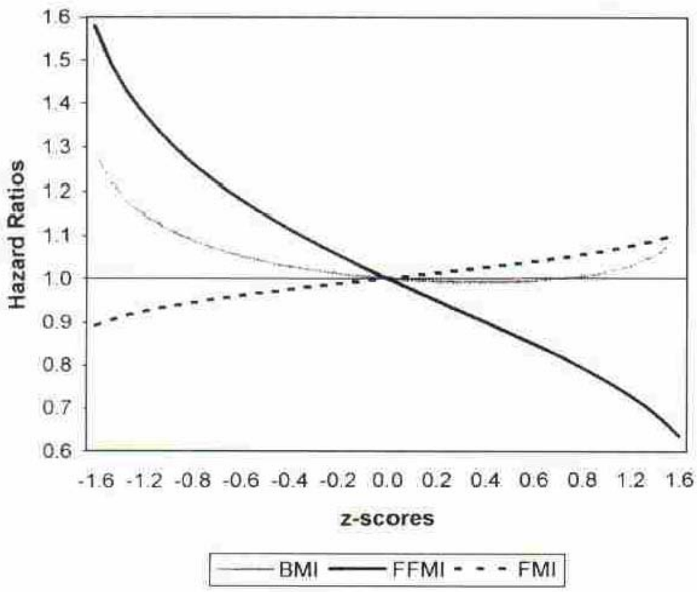
[24] FFM is sometimes referred to as lean body mass (LBM). The technical difference between the two terminologies is that LBM contains trace amounts of fat naturally existing in the muscle tissues, but FFM includes everything except the fat (Caterson 2002; Heshka, Buhl, and Heymsfield 1994). The conversion factor between LBM and FFM is 0.97 for men and 0.92 for women, indicating that women’s LBM contains more trace fat than men’s (Lohman 1992).

Figure 4

Men’s Mortality-BMI Profile and Fat-Free Mass Index and Fat-Mass Index



Source: From Figure 1 in Allison, et al. (2002, p 413). Reprinted by permission.

It is important to stress here that body composition is the standard by which the reliability of BMI is judged (Bray, Bouchard, and James 1998; Gallagher et al. 1996; Garn, Leonard, and Hawthorne 1986). Obesity is a different concept than being overweight, which is excessive body weight for height (Bray 1976; Scott 1997; Sjostrom 1993). Muscular individuals, for instance, can be heavy for their height and be overweight, but still not be obese. An expert panel from the National Institute of Health (NIH) notes that not all overweight individuals are obese, though all obese individuals are overweight (NIH Expert Panel 1998). Both the NIH and the World Health Organization (WHO) recommend using BMI for its ease and availability, but not necessarily for its accuracy. An expert report by NIH states that BMI does not measure obesity, which would imply the knowledge of body composition, but only measures the state of being overweight (NIH Expert Panel 1998).

The conceptual definition of obesity as body fatness is in contrast to the practical definition of obesity in terms of BMI. In response to the growing obesity epidemic, WHO established the practical definition of obesity as a condition existing in individuals with BMI of 30 or higher (World Health Organization 1998).While the WHO definition has been well received, it is widely known among health professionals that the primary advantage of using BMI is the ease and simplicity of its measurement (Antipatis and Gill 2001; Dwyer 1994; Lohman 2002; Watson and Wall 2002). BMI can serve as a practical surrogate when no other information is available (Deurenberg and Deurenberg-Yap 2003; Prentice and Jebb 2001; Roubenoff, Dallal, and Wilson 1995).[25] WHO itself states that while BMI "provides the most useful, albeit crude, population measure of obesity," it does not account for the wide variations in body fatness across populations and can not distinguish between muscle and fat (1998, p7-10).

The ease of calculating BMI from self-reported height and weight is the primary reason for the widespread use of BMI in research. The investigation into its reliability has shown that BMI computed from self-reported height and weight is a remarkably accurate way of calculating BMI in epidemiological studies (Stunkard and Albaum 1981). In contrast to the availability of BMI figures, the vast majority of the population does not know and can not report their body composition. The clinical measurement of body composition requires trained technicians using costly, cumbersome equipment (Heymsfield et al. 1997b). Expense and logistical difficulties have previously prevented

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[25] "A general consensus has been reached for using weight/height^2, when only height and weight data are available," (Lohman 2002, p63) meaning that BMI should be used when no further information is available.

researchers from measuring body composition in large field-studies (Heymsfield et al. 1996).

Given the existing tradeoff between the accuracy and the availability of measurement, we should use body composition when it is available and use BMI only when body composition is not readily available. Since BMI provides only an approximate measure of body fatness, the direct estimates of body fatness in body composition should yield more consistent estimates, while also avoiding the aforementioned statistical difficulties associated with using BMI.

Estimation using NHANES III and NLSY 1979

This dissertation proposes to re-specify Equation 2.1 by replacing the BMI measure with the estimated measures of its components that can more accurately reflect various degrees of body composition. The anthropometric measurements necessary to estimate body composition are increasingly available in health surveys collected by government agencies such as NIH and CDC. Unfortunately, health surveys generally do not collect detailed information on socioeconomic variables. On the other hand, economic surveys customarily do not collect enough anthropometric information to estimate body composition.

This dissertation proposes to overcome this lack of a single source of data by augmenting an economic survey with a health survey. There are three steps in the estimation strategy. First, body composition is obtained from a health survey. Second, a generalized predictive equation for body composition is generated by regressing body composition on the health survey anthropometric variables that are also available in the economic surveys. Third, the generalized predictive equation is applied to an economic survey using the same set of anthropometric variables that generated the generalized predictive equation. This data augmentation can thus transform rudimentary anthropometric information found in the economic survey into meaningful estimates of body composition.

To our knowledge, the only existing nationally representative survey to collect information on body composition is the National Health and Nutrition Examination Survey 1988-94 (NHANES III). NHANES III is a survey that was designed to collect representative information on the health and nutritional status of the population through interviews and direct physical examinations. Using mobile laboratories, trained technicians collected the necessary information to calculate body composition for those over the age of 12 who were not known to be physically handicapped or pregnant at the time. Unfortunately, NHANES III did not collect sufficient information to calculate hourly wages.

The National Longitudinal Survey of Youth 1979 (NLSY 1979) is an economic survey designed to provide information regarding the rich variation of labor market experience of young workers. The cohort of men and women aged 14-21 in 1979 are followed annually until 1993, and biannually thereafter, to provide labor force observations, socioeconomic and demographic information, and the environmental factors that provide detailed variations in the labor market outcomes. Although NLSY 1979 does not provide a direct measure of body composition, it is one of the very few economic surveys that collect longitudinal information on the basic body measurements, such as height and weight, in addition to the economic data. The NHANES III will be used to translate characteristics available in the NLSY 1979 into the estimated measures of body composition as described below. The estimated body composition in NLSY 1979 should provide a superior measure of obesity by avoiding the gender- and ethnic-specific misidentifications associated with BMI. The prediction coefficients can be considered acceptable if they can predict a sufficiently high proportion of the variability within the reference data, which in this case is the body composition information in NHANES III.

An Estimation of Body Composition

According to the WHO Expert Committee, anthropometry provides inexpensive and non-invasive assessment of body composition that reflects nutritional status, insufficient exercise, and the presence of diseases (WHO Expert Committee 1995).[26] Unfortunately, a drawback of anthropometry for calculating body composition is the relative lack of precision (Lukaski 1987). To provide the desired precision, bioelectrical impedance analysis (BIA) has been developed as an inexpensive, non-invasive, and easy alternative for determining human body composition in clinical or field settings (Lukaski 1999).[27] In the BIA procedure, which was implemented in the NHANES III, the electrical resistance of human body is measured by attaching electrodes to the opposing wrist and ankle (Heshka, Buhl, and Heymsfield 1994). Since body fat is a poor electrical conductor, the magnitude of electrical resistance indicates the degree of body fatness. The total amount of body fat is calculated by entering the resistance into a predetermined

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[26] Anthropometry is the measurement of physical dimensions of the human body such as height, weight, and skinfold thickness (Lohman et al., 1988).

[27] Other possible methods of measuring body fatness include skinfold thickness, underwater weighting, dual x-ray absorptiometry (DXA), magnetic resonance imaging (MRI), etc. (Caterson 2002; Heshka, Buhl, and Heymsfield 1994; Heymsfield et al. 1998). BIA is considered to be the most attractive measurement choice given its reasonable accuracy and relatively low cost.

predictive equation along with ancillary information, such as weight, height, age, and sex. The predetermined predictive equations are obtained in advance from a reference established by more sophisticated methods, such as hydrodensiometry or DXA (dual x-ray absorptiometry). Validation studies show BIA is superior in predicting changes in FFM than any anthropometry measure including BMI (1990; Roubenoff, Dallal, and Wilson 1995).

The following steps were taken to translate the anthropometric information in the NLSY 1979 into body composition information. First, FFM was first calculated for individuals in the NHANES III using the detailed directions provided by Chumlea et al (2002), who have calculated body composition in the NHANES III using the BIA method.[28] FFM is calculated by using the estimates from sex-specific predictive equations provided by Sun et al. (2003) that predict FFM as a function of resistance R in ohms (a unit of electrical resistance), measured height (in centimeters), and measured weight (in kilograms).

$$\text{Men:} \qquad FFM = -10.68 + 0.65\frac{(height*100)^2}{R} + 0.26\, weight + 0.02R \qquad (2.6)$$

$$\text{Women:} \quad FFM = -9.53 + 0.69\frac{(height*100)^2}{R} + 0.17\, weight + 0.02R \qquad (2.7)$$

Sun et al. (2003) tested and rejected the hypothesis that separate equations should be used for each race. They mention, however, that certain ethnic groups tend to be over/under predicted by a known amount. The calculated FFM variable is adjusted accordingly: add 2.1 kg for black men, subtract 0.4 kg for white men, add 1.6 kg for black women, and subtract 0.3 kg for white women.

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[28] Chumlea et al. (2002) suggest adjusting a Valhalla impedance used in NHANES III as follows: For males, R = 2.5 + 0.98 Valhalla resistance; for females: R = 9.6 + 0.96 Valhalla resistance.

Second, in order to obtain the translating coefficients, the calculated FFM in NHANES III is regressed only on variables that are also available in the NLSY. In order to provide better identification, various powers and interactions of age and self-reported height (in meters) and weight (kilograms) in addition to some of the variables from the wage equations are used to predict FFM:

(2.8) $FFM_i = \delta_1 x_{1i} + \delta_2 x_{2i} + e_i$

where x_1 represents the covariates included in the wage equation and x_2 denotes the covariates excluded from the wage equation (height-squared, height-cubed, weight-squared, weight-cubed, height times weight, age times weight, age times height). Self-reported measures of height and weight are used instead of measured height and weight because only self-reported measures are available in the NLSY.[29] Such substitutions in the estimation make it unnecessary to have clinically measured height and weight in order to predict FFM. The specification and the estimated parameters are contained in Table 1. Because we are interested in the effect of body composition on hourly wages, individuals who indicated themselves to be out of labor force or whose primary activity was attending school were excluded from both samples. Military samples and supplemental observations for poor white were also excluded from the NLSY.

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[29] The NHANES III contains both self-reported and clinically measured height and weight. There are slight differences between them.

Table 1

Predictive Equation for Fat-Free Mass by the Gender-Ethnic/Racial Groups

FFM in kilograms	White Men	Black Men	Hispanic Men	White Women	Black Women	Hispanic Women
Age	-0.737	-2.095**	-0.728	0.0663	-0.725	0.0232
	(0.79)	(0.81)	(0.75)	(0.51)	(0.53)	(0.58)
Age Squared / 100	-0.293	7.703***	1.657	-1.720	2.260	1.367
	(2.28)	(2.53)	(2.18)	(1.52)	(1.62)	(1.63)
Age Cubed / 100	0.00556	-0.0793***	-0.0137	0.0141	-0.0230	-0.0164
	(0.025)	(0.028)	(0.023)	(0.016)	(0.018)	(0.018)
Weight	0.523	-0.214	-0.187	0.263	-0.543**	-0.343
	(0.40)	(0.39)	(0.35)	(0.26)	(0.21)	(0.26)
Weight Squared / 100	-0.309	0.297	0.0879	0.00558	0.684***	0.521
	(0.34)	(0.41)	(0.38)	(0.33)	(0.23)	(0.38)
Weight Cubed / 100	0.000809	-0.00139	-0.000826	0.0000662	-0.00317***	-0.00263
	(0.0012)	(0.0014)	(0.0014)	(0.0014)	(0.00092)	(0.0017)
Height	1245	-687.6	-786.4***	-615.8**	-142.3	-336.5**
	(989)	(1033)	(270)	(253)	(319)	(135)
Height Squared	-718.5	390.1	435.4***	390.1**	83.37	207.7***
	(556)	(582)	(147)	(167)	(201)	(76.8)
Height Cubed	137.6	-73.75	-81.26***	-80.67**	-16.06	-41.46***
	(104)	(109)	(26.0)	(36.4)	(41.9)	(14.2)
Height x Weight	0.152	0.316*	0.396***	0.0147	0.274***	0.234**
	(0.19)	(0.17)	(0.13)	(0.11)	(0.10)	(0.12)
Age x Weight / 100	0.265**	0.0184	0.152	0.0953	-0.0576	-0.0173
	(0.13)	(0.13)	(0.12)	(0.093)	(0.089)	(0.10)
Age x Height / 100	29.52	-18.82	-0.566	32.39**	4.916	-23.07
	(24.3)	(20.1)	(19.8)	(13.8)	(15.5)	(17.1)
Urban	-0.0577	1.010***	0.368	-0.0652	0.600***	0.182
	(0.25)	(0.28)	(0.23)	(0.16)	(0.19)	(0.17)
Northeast	1.219***	-0.143	-0.249	0.428**	-0.121	0.221
	(0.33)	(0.37)	(0.61)	(0.22)	(0.25)	(0.35)
West	0.887**	0.0406	-0.698***	0.628***	-0.307	-0.466***
	(0.38)	(0.49)	(0.24)	(0.22)	(0.32)	(0.17)
Midwest	0.932***	0.241	-0.155	0.873***	0.124	0.239
	(0.29)	(0.36)	(0.36)	(0.19)	(0.21)	(0.28)
Married	-0.187	0.0467	0.334	-0.133	-0.129	-0.160
	(0.34)	(0.32)	(0.30)	(0.24)	(0.21)	(0.21)
Constant	-702.1	450.4	502.9***	333.0***	116.6	204.4***
	(586)	(607)	(163)	(128)	(169)	(79.2)
Observations	1199	1307	1415	1375	1467	1260
Adjusted R-squared	0.83	0.82	0.80	0.81	0.81	0.79

Robust standard errors in parentheses
* p<0.10, ** p<0.05, *** p<0.01
Source: NHANES III

To help account for differences across race, the FFM equations were estimated separately by race and gender, yielding four sets of coefficients with which FFM could be predicted for individuals in the NLSY according to their race and gender. Table 1 shows that the most significant determinant of men's skeletal-muscularity, as measured by FFM, appears to be the non-linear terms in body weight: weight squared, weight cubed, and the interactions of weight with age and with height. The relationship between body weight and skeletal-muscular mass is highly nonlinear for the men. A similar pattern exists for the women, but the overall profile is much less pronounced for them. For women, the most statistically significant determinant of body fat appears to be age and its interaction with weight. In regards to ethnicity, Hispanics are remarkably non-linear in the effect of height on their FFM, perhaps reflecting the greater diversity in height among Hispanics with different nutritional backgrounds. The R^2 is about 0.83 for the men's equation and about 0.81 for the women's equation. The results slightly improve when they are further separated by the ethnic groups, perhaps due to the benefits of improved homogeneity. The adjusted coefficients of variation for the six gender-ethnic/racial/racial groups are in the fairly narrow range between 0.79 and 0.83. The relatively high R^2 suggests that the marginal contribution by the electrical resistance *R* used to estimate the original FFM in the NHANES sample was relatively small.

The third and final step in exporting the FFM information is to use the translating coefficients generated in the second step to calculate the FFM for the individuals in the NLSY 1979. The parameters obtained from estimating the Equation 2.8, δ_1 and δ_2, for the individuals in the NHANES III are used to translate the available information in the NLSY into the translated measures of FFM and BF for each individual in the NLSY:

$$F\hat{F}M_i = \hat{\delta}_1 x_{1i} + \delta_2 x_{2i} \tag{2.9}$$

$$B\hat{F}_i = bodyweight_i - F\hat{F}M_i \tag{2.10}$$

where $F\hat{F}M_i$ and $B\hat{F}_i$ are the predicted FFM and BF, respectively. Because the R^2 for each specification in the second step was relatively high, it appears the specification for predicting FFM can be safely applied to a comparable population in NLSY 1979. Both the NHANES III and the NLSY samples were similar in BMI (10-45), in age (7-45), and labor market participation.

Table 2 contains the descriptive statistics for the NLSY sample, including the predicted FFM and BF. It shows that white men and white women are the tallest for their respective genders out of the three ethnic groups. Black women and black men have the highest average FFM for their respective genders, even though they are slightly shorter than whites. Black women and Hispanic men possess the highest average BF. These findings tell us that blacks and Hispanics on average are built more heavily than are whites. Although whites and blacks have almost the same average height, Hispanics are considerably shorter. This tells us that black men have a more solid build due to the higher presence of FFM, while Hispanic men are less solidly built due to the disproportionately higher presence of BF.

Table 2

Descriptive Statistics (Mean and Standard Error) of NLSY 1979

Variable	Units	White Men	Black Men	Hispanic Men	White Women	Black Women	Hispanic Women
Log Hourly wage	Log of cents per	6.91	6.66	6.82	6.67	6.52	6.62
		(0.63)	(0.57)	(0.62)	(0.62)	(0.57)	(0.61)
Height	Meters (m)	1.79	1.78	1.74	1.64	1.63	1.60
		(0.07)	(0.08)	(0.07)	(0.07)	(0.07)	(0.07)
Weight	Kilograms (kg)	82.59	81.97	80.36	64.25	70.89	64.05
		(14.77)	(15.12)	(15.81)	(14.17)	(16.54)	(13.89)
BMI	m/kg^2	25.60	25.84	26.60	23.80	26.60	25.08
		(4.11)	(4.36)	(4.7)	(5.01)	(6.08)	(5.22)
Constructed BF	Body Fat kg	18.77	16.77	19.42	19.08	22.49	20.99
		(6.9)	(6.79)	(7.53)	(9.28)	(10.72)	(9.08)
Constructed FFM	Fat Free Mass kg	63.82	65.20	60.95	45.17	48.40	43.06
		(8.10)	(8.64)	(8.58)	(5.19)	(6.17)	(5.05)
Married	1 if Married	0.53	0.36	0.52	0.60	0.41	0.58
		(0.50)	(0.48)	(0.5)	(0.49)	(0.49)	(0.49)
Education	Years	13.18	12.45	12.11	13.34	13.03	12.51
		(2.40)	(2.05)	(2.44)	(2.20)	(1.93)	(2.42)
Age	Years	29.31	29.16	28.98	29.44	29.81	29.32
		(6.00)	(5.88)	(5.94)	(6.05)	(5.87)	(6.08)
Tenure	Weeks	201.95	150.91	179.63	172.07	167.01	167.78
		(221.2)	(184.7)	(206.5)	(197.0)	(200.5)	(193.0)
Experience	Weeks	451.74	380.46	420.99	412.60	352.82	371.20
		(251.2)	(235.9)	(245.3)	(239.1)	(236.1)	(239.8)
Urban	1 if urban	0.74	0.83	0.92	0.74	0.84	0.92
		(0.44)	(0.38)	(0.26)	(0.44)	(0.37)	(0.27)
Northeast	1 if Northeast	0.19	0.15	0.14	0.19	0.14	0.14
		(0.39)	(0.36)	(0.35)	(0.39)	(0.35)	(0.34)
West	1 if West	0.17	0.07	0.51	0.17	0.07	0.47
		(0.37)	(0.26)	(0.50)	(0.37)	(0.25)	(0.50)
Midwest	1 if Midwest	0.36	0.18	0.06	0.32	0.17	0.08
		(0.48)	(0.38)	(0.24)	(0.47)	(0.38)	(0.27)
Observations		18318	9524	6333	17724	9514	5697

Source: NLSY 1979

The Augmented Wage Equation

The predicted variables, $F\hat{F}M$ and $B\hat{F}$, are then used to augment the wage equation. The estimated wage equation therefore looks like Equation 2.11, where z represents the demographic covariates not included in x_1, and g is the error term:

$$\log w_i = \eta_1 \widehat{BF}_i + \eta_2 F\widehat{FM}_i + \eta_3 \widehat{BF}_i \cdot F\widehat{FM}_i + \eta_4 x_{1i} + \eta_5 z_i + g_i \tag{2.11}$$

Hourly wages were deflated to the 1991 dollar using the Consumer Price Index. The years of observations spanned from 1980 to 2000. The interaction terms are included in the specification to reflect the presence of essential body fat considered to be the minimum required levels of BF (International Commission on Radiological Protection 1975; Rodahl and Issekutz 1964).[30] The demographic covariates include customary economic variables, including years of education, age, employment tenure, and weeks of employment experience, and binary indicators for local unemployment rates and regions. Ten occupational dummies and 13 industry dummies are also included in the regressions to control for the known correlation between physically strenuous work and body characteristics. To avoid changes in body composition, observations from nine months prior, during, and nine months after a childbirth event are excluded for both sexes.[31] The evidence from military training, which is representative of physically strenuous occupational requirement, indicates that both men and women gain about 2.5 kilograms of FFM during the basic training (Harman and Frykman 1992). To avoid such rapid

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[30] As discussed in Chapter 1.

[31] Observations for men as well as women are excluded to avoid introducing gender bias in the treatment of data.

change during the initial periods of employment, the observations of individuals with less than six months of tenure are also excluded.[32]

It is important to note here that Equation 2.11 represents a reduced form of structural equations represented by Equations 2.8-2.10. Height, weight, and their interactions terms are the instruments excluded from Equation 2.11 that address the possible endogeneity of FFM and BF. As discussed in Chapter 1, it is argued in this dissertation that height and weight do not have direct effect on the worker productivity. Instead, it is FFM and BF that are closely correlated with worker productivity. By predicting FFM and BF as a function of the excluded instruments, we avoid the possible endogeneity of FFM and BF.

The OLS results from estimating Equation 2.11 are show in Tables 3-4 for men and Tables 5-6 for women.[33] Specifications 1 and 2 replicate the previous results reported by Cawley (2004) and Averett and Korenman (1996) using BMI. They had reported that the quadratic term for BMI was significant for men but not for women. Similar to the previously reported findings, black women in our study appear to suffer from a relatively small obesity penalty. Black men appear to enjoy the obesity premium whether the linear or the quadratic term of BMI is used to indicate the degree of obesity. The marginal effect of BMI in the quadratic specification looks like this:

$$d \ln w / dBM \ = \beta_{BMI} - 2\ \beta_{BMI\,2} \cdot BMI \tag{2.12}$$

Based on statistical significance, the quadratic terms are the preferred specification for men. Because the marginal effects of the quadratic terms depend on the level of BMI, they are calculated for the mean and plus or minus one standard deviation

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[32] It merely reduces the noise. This does not affect the main outcome.

[33] Log-likelihood tests indicate that the coefficients for the six gender-ethnic groups are significantly different from each other at the significance of 99 percent.

of BMI for each estimation sample. They are reported near the bottom of Tables 3-6. The change in the sign of the marginal effect from positive to negative indicates that the wage-BMI is concave for white men. For black men, the wage-BMI profile is continuously linear. All ethnicities of women can be adequately represented using the linear specification over the quadratic specification for BMI, because the addition of the quadratic terms does not significantly change the marginal effects.

Table 3

Men Pooled Cross-Section with BMI

		(1)			(2)	
	White	**Black**	**Hispanic**	**White**	**Black**	**Hispanic**
BMI	-0.00254	0.00314	-0.00564**	0.0555***	0.0287**	0.0212
	(0.0017)	(0.0019)	(0.0022)	(0.012)	(0.012)	(0.017)
BMI Squared				-0.0010***	-0.00045**	-0.00046*
				(0.00021)	(0.00021)	(0.00027)
Observations	18318	9524	6333	18318	9524	6333
R-squared	0.32	0.32	0.27	0.32	0.32	0.27
Joint Test of Significance[1] (P-values)	(0.141)	(0.105)	(0.0103)	(0.000001)	(0.0264)	(0.00119)
Marginal Effect[2] for BMI						
at Mean BMI – SD				0.0108	0.00939	0.00104
at Mean BMI				0.00232	0.00549	-0.00324
at Mean BMI + SD				-0.00620	0.00160	-0.00751

Also controlled for married, education, age, tenure, experience, education-squared, age-squared, tenure-squared, experience-squared, 4 unemployment rates, urban, 4 regions, 10 occupational and 13 industry categories, not shown

[1] Respective joint test for variables with quadratic terms or interactions terms.

[2] Marginal effects evaluated at the mean and plus/minus one standard deviations (SD) for the quadratic terms and the interactions terms. See the text for a description.

Robust t statistics in parentheses, clustered around individuals.

* p<0.10, ** p<0.05, *** p<0.01

Table 4

Men Pooled Cross-Section with Body Composition

		(3)			**(4)**	
	White	**Black**	**Hispanic**	**White**	**Black**	**Hispanic**
FFM	0.0110***	0.00559**	0.00970***	0.0152***	0.00730***	0.0125***
	(0.0026)	(0.0023)	(0.0034)	(0.0028)	(0.0025)	(0.0039)
BF	-0.0139***	-0.00391	-0.0129***	0.00616	0.00483	-0.000841
	(0.0033)	(0.0030)	(0.0038)	(0.0063)	(0.0072)	(0.0088)
FFM x BF				-0.000259***	-0.000112	-0.000164
				(0.000068)	(0.000081)	(0.00011)
Observations	18318	9524	6333	18318	9524	6333
R-squared	0.32	0.32	0.27	0.32	0.32	0.27
Joint Test of Significance[1] (P-values)	(0.00010)	(0.00532)	(0.00195)	(0.0000002)	(0.00443)	(0.00126)
Marginal Effect[2] for FFM						
at Mean BF – S.D.				0.0116	0.00596	0.0101
at Mean BF				0.00987	0.00522	0.00895
at Mean BF + SD				0.00815	0.00448	0.00776
Marginal Effect[2] for BF						
at Mean FFM – SD				-0.00787	-0.00133	-0.00909
at Mean FFM				-0.0100	-0.00232	-0.0105
at Mean FFM + SD				-0.0122	-0.00332	-0.0120

Also controlled for married, education, age, tenure, experience, education-squared, age-squared, tenure-squared, experience-squared, 4 unemployment rates, urban, 4 regions, 10 occupational and 13 industry categories, not shown

[1] Respective joint test for variables with quadratic terms or interactions terms.

[2] Marginal effects evaluated at the mean and plus/minus one standard deviations (SD) for the quadratic terms and the interactions terms. See the text for a description.

Robust t statistics in parentheses, clustered around individuals.

* p<0.10, ** p<0.05, *** p<0.01

Table 5

Women Pooled Cross-Section with BMI

	(1)			**(2)**		
	White	**Black**	**Hispanic**	**White**	**Black**	**Hispanic**
BMI	-0.0076***	-0.0040***	-0.0074***	-0.00914	0.00825	-0.00150
	(0.0013)	(0.0014)	(0.0022)	(0.0074)	(0.0080)	(0.013)
BMI Squared				0.0000272	-0.000203	-0.000103
				(0.00013)	(0.00013)	(0.00022)
Constant	5.985***	5.752***	6.032***	6.005***	5.582***	5.957***
	(0.075)	(0.11)	(0.12)	(0.12)	(0.16)	(0.21)
Observations	17724	9514	5697	17724	9514	5697
R-squared	0.37	0.37	0.31	0.37	0.37	0.31
Joint Test of Significance (p-values)	(1.98e-09)	(0.00345)	(0.000940)	(0.00000002)	(0.00654)	(0.00366)
Marginal Effect[2] for BMI						
at Mean BMI – SD				-0.00811	-0.000177	-0.00564
at Mean BMI				-0.00783	-0.00267	-0.00672
at Mean BMI + SD				-0.00756	-0.00516	-0.00781

Also controlled for married, education, age, tenure, experience, education-squared, age-squared, tenure-squared, experience-squared, 4 unemployment rates, urban, 4 regions, 10 occupational and 13 industry categories, not shown

[1] Respective joint test for variables with quadratic terms or interactions terms.

[2] Marginal effects evaluated at the mean and plus/minus one standard deviations (SD) for the quadratic terms and the interactions terms. See the text for a description.

Robust t statistics in parentheses, clustered around individuals

* p<0.10, ** p<0.05, *** p<0.01

Table 6

Women Pooled Cross-Section with Body Composition

	(3)			(4)		
	White	**Black**	**Hispanic**	**White**	**Black**	**Hispanic**
FFM	0.0122***	0.00485	0.00436	0.0116***	0.00530	0.00428
	(0.0030)	(0.0031)	(0.0067)	(0.0033)	(0.0034)	(0.0063)
BF	-0.0103***	-0.0047**	-0.00658*	-0.0118***	-0.00358	-0.00679
	(0.0018)	(0.0019)	(0.0039)	(0.0042)	(0.0056)	(0.010)
FFM x BF				0.0000288	-0.000021	0.0000041
				(0.000073)	(0.000092)	(0.00016)
Constant	5.513***	5.545***	5.821***	5.542***	5.522***	5.824***
	(0.11)	(0.15)	(0.22)	(0.13)	(0.17)	(0.23)
Observations	17724	9514	5697	17724	9514	5697
R-squared	0.37	0.37	0.31	0.37	0.37	0.31
Joint Test of Significance (p-values)	(1.98e-10)	(0.00852)	(0.00122)	(9.35e-10)	(0.0207)	(0.00273)
Marginal Effect^2 for FFM						
at Mean BF – SD				0.0120	0.00500	0.00434
at Mean BF				0.0122	0.00477	0.00438
at Mean BF + SD				0.0125	0.00455	0.00442
Marginal Effect^2 for BF						
At Mean FFM – SD				-0.0107	-0.00445	-0.00664
at Mean FFM				-0.0105	-0.00458	-0.00662
at Mean FFM + SD				-0.0104	-0.00472	-0.00660

Also controlled for married, education, age, tenure, experience, education-squared, age-squared, tenure-squared, experience-squared, 4 unemployment rates, urban, 4 regions, 10 occupational and 13 industry categories, not shown

[1] Respective joint test for variables with quadratic terms or interactions terms.

[2] Marginal effects evaluated at the mean and plus/minus one standard deviations (SD) for the quadratic terms and the interactions terms. See the text for a description.

Robust t statistics in parentheses, clustered around individuals

* p<0.10, ** p<0.05, *** p<0.01

Specifications 3 and 4 test the double hypothesis that the marginal effect of FFM and BF should be positive and negative, respectively. Combinations of estimated FFM and BF are tested. In general, both FFM and BF have the expected signs and are highly significant. The marginal effects provided in the table indicate that the signs are valid through the expected ranges.[34]

In terms of the magnitude, a gain of one pound (2.2 kilograms) of FFM is roughly equivalent to about a 2.5 % increase in hourly wage for both white men and women, using Specification 3 or 4 for whites. For the minority groups, a similar gain in FFM roughly equals half of the effects for whites. The weakening of the effect for the minorities is consistent with the idea that FFM and BF have been predicted with more error for blacks and Hispanics. Because a majority of clinical research is conducted with white samples, BIA methods are thought to be less accurate for minority populations (Bellizzi et al. 2003). The errors in the variable for the translated FFM and BF lead to the attenuation bias in which the estimated coefficient will be biased towards zero.

Appendixes A1 and A2 contain the random effects specification for men and women. Random effects specification assumes individual differences as random drawings from some specified distribution. The results for the random effects are slightly weaker, yet generally similar to the results for the pooled cross-sections.

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[34] Quadratic terms in FFM and BF have proved very noisy without significantly altering the marginal effect. Therefore, they are not reported here.

Graphical Simulations

It is important to realize that the marginal effects discussed above are *ceteris paribus*. FFM and BF are companion body components that usually change together in the same direction (Forbes 2003). It is very rare to lose or gain one body component without incurring similar changes in the other component. Thus, the interactions of FFM, BF, BMI, and hourly wage are better illustrated graphically. The key to understanding the role of FFM and BF on earnings is to draw hourly wage as a level set in the body components space. Level sets for BMI are also generated to help explain the failure of BMI to correctly account for FFM or BF. The results for blacks and Hispanics are similar to those for whites. Only white men and women will be presented here.

The heavy, solid line graph in Figure 5 shows the likely pathway as body mass increases in the BF-FFM space. Arbitrary combinations of BF and FFM, such as too much of one without the other, are not biologically possible. As discussed before, the human body develops BF in relation to FFM at each particular body size. The BF-FFM pathway in the graph was generated by fitting a quadratic line over scattered observations of 2 percent samples. Although not all individuals necessarily follow this pathway, the BF-FFM pathway represents the dominant direction of movement in the BF-FFM space.

Three iso-wage curves were overlaid by numerically solving the wage equation for a given value of wage.[35] The middle iso-wage curve represents the mean of wage for white men. If we trace the BF-FFM pathway, we can see that it will cross the middle iso-wage curve twice, meaning that hourly wage is not uniquely determined by the BF-FFM pathway. The multiple existence of the same hourly wage on the BF-FFM pathway is the

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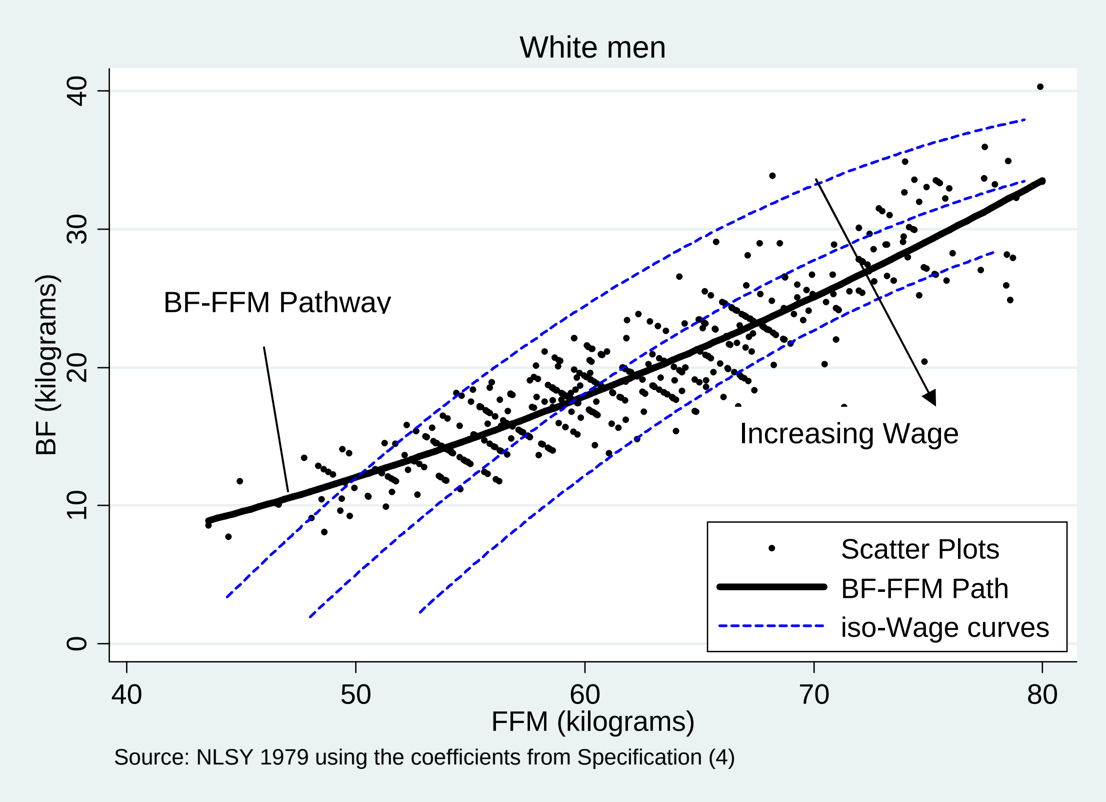
[35] Various combinations of BF and FFM were entered into the equation until a given value of wage was obtained.

reason behind the non-linearity in returns to BMI. To better illustrate this point, three iso-BMI curves were superimposed in Figure 6 without the scatter plot. The iso-BMI curves were generated empirically by isolating individuals who possessed a particular level of BMI and plotting their BF against FFM. The middle iso-BMI curve represents the mean of BMI for white men.

Figure 5

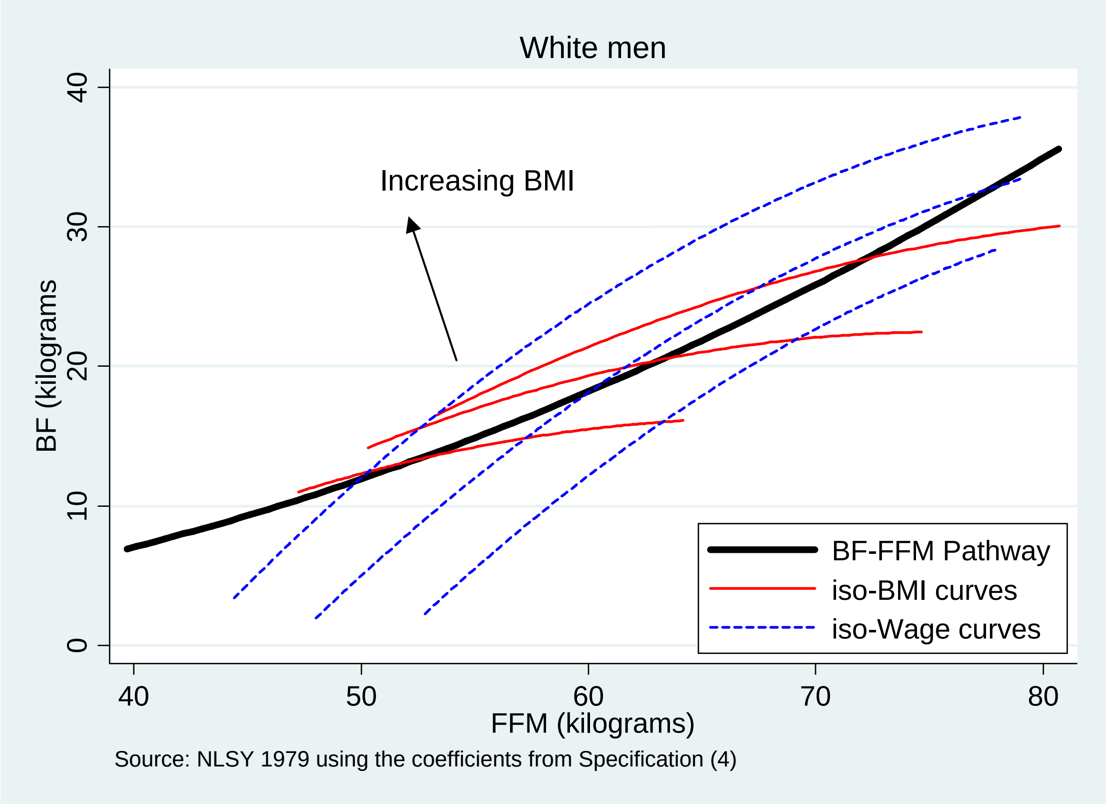
Scatter Plots, BF-FFM Pathway, and iso-Wage Curves



Source: NLSY 1979 using the coefficients from Specification (4)

Figure 6

Scatter Plots, BF-FFM Pathway, and iso-Wage Curves



Source: NLSY 1979 using the coefficients from Specification (4)

We can see that each iso-BMI curve uniquely crosses the BF-FFM pathway. If we imagine that each point of the BF-FFM pathway is uniquely associated with an iso-BMI curve, then it is clear that the association between BMI and hourly wage will be non-linear because the association between the BF-FFM pathway and hourly wage is non-linear. We can further confirm that the non-linearity will be concave, because the highest iso-wage curve will be reached by the middle portion of the BF-FFM pathway. The remainder of the BF-FFM pathway will correlate with lower iso-wage curves.

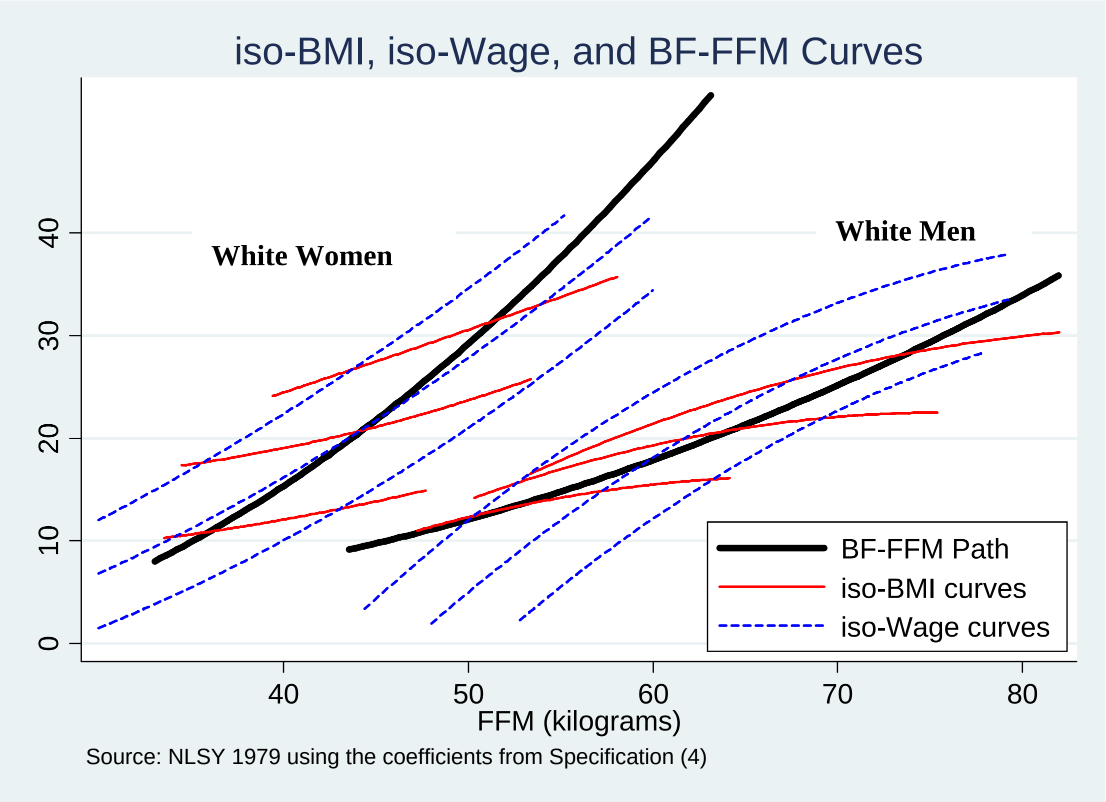
The BF-FFM pathway curves upward, indicating that white men gain more BF in relation to FFM as more body mass is gained. According to this graph, the average white man can reach the middle iso-wage curve at FFM of 60 and again at FFM of 75. A disproportionate gain in BF associated with FFM of 75 brings hourly wage down to the earlier level. The three iso-wage curves are rising upwards due to the competing and opposite effects of BM and FFM on hourly wage. Any benefits attributable to FFM will be offset if a similar gain in BF has been made. As discussed earlier, FFM and BF are companion body components that usually change together.

To underline the gender differences in the obesity penalty, we now turn to Figure 7, which displays a similar graph for both white men and women. Tracing the women's BF-FFM pathway, we can see that it is initially parallel or almost parallel to the middle iso-wage curve. Like men, the women's BF-FFM pathway traces upwards. Unlike men, however, all of the iso-wage curves are concave upwards. Such a shape better ensures that women will cross each iso-wage curve only once as they gain body mass along the BF-FFM curve.

These two graphs make several clarificaitons. First, there exists a wide swath of indeterminacy for any given level of BMI or hourly wage. Various combinations of FFM and BF can reach the same levels of BMI. Similarly, any combination of BF and FFM can be used to reach any hourly wage. Therefore, BMI can not adequately reduce variations in hourly wage due to variations in FFM and BF. Muscular individuals with high FFM would be categorized together with obese individuals with high BF.

Figure 7

White Men and Women's iso-BMI, iso-Wage, and BF-FFM Pathway



Source: NLSY 1979 using the coefficients from Specification (4)

Second, the human body contains far more FFM than BF at smaller body sizes. It is also true that more FFM and less BF are found at lower BMI. It is only after a certain size has been reached that an increasingly larger amount of BF is gained. Such a relationship causes BMI to be more strongly correlated with FFM.

Third, the slope of iso-BMI curves in the body composition space tilts closer to BF as BMI increases. This means the covariance between BMI and BF increases as a function of BMI, while the covariance between BMI and FFM decreases as a function of BMI. This finding confirms the hypothesized relationship between FFM, BF, and BMI in

Equations 2.5-2.7. Such conditional covariances would make the omitted variable bias, attributable to muscularity represented by FFM, conditionally expressed as a function of BMI.

Fourth, as suggested earlier in the analysis of Specification 4, it appears iso-wage curves shift in almost parallel fashion around BF-FFM space. The marginal effect of additional BF or FFM is thus nearly constant through the relevant ranges. Fifth, the marginal effect of BF is everywhere negative, while the marginal effect of FFM is always positive. White men, therefore, do not enjoy an obesity premium anywhere in the body composition space. The misidentification caused by BMI merely makes it look as if white men would be better off being mildly obese. Lastly, the level sets alone are not sufficient to predict the association between BMI and hourly wage. While iso-wage curves increase towards FFM and iso-BMI curves increase towards BF, their directions are not completely opposite to one another. The solution to this problem is provided below.

Three main findings are notable from the wage equations. First, these results suggest that increasing body fatness at any level of original body fatness has a linear and negative impact on the hourly wage, regardless of gender or ethnicity. This means that the obesity penalty is suffered not only by those who are clearly obese but also by others with varying degrees of body fatness. The obesity penalty merely becomes more noticeable among the more severe cases of obesity.

Second, and perhaps more importantly, the increases in the skeletal-muscular component (as measured by FFM) at any level has a linear and positive impact on the hourly wage, regardless of gender or ethnicity. Since FFM can be interpreted to represent lean body mass, we can construe this result as the evidence of a wage premium for skeletal-muscular development. The negative obesity penalty and the positive musculoskeletal premium together offer a straightforward explanation for the recent attention to diet and exercise. The presence of musculoskeletality and the absence of obesity may be associated with the unobserved productivity factor, or they may constitute in of themselves the embodied forms of human capital that are subject to reward and punishment in the labor market, similar to an investment in education.

The third noteworthy finding when using body composition rather than BMI is that black men and black women also clearly suffer an obesity penalty and enjoy a musculoskeletal premium. The magnitude of the estimated coefficients, however, does appear to be smaller than their white counterparts. Given the aforementioned observation by Sun et al. (2003) that the BIA equations tend to predict the body composition with more errors for blacks than for whites, it is likely that the estimated coefficients for blacks suffer from an attenuation bias that squeezes the estimated coefficient towards zero.

Conclusion

The question of obesity is no longer solely focused on the reduction of body fat. It now also emphasizes the improvement in lean body mass. In *Healthy People: 2000*, the Surgeon General for the first time included exercise as a vital component of healthy nutrition. In addition, the U.S. Agriculture Department has recently redesigned its trademark food pyramid to display climbing stairs to emphasize the need for daily activity.[36]

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[36] MyPyramid is accessible at mypyramid.gov.

The theoretical definition of obesity as excessive body fatness, rather than the expedient definition based on BMI, can improve the understanding and the interpretation of research results. The generalized predictive equation offered in this paper can be easily adapted to other existing economics data. The increased availability of measures of body composition can improve future research by making available for the first time a theoretically consistent measure of obesity.

The empirical results presented in this paper suggest that growing obesity will likely reduce the hourly productivity of workers. Not only have we observed the obesity penalty but also the skeletal-muscular premium. It may be that what is currently thought of as obesity discrimination is only a part of the story. It is not the presence of undesirable characteristics alone, but also the lack of desirable attributes that may negatively affect the earnings of obese workers. Since the marginal effects of the obesity penalty and the skeletal-muscular premium appear to be nearly constant and experienced by almost everyone in the wide range of the continuum, it may be difficult to ascribe such an outcome purely to a matter of taste or discrimination. It may be difficult to justify any policy initiative that proposes to bestow additional protection against discrimination based on body size alone.

Growing incidences of obesity will also impact the existing research efforts by unexpectedly changing the underlying structure of the labor market. An estimation of the returns to education that fails to take into account the unobserved differences in body size would be biased. Because education, early nutrition, and unobserved investment are likely to be correlated, any estimation between populations, across time or place, would be questionable in the presence of body size heterogeneity. Any future research in the presence of such rapid changes in the population may need to take these parameters into consideration.

Chapter 3

The Role of Body Composition in the Gender Gap in Wages

Introduction

Although there has been a considerable body of literature attempting to explain the gender gap in wages, the persistence of the gender gap in wages still presents a puzzle for researchers. Despite the nearly equal participation in the labor market by women and the new generations of workers who entered the labor market after the passage of anti-discrimination laws, the gender gap in wages has yet to close or give any indication of disappearing anytime soon (Blau and Kahn 2004; O'Neill 2003). The decline of male participation and the increase of female participation in the labor market are two of the most important changes in labor force behavior over the last 50 years. The gap in wages between women and men cannot be attributed to discrimination completely. This is because competitive models of labor market predict that discriminatory practices cannot be sustained in the long run (see Lazear 1991b).

Before improving during the 1980s, the ratio of wages between women and men in the United States had remained fairly stable at around 60 percent for most of the 20th century (Blau and Kahn 1992; Goldin 1990; O'Neill and Polachek 1993).[37] Similar wage ratios of approximately 60 percent have been observed in other countries at various stages of economic development (Blau and Kahn 2000; Moroney 1979). As pointed out by Fuchs (1971), the ubiquitous ratio is also found in the Book of Leviticus (27: 2– 5), which declares that a women is worth 30 shekels of silver compared to a man's 50

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[37] The 60 percent ratio is a stylized fact. See Smith and Ward (1989) for arguments that a slow, gradual progress has been made during the 20th century.

shekels.[38] The biblical ratio of 60 percent is the Leviticus ratio that apparently persists to this day.

The stylized ratio of Leviticus raises a relevant question of whether this gender gap occurred by chance. Chance combinations of fertility and discrimination could have given a rise to the Leviticus ratio, yet there is no apparent reason for the gender gap to have stayed at that particular ratio.[39] Productivity-related factors are provincial and subject to change. Because they fluctuate widely between eras and regions, they are unlikely candidates for giving rise to a widely shared outcome.

Perhaps there exists another factor that made the emergence of a gender gap likely. While it would be unusual for an economist to attribute it to God, biblical scholars themselves have attributed it to physical factors.[40] The Jewish Study Bible suggests out that the ratio found in Leviticus is “evidently based on size and strength, and thus on potential productivity in terms of physical labor" (Berlin et al. 2004). According to this interpretation, it is not discrimination or cultural expectations that determine the gender gap in wages, but rather the physical differences in work capacity as measured by size and strength.[41]

The physical explanation for the gender gap in wages is perhaps the oldest explanation for the observed gender gap in wages. Men have often claimed in the past

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[38] Leviticus declares an even smaller ratio for female children and teenagers at 50 percent.

[39] Explanations for the existence of the gender gap in wages include discrimination (Treiman and Hartmann 1981), gender differences in human capital (Mincer and Polachek 1974; Polachek 1975b), and occupational overcrowding (Bergman 1974).

[40] Bergmann (1989) jokingly refers to the “Biblical Theory of Wages” in which God ordains permanently lower wages for women.

[41] It is generally agreed among the biblical scholars that the Leviticus ratio reflects monetary values of work capacity (see e.g., Carson 1994; Dunn and Rogerson 2003; Levine 1989; Noth 1965). The economic interpretation is bolstered by Leviticus (27: 7), which declares that pledges made by the poor shall be adjusted accordingly (since the poor cannot pay as much). Since the Leviticus passages provide the estimates of individual worth as a guide for pledges to be made towards the upkeep of the sanctuary, we can interpret these estimates as a form of taxation levied on individual work capacities. For additional theories, see Milgrom (2001, p.2370-75).

that women are not strong enough to do men's jobs. Employers have also made similar claims that women lack the necessary physical strength to perform satisfactorily in certain jobs (see e.g., Beechey and Perkins 1987, p102-12; Reskin and Hartmann 1986, p 41).

Clinical evidence documents the gender differences in physical strengths. A frequently mentioned estimate in the ergonomics and exercise physiology literature is that the average woman's strength is about 2/3 that of the average man (Astrand and Rodahl 1986, p.341-46; Chaffin, Andersson, and Martin 1999, p.119-25; Miller et al. 1993).[42] Overlaps exist, but the strength of the average woman is still less than that of the average man. Clinical studies show that women have 25-45 percent smaller muscles and muscle fibers, which would imply the strength ratio of 65-75 percent A report by the Institute of Medicine notes that the higher muscle mass of men is associated with higher physical strength (Wizemann and Pardue 2001, p.131).

This paper proposes to test the physical explanation for the gender wage differential. Although individual information on physical strength is rarely available, physical measurements can be used as a proxy for strength and work capacity. The evidence from the ergonomics literature suggests that the main determinants of physical strength are age, gender, and anthropometry (Chaffin, Andersson, and Martin 1999). Of these three factors, anthropometry – which is the measurement of body parts – displays the largest explanatory power to the point of obviating the gender variable.

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[42] While reasonable variations exist among strenuous tasks, such variations in the strength ratio are highly correlated with each other and centered around the average ratio of 2/3(see Chaffin, Herrin, and Keyserling 1978; Kumar 1991; Miller et al. 1993; Webb Associates 1978). The variability between trained athletes is smaller with women performing 5-15 percent less then men (Ransdell and Wells 1999).

One potential anthropometric method for reducing variations in physical performance is body composition. Body composition partitions the human body into body fat (BF) and fat-free mass (FFM). FFM includes the musculoskeletal system. As one would expect, BF is shown to be negatively correlated with activities involving movement of bodies over a distance, while FFM is positively correlated with activities involving application of physical force (Boileau and Lohman 1977; Wilmore 1983). Regression analyses show that almost all gender differences in strength can be explained by individual differences in muscle size as estimated by FFM and BF (Bishop, Cureton, and Collins 1987; Wilmore 1974). This suggests that body composition represents a gender-neutral measure of physical endowments that can help predict physical performance. Women and men with similar physical performances in distance running possess a remarkably similar body composition (Pate, Barnes, and Mivler 1985). The higher presence of body fat also causes women to require more oxygen per unit of body weight, and body fatness is the largest determinant of the gender difference in performance of running (Cureton and Sparling 1980; Sparling and Cureton 1983).[43]

This chapter uses individual anthropometric measurements from the National Longitudinal Survey of Youth 1979 (NLSY 1979) and the Third National Health and Nutrition Examination Survey 1988-94 (NHANES III) to examine the role of body composition in explaining the gender wage gap.[44] Using the methodology presented in Chapter 2, estimates of body composition have been provided for the respondents in the NLSY 1979 from the body composition information gathered from the NHANES III survey. Basic theory and decomposition results are presented below.

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[43] Experimental weight gain shows that the added weight contributes to decreased physical performance (Cureton et al. 1978).

[44] Anthropometry deals with physical measurements of the human body.

Decomposing the Gender Gap

In Oaxaca-Blinder decomposition (Blinder 1973; Oaxaca 1973), residuals are interpreted to indicate the presence of discrimination. As has been pointed out, the technique of residual estimation is sensitive to the specification that is chosen. If all productivity-enhancing variables are not included in the model, then we may overstate the extent of discrimination. On the other hand, if the differences in the included variables are the result of discrimination, then we may understate the extent of discrimination.

A portion of the gender gap may be due to the differences in body fatness and musculoskeletal development. Although labor economists have not directly incorporated strength and size into their analysis, some indirect evidence can be found in their study. In their study of piece-rates from a century ago, Goldin and Polacheck (1987) estimate that men’s physical productivity in manufacturing firms was 30% higher than that of their female counterparts. Using information from the Dictionary of Occupational Titles (DOT), McLaughlin (1978) and Macpherson and Hirsch (1995) find that male-dominated occupations are indeed more associated with physical strength and to a much lesser extent with cognitive and manipulative skills. A pay reduction for working in a female-dominated occupation is larger for men than for women (Macpherson and Hirsch 1995). This may be due to self-selection by smaller men into female-dominated occupations.

In an opposing view, Fuchs (1971) argues that it is differential roles rather than differential strength that leads to the gender gap. He bases his conclusion on the fact that a narrowing of occupational categories tends to reduce the wage differential. This interpretation is questionable, since a dramatic increase in the number of occupational categories allows the categories to increasingly capture unobserved heterogeneity. Goldin (1990, p.81, 104), on the other hand, argues that strength alone is unlikely to cause large earning differences even in physically strenuous occupations because such jobs were male-dominated by “custom” in previous centuries. But Goldin (1990, p.59) also states that adoption of machinery ought to decrease the labor market’s rewards for strength. And if the labor market still rewards strength, it may be due to discrimination by employers and consumers. The question of physical size and strength is an empirical one that is better addressed by directly incorporating these factors into the estimation.

Question of Occupational Characteristics in Estimation

Direct incorporation of individual body size in the estimation avoids the spirited debate over the proper role of occupation and occupational characteristics in the gender gap. A popular strategy is to use occupational characteristics as a proxy for unobserved productivity and explain as much as possible with observed differences in productive endowments. Up to 90 percent of the gender gap can be explained when occupational characteristics are included (Macpherson and Hirsch 1995; O'Neill 2003).[45] The inclusion of occupational characteristics is criticized by a number of researchers who see the existence of occupational segregation itself as an evidence of discrimination (e.g., Bielby and Baron 1986; Edgeworth 1922; Groshen 1991; Treiman and Hartmann 1981).[46] It is also hard to argue that occupational choice is not affected by discrimination or to argue

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[45] The alternative is to include occupational categories. Treiman and Hartmann (1981) show that detailed categories explain a much larger portion of the gender gap than broad categories. Gunderson (1989) suspects board occupational categories mask the effect of segregation in the lower-wage jobs.

[46] Occupation alone accounts for a large portion of the gender wage gap, up to 40 percent according to Treiman and Hartmann (1981). Gender compositions within occupations appear to be correlated with occupational characteristics and unobserved worker attributes (Macpherson and Hirsch 1995)

that it is not affected by making occupational characteristics act as a proxy for discrimination (Gunderson 1989; Kidd and Shannon 1996).[47] Although some researchers argue that occupational segregation is due to pre-market factors instead of discrimination (i.e. Polachek and Siebert 1994), pre-market factors themselves received remarkably little attention.[48]

Furthermore, occupational characteristics are often inferred for each occupational category using the average values from secondary sources. The assignments of the average values are not suitable for the decomposition analysis of the gender wage gap because the distribution of occupational characteristics is often associated with gender. If the average value is assigned to all respondents, then the stratification of the sample by gender will cause one gender's average endowment to be understated and the other gender's average endowment to be overstated. This is illustrated in Figure 8 for a hypothetical case of physical strength.

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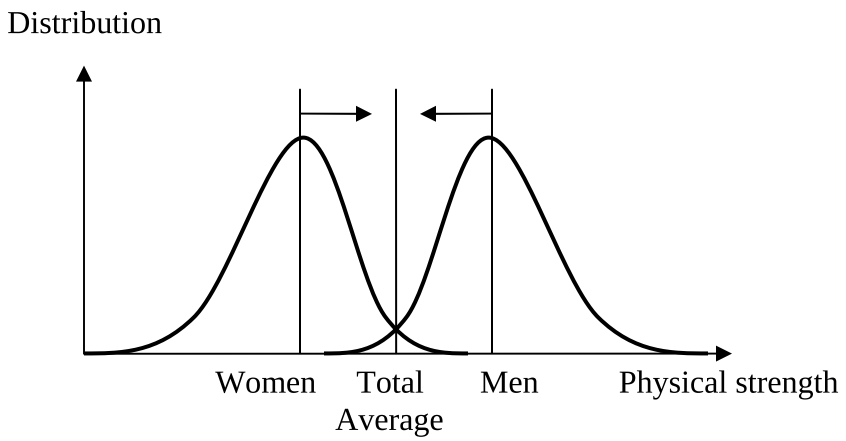
[47] Pre-market factors have been described as role differentiation (Fuchs 1971), socialization (Polachek 1975a; Treiman and Hartmann 1981), circumscribing norms (Goldin 1990), or sexual stereotyping (Watts and Rich 1993). For extended discussions of sex-roles and socialization, see Reskin and Hartmann (1986). See Corcoran and Courant (1998) for tentative exploration into the role of socialization as a pre-market factor.

[48] Polachek (1978) also notes that differential expectations are not distinguished from innate differences in preferences.

Figure 8

Stratification Bias due to Gender-Specific Heterogeneity When Assigning Occupational Averages



Due to gender differences in distribution, the assignment of the average will cause the majority of the men’s observations to be downwardly biased and the majority of the women’s observations to be upwardly biased. Thus, the differences in physical strength between the two genders would be artificially narrowed within each occupation, and the portion of the gender gap attributed to the gender differences in endowments would be systematically understated.[49] Assuming the true magnitude of the men’s coefficient is larger than for women, this would cause the unexplained portion of the gender wage gap to be overstated if the return to physical strength is positive; the unexplained would be understated if the return to physical strength is negative. Depending on the true direction and magnitude, many combinations of biases are possible, and it is not possible to isolate such a mixture of biases.

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[49] Moreover, gender distributions of occupational characteristics may even reverse in some occupations, meaning that the gender distribution many not be consistent across all occupations.

Finally, in addition to these biases, the inclusion of occupational characteristics is ultimately questionable due to the disparity between the theoretical and empirical evidence concerning the average occupational characteristics, which casts a doubt on the validity of using them to control for unobserved productivity. The most common explanation for the mixed result concerning occupational characteristics is that productivity has been somehow mismeasured (Brown 1980; Hwang, Reed, and Hubbard 1992).[50] But if productivity appears to be mismeasured with respect to occupational characteristics, then we can not reliably make use of them to control for unobserved productivity in the gender gap studies.

Theory of Decomposition

In order analyze individual level data, this paper implements wage decomposition as proposed by Oaxaca and Ransom (1994). Wage decomposition is an empirical implementation of the discrimination index as developed by Becker (1971).[51] Becker's original equation was implemented in the following manner by Cotton (1988):[52]

$$\ln \overline{W_M} - \ln \overline{W_W} = \ln MP_M - \ln MP_W + \ln(1+\delta) \qquad (3.1)$$

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[50] Controlling for unobserved heterogeneity through individual fixed effects does not consistently solve the problem (Brown 1980; Duncan and Holmlund 1983).

[51] Discrimination index δ is the difference between the two average wage ratios observed in the presence and the absence of discrimination.

$$\delta = \left[\left(\frac{\overline{W_M}}{\overline{W_W}}\right) - \left(\frac{MP_M}{MP_W}\right)\right] \Big/ \left(\frac{MP_M}{MP_W}\right)$$

W_m and W_W are men's and women's wages and MP_M and MP_F are the marginal products of men and women.

[52] Oaxaca (1973) implemented it through a logarithmic approximation:

$$\frac{(\overline{W}_M - \overline{W}_F)}{\overline{W}_F} \cong \ln \frac{\overline{W_M}}{\overline{W_W}} = \ln \overline{W_M} - \ln \overline{W_W}$$

Assuming that men’s and women’s earnings functions are comparable, the wage equations are estimated separately,

$$\ln W_M - \ln \overline{W_W} = \beta_M X_M + \beta_W X_W \tag{3.2}$$

where *X* indicates the vector of variables relevant to the marginal productivity. It has been shown that the wage differential can be decomposed into two parts (Blinder 1973; Oaxaca 1973). This equation uses the men’s wage structure as the base, meaning that the men’s equation would be observed in the absence of discrimination.

$$\ln \overline{W_M} - \ln \overline{W_W} = \hat{\beta}_M (\overline{X}_M - \overline{X}_F) + (\hat{\beta}_M - \hat{\beta}_F)\overline{X}_F \tag{3.3}$$

Using the women’s wage structure as the base yields a very similar equation.

$$\ln \overline{W_M} - \ln \overline{W_W} = \hat{\beta}_F (\overline{X}_M - \overline{X}_F) + (\hat{\beta}_M - \hat{\beta}_F)\overline{X}_M \tag{3.4}$$

In both equations, the first component is interpreted to indicate the explained part of the wage differential due to the differences in average endowment between groups. The second component is the unexplained residuals due to differences in returns to the endowments or intercepts between groups.

Because the two forms of equations yield different results, various forms of the weighting matrix has been proposed to find the coefficient $\hat{\beta}^*$, which would be observed in the absence of discrimination (Cotton 1988; Neumark 1988). The decomposition equation would now look like this,

$$\ln \overline{W_M} - \ln \overline{W_W} = \hat{\beta}^* (\overline{X}_M - \overline{X}_F) + (\hat{\beta}_M - \hat{\beta}^*)\overline{X}_M + (\hat{\beta}^* - \hat{\beta}_F)\overline{X}_F \tag{3.5}$$

where $\hat{\beta}^* = [\hat{\beta}_M D + \hat{\beta}_F (I - D)]$ and D is the weighting matrix. The weighting matrix, attributable to Oaxaca and Ransom (1994), implemented here looks like this,

$$D = \left(X'X\right)^{-1} X_M' X_M \tag{3.6}$$

where X_M is the vector of men's observations only.

Data Source

Information used to estimate body composition is increasingly available in health surveys collected by government agencies such as NIH and CDC. Unfortunately, health surveys generally lack detailed information on socioeconomic variables. On the other hand, economic surveys usually do not collect information on body composition. As proposed earlier in Chapter 2, this lack of a single source of data is addressed here by exporting body composition information from a health survey to an economic survey. The information is exported in three steps. First, the information on fat-free mass (FFM) is obtained from the NHANES III, which is a national health survey containing detailed anthropometric information on a representative sample of the U.S. working population. Second, FFM in the NHANES III sample is regressed on age, height, weight, their various powers, and various interactions between them in order to obtain the translating coefficients. In order to improve predictive accuracy, the regressions are conducted by the six gender- and ethnic-groups consisting of white men, white women, black men, black women, Hispanic men, and Hispanic women. Third, the translating coefficients and their specifications from the NHAHES III are applied to the individuals in the NLSY 79. The constructed FFM are calculated for each individual using the coefficients for his or her gender and ethnicity. Body fat (BF) can then be calculated as the difference between body weight and FFM. For details, see Chapter 2.

Table 7 contains descriptive statistics, including the constructed FFM and BF. Table 7 tells us that the average FFM are 45 and 64 kilograms for women and men respectively. Thus, the gender gap in FFM between women and men is about 70 percent.[53] The 70 percent ratio in FFM is quite close to the strength ratio of 66 percent reported by the ergonomics literature (see Astrand and Rodahl 1986, p.341-46; Chaffin, Andersson, and Martin 1999, p.119-25; Miller et al. 1993). In contrast, the average BF is almost the same for women and men at 19.1 and 18.7 kilograms. Still using men as the base, the gender gap in BF is about 102 percent, which means that the average woman possesses slightly more BF than the average man.

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[53] 45 kilograms divided by 65 kilograms.

Table 7

Descriptive Statistics (Mean and Standard Error) of NLSY 1979, Pooled Cross-Section, including the Estimated BMI and BF

Variable	Units	White Men	Black Men	Hispanic Men	White Women	Black Women	Hispanic Women
Log Hourly wage	Log of cents per	6.91	6.66	6.82	6.67	6.52	6.62
		(0.63)	(0.57)	(0.62)	(0.62)	(0.57)	(0.61)
Height	Meters (m)	1.79	1.78	1.74	1.64	1.63	1.60
		(0.07)	(0.08)	(0.07)	(0.07)	(0.07)	(0.07)
Weight	Kilograms (kg)	82.59	81.97	80.36	64.25	70.89	64.05
		(14.77)	(15.12)	(15.81)	(14.17)	(16.54)	(13.89)
BMI	m/kg^2	25.60	25.84	26.60	23.80	26.60	25.08
		(4.11)	(4.36)	(4.7)	(5.01)	(6.08)	(5.22)
Constructed BF	Body Fat kg	18.77	16.77	19.42	19.08	22.49	20.99
		(6.9)	(6.79)	(7.53)	(9.28)	(10.72)	(9.08)
Constructed FFM	Fat Free Mass kg	63.82	65.20	60.95	45.17	48.40	43.06
		(8.10)	(8.64)	(8.58)	(5.19)	(6.17)	(5.05)
Married	1 if Married	0.53	0.36	0.52	0.60	0.41	0.58
		(0.50)	(0.48)	(0.5)	(0.49)	(0.49)	(0.49)
Education	Years	13.18	12.45	12.11	13.34	13.03	12.51
		(2.40)	(2.05)	(2.44)	(2.20)	(1.93)	(2.42)
Age	Years	29.31	29.16	28.98	29.44	29.81	29.32
		(6.00)	(5.88)	(5.94)	(6.05)	(5.87)	(6.08)
Tenure	Weeks	201.95	150.91	179.63	172.07	167.01	167.78
		(221.2)	(184.7)	(206.5)	(197.0)	(200.5)	(193.0)
Experience	Weeks	451.74	380.46	420.99	412.60	352.82	371.20
		(251.2)	(235.9)	(245.3)	(239.1)	(236.1)	(239.8)
Urban	1 if urban	0.74	0.83	0.92	0.74	0.84	0.92
		(0.44)	(0.38)	(0.26)	(0.44)	(0.37)	(0.27)
Northeast	1 if Northeast	0.19	0.15	0.14	0.19	0.14	0.14
		(0.39)	(0.36)	(0.35)	(0.39)	(0.35)	(0.34)
West	1 if West	0.17	0.07	0.51	0.17	0.07	0.47
		(0.37)	(0.26)	(0.50)	(0.37)	(0.25)	(0.50)
Midwest	1 if Midwest	0.36	0.18	0.06	0.32	0.17	0.08
		(0.48)	(0.38)	(0.24)	(0.47)	(0.38)	(0.27)
Observations		18318	9524	6333	17724	9514	5697

Table 8 shows the ratio between the two genders stratified by the three ethnic groups. On average women are 8 percent shorter than men. However, we can see that black women possess much more BF than black men, while white women and Hispanic women only possess slightly more BF. Such drastic differences are not discernable by examining BMI. All three ethnicities of women have slightly more years of education than their gender counterparts.

The gender differences in FFM and BF are evident when their distributions are graphed. Figures 9-10 depict the gender distributions of FFM and BF. From Figure 9, it is clear that the major difference in body composition between women and men is the higher amount of FFM that men possess. Men's distribution of FFM is also wider. In Figure 10, the distributions of BF for women and men are almost identical. Thus, the physical difference in body composition is driven primarily by the gender differences in FFM. Contrary to popular notion, women do not possess far more body fat than men. According to our data, women appear to have much greater body fatness by possessing 30 percent less FFM than men, which in turn makes their bodies comparatively less dense and relatively high in body fatness.

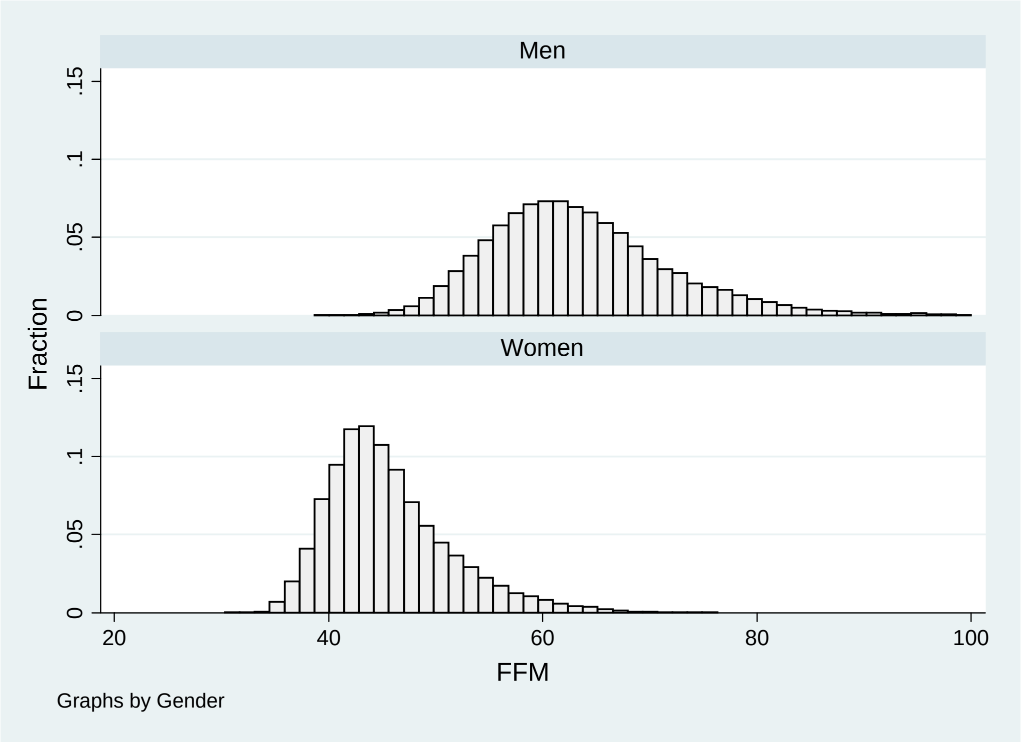
Table 8

Ratios between Genders by Ethnic Groups

Variable	Units	Whites	Blacks	Hispanics
Hourly wage	Dollar per hour	0.79	0.87	0.82
Height	Meters (m)	0.92	0.92	0.92
Weight	Kilograms (kg)	0.78	0.86	0.80
BMI	m/kg^2	0.93	1.03	0.94
Estimated BF	Body Fat kg	1.02	1.34	1.08
Estimated FFM	Fat Free Mass kg	0.71	0.74	0.71
Education	Years	1.01	1.05	1.03

Figure 9

Distribution of FFM by Genders



Basic Results

The decomposition results are presented separately for whites, blacks, and Hispanics in Tables 9-11. The gender gap in wages is 0.246 for whites, 0.137 for blacks, and 0.198 for Hispanics. At the top of each table, traditional specifications for gender decompositions are replicated. The traditional human capital variables explain only 17 percent of the gender gap.[54] In contrast, a parsimonious specification using only a set of indicator variables for nine occupations and 12 industries manages to explain 41 percent of the gender gap. If we combine occupations and industries with the traditional human capital variables, approximately 59 percent of the gender gap can be explained.

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[54] There are other studies that manage to squeeze out a higher yield through more extensive inclusions of variables.

Therefore, differences in occupations and industries account for a sizable portion of the gender gap, while almost half of the gender gap is left unexplained. These results are consistent with past studies that focused on the role of occupational segregation in the gender wage gap (see e.g., Bayard et al. 2003; Oaxaca 1973; Treiman and Hartmann 1981).

Figure 10

Distribution of BF by Genders

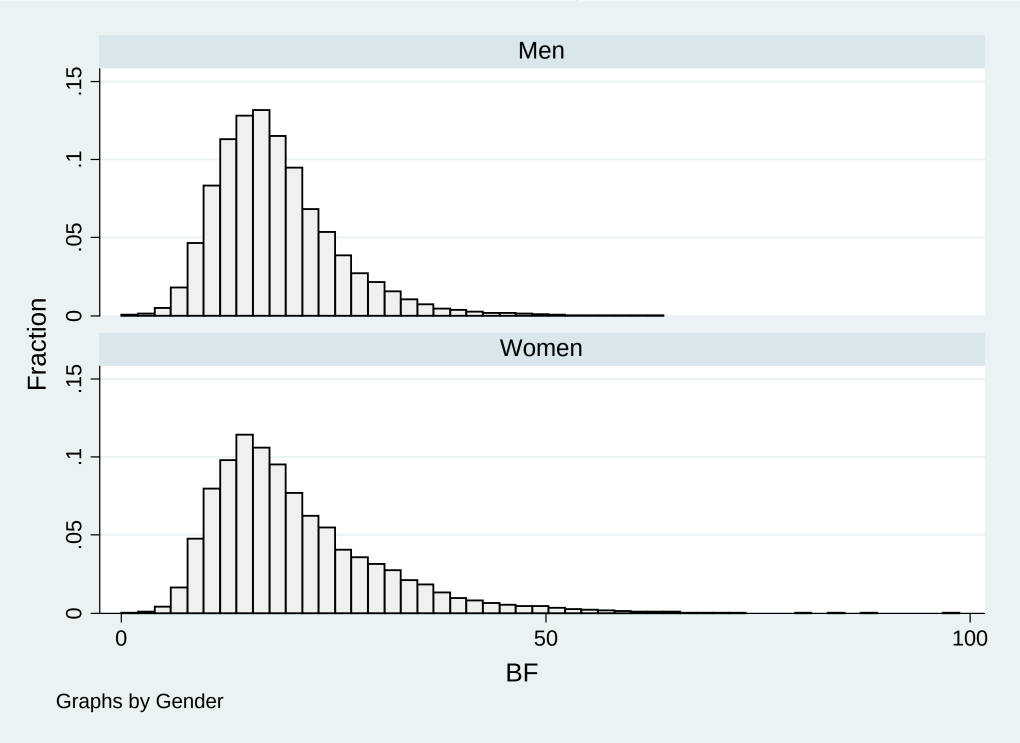

Table 9

Gender Decomposition for Whites with the Gender Gap of 0.246

Variables	Raw Explained	Raw Unexplained	Percent Explained	Percent Unexplained
Traditional Controls*	0.042	0.205	0.17	0.83
9 Occupations and 12 Industries	0.101	0.145	0.41	0.59
Trad Controls, 9 Occ, and 12 Ind	0.144	0.102	0.59	0.41
Anthropometric only:				
Height	0.183	0.063	0.74	0.26
Weight	0.107	0.140	0.43	0.57
Height, Weight	0.19	0.057	0.77	0.23
BMI, BMI-Sq	0.053	0.193	0.22	0.78
FFM, BF	0.255	-0.009	1.04	-0.04
FFM, BF, FFMxBF	0.263	-0.017	1.07	-0.07
With Traditional Controls Variables*				
Height	0.177	0.069	0.72	0.28
Weight	0.090	0.156	0.37	0.63
Height, Weight	0.174	0.072	0.71	0.29
BMI, BMI-Sq	0.06	0.187	0.24	0.76
FFM, BF	0.243	0.003	0.99	0.01
FFM, BF, FFMxBF	0.248	-0.002	1.01	-0.01
With 9 Occupations and 12 Industries:				
Height	0.195	0.051	0.79	0.21
Weight	0.153	0.093	0.62	0.38
Height, Weight	0.200	0.047	0.81	0.19
BMI, BMI-Sq	0.127	0.12	0.52	0.49
FFM, BF	0.249	-0.003	1.01	-0.01
FFM, BF, FFMxBF	0.255	-0.009	1.04	-0.04
With Traditional Control Variables*, 9 Occ and 12 Industries:				
Height	0.208	0.038	0.85	0.15
Weight	0.161	0.085	0.65	0.35
Height, Weight	0.205	0.041	0.83	0.17
BMI, BMI-Sq	0.15	0.096	0.61	0.39
FFM, BF	0.247	-0.001	1.00	0.00
FFM, BF, FFMxBF	0.251	-0.005	1.02	-0.02

* Traditional controls include marital status, years of education, education-squared, age in years, age-squared, tenure in weeks, tenure-squared, work experience in years, experience-squared, dummies for unemployment rates as very high, high, and medium (low excluded), and region dummies for Northeast, West, and Midwest (South excluded).

Table 10

Gender Decomposition for Blacks with the Gender Gap of 0.137

Variables	Raw Explained	Raw Unexplained	Percent Explained	Percent Unexplained
Traditional Controls*	-0.009	0.146	-0.07	1.07
9 Occupations and 12 Industries	0.028	0.107	0.20	0.78
Trad Controls, 9 Occ, and 12 Ind	0.057	0.078	0.42	0.57
Anthropometric only:				
Height	0.106	0.031	0.77	0.23
Weight	0.054	0.083	0.39	0.61
Height, Weight	0.108	0.029	0.79	0.21
BMI, BMI-Sq	0.012	0.125	0.09	0.91
FFM, BF	0.157	-0.020	1.15	-0.15
FFM, BF, FFMxBF	0.159	-0.022	1.16	-0.16
With Traditional Controls Variables*				
Height	0.081	0.056	0.59	0.41
Weight	0.012	0.125	0.09	0.91
Height, Weight	0.081	0.056	0.59	0.41
BMI, BMI-Sq	0.000	0.137	0.00	1.00
FFM, BF	0.136	0.001	0.99	0.01
FFM, BF, FFMxBF	0.137	0.000	1.00	0.00
With 9 Occupations and 12 Industries:				
Height	0.091	0.044	0.66	0.32
Weight	0.056	0.078	0.41	0.57
Height, Weight	0.091	0.043	0.66	0.31
BMI, BMI-Sq	0.033	0.101	0.24	0.74
FFM, BF	0.137	-0.002	1.00	-0.01
FFM, BF, FFMxBF	0.139	-0.005	1.01	-0.04
With Traditional Control Variables*, 9 Occ and 12 Industries:				
Height	0.102	0.033	0.74	0.24
Weight	0.066	0.069	0.48	0.50
Height, Weight	0.101	0.033	0.74	0.24
BMI, BMI-Sq	0.061	0.073	0.45	0.53
FFM, BF	0.134	0.000	0.98	0.00
FFM, BF, FFMxBF	0.135	-0.001	0.99	-0.01

* Traditional controls include marital status, years of education, age in years, tenure in years, work experience in years, dummies for unemployment rates as very high, high, and medium (low excluded), and region dummies for Northeast, West, and Midwest (South excluded).

Table 11

Gender Decomposition for Hispanics with the Gender Gap of 0.197

Variables	Raw Explained	Raw Unexplained	Percent Explained	Percent Unexplained
Traditional Controls*	0.045	0.153	0.23	0.78
9 Occupations and 12 Industries	0.074	0.123	0.38	0.62
Trad Controls, 9 Occ, and 12 Ind	0.127	0.07	0.64	0.36
Anthropometric only:				
Height	0.155	0.043	0.79	0.22
Weight	0.075	0.123	0.38	0.62
Height, Weight	0.159	0.039	0.81	0.20
BMI, BMI-Sq	0.023	0.175	0.12	0.89
FFM, BF	0.211	-0.013	1.07	-0.07
FFM, BF, FFMxBF	0.217	-0.019	1.10	-0.10
With Traditional Controls Variables*				
Height	0.142	0.056	0.72	0.28
Weight	0.066	0.132	0.34	0.67
Height, Weight	0.137	0.061	0.70	0.31
BMI, BMI-Sq	0.046	0.152	0.23	0.77
FFM, BF	0.195	0.003	0.99	0.02
FFM, BF, FFMxBF	0.198	-0.001	1.01	-0.01
With 9 Occupations and 12 Industries:				
Height	0.154	0.043	0.78	0.22
Weight	0.108	0.089	0.55	0.45
Height, Weight	0.156	0.041	0.79	0.21
BMI, BMI-Sq	0.084	0.113	0.43	0.57
FFM, BF	0.201	-0.005	1.02	-0.03
FFM, BF, FFMxBF	0.206	-0.009	1.05	-0.05
With Traditional Control Variables*, 9 Occ and 12 Industries:				
Height	0.172	0.025	0.87	0.13
Weight	0.129	0.068	0.65	0.35
Height, Weight	0.167	0.029	0.85	0.15
BMI, BMI-Sq	0.125	0.072	0.63	0.37
FFM, BF	0.200	-0.003	1.02	-0.02
FFM, BF, FFMxBF	0.202	-0.005	1.03	-0.03

* Traditional controls include marital status, years of education, education-squared, age in years, age-squared, tenure in weeks, tenure-squared, work experience in years, experience-squared, dummies for unemployment rates as very high, high, and medium (excluded: low unemployment rates), and region dummies for Northeast, West, and Midwest (South excluded).

The middle panels of Tables 9-11 display parsimoniously specified anthropometric specifications. The anthropometric specifications compare very favorably against the traditional human capital specifications. Height alone explains about 74 percent of the observed gender gap for whites. Weight alone explains about 43 percent. The superior result using height compared to those using weight are expected since height is a relatively clean indicator of musculoskeletal development. Weight is a more questionable indicator due to its confusion between musculoskeletal development and obesity. The combination of height and weight does not explain much more than height alone. Body mass index (BMI) and its square term explain only 22 percent of the gender gap. This is not unexpected, since BMI indicates obesity with a considerable degree of error, and the error is strongly correlated with gender (see Chapters 1 and 2). Most notably, FFM and BF together explain 104 percent by themselves or 107 percent when combined with the interactions term. This “over-explanation” is likely due to the omission of other productivity-enhancing variables such as schooling and experience from the specification. We see in the enhanced specification using both anthropometric and traditional human capital variables that the phenomenon of “over-explanation” largely disappears. About 99-101 percent of the gap can be explained by such a combined specification. We see that further adding the binary indicators for occupations and industries will result in negligibly small improvements over anthropometric variables alone. Since the specifications without the anthropometric variables perform significantly worse, it is clear that much of the explanatory power comes from the anthropometric variables when they are all combined with the traditional human capital variables.[55]

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[55] Although an ordered probit analysis shows an effect of body composition on the occupational strength requirement

A suspicion arises that these results are too good to be true. Perhaps the anthropometric variables are acting as proxies for the genders. However, the evidence from ergonomics literature (see earlier discussion) suggests that anthropometric variables, especially body compositions, are gender-neutral predictors of physical performance. In fact, the evidence implies the opposite: the inclusion of the gender variable in the regression makes the gender variable act as a proxy for physical performance in absence of anthropometric variables. Thus, it is not completely surprising that the addition of body composition information to the traditionally specified human capital specification would significantly improve its explanatory power. Furthermore, anthropometric variables explain wage differentials within each gender as well as between the genders. Taller women earn more than shorter women; obese women earn less than slimmer women. Such results are gender-neutral, and it would be inconsistent to argue that the same anthropometric variables that can explain the within-gender wage differential cannot be used to explain the between-gender wage differentials.

To further test this point, the data set has been merged with the *4th Dictionary of Occupational Statistics* using the three-digit CPS descriptions of occupation, three-digit CPS descriptions of industries, and years of education. Such merging provides more accurate measures by matching using smaller “cells.” When no match was found, education was dropped from the criteria. For further unmatched observations, a merging was done using the first two digits of occupation and industry descriptions only. The three-step merging finds about 25-30 percent matched samples at each step. About 85 percent of the NLSY sample is ultimately matched with DOT characteristics.

The DOT characteristics of physical strength range from one to five (very light to very heavy). We would expect the traditional human capital variables to have higher explanatory power in non-physical occupations characterized by light physical strength characteristics. We would also expect the body composition information to have higher explanatory power in physical occupations characterized by heavy physical strength characteristics.

The results are posted in Table 12. For whites, it is clear that the explanatory power of the traditional specifications including education, experience, age, tenure, and indicators for occupations and industries is highest in very light physical strength occupations at about 50 percent. The explained portion declines to 16 percent in very heavy physical strength occupations. The augmented specification using body composition shows that it explains 94 to 100 percent of the gender gap in wages for whites. This means that the augmented specifications containing the body composition automatically pick up what has been left unexplained by the traditional control variables. This means that the body composition picks up the unexplained portions left by the traditional models. The amount explained by the body composition information is the least among the very light physical strength occupations and the highest among the very heavy physical strength occupations.

The results for blacks and Hispanics are slightly noisier, but similar to those for whites.

Table 12

Decomposition Stratified Strengths Requirements*

DOT Strengths	Specifications	Raw Total	Raw Explained	Raw Unexplained	Percent Explained	Percent Unexplained
WHITES						
Very light	Traditional only*	0.445	0.221	0.223	0.50	0.50
Light	Traditional only	0.452	0.150	0.302	0.33	0.67
Moderate	Traditional only	0.200	0.036	0.163	0.18	0.82
Heavy	Traditional only	0.304	0.054	0.250	0.18	0.82
Very Heavy	Traditional only	0.355	0.058	0.298	0.16	0.84
Very light	Augmented**	0.445	0.443	0.001	1.00	0.00
Light	Augmented	0.452	0.444	0.008	0.98	0.02
Moderate	Augmented	0.200	0.205	-0.005	1.03	-0.03
Heavy	Augmented	0.304	0.286	0.017	0.94	0.06
Very Heavy	Augmented	0.355	0.352	0.003	0.99	0.01
BLACKS						
Very light	Traditional only	0.334	0.159	0.175	0.48	0.52
Light	Traditional only	0.284	0.078	0.206	0.27	0.73
Moderate	Traditional only	0.166	0.025	0.141	0.15	0.85
Heavy	Traditional only	0.171	0.045	0.126	0.26	0.74
Very Heavy	Traditional only	0.378	0.057	0.321	0.15	0.85
Very light	Augmented	0.334	0.334	0.000	1.00	0.00
Light	Augmented	0.284	0.279	0.005	0.98	0.02
Moderate	Augmented	0.166	0.163	0.003	0.98	0.02
Heavy	Augmented	0.171	0.18	-0.009	1.05	-0.05
Very Heavy	Augmented	0.378	0.335	0.043	0.89	0.11
HISPANIC						
Very light	Traditional only	0.246	0.192	0.054	0.78	0.22
Light	Traditional only	0.355	0.135	0.220	0.38	0.62
Moderate	Traditional only	0.294	0.094	0.200	0.32	0.68
Heavy	Traditional only	0.343	0.125	0.217	0.36	0.63
Very Heavy	Traditional only	0.523	0.254	0.269	0.49	0.51
Very light	Augmented	0.246	0.260	-0.014	1.06	-0.06
Light	Augmented	0.355	0.336	0.018	0.95	0.05
Moderate	Augmented	0.294	0.301	-0.006	1.02	-0.02
Heavy	Augmented	0.343	0.337	0.005	0.98	0.01
Very Heavy	Augmented	0.523	0.452	0.071	0.86	0.14

* Traditional controls include marital status, years of education, education-squared, age in years, age-squared, tenure in weeks, tenure-squared, work experience in years, experience-squared, dummies for unemployment rates as very high, high, and medium (low excluded), and region dummies for Northeast, West, and Midwest (South excluded).

** Augmented specification includes FFM, FFM x BF, and BF, in addition to the traditional controls described above.

Reverse Causality and Pre-Market Factors

A particular concern when estimating wage decomposition is the possibility of reverse causality. It is possible that wages influence body weight and composition instead of the other way around. One way to deal with such bias is to use pre-market measurements (Neal 2004). In this respect, height is a pre-market factor. Since most of adult height is reached by the end of one's teenage years, we can interpret our result using height as the estimate of the gender gap attributable to physical development prior to entering the labor market. At the cost of efficiency, potential biases are largely eliminated when height is used instead of body composition in the specification. The largely robust results obtained by using height indicate that body composition is strongly associated with the gender gap, regardless of the potential presence of reverse causality.

Discussion

The purpose of this chapter was to investigate the role of physical factors as measured by body composition in giving rise to the gender gap in wages.

The use of anthropometry in economics is not new. In development economics, human stature is treated as an investment in human capital (Schultz 2002). Economic historians also use physical stature to capture the nutritional standard of living during a particular period (Steckel 1995). Labor and health economists widely agree that body size affects the labor market outcome (see e.g., Averett and Korenman 1996; Cawley 2004; Pagan and Davila 1997; Register and Williams 1990).

The physical difference between women and men is a neglected area of research in the gender gap literature. Previous discussions of pre-market factors for the gender gap focused exclusively on preference and discrimination, to the exclusion of physical factors.[56] Given the known sensitivity of residual discrimination to misspecification, the omission of physical strength differences will likely contaminate the estimation result.

Although physical factors have not been previously integrated into the research, its neglect is unwarranted. Various researchers suspect the gender differences in strength to be one of the many causes for the existence of the gender gap in wages (see e.g., Goldin 1990, p.7, 104; Welch 2000). Notable economists and philosophers such as Adam Smith, Nicolas de Condorcet, and John Stuart Mill have speculated that gender equality may be brought about by the declining importance of physical strength in association with economic development (Dimand, Forget, and Nyland 2004).

The physical explanation for the gender gap can be viewed as a subset of the human capital explanation. Physical performance is easily observed or estimated by employers, even if they remain unobserved by researchers. Unlike the standard human capital explanation, however, the physical theory allows fundamental differences to exist between the genders. For women, this means an increased degree of difficulty in the development of their musculature. Such physical differences between women and men exist regardless of the levels of economic development. Schooling and cultural sentiments may change across continents, but the physical differences remain constant. A relatively stable gender gap in wages can emerge and give rise to the Leviticus ratio.

The Leviticus ratio would no longer hold constant if production technology had changed substantially. A number of researchers have attributed the narrowing of the

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[56] Lazear (1991a) and Polachek (1978), for example, only consider discrimination (in which women are prevented from gainfully working) and innate differences in preferences (in which women do not want to work) for possible sources of the gender differences in expectations. Reskin and Hartmann (Reskin and Hartmann 1986, p 41) serve as an exception by addressing the theoretical possibility of “innate differences” between sexes.

gender gap during the 1980s to the increasingly important role of technology in the workplace. Recent technological changes have favored white-collar workers (Berman, Bound, and Griliches 1994), and increasing computerization has deemphasized the role of physical strength on the job (Weinberg 2000). Using Canadian data, Baker, et al (1995) find that most of the wage convergence occurred in the unexplained component. Such technological changes may have favored women over men. Indeed, one puzzle has been the narrowing of the gender gap even as the overall wage inequality was increasing (Blau and Kahn 2000). This outcome is unexpected since women generally receive lower wages and work in lower-wage occupations. Blau and Kahn (2000) speculate that it may have occurred due to a rise in the unmeasured skills of women, a decline in labor market discrimination, or the technological shift that harmed blue-collar workers, who are mostly men. The whittling away of the strength premium would increase overall inequality by hurting blue-collar workers but would reduce gender inequality by hurting men more than women.[57] Consistent with this view, O'Neill and Polachek (1993) report that approximately 22 percent of the improvement in the gender gap can be attributed to declining wages in blue-collar occupations, which are predominantly held by men. Similar sentiments have been expressed by Galor and Weil (1996).

The speed of change in the gender gap would depend on the degree of technological upheaval. The reported slowdown in the narrowing of the gender gap in the 1990s and 2000s might be attributed to the slowing down of technological changes. While up to half of the narrowing of the gender gap has been attributed to the rise in women's schooling and work experience (see O'Neill 1985; O'Neill and Polachek 1993),

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[57] Krueger (1993) reports that women's computer usage has increased more rapidly than that of men's and that approximately half of the rise in women's wages appears to be associated with computer usage at work.

a spurious result may be reported if the concurrent increase in women's experience and rapid changes in technology took place and only one of the two elements was controlled for in a study. Indeed, the narrowing of the gender gap slowed down during the 1990s, even as women's schooling and work experience continued to improve (Blau and Kahn 2004).

Conclusion

One of the enduring questions in the gender literature concerns the lower wages earned by women. An intuitively attractive approach is to see it as a problem of anticipated differences in market participation. The purely human capital approach, however, has been criticized due to its inability to explain a large portion of the gender gap without resorting to aggressive inclusions of explanatory variables.

One unabashed alternative explanation for the gender gap is that women are smaller and lack men's physical strength. The gender differences in physical strength have been previously mentioned but never investigated extensively by economists.

This paper develops and presents a parsimonious model using tractable measures of physical endowments previously unaddressed in the literature. The gender difference in physical endowments is obvious in sports, and it should be obvious in the labor market as well. The average woman may earn less than the average man in occupations with heavy physical strength requirements.

The policy implications of the findings presented here are depends on interpretation of the evidence. If we value the opportunity of participation, then no further intervention is necessary in the labor market. This does not mean that the current level of policy intervention is not necessary. It is quite possible that women may be suffering from obesity discrimination instead of gender discrimination. The findings also does not show that past policy intervention was not necessary in order to bring out the efficient equilibrium during the tumultuous time during the 20th century when women's labor market participation increased rapidly. The evidence presented here merely suggests that neither gender appears to earn unexplained differentials compared to the other gender.

While technological change is not the primary focus of this paper, it is beginning to be recognized that a silent benefactor for gender equality has been technology. The evidence presented here supports the notion that technological change may have been responsible for bringing about the gradual narrowing of the gender gap in wages. Given three parallel gender gaps in wages, strength, and body composition, it would take strength-obviating technology to narrow the gender gap in wages. Strength-augmenting technology would not do, since it would only increase the returns to strength.[58] This interesting possibility is left for the future research.

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[58] Industrial and information technologies may be defined in terms of their complimentarity with physical strength.

Chapter 4

Summary Conclusion

One of the perennial problems facing health researchers is the measurement of health. While the concept of health capital has been accepted as a form of investment similar to human capital, there is no widely accepted proxy for measuring health capital. In comparison, human capital is commonly measured using years of schooling. Various strategies adopted for measuring health have yielded conflicting results. The inconsistency sometimes results from using negative proxies that measure disabilities rather than health itself. Studies based on disabilities might not be comparable to steady-state outcomes in which normal levels of health are maintained.

A surrogate for health does not need to be perfect. Although years of schooling do not address quality or atrophy of human capital investment, years of schooling have been used effectively as a proxy for human capital, and the empirical studies using years of schooling have achieved wide ranging success at estimating returns to human capital investment (Grossman et al. 1997). An acceptable proxy for health capital should be an extant measure that is closely associated with capital endowments of health rather than with disability, which is the lack of health.

This dissertation has proposed to use body composition as a surrogate for measuring health, especially for studying obesity and physical fitness. Although it represents only one measure of heath, body composition provides a meaningful measure by providing a positive, physically justified measure of health capital. While it is true that body composition measures health inputs rather than health itself, so do years of schooling measure human capital by serving as educational inputs rather than human capital itself. If health is defined as the capacity for living and not merely the lack of sickness or disease, then differential amounts of body components can effectively represent the physical capacity to work and live without undue limits. Body composition also appears to be correlated with many other diseases and physical conditions that can impact health and work productivity.

A singular contribution of the concept of body composition is that not all types of growth are healthy or desirable. It is not only the lack of health that may adversely affect physical performance but also the presence of harmful body components. A major body component plainly distinguishable from the rest of body in its harmful effect is body fat. Body fat is the component strongly associated with the ill effects of obesity. While a small amount of body fat is essential for physiological functioning, body fat imposes predominantly adverse effects on health and work performance. In contrast, lean body mass is metabolically active and provides a foundation for physical functions such as eating, working, and fighting off disease.

The relevance of body composition to modeling health is an empirical question. Chapter 2 implements a method for translating commonly available anthropometric variables present in an economic survey into useful measures of body composition information. The translated body composition information is then used to test the double hypotheses regarding the combined but opposite effects of lean body mass and body fat. The results show that the marginal effect of lean body mass on hourly wage is positive, while the marginal effect of body fat on hourly wage is negative. The result holds for all six gender-ethnic/racial groups. Chapter 2 also explains the mixed results reported by previous studies using body mass index as a result of an index number problem in which the positive effects of lean body mass and the negative effects of body fat were confused within a single index in BMI. For the average man, the incremental gains in his body weight or body mass index are at first dominated by lean body mass, until eventually the trend reverses itself and an increasing amount of body fat is contained in each additional body mass. However, the average woman’s body always gains more body fat than lean body mass. Hence, the estimated returns using BMI have been non-monotonic for men and monotonic and linear for women.

The constructed estimates of body composition are next applied towards studying the gender gap in wages in Chapter 3. One of the main suspected causes for the existence of the gender differential in wages has been gender differences in physical performance. To our knowledge, no prior study has tested this claim using individual level data. Body composition is an ideal method for reducing variations in physical work performance, because work performance is a direct function of physical endowments. Excessive body fat reduces physical performance during physical activities involving translocation of body mass. Physical activities involving the application of muscular force are a direct function of musculoskeletal mass. Lean body mass is an ideal proxy for strength because up to 67 percent of men’s lean body mass and 56 percent of women’s lean body mass is composed of muscle tissue [59] The empirical results from Chapter 3 suggest that almost all gender residuals, after controlling for age, education, and experience, can be attributed to the gender differences in body composition. This stark conclusion has been further supported by the stratification of the estimation by physical strength requirements. The stratification study shows that traditional human capital measures such as years of

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[59] The information is from McArdle, Katch et al. (1996, p.601).

schooling and work experience have more explanatory power in job categories associated with very little physical demand, while the translated body composition measures have more explanatory power in job categories involving heavier physical demand. This result is consistent with the view that the remaining gender gap in pay, after controlling for the traditional measures of productivity, can be attributed to the gender differences in physical performance associated with the gender differences in body composition.

It is important to note that the conclusions reached in this dissertation are limited in a number of important ways. First, the construction of body composition information in an economic survey using the translating coefficients from a health survey is dependent on the comparability between the two surveys. The ethnic category of Hispanic, for example, could differ considerably between the two surveys due to a lack of geographical overlap in the surveys. Second, body composition information gleaned from a health survey relies on the validity of predicting equations developed by health researchers under clinical settings. While the reliabilities of such methods have been closely studied and vetted by verification studies, such calculations are dependent on a number of operating assumptions, such as the constant degree of hydration for lean body mass. Third, the two-compartment method of body composition presented here is the most popular method for conducting body composition analysis, but it is not the only one. Models using multiple components are possible, and there are other ways of partitioning the human body into component parts. This dissertation was limited to using the two-compartment method involving lean body mass and body fat by the available technology. Fourth, because body composition was estimated in the first stage, the standard errors of the estimated coefficients in the second stage tend to be underestimated.

The overall findings presented in this dissertation present a strong case that body composition can used to explain a number of previously unexplained anomalies in the studies of the modern labor market. Future studies might investigate the effect of body composition on labor market participation. It is important that future survey efforts be directed towards the inclusion of body composition information along with economic information in their coverage. Such coupling of body composition and economic information can be achieved rather inexpensively by health surveys that collect body composition information. A more involved solution would be for economic surveys to conduct field measurements using portable instruments designed for the gathering of body composition information.

This dissertation proposed to use body composition as a proxy for measuring health, especially related to the role of obesity and physical fitness in the labor market. In the preceding chapters, the usefulness of body composition has been theoretically established and empirically demonstrated. An incorporation of body composition into the wage equation apparently resolves the mixed results previously reported by studies using BMI. Perhaps more intriguingly, this dissertation has also demonstrated that body composition presents a useful method of controlling for unobserved worker attributes, especially in the context of the gender wage gap. Wage residuals currently left unexplained by traditional measures of human capital, such as education, can be attributed to worker differences in body composition. This is an important insight that confirms the role of labor demand in wage determination, meaning that returns to human capital investment is contingent on being suitably matched to occupational requirements.

The policy implications of the findings presented by this dissertation are wide-ranging and therefore would require careful consideration. A majority of government funded nutritional interventions are based on the premise that increasing body size and increased nutrient intake consistently improve health and worker earnings. The evidence presented in this dissertation suggests differently; an increased body size does not always improve health or worker earnings. A reorientation in the policy focus away from body size and towards body composition may be warranted. A public health policy that can successfully increase the average lean body mass and decrease the average body fat mass can help improve individual levels of health, physical fitness, and hourly earnings.

The policy implications of this dissertation for the gender gap in wages are more debatable and less clear cut than for public health. Women earn less hourly earnings than men. The unexplained wage differentials between the genders have been previously interpreted as a proof of gender discrimination. This dissertation has demonstrated that the previously unexplained wage differentials between the genders can be explained by the gender differences in body composition. The explanatory power of body composition with respect to the gender differences between the genders is the highest among physically strenuous occupations. These findings strongly suggest that the problems of the gender gap in wages may be more complex than previously thought. It may be that gender discrimination is actually a form of discrimination against obesity or physical limitations. It may simply be that women earn less than men in physically strenuous occupations. While any policy recommendation with respect to the gender differences in body composition would require additional studies, we can reasonably conclude that body composition is related to occupational requirements and there needs to be taken into consideration with respect to the gender differences in wages.

Appendix A1

Men Random effects with BMI

		(1)			(2)	
	White	**Black**	**Hispanic**	**White**	**Black**	**Hispanic**
BMI	-0.00195	0.00390**	-0.00518**	0.0400***	0.0146	0.0295**
	(0.0016)	(0.0018)	(0.0022)	(0.0090)	(0.011)	(0.015)
BMI Squared				-0.0007***	-0.000186	-0.0006**
				(0.00016)	(0.00019)	(0.00024)
Constant	5.690***	5.761***	6.342***	5.131***	5.619***	5.851***
	(0.081)	(0.10)	(0.11)	(0.14)	(0.17)	(0.23)
Observations	18318	9524	6333	18318	9524	6333
Number of id	2162	1257	806	2162	1257	806
Joint Test of Significance[1] (P-values)	(0.211)	(0.0340)	(0.0168)	(0.00001)	(0.0568)	(0.00126)
Marginal Effect[2] for BMI						
at Mean BMI – SD				0.00784	0.00656	0.00346
at Mean BMI				0.00171	0.00493	-0.00205
at Mean BMI + SD				-0.00443	0.00330	-0.00757

Also controlled for married, education, age, tenure, experience, education-squared, age-squared, tenure-squared, experience-squared, 4 unemployment rates, urban, 4 regions, 10 occupational and 13 industry categories, not shown

[1] Respective joint test for quadratic terms or interactions terms.

[2] Marginal effects evaluated at the mean and plus/minus one standard deviations (SD) for the quadratic terms and the interactions terms. See the text for a description.

Robust t statistics in parentheses, clustered around individuals

* p<0.10, ** p<0.05, *** p<0.01

Appendix A2

Men Random effects with Body Composition

	(3)			(4)		
	White	**Black**	**Hispanic**	**White**	**Black**	**Hispanic**
FFM	0.00974***	0.00444*	0.00945***	0.0132***	0.00499**	0.0121***
	(0.0028)	(0.0023)	(0.0033)	(0.0028)	(0.0024)	(0.0036)
BF	-0.0119***	-0.00184	-0.0122***	0.00492	0.00195	0.00133
	(0.0034)	(0.0030)	(0.0036)	(0.0056)	(0.0074)	(0.0087)
FFM x BF				-0.000217***	-0.000046	-0.000178*
				(0.000053)	(0.000079)	(0.00010)
Constant	5.293***	5.642***	5.937***	5.037***	5.596***	5.728***
	(0.13)	(0.14)	(0.15)	(0.13)	(0.15)	(0.19)
Observations	18318	9524	6333	18318	9524	6333
Number of id	2162	1257	806	2162	1257	806
Joint Test of Significance[1] (P-values)	(0.00175)	(0.00313)	(0.00297)	(0.0000)	(0.00595)	(0.00167)
at Mean BF – S.D.				0.0103	0.00444	0.00939
at Mean BF				0.00884	0.00414	0.00808
at Mean BF + SD				0.00739	0.00383	0.00678
Marginal Effect[2] for BF						
at Mean FFM – SD				-0.00690	-0.000590	-0.00747
at Mean FFM				-0.00872	-0.00100	-0.00907
at Mean FFM + SD				-0.0105	-0.00141	-0.0107

Also controlled for married, education, age, tenure, experience, education-squared, age-squared, tenure-squared, experience-squared, 4 unemployment rates, urban, 4 regions, 10 occupational and 13 industry categories, not shown

[1] Respective joint test for quadratic terms or interactions terms.

[2] Marginal effects evaluated at the mean and plus/minus one standard deviations (SD) for the quadratic terms and the interactions terms. See the text for a description.

Robust t statistics in parentheses, clustered around individuals

* p<0.10, ** p<0.05, *** p<0.01

Appendix A3

Women Random effects with BMI

		(1)			(2)	
	White	**Black**	**Hispanic**	**White**	**Black**	**Hispanic**
BMI	-0.0064***	-0.0036***	-0.0053***	-0.00878	0.0134**	-0.00529
	(0.0012)	(0.0013)	(0.0020)	(0.0065)	(0.0067)	(0.011)
BMI Squared				0.0000417	-0.00028**	-0.00000
				(0.00011)	(0.00011)	(0.00018)
Constant	5.798***	5.639***	5.977***	5.830***	5.402***	5.976***
	(0.072)	(0.096)	(0.11)	(0.11)	(0.13)	(0.19)
Observations	17724	9514	5697	17724	9514	5697
Number of id	2223	1300	810	2223	1300	810
Joint Test of Significance (p-values)	(0.00000)	(0.00450)	(0.00808)	(0.0000)	(0.00122)	(0.0302)
Marginal Effect[2] for BMI						
at Mean BMI – SD				-0.00720	0.00188	-0.00529
at Mean BMI				-0.00678	-0.00152	-0.00530
at Mean BMI + SD				-0.00636	-0.00493	-0.00530

Also controlled for married, education, age, tenure, experience, education-squared, age-squared, tenure-squared, experience-squared, 4 unemployment rates, urban, 4 regions, 10 occupational and 13 industry categories, not shown

[1] Respective joint test for quadratic terms or interactions terms.

[2] Marginal effects evaluated at the mean and plus/minus one standard deviations (SD) for the quadratic terms and the interactions terms. See the text for a description.

Robust t statistics in parentheses, clustered around individuals

* p<0.10, ** p<0.05, *** p<0.01

Appendix A4

Women Random effects with Body Composition

	(3)			(4)		
	White	**Black**	**Hispanic**	**White**	**Black**	**Hispanic**
FFM	0.0138***	0.00508*	0.00728	0.0136***	0.00673**	0.00633
	(0.0032)	(0.0030)	(0.0067)	(0.0033)	(0.0032)	(0.0064)
BF	-0.0106***	-0.0046**	-0.00698*	-0.0112***	0.00121	-0.0107
	(0.0018)	(0.0018)	(0.0039)	(0.0039)	(0.0049)	(0.0089)
FFM x BF				0.0000113	-0.000100	0.0000701
				(0.000064)	(0.000075)	(0.00013)
Constant	5.291***	5.432***	5.708***	5.303***	5.336***	5.760***
	(0.11)	(0.14)	(0.23)	(0.13)	(0.15)	(0.23)
Observations	17724	9514	5697	17724	9514	5697
Number of id	2223	1300	810	2223	1300	810
Joint Test of Significance (p-values)	(2.56e-10)	(0.00755)	(0.0129)	(1.39e-09)	(0.00509)	(0.0324)
Marginal Effect^2 for FFM						
at Mean BF – SD				0.0137	0.00532	0.00738
at Mean BF				0.0138	0.00426	0.00800
at Mean BF + SD				0.0139	0.00320	0.00863
Marginal Effect^2 for BF						
At Mean FFM – SD				-0.0108	-0.00286	-0.00824
at Mean FFM				-0.0107	-0.00351	-0.00786
at Mean FFM + SD				-0.0106	-0.00416	-0.00747

Also controlled for married, education, age, tenure, experience, education-squared, age-squared, tenure-squared, experience-squared, 4 unemployment rates, urban, 4 regions, 10 occupational and 13 industry categories, not shown

[1] Respective joint test for quadratic terms or interactions terms.

[2] Marginal effects evaluated at the mean and plus/minus one standard deviations (SD) for the quadratic terms and the interactions terms. See the text for a description.

Robust t statistics in parentheses, clustered around individuals

* p<0.10, ** p<0.05, *** p<0.01

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VITA

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