U.S. Department of Health and Human Services
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EXAMINING THE RELATIONSHIPS BETWEEN EXCESS BODY WEIGHT, HEALTH AND DISABILITY

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ABSTRACT

The recent rise in the prevalence of obesity and overweight in the overall United States population has raised many concerns about the future. In addition to concerns about the medical costs of treating obesity-related illness, an apparent correlation between obesity and disability has led to concern that the recent declines in rates of disability among the elderly may cease or reverse. In this report, we explore the relationship between excess weight and obesity in a series of cross-sectional and longitudinal analyses in an attempt to evaluate these concerns. Using data from the 1998-2004 waves of the Health and Retirement Study (HRS), we find evidence that the risks of developing difficulties with activities of daily living (ADLs) does increase with the prevalence of obesity, but the effects appear to be less dramatic than the effects on the limitations in physical functioning, which can be precursors of ADL disability. Further, we find only a weak relationship between excess weight and the onset of difficulties with instrumental activities of daily living (IADLs).

EXECUTIVE SUMMARY

The recent rise in the prevalence of overweight and obesity in the United States has raised alarm over present and future impacts on public programs. Of most immediate concern is the effect on increased use of medical services to treat diseases related to excess body weight and fat. However, the apparent link between disability and obesity raises longer-run concerns about the use of long-term care services.

Given the rising rates of obesity at middle ages, it is possible that the declines we have observed in rates of late-life disability will not continue, and long-term care costs could increase. How much obesity will influence late-life disability rates, and the modifiable mechanisms through which obesity influences disability, are key questions. Yet, past projections of the effects of obesity trends on future disability trends have been based on a cross-sectional association between obesity and disability, and the causal pathways between these markers are not well understood. We approach these concerns by attempting to answer the following three research questions.

- What is the nature of the cross-sectional relationship between obesity and disability, as well as other health outcomes among the elderly?
- What is the nature of the dynamic relationship among obesity, disability, and other health outcomes in the elderly?
- If it is found that obesity is a significant independent determinant of health and disability status, what are the intervening mechanisms?

The most alarming findings in the literature focus on the relationship between obesity and work disability rather than on the types of disability (ADL and IADL) that have been declining in recent years and that are most relevant for aging and long-term care policy. In addition, most studies are based on cross-sectional analyses. The purpose of this study is to focus on measures of disability more relevant for elderly individuals and to examine whether cross-sectional associations arise because of actual increased risk of disability onset for those with overweight and obesity, or whether they are simply correlated outcomes without a causal link between them.

The data for this study come from the 1998-2004 waves of the HRS. To answer Question 1, we conducted cross-sectional analyses using pooled data from all of these waves. To address Question 2, we did several analyses using weight and health status in 1998 as predictors of changes in functional status between 1998 and 2004. We also examined changes in one set of measures between 1998 and 2000 as potential predictors of changes in other measures between 2000 and 2004. Finally, to explore potential clinical pathways, we conducted several analyses of the effects of excess weight interacted with specific profiles of chronic disease to determine which disease pathways were most relevant for the development of functional limitation and disability.

Relevant to the first research question, the cross-sectional analyses produced results consistent with other findings in the literature, namely of a strong relationship between obesity and functional limitations as well as ADL disability. The relationship between excess weight and lower body limitations is especially striking with significant limitation risks beginning at values of body mass index (BMI) below the obesity threshold. The correlation with IADL disability was much weaker, and shows that moderate excess weight is actually associated with lower disability prevalence. This finding suggests that as the cohorts with high rates of obesity age, we might expect an increase in the physical limitations that contribute to disability, but that the increase in the level of dependency requiring long-term care will be less dramatic. Further, since the overall trend in disability is most directly a result of downward trends in IADL disability, and IADL disability only appears to increase at extreme levels of obesity, the effect of trends in overweight and obesity on overall disability trends is likely to be modest.

The analyses framed by the second research question were less conclusive. Longitudinal analyses that use baseline weight as a predictor of disability onset generally confirm that among persons who are not already disabled, those who are obese are at greater risk of developing disabilities. Among those reporting disabilities at baseline, the probability of recovery of functioning is lower for those who are obese.

More stringent tests based on longitudinal analyses are less clear, however. We find no relationship between a change in weight and subsequent disability onset or recovery. While this may imply that weight loss interventions among the elderly and near-elderly would be ineffective in reducing future disability, a longer observation period should be studied before such a conclusion is reached. Second, the analyses we conducted to understand the relative timing of disability and excess weight did not produce a clear answer to the question of whether excess weight causes disability or vice versa.

Similarly, in analyzing the third research question, we are unable to find a significantly different pattern of disability onset associated with a particular disease pathway. While clinical evidence suggests differences in the effects of overweight by disease, observational studies like ours may require a longer follow-up period, or more reliable methods for measuring disease than are available in survey data to identify these differences.

Preliminary 2006 data were recently released, and next year the 2008 data from the HRS will be available, providing a ten year follow-up period. The longer time period will provide both a more meaningful estimate of longer-run implications of past obesity trends, but also allow a more complicated set of disability onset models using up to five repeated observations on which hazard models might be more reliably estimated. Any future improvements in the measurement of obesity (such as using actual measurement of height and weight instead of reliance on respondents’ self-reports, and using measures of obesity other than BMI) can also lead to improvements in examining the effects of obesity on disability as well as other health outcomes.

A. INTRODUCTION

The recent rise in the prevalence of overweight and obesity in the United States has raised alarm over present and future impacts on public programs. Of most immediate concern is the effect on increased use of medical services to treat diseases related to excess body weight and fat. The apparent link between disability and obesity raises longer-run concerns about reversals in trends in elderly disability and use of long-term care services. Past projections of the effects of obesity trends on future disability trends, however, have been based on a cross-sectional association between obesity and disability, but the causal pathways between these markers is not well understood.

Given the rising rates of obesity at middle ages, it is possible that the declines we have observed in rates of late-life disability will not continue. How much obesity will influence late-life disability rates, and the modifiable mechanisms through which obesity influences disability, are key questions. We approach these questions by attempting to answer the following three research questions.

1. What is the nature of the cross-sectional relationship between obesity and disability, as well as other health outcomes among the elderly? Are obesity and overweight independently associated with adverse or positive health outcomes?

2. What is the nature of the dynamic relationship among obesity, disability, and other health outcomes in the elderly? Do obesity and overweight at baseline independently predict improvements or declines in functional status and health? Do changes in weight alter the trajectories of disability and disease? Conversely, does the presence of disability reduce physical activity and contribute to weight gain leading to obesity?

3. If it is found that obesity is a significant independent determinant of health and disability status, what are the intervening mechanisms? For example, is it primarily the increase in specific diseases associated with obesity that leads to deterioration of function? Or is weight-for-height itself a physically disabling factor? Which diseases associated with obesity are most likely to be disabling? We will also examine variation by socio-economic and demographic factors such as gender, wealth and education.

B. LITERATURE REVIEW

Given the aging of a United States population with higher rates and an earlier onset of obesity than ever experienced (Alley & Chang, 2007), the relationship between obesity at middle ages and disability in later life has important public health and public policy implications. According to the most recent data, 66 percent of adult Americans are estimated to be overweight and 32 percent obese (Ogden, et al., 2006). Concurrently, rates of disability in the population have appeared to increase among younger Americans (Lakdawalla, Bhattacharya & Goldman, 2004), and there is some evidence of increased prevalence of physical limitations among elderly Americans (Kramarow, et al., 2007; Alley & Chang, 2007). Evidence suggests that the rise in obesity could result in higher rates of disability at older ages (Sturm, et al., 2004), lower life expectancy (Olshansky, et al., 2005), or increased years of disability in later life (Reynolds, Saito, & Crimmins, 2005). As an increasingly obese population ages, it is important to understand how this population may affect disability rates and health care needs in the future, and how focusing on modifiable risk factors for morbidity and disability at present may offset or delay disability and improve quality in later life.

1. Obesity

Body fat, or adipose tissue, serve as high-energy storage sites in the human body, and are necessary elements during increased metabolic demands. Obesity, on the other hand, is the accumulation of excess body fat, whereby a sizeable amount of adipose tissue goes untapped. At the most basic level, obesity results from the imbalance between energy intake and energy expenditure. This imbalance may be the result, individually or concomitantly, of excess caloric intake, decreased physical activity, metabolic disorders, and genetics (National Institutes of Health, 1998; Berg, 1993). Genetics are seen to influence whether an individual can become obese, while environment determines whether the individual actually does become obese, as well as the extent of the obesity (Meyer & Stunkard, 1993).

2. Measurement of Obesity

The most standard measure of obesity across scientific studies is the body mass index (BMI), calculated as weight (in kilograms) per height (in meters) squared. The National Heart, Lung, and Blood Institute issued the first federal guidelines on the evaluation and treatment of obesity (NIH, 1998) in which they defined overweight as a BMI of 25-29.9 kg/m^2, and obesity as a BMI of 30 kg/m^2 or greater. Within the obese category, further distinctions are made among: Class I obesity, BMI between 30 and 35; Class II obesity, BMI between 35 and 40; and Class III obesity, BMI exceeding 40. These guidelines are consistent with those adopted by the World Health Organization (2000) and have now become standard in the literature.

The use of BMI as a measure of body composition has met with some criticism (Blew, et al., 2002; Duerenberg, Yap & van Staveren, 1998; Gallagher, et al., 1996; Prentice & Jebb, 2001). Clinical and laboratory studies often employ more sophisticated measures of body composition and distribution, such as: measures of electrical impedance; underwater weighing; or circumference measures determining fat distribution via a waist to hip ratio. While these measures allow for a very detailed examination of body composition, they require specialized equipment and training to collect, and are not practical for large surveys. Notwithstanding, BMI has shown to be a relatively strong metric for body composition. Recent studies show that electrical impedance is not superior to BMI as a predictor of overall adiposity (Willett, et al., 2006) and in clinical samples, Ensrud and colleagues (1994) found the relationship between BMI and functioning to be stronger than that for waist to hip ratio and functioning.

3. Population Estimates of Body Size

The prevalence of overweight and obesity at all ages has increased dramatically in the United States over the last four decades. Based on comparisons of data from the 2003-2004 National Health and Nutrition Examination Survey (NHANES) with--using BMI indices for overweight and obese--the proportion of adult men (age 20 and older) who were overweight rose from 50 percent to 70 percent, and the proportion of women who were overweight rose from 40 percent to over 60 percent between 1960 and 2000 (Flegal, et al., 2002). There has been a slight change in obesity trends between the genders in recent years, however. Between 2000 and 2004, the percentage of men who were obese rose from 27.5 percent to 31.1 percent, but the proportion of women who were obese showed no significant increase, remaining static at about 33 percent over that time period (Ogden, et al., 2006).

4. Patterns of Obesity in the Population

The composition of the body and how fat is stored changes with age, and different metabolic and hormonal factors influence body fat accumulation throughout the life spectrum (Schwartz, 1995; Beaufrere & Morio, 2000). In cross-sectional studies, peak values of BMI are observed in the age range 50-59 in both men and women, with gradual declines in BMI after age 60 (Flegal, et al., 1998; Hedley, et al., 2004; Ogden, et al., 2006), although premature mortality of the obese may influence these cross-sectional relationships (Williamson, 1993). Rates of overweight and obesity in longitudinal studies generally increase with age until age 75, when there is a small drop (Ferraro, Thorpe & Wilkinson, 2003; Flegal, et al., 1998; Must & Strauss, 1999).

Men are more likely than women to be overweight, but women are more likely to be obese, especially with BMIs greater than 35 (Hedley, et al., 2004). Differences in overweight and obesity rates for women vary starkly by race and ethnicity but are not as apparent for men (Flegal, et al., 1998; Hedley, et al., 2004). According to the National Center for Health Statistics analysis of NHANES data (Hedley, et al., 2004), 77.5

percent of Black women are overweight, compared to 71.4 percent of Mexican women and 57 percent of White women. The prevalence of obesity is similarly skewed with the rates for Black, Mexican and White women at 49.6 percent, 38.9 percent and 31.3 percent, respectively. In fact, over 10 percent of middle-aged Black women have BMIs greater than 40 (Flegal, et al., 1998).

Social class appears to be related to body size in complex ways as well, with social class being both a cause and an effect of body size. Most evidence suggests the causality between socio-economic characteristics and poor health behaviors (poor diet, lack of exercise), which in turn lead to higher rates of overweight and obesity (Goldblatt, Moore & Stunkard, 1965; Stunkard & Sorenson, 1993). Other studies support that body size is a causal agent that leads to lower educational attainment and income through discrimination and lower self-esteem (Gortmaker, et al., 1993).

5. Relationship of Body Size to Mortality and Disease

It is well established that overweight and obesity are significantly related to higher rates of several chronic health conditions including diabetes, hypertension, high cholesterol, coronary heart disease, arthritis, and certain types of cancer (Mokdad, et al., 2003; Paul & Townsend, 1995; Wolf & Colditz, 1998; Villareal, et al., 2005; Flegal, et al., 2007). The relationship between obesity and mortality has been less definitive, but recent research has documented a stronger association than years past.

Recent Centers for Disease Control (CDC) studies on the obesity-mortality link found that obese persons had higher relative risks of death across all age groups (25 years old to >=70), and accounted for 111,909 excess deaths compared to normal weight persons in 2000. The risk is highest for those who have been overweight for longer periods of time and decreased if one did not become overweight or obese until after age 50 (Flegal, et al., 2005; Paul & Townsend, 1995; Stevens, et al., 1998). In longitudinal analyses, obesity in middle adulthood (ages 30-49) has been shown to be associated with an approximately six year lesser life expectancy when compared to normal weight individuals (Peeters, et al., 2003). In a 2007 follow-up study by Flegal and colleagues, excess death among obese individuals was linked with significantly increased cardiovascular disease (CVD) mortality, but not overall cancer mortality or non-cancer, non-CVD mortality. Obesity was related to increased mortality from cancers considered obesity-related, however, and further analysis revealed that overweight and obesity combined were significantly associated with increased mortality from diabetes and kidney disease (Flegal et al., 2007).

6. Relationship of Body Size to Functional Status

In cross-sectional analyses, obese individuals tend to have an increased prevalence of both upper and lower body functional limitations (Apovian, et al., 2002), and the relationship between obesity and limitations appears to be slightly higher for elderly women than elderly men (Davison, et al., 2002). Longitudinal studies find that these relationships hold for the onset of limitations as well (Ferraro, et al., 2002; Himes, 2000; Jenkins, 2004). Excess weight adds stress to the skeleton and weight-bearing joints, increasing the likelihood of arthritis and joint problems. Physiologically, excess weight leads to increased insulin resistance, damages connective tissues and leads to atherogenesis. It is hypothesized that these changes can lead to decreased functioning (Ferraro & Booth, 1999).

Obesity may also limit physical activity, depriving individuals of the benefits of exercise and leading to the development of limitations in activities of daily living (ADLs) and instrumental activities of daily living (IADLs) such as climbing stairs, getting out of bed, or going shopping. (For cross-sectional studies see Freedman & Martin, 2000; Sturm, et al., 2004. For longitudinal studies see Himes, 2000; LaCroix, et al., 1993; Launer, et al., 1994; Kahng, Dunkle & Jackson, 2004; Jenkins, 2004.) Other longitudinal studies on elderly persons find that obese individuals are more likely to suffer the onset of functional limitations than those who are not obese, and that obesity is associated with more rapid increases in disability over time (Ferraro & Booth, 1999; Ferraro, et al., 2002). Another recent cross-sectional study confirms that alternative obesity indicators (such as waist to hip ratios) are also associated with increased disability risk among elderly Americans (Chen & Guo, 2007).

The severity of obesity is associated with the likelihood of disability as well. Sturm, et al., (2004) find that for women, the probability of developing ADL limitations doubles for those with moderate obesity and quadruples for those with severe obesity. However, Alley & Chang (2007) found that the overall increase in rates of physical limitation among obese persons 60 years of age and older throughout the 1990s was due to Class I and Class II obese persons but concede that a relatively small sample size of the most obese compounded with substantially higher rates of disability in the baseline years most likely accounts for their findings.

Studies have not been limited to elderly persons, although long-term, longitudinal analyses have been relatively infrequent. One such example was conducted by Peeters, et al. (2004), who found that obesity in middle adulthood (ages 30-49) was associated with a two-fold increased risk of ADL limitations during the 46 years of follow-up of the Framingham, Massachusetts population. In another study, analyses from the Atherosclerosis Risk in Communities study showed that obesity at age 25 was associated with functional impairments at ages 52-75 for both White and Black men and women (Houston, et al., 2005).

7. Summary of Limitations

In addition to the scarcity of longitudinal studies with long follow-up periods like the two mentioned above, an important limitation in the literature is that most studies are constrained by self-reports of body size, although a few clinical samples have directly measured height and weight (Apovian, et al., 2002; Houston, et al., 2005; Jensen

& Friedmann, 2002) or waist and hip circumference measures (Alley & Chang, 2007). Perhaps most important however, comparability of past studies is hampered by the wide variety of definitions used to indicate disability and functioning: overall health (Ford, et al., 2001); ADL and IADL limitations (Jenkins, 2004; Reynolds, Saito & Crimmins, 2005; Sturm, et al., 2004); Nagi or Rosow-Breslau scales (Davison, 2002; Kahng, Dunkle & Jackson, 2004); among others.

C. DATA AND MEASURES

1. The Health and Retirement Study (HRS)

The data for this study come from the 1998-2004 waves of the Health and Retirement Study (HRS). While components of the study sample had been interviewed since 1992, in 1998, the original HRS sample--persons born between 1931 and 1941 was merged with the Asset and Health Dynamics among the Oldest Old (AHEAD) sample--persons born before 1923--and two additional cohorts covering 1924-1930 (Children of the Depression) and 1942-1947 (War Babies). In addition to making the sample representative of the entire United States population ages 51 and above, several differences between the HRS and AHEAD survey instruments were standardized making the combined analysis of the surveys possible. Respondents are re-interviewed at two-year intervals, and new cohorts are added to the sample every six years to regain representation of persons in their early 50s, thereby making the survey cross-sectionally representative of those 51 and older.

The HRS includes a rich variety of measures of demographic, health, disability, work, family structure, income, and wealth. In an effort to be responsive to the evolution of social science research, the study has offered researchers the opportunity to design and collect additional data through supplemental survey “modules” on a subset of the sample, often covering topics on the frontiers of research in aging. Several advances in the field of disability measurement (e.g., physical measures, time use, blood and DNA collection, and anchoring vignettes) have been included in recent rounds of the survey, either as modules or as full-survey components.

After eliminating the observations with missing data on the independent and dependent variables included in our models, and observations on spouses outside of the age range (younger than 50 in 1998), we have 53,956 person-wave observations for the cross-sectional analyses. All analyses incorporate person-level sampling weights provided by the HRS.

2. Disability

In this report we focus on four types of disability: difficulty with ADLs, difficulty with IADLs, physical limitations in upper body function and lower body function. For six ADLs (dressing, walking across the room, bathing/showering, eating, getting in or out of bed, and toileting) the HRS asks, “Because of a health or memory problem do you have any difficulty with…?” We classify an individual as having an ADL difficulty if they answer any of these questions affirmatively, or if she responds that she cannot or does not do an activity. For five IADLs (preparing meals, shopping for groceries, making phone calls, taking medications, and managing money), the survey asks a similar question. If she responds that she does not or cannot do the activity, the interviewer asks if that is because of a health or memory problem. We classify a respondent as having an IADL difficulty if they answer yes to either the first or second question on any activity. The survey also asks about limitations of physical functioning developed by Nagi (1969). Following Freedman, Aykan & Kleban's (2003) factor analysis of these items using 1994 data, we group these into six upper body functions (reaching overhead, lifting ten pounds, picking up a dime, sitting for two hours, standing after sitting for a long period, and pushing or pulling large objects) and five lower body functions (walking several blocks, walking one block, climbing several flights of stairs, climbing one flight of stairs, and stooping or kneeling).

3. Obesity and Body Weight

To measure obesity-related disability risks, we take several approaches. First, we use the standard definitions of overweight and obesity defined by BMI (BMI=weight in meters/height in kilograms^2). The following table defines the ranges used.

Classification	BMI Range
Underweight	<18.5
Normal Weight	18.5 - 24.9
Overweight	25.0 - 29.9
Obese, Class I	30.0 - 34.9
Obese, Class II	35.0 - 39.9
Obese, Class III	>=40

At the suggestion of the technical advisory panel, in addition to measuring relative risks of disability across these categories, in some model specifications, we also examine relative risks by integer values of BMI, or by using BMI as a continuous variable.

Note that height is not re-measured or re-surveyed after the respondent's first interview, whereas weight is reported at each wave. Thus BMI varies across years for each individual.

4. Other Measures

We also include in cross-sectional and longitudinal models age, sex, wealth and education. Because obesity is often accompanied by chronic disease that may cause disability even without the presence of overweight or obesity, we also estimate a set of models that controls for four potentially disabling conditions: diabetes, heart disease, arthritis and psychiatric conditions. In addition, in the longitudinal models we include a measure of physical activity at baseline (whether the respondent engages in vigorous exercise at least three times a week). We do not include this measure in models of current disability because the physical limitations are likely to influence the likelihood of exercise, making it endogenous.

We estimate disability risks by means of logistic regression models and report the relative odds of disability prevalence, onset, or recovery and indicate the statistical significance (at the 5 percent and 1 percent levels) of the estimates. For each disability measure, we estimate one set of models controlling only for age, sex, wealth, education, race/ethnicity, whether the individual lives with a spouse/partner, and survey wave. Because obesity is often accompanied by chronic disease that may cause disability even without the presence of overweight or obesity, we also estimate a set of models that controls for four potentially disabling conditions: diabetes, heart disease, arthritis and psychiatric conditions.[1] Because of the positive correlation of these conditions with overweight and obesity, we expect the inclusion of the disease indicators to reduce the magnitudes of the risks associated with overweight, but the effect that remains may be thought of as more directly an effect of excess body weight as opposed to an effect of an associated disease. Similarly, controlling for wealth and education is also an attempt to isolate the effects of excess weight from the effects of other factors associated with it.

We also estimate several models where weight change is the dependent variable, and functional status is the key independent variable. In these models, we use ordinary least squares regression.

[1] The HRS question ("Have you ever had or has a doctor ever told you that you have any emotional, nervous, or psychiatric problems?") does not distinguish between different psychiatric diagnoses. However, depressive disorders are a major cause of disability, and among psychiatric diagnoses, they are the second most common (behind anxiety disorders). For these reasons, we interpret this variable as a proxy for depression.

D. ANALYSES AND RESULTS

To answer the research questions posed at the beginning of this report, we perform a variety of analyses. In the next section, we address the cross-sectional relationships between overweight/obesity and disability as well as physical limitation. The second research question--whether the cross-sectional relationship persists in longitudinal analysis--is addressed in Sections 2-5. The final research question, dealing with potential pathways linking excess weight and disability, is addressed in Section 6.

1. Current BMI and Disability Prevalence (1998-2004)

The first set of models includes every observation available (n=53,956) in every wave between 1998 and 2004. As mentioned above, BMI can vary between waves for an individual, as can disability status and the presence of chronic conditions. Age is updated at each wave as well. Since repeated observations from the same individual are not independent, however, we estimated the covariance matrix for each model using the Huber-White correction for heteroskedasticity, clustering observations at the person level. The effect of this correction is generally to increase the standard errors and confidence intervals on coefficient estimates, as the number of independent observations is reduced.

Table 1 presents results from a set of cross-sectional models of disability using weight classes as the key independent variables. For ADL disability, when we control only for socio-demographic characteristics (age, sex, education, and wealth), any deviation from the normal weight category carries a significantly increased risk of disability. Those with a BMI under 18.5 are 70 percent more likely (Odds Ratio=1.69) than those in the normal range to have difficulty with at least one ADL. The effects of *excess* weight increase monotonically. While those in the "overweight" category are 12 percent more likely to have ADL difficulties, those with a BMI over 40 have six times the risk of being having a difficulty.[2] Age, education, wealth and sex are all highly significant ($p<0.01$) predictors of ADL difficulty in the expected directions. However, controlling for these economic differences race and ethnicity are not significant predictors of disability. As expected, when we control for the presence of four potentially disabling chronic diseases, the estimated risk profile of excess weight flattens considerably. At top of the BMI scale, those classified with Class III obesity (BMI>=40) have four times the risk of ADL difficulty, and those in the "overweight" category are no longer statistically distinguishable from those in the normal category.

[2] The HRS ADL question on dressing, "Because of a health or memory problem do you have any difficulty with dressing, including putting on shoes and socks?" because it includes reference to putting on shoes and socks. It is thought that the unusually high frequency on this question is partly due to that difference. For this analysis, the ability to reach one's feet may be especially compromised in the obese, so the sensitivity of the ADL difficulty measure may overstate what would be found using another survey. Indeed, removing just the dressing item has the effect of reducing the relative risk of Class III obesity by about one-third.

While chronic disease also elevates IADL difficulty, the correlation of excess weight with IADLs is much less strong than with ADLs. Those most at risk are the underweight, and the overweight are actually significantly less likely to have IADL difficulty than those of normal weight. Further, after controlling for disease, even the Class I obese group has lower rates of IADL difficulty than the normal weight group. The Class III obese group is still at increased risk (OR=1.68), but the risk elevation is much less pronounced than in the case of ADL difficulties.

Upper body limitations show a similar pattern to ADL difficulty: after controlling for the presence of disease at baseline, moderate overweight carries no excess risk, and Class I obesity elevates risk by approximately 40 percent. Risks are significantly higher in the Class II and III obese groups than in the normal weight group, even after controlling for disease prevalence. Compared to ADL difficulty, however, the risk of upper body limitations for the extremely obese is somewhat smaller (OR=3 vs. 4)

Of all the types of disability considered, lower body limitations show the strongest association with excess weight. Elevated risk exists beginning in the overweight category, and the relative risk increases more than twice as rapidly as the risks for ADL disability. Class III obesity carries a relative risk of limitation nine times that of normal weight after controlling for the presence of disease.

Using the BMI group classifications above is useful in that the categories correspond to other work in the health literature. However, BMI is a continuous index, and the break points between categories are essentially arbitrary, so any grouping can mask underlying variability and patterns within categories. In addition, clinical recommendations to reduce BMI below a single threshold may be incomplete if every reduction in weight produces benefit. Thus, in Table 2 we look more closely at disability risks at each integer value of BMI up to 34, and then in groups at higher levels where frequencies are small. Relative risk findings from the models that control for disease are also presented in Figure 1.

While consistent with the findings in Table 1, several points seem worth making. The value of BMI at which the minimum disability risk is observed varies markedly across types of disability. For ADL difficulty, the lowest point in the risk profile occurs at a BMI of 24, at the high end of “normal.” For IADL difficulty, the lowest point is at a BMI of 29, just below the Class I obesity threshold, though there is very little apparent trend throughout the range of BMI values between the upper and lower extremes. Not as apparent in Table 1, however, the BMI risk gradient for upper body limitations appears to be between ADL and IADL gradients. Finally, with one deviation, the risk profile for lower body limitations is remarkably smooth between its lows point at a BMI of 19 and 20 and its high above 40. For both ADL difficulty and lower body limitations, any reduction in body weight appears to reduce risk, even if that weight loss does not result in a change in BMI category.

2. BMI (1998) and Disability Onset/Recovery (1998-2004)

Because we are concerned about the possibility that disabilities and physical limitations may reduce activity and increase the probability of carrying excess weight and overestimate the extent to which obesity "causes" disability, we also exploit the panel design of the HRS to estimate models of disability onset and recovery. In this way, we address the second research question, regarding the longitudinal relationship between obesity and disability. Each set of onset and recovery models are stratified to include only persons with a particular disability status at baseline and measure changes in that status over time as a function of body mass or weight category. In the onset models, the samples are restricted to persons who do not report a particular type of disability at baseline. The key independent variable in these models is obesity status or BMI at baseline. In addition to the control variables discussed above, in these models we also include a measure of physical activity at baseline (whether the respondent engages in vigorous exercise at least three times a week, on average). The control variables perform as expected in these models, and regular exercise at baseline dramatically reduces the probability of developing any type of disability (ORs between 0.62 and 0.85).

Similar to the findings in the cross-sectional analyses, we find that controlling for the presence of chronic disease at baseline reduces the risk gradient on weight status in each case (Table 3a). For ADL difficulty, the risk of disability onset does not increase significantly until BMI exceeds the Obesity (Class I) threshold. At that point, the risk of onset is 1.35 times that in the normal weight category. The odds ratio for those with more severe obesity is between 2 and 3.

In the models of onset for IADL difficulty, even before controlling for baseline health, the risk of developing an IADL difficulty is significantly higher only for those with BMI values above 40, and the relative risk in that category decline in magnitude and significance when we control for diseases present at baseline.

There does appear to be an increased risk of developing new upper body limitations associated with baseline weight class, although the pattern is not monotonic (i.e., odds ratio for Class II obesity is lower than for Class I). The risk of a lower body limitation is substantially stronger in the highest weight class (BMI>=40) but only moderately higher than the risks of upper body limitation for individuals with BMI values in the 30s.

In Table 4a, and in Figure 2, we examine the relative risks using continuous BMI, and find that the patterns are remarkably noisy, most notably for the risk of new lower body limitations. In general, the p-values in the onset models are smaller than in the cross-sectional models.

We also estimate models restricted to those who report a disability at baseline to determine if excess body weight increases or reduces the chance of functional recovery during the follow-up period. Table 3b presents results from models of disability recovery.

For ADL disability, the only significant difference by weight class is found in the Class III obesity group. We find that persons with extreme obesity are substantially less likely to regain ADL functioning than those of normal weight. For those with IADL disability, once we control for disease, weight category is not significantly predictive of functional recovery. However, for persons with either upper or lower body limitations, there is a substantially diminished probability of recovery associated with obesity at baseline. For those with lower body limitation, any excess weight, appears to reduce the odds of recovery substantially. Looking at the risk profile by BMI value (Table 4b), we find that significantly diminished recovery prospects from upper body limitations do not start until higher values of BMI than they do for lower body limitations.

In all cases, regular vigorous exercise is associated with a lower risk of onset and a greater likelihood of recovery. However, the endogeneity of this variable with respect to baseline functioning still suggests caution in interpreting this result.

3. Functional Status (1998) and Weight Change (1998-2004)

Because we are concerned about the possibility that disabilities and physical limitations may reduce activity and increase the probability of carrying excess weight and overestimate the extent to which obesity "causes" disability, we also estimate models of weight change, using baseline disability status as a risk factor, controlling for baseline weight and health.

Table 5 reports the results from these models. In the first model, we control only for demographic factors, and test the effects of four baseline disability measures. The only disability that significantly predicts subsequent weight change in this model is ADL difficulty, which predicts a one kilogram drop in body weight over six years.

When we include controls for baseline BMI in the second model, we find some suggestion of mean reversion as the overweight and obese lose weight (in increasing amounts as baseline BMI increases), and those in the underweight group experience a gain. These controls reduce the size and significance of the ADL effect from the first model. Finally, when we add controls for baseline health, the estimated ADL effect (a modest 0.7 kg weight loss) is again statistically significant ($p=0.05$).

4. Weight Change (1998-2000) and Disability Onset/Recovery (2000-2004)

As a more stringent test of the causal link between weight and disability, we also estimate models of disability onset as a function of **change** in weight. In the first of these longitudinal models, we examine the hypotheses that: (1) increases in body weight cause the onset of disability, and conversely; and (2) decreases in body weight lead to recovery of function. We limit ourselves to models of lower body limitation, on both empirical and theoretical grounds: the cross-sectional relationships estimated in

Table 1 and Table 2 are strongest for these limitations, and the mobility implications of carrying excess weight are plausibly the most immediate consequence.

However, the estimates reported in Table 6 suggest no discernible relationship. Even if the estimates were statistically significant, each kilogram increase in weight implies an increased risk of lower body limitation of 0.4 percent (OR=1.004). Even a 10 kg (22 lb) weight gain implies only a 3.6 percent increase in the risk of developing a limitation. Any improvement in the odds of recovery from a lower body limitation because of weight loss are also small. A 10 kg loss translates to a 7 percent increase in the likelihood of recovery.

5. Disability Onset/Recovery (1998-2000) and Weight Change (2000-2004)

On the other hand, the evidence for the reverse causal story is no more convincing. In Table 7 we report the findings from two models. In the first, we use a sample of persons without lower body limitation at baseline (1998) and estimate no effect on later weight gain/loss of losing some lower body function. Then in the second model, using a sample of only people with lower body limitations at baseline, we find no significant effect on subsequent weight gain/loss of recovery of full lower body function.

While these tests are somewhat disappointing, we did one further analysis of individuals who were neither obese nor limited (Lower body) at baseline (1998) and both obese and limited at follow-up (2004), and observed the onset of both obesity and disability. Of the 133 cases meeting these criteria, 41 percent experienced lower body limitation before they became obese, 25 percent experienced obesity before limitation, and 33 percent experienced onset of the two conditions in the same wave. Again, while not conclusive, these analyses suggest that the concept of obesity as only a potential cause of disability rather than a consequence may color our interpretation of cross-sectional evidence of correlation.

6. The Interactive Effects of Disease and Overweight

Finally, to explore the third research question of identifying pathways between obesity and disability, we examine whether disease and body weight have joint effects that either exacerbate or attenuate the effects of disease or obesity alone. We have already seen that the inclusion of disease variables that are known to be linked to carrying either excess body fat (diabetes, heart disease) or excess weight (arthritis) reduces the magnitude of the disability risk of obesity in both prevalence and onset models. This suggests that some of the risk associated with excess weight is indirect. To most parsimoniously estimate interaction effects, we model the disability effects of BMI as a piecewise linear function (a spline) with “knots” at 18.5 and 25 (the underweight and overweight thresholds). Of most interest is the effect of the overweight portion of the spline. The main effect of excess weight is estimated by the BMI_{over} term.

The coefficient on the interaction terms can be interpreted as the additional (or reduced) burden of excess weight that is associated with a condition. Thus, if arthritis is more disabling as weight increases, we would expect to see a positive and significant coefficient on the interaction term.

Table 8 reports the results from these analyses. The coefficients on the variable BMI_{over} represent the risk increase posed by each additional unit of BMI for those with overweight or obesity. Thus for a person 5'6" tall, a 6.2 lb weight gain increases the odds of developing an ADL disability by 8 percent (OR=1.08).

For the most part, however, there is little evidence of interaction between disease and body mass in producing disability. The only two interaction terms reaching statistical significance are the diabetes term in the model of upper body limitations and the heart disease term in the model of lower body limitations. In the first case, the interaction term cancels out the main effect of body mass. Thus, while diabetes itself doubles the onset risk of upper body limitations, among diabetics there is no added risk of upper body limitation caused by higher body mass.

In the second case, the coefficient on the heart disease interaction term in the lower body limitation model suggests that the effect of body mass on lower body limitations is doubled for those with heart disease. We had expected a similar finding that the debilitating effects of arthritis may be made worse by body mass, but no significant results were found.

E. DISCUSSION

1. Summary of Results

The cross-sectional analysis of disability prevalence and its correlation with excess weight found strong risk gradients for ADL difficulty and both upper and lower body limitations. The gradient for IADL difficulty is less pronounced. In fact, overweight and moderate obesity are even associated with lower levels of IADL difficulty. In all cases, controlling for four common disabling conditions with connections to obesity reduces the magnitude of the risk gradient.

Longitudinal analyses tend to reflect these findings, though for certain disability measures, the effects are less dramatic. In particular, while the cross-sectional model finds that those with Class III obesity are more than four times as likely as those in the normal weight range to have an ADL difficulty, the relative risk of *onset* for ADL is less than three. Our analyses of the timing of onset of disability and excess weight were inconclusive. We estimate no additional risk of disability onset after weight gain, and conversely, no significant weight gain after the onset of disability. The analyses of clinical pathways to disability are also inconclusive. We find no consistently significant interaction effects. While it may be the case that the connection between excess weight and physical limitation is nor associated with one type of disease relative to another, it seems more likely that the self-reported data on disease prevalence does not measure actual clinical condition with sufficient precision to estimate this type of model.

2. Limitations

One limitation that might be overcome is the shortness of the elapsed time between baseline and final follow-up. Preliminary 2006 data were recently released, and next year the 2008 data from the HRS will be available, providing a ten year follow-up period. The longer time period will provide both a more meaningful estimate of longer-run implications of past obesity trends, but also allow a more complicated set of disability onset models using up to five repeated observations on which hazard models might be more reliably estimated.

A second notable limitation of the research presented here is its reliance on self-reported height and weight. It has been shown that individuals systematically underreport weight and overreport height, biasing average BMI values downward, and substantially biasing estimates of the prevalence of overweight and obesity (Spencer, et al., 2001; Ezzati, et al., 2006). In the Appendix Table A1 and Table A2 (corresponding to text Table 1 and Table 2), we present models estimated on data that have been transformed according to age and sex-specific adjustment factors that undo mis-reporting *on average (by age and sex).* We caution, however, that while we can correct estimates of obesity prevalence with these adjustments, this approach may not improve the accuracy of estimates of disability risks associated with excess weight. This is particularly true if mis-reporting varies by disease and disability risk. Indeed, Spencer, et al. (2001) found that while self-reported data produce biased estimates of obesity prevalence, they are still valid for identifying epidemiological relationships. Nonetheless, we present these alternative tabulations for completeness. In general, results agree with those reported in the main body of the report; however, in the BMI-adjusted models disability risks associated with elevated BMI are attenuated and begin at higher levels.

Second, there is some concern that it is not current body weight, or a change in body weight, that primarily drives disease and disability risk, but rather the weight one carried throughout ones life. Unfortunately, the HRS series is not long enough, and does not extend to young enough ages to get a complete history of body weight.

Finally, the use of BMI, either measured or self-reported, has been criticized because it is only a crude measure of body fat and fitness. Fit individuals with well developed musculature can also tend to have elevated BMI levels. Alternative suggestions have included measures of waist circumference or skin-fold measurement that distinguish fat from muscle. While more recent waves of the HRS have included measurements of height, weight, and waist circumference, they are not available for analysis for the 1998-2004 period.

3. Implications

Several implications for research and policy arise from these analyses. First, a comparison of cross-sectional and longitudinal models indicates that the well documented cross-sectional evidence of a link between obesity and disability overstates the strength of that relationship, particularly in the case of ADL disability, but we still do find a statistically significant relationship, and increasing levels of extreme obesity in late middle age cohorts will likely increase the incidence of ADL disability.

The analyses presented here suggest IADL disability--which has been the most rapidly declining type of disability and is most responsible for downward disability trends (Spillman, 2004)--is little affected by obesity, except at its most severe. In fact, there may be some evidence that moderately excess weight may be protective, though this is only true in the crudest cross-sectional models.

We find stronger evidence that moderate overweight and obesity increase the risks of limitations to basic physical functioning. Since these are theoretical (and empirical) precursors to disabilities, warnings about implications for the future of disability are relevant, but perhaps they are not as severe as some estimate. In some sense, however, this finding is good news. Mobility limitations are amenable to relatively simple and inexpensive technological solutions, such as canes and walkers, and do not typically require human assistance or institutional care. Perhaps the most useful recommendation that might be drawn from this research is that interventions that keep people mobile and active earlier in life may have returns later in life.

Finally, the evidence on the dynamics of causality is inconclusive. While there is fairly strong evidence that obesity status at baseline is associated with future onset of disability, we found no evidence that changes in weight have any effect on the subsequent incidence of disability, even when we define disability liberally as the presence of any lower body limitation. It may be that the physiological effects of overweight and obesity only develop over a longer period of time than we have allowed with these analyses, or that the disability trajectory late in life is determined more by weight carried over long periods of time rather than short-term fluctuations. Whatever the explanation, however, it is not clear from these analyses that policies targeted at reducing weight late in life will be beneficial.

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FIGURE 1: Relative Risks of Disability
(Cross-section models controlling for demographic and disease variables)

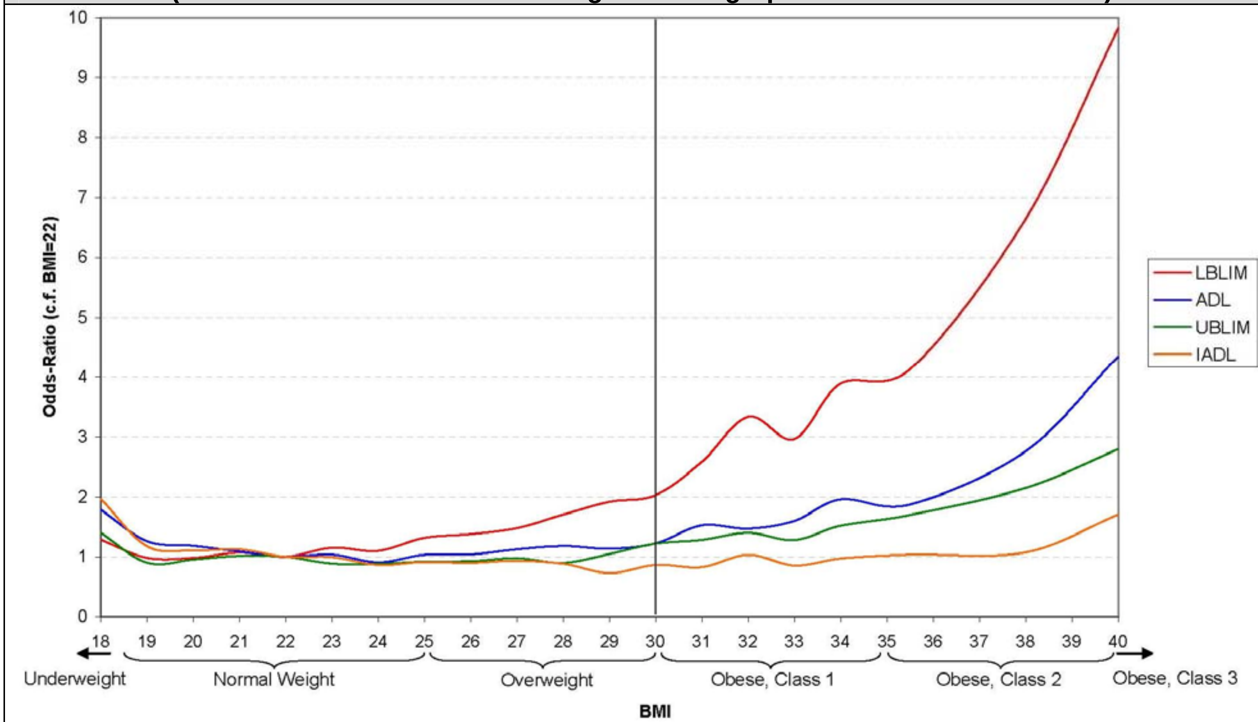

FIGURE 2: Relative Risks of Disability Onset
(Longitudinal models controlling for demographic and disease factors)

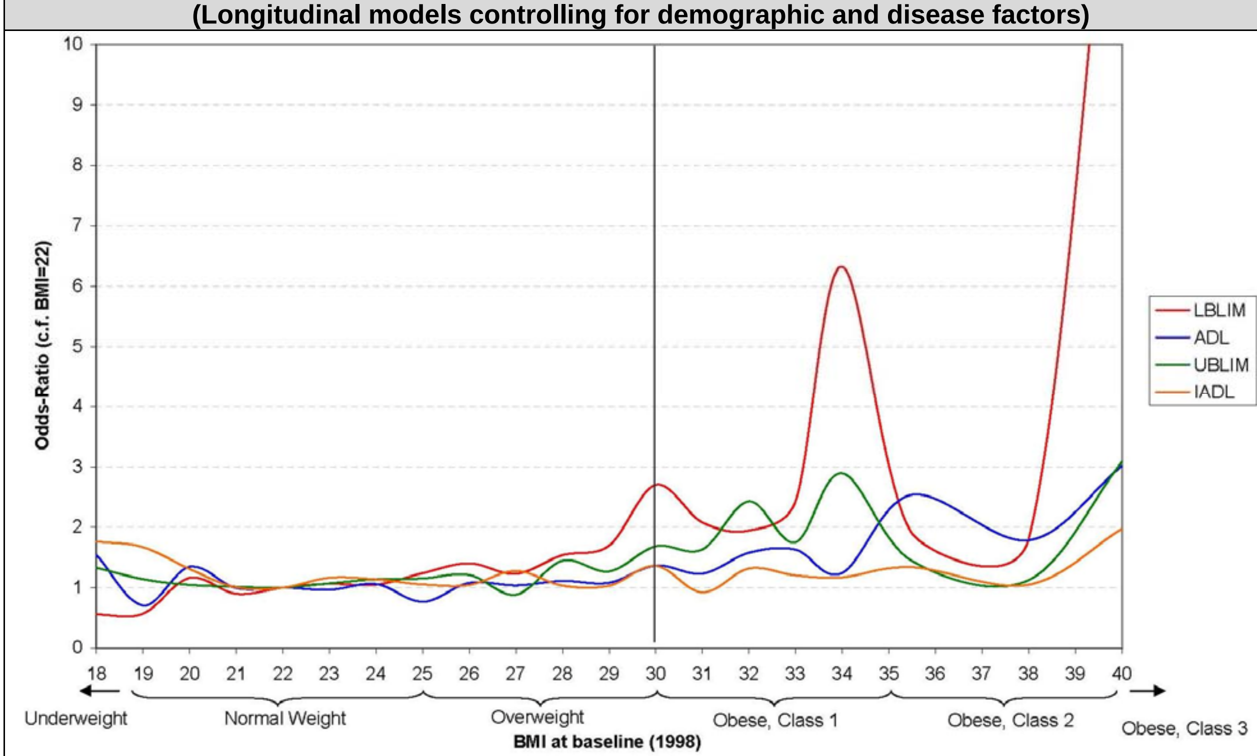

TABLE 1: Relationship Between Obesity Status and Disability Status								
	Relative Odds of Disability							
	ADL Disability		IADL Difficulty		Upper Body Limit		Lower Body Limit	
Underweight	1.69**	1.78**	2.14**	2.13**	1.52**	1.62**	1.21*	1.26*
Overweight	1.12**	1.04	0.88**	0.86**	1.12**	1.01	1.51**	1.40**
Obese, Class I	1.68**	1.40**	0.93	0.88**	1.71**	1.39**	2.88**	2.47**
Obese, Class II	2.73**	2.10**	1.14	1.04	2.65**	1.99**	5.71**	4.57**
Obese, Class III	6.05**	4.10**	2.00**	1.68**	4.71**	2.98**	13.26**	9.07**
Age	1.06**	1.06**	1.06**	1.06**	1.05**	1.04**	1.06**	1.05**
High School Grad	0.73**	0.82**	0.63**	0.67**	0.67**	0.75**	0.72**	0.81**
Wealth Quintile 2	0.49**	0.54**	0.54**	0.59**	0.63**	0.71**	0.61**	0.68**
Wealth Quintile 3	0.43**	0.49**	0.47**	0.52**	0.57**	0.66**	0.53**	0.60**
Wealth Quintile 4	0.36**	0.43**	0.43**	0.48**	0.48**	0.57**	0.45**	0.53**
Wealth Quintile 5	0.31**	0.38**	0.41**	0.46**	0.41**	0.49**	0.37**	0.45**
Female	1.17**	1.03	0.54**	0.51**	1.78**	0.65**	1.81**	1.71**
Hispanic	0.95	1.07	0.97	1.01	0.83**	0.96	0.77**	0.88*
Black	1.03	1.16**	0.95	1.03	0.89**	0.98	0.78**	0.85**
Other Race	1.14	1.25*	1.12	1.17	0.90	0.98	0.88	0.95
In Couple	0.92*	0.94	1.17**	1.20**	1.01	1.01	1.02	1.02
Year 2000	0.94*	0.86**	0.65**	0.63**	0.95*	0.86**	0.95*	0.87**
Year 2002	0.93*	0.80**	0.74**	0.70**	1.04	0.90**	1.09**	0.95
Year 2004	0.86**	0.71**	0.77**	0.72**	1.02	0.85**	1.10**	0.93*
Diabetes		1.46**		1.20**		1.45**		1.61**
Heart Disease		1.62**		1.28**		1.75**		1.91**
Psychiatric Illness		2.50**		2.23**		2.29**		2.20**
Arthritis		2.79**		1.10**		3.15**		2.99**
Observations	53956							
* significant at 5%; ** significant at 1%.								

TABLE 2: Relationship Between BMI and Disability Status								
	Relative Odds of Disability							
	ADL Disability		IADL Difficulty		Upper Body Limit		Lower Body Limit	
BMI < 19	1.74**	1.79**	1.99**	1.97**	1.35**	1.40**	1.25*	1.29**
BMI = 19	1.28*	1.26*	1.19*	1.17	0.92	0.90	0.99	0.98
BMI = 20	1.17	1.18	1.09	1.11	0.94	0.95	0.96	0.98
BMI = 21	1.09	1.09	1.13	1.13	0.99	1.01	1.04	1.07
BMI = 23	1.05	1.04	0.99	0.99	0.91	0.89*	1.15*	1.15*
BMI = 24	0.97	0.91	0.88	0.86*	0.94	0.88*	1.14*	1.10
BMI = 25	1.07	1.03	0.92	0.91	0.97	0.92	1.34**	1.32**
BMI = 26	1.15	1.04	0.92	0.90	1.05	0.93	1.51**	1.38**
BMI = 27	1.24**	1.12	0.95	0.93	1.11	0.97	1.61**	1.48**
BMI = 28	1.36**	1.18	0.92	0.88	1.07	0.90	1.91**	1.71**
BMI = 29	1.31**	1.13	0.76**	0.73**	1.24**	1.05	2.14**	1.92**
BMI = 30	1.47**	1.22*	0.92	0.86	1.49**	1.22**	2.36**	2.03**
BMI = 31	1.82**	1.52**	0.88	0.83*	1.58**	1.28**	2.98**	2.58**
BMI = 32	1.83**	1.47**	1.10	1.03	1.74**	1.40**	3.79**	3.34**
BMI = 33	2.00**	1.60**	0.91	0.85	1.67**	1.28**	3.59**	2.97**
BMI = 34	2.55**	1.96**	1.05	0.97	2.02**	1.52**	4.76**	3.89**
BMI = 35, 36	2.48**	1.88**	1.14	1.04	2.29**	1.70**	5.14**	4.13**
BMI = 37-39	3.68**	2.76**	1.20	1.07	2.96**	2.15**	8.41**	6.64**
BMI >= 40	6.53**	4.35**	2.05**	1.71**	4.50**	2.80**	14.37**	9.82**
Age	1.06**	1.06**	1.06**	1.06**	1.05**	1.04**	1.06**	1.05**
High School Grad	0.74**	0.83**	0.64**	0.67**	0.68**	0.75**	0.72**	0.81**
Wealth Quintile 2	0.49**	0.54**	0.54**	0.59**	0.63**	0.71**	0.61**	0.68**
Wealth Quintile 3	0.43**	0.49**	0.47**	0.52**	0.57**	0.66**	0.53**	0.60**
Wealth Quintile 4	0.36**	0.43**	0.43**	0.48**	0.49**	0.58**	0.45**	0.53**
Wealth Quintile 5	0.31**	0.38**	0.40**	0.46**	0.41**	0.50**	0.37**	0.45**
Female	1.16**	1.02	0.54**	0.51**	1.77**	1.64**	1.82**	1.72**
Hispanic	0.95	1.07	0.98	1.02	0.83**	0.97	0.77**	0.88*
Black	1.03	1.15**	0.95	1.03	0.89**	0.98	0.78**	0.84**
Other Race	1.14	1.25*	1.11	1.16	0.90	0.98	0.89	0.96
In Couple	0.93	0.94	1.18**	1.21**	1.01	1.02	1.01	1.02
Year 2000	0.94*	0.86**	0.65**	0.63**	0.95*	0.86**	0.95*	0.87**
Year 2002	0.93*	0.80**	0.75**	0.70**	1.04	0.90**	1.09**	0.95
Year 2004	0.85**	0.71**	0.77**	0.72**	1.01	0.85**	1.10**	0.93*
Diabetes		1.46**		1.22**		1.45**		1.57**
Heart Disease		1.61**		1.28**		1.75**		1.91**
Psychiatric Illness		2.51**		2.23**		2.30**		2.22**
Arthritis		2.78**		1.10**		3.15**		2.97**
Observations	53956							
* significant at 5%; ** significant at 1%.								

TABLE 3a: Relationship Between Obesity Status (1998) and Disability Onset (1998-2004)								
	Relative Odds of Disability Onset							
	ADL Disability		IADL Difficulty		Upper Body Limit		Lower Body Limit	
Underweight	1.32	1.49	1.38	1.43	1.08	1.09	0.61	0.61
Overweight	1.05	0.97	1.00	0.95	1.14	1.08	1.43**	1.39**
Obese, Class I	1.66**	1.35**	1.19	1.03	1.90**	1.72**	2.69**	2.49**
Obese, Class II	2.96**	2.19**	1.32	1.06	1.48*	1.22	2.09**	1.88**
Obese, Class III	4.43**	2.91**	2.27**	1.71*	3.55**	2.83**	16.55**	15.43**
Age	1.07**	1.06**	1.07**	1.06**	1.05**	1.04**	1.06**	1.06**
High School Grad	0.78**	0.84*	0.65**	0.68**	0.85*	0.87	0.89	0.94
Wealth Quintile 2	0.79*	0.87	0.85	0.90	0.93	0.95	0.97	0.99
Wealth Quintile 3	0.58**	0.65**	0.67**	0.73**	0.84	0.88	0.91	0.91
Wealth Quintile 4	0.47**	0.55**	0.61**	0.69**	0.71**	0.75*	0.77*	0.80
Wealth Quintile 5	0.47**	0.56**	0.68**	0.78*	0.62**	0.65**	0.62**	0.65**
Female	1.08	0.96	0.59**	0.55**	1.52**	1.48**	1.63**	1.57**
Hispanic	0.98	1.06	1.15	1.22	1.02	1.10	1.09	1.15
Black	1.22	1.25	0.97	0.99	0.99	1.02	0.82	0.85
Other Race	0.99	1.02	1.24	1.24	0.77	0.79	1.02	1.00
In Couple	0.85	0.85	1.12	1.15	1.05	1.04	0.98	0.98
Diabetes		1.75**		1.50**		1.60**		1.48**
Heart Disease		1.19		1.36**		1.29**		1.38**
Psychiatric Illness		1.70**		1.51**		1.65**		1.72**
Arthritis		1.88**		1.24**		1.68**		1.57**
Regular Exercise		0.62**		0.71**		0.85**		0.72**
Observations	11367		10232		6329		5734	
* significant at 5%; ** significant at 1%.								

TABLE 3b: Relationship Between Obesity Status (1998) and Disability Recovery (1998-2004)								
	Relative Odds of Disability Onset							
	ADL Disability		IADL Difficulty		Upper Body Limit		Lower Body Limit	
Underweight	0.62	0.62	0.54	0.53	0.69	0.61	0.41	0.35*
Overweight	1.23	1.25	1.15	1.24	0.94	1.02	0.71**	0.75**
Obese, Class I	0.98	1.03	0.88	1.03	0.63**	0.73**	0.38**	0.41**
Obese, Class II	0.59*	0.66	0.59*	0.78	0.37**	0.47**	0.22**	0.26**
Obese, Class III	0.38**	0.42**	0.60	0.84	0.27**	0.35**	0.17**	0.23**
Age	0.98**	0.98**	0.94**	0.95**	0.96**	0.97**	0.96**	0.97**
High School Grad	1.00	1.00	1.53**	1.41**	1.58**	1.41**	1.39**	1.25*
Wealth Quintile 2	1.18	1.13	1.82**	1.55**	1.26	1.14	1.36*	1.23
Wealth Quintile 3	1.30	1.18	1.86**	1.54*	1.61**	1.45**	1.31	1.14
Wealth Quintile 4	1.38	1.31	2.29**	1.80**	1.98**	1.75**	2.08**	1.79**
Wealth Quintile 5	1.20	1.02	2.34**	1.81**	1.93**	1.61**	1.84**	1.52**
Female	1.01	1.04	1.17	1.41**	0.64**	0.68**	0.55**	0.59**
Hispanic	1.00	1.01	1.40	1.28	1.33	1.20	1.62**	1.43*
Black	0.79	0.77	1.18	1.15	1.00	1.00	1.40*	1.47**
Other Race	0.64	0.68	1.23	1.26	1.08	1.08	0.91	0.90
In Couple	1.17	1.18	0.70**	0.73*	1.06	1.06	1.07	1.08
Diabetes		0.63**		0.69*		0.65**		0.57**
Heart Disease		1.03		0.77*		0.66**		0.72**
Psychiatric Illness		0.85		0.62**		0.81		0.74*
Arthritis		0.88		0.72**		0.49**		0.43**
Regular Exercise		1.52**		1.63**		1.42**		1.50**
Observations	1447		2582		6485		7080	
* significant at 5%; ** significant at 1%.								

TABLE 4a: Relationship Between BMI (1998) and Disability Onset (1998-2004)								
	Relative Odds of Disability Onset							
	ADL Disability		IADL Difficulty		Upper Body Limit		Lower Body Limit	
BMI < 19	1.41	1.54	1.72*	1.76*	1.32	1.33	0.56*	0.56*
BMI = 19	0.71	0.70	1.67*	1.67*	1.13	1.14	0.56*	0.57*
BMI = 20	1.31	1.35	1.29	1.31	1.02	1.04	1.13	1.16
BMI = 21	0.96	0.99	0.99	1.01	1.00	1.02	0.89	0.90
BMI = 23	0.95	0.97	1.16	1.16	1.07	1.07	1.04	1.06
BMI = 24	1.08	1.06	1.14	1.14	1.19	1.14	1.06	1.05
BMI = 25	0.78	0.76	1.08	1.05	1.18	1.15	1.24	1.24
BMI = 26	1.14	1.08	1.09	1.04	1.24	1.21	1.44*	1.40*
BMI = 27	1.16	1.04	1.36	1.28	0.97	0.88	1.28	1.23
BMI = 28	1.23	1.11	1.11	1.04	1.56**	1.45*	1.59**	1.54*
BMI = 29	1.25	1.08	1.12	1.03	1.39	1.27	1.73**	1.70**
BMI = 30	1.63*	1.37	1.53*	1.36	1.85**	1.69**	2.99**	2.70**
BMI = 31	1.48	1.23	1.04	0.92	1.82**	1.63*	2.19**	2.08**
BMI = 32	1.96**	1.58	1.50	1.32	2.61**	2.43**	1.99**	1.95*
BMI = 33	1.99**	1.63	1.42	1.21	1.97**	1.75*	2.53**	2.43**
BMI = 34	1.64	1.24	1.44	1.17	3.49**	2.89**	7.12**	6.32**
BMI = 35, 36	3.39**	2.54**	1.66*	1.34	1.71*	1.44	2.04**	1.90*
BMI = 37-39	2.44**	1.79*	1.30	1.05	1.42	1.13	2.12	1.81
BMI >= 40	4.56**	3.01**	2.62**	1.97**	3.88**	3.09**	16.45**	15.53**
Age	1.07**	1.06**	1.07**	1.06**	1.05**	1.04**	1.06**	1.06**
High School Grad	0.78**	0.85	0.64**	0.67**	0.86	0.88	0.88	0.93
Wealth Quintile 2	0.80*	0.88	0.85	0.90	0.94	0.96	0.99	1.01
Wealth Quintile 3	0.59**	0.65**	0.67**	0.73**	0.85	0.88	0.93	0.93
Wealth Quintile 4	0.47**	0.55**	0.62**	0.69**	0.72**	0.76*	0.79	0.81
Wealth Quintile 5	0.48**	0.57**	0.68**	0.78*	0.63**	0.67**	0.64**	0.67**
Female	1.07	0.95	0.58**	0.55**	1.52**	1.48**	1.65**	1.59**
Hispanic	0.97	1.05	1.15	1.21	1.02	1.10	1.09	1.16
Black	1.20	0.23	0.97	0.98	0.99	1.02	0.80	0.83
Other Race	0.99	1.03	1.25	1.24	0.77	0.79	1.01	1.00
In Couple	0.85	0.85	1.13	1.15	1.05	1.04	0.98	0.97
Diabetes		1.74**		1.50**		1.59**		1.45**
Heart Disease		1.19		1.35**		1.30**		1.39**
Psychiatric Illness		1.70**		1.49**		1.66**		1.74**
Arthritis		1.86**		1.25**		1.68**		1.57**
Regular Exercise		0.62**		0.71**		0.85**		0.72**
Observations	11367		10232		6329		5734	
* significant at 5%; ** significant at 1%.								

TABLE 4b: Relationship Between BMI (1998) and Disability Recovery (1998-2004)								
	Relative Odds of Disability Onset							
	ADL Disability		IADL Difficulty		Upper Body Limit		Lower Body Limit	
BMI < 19	0.53	0.52	0.59	0.55	0.65	0.60	0.55	0.48
BMI = 19	0.78	0.73	111	0.98	0.73	0.74	1.19	1.16
BMI = 20	0.34	0.36	0.54	0.51	0.67	0.64	0.87	0.83
BMI = 21	0.55	0.51	0.89	0.83	1.00	0.97	1.04	0.94
BMI = 23	0.81	0.82	0.85	0.81	1.17	1.18	1.06	1.01
BMI = 24	0.97	0.95	1.02	0.97	1.05	1.07	0.77	0.75
BMI = 25	0.81	0.81	1.23	1.17	1.05	1.11	0.74	0.73
BMI = 26	0.97	0.98	0.97	0.96	0.83	0.91	0.63*	0.63*
BMI = 27	0.85	0.86	1.11	1.21	0.91	1.00	0.69	0.71
BMI = 28	0.98	0.99	0.82	0.87	0.94	1.04	0.68	0.69
BMI = 29	1.09	1.09	1.03	1.11	0.90	0.98	0.61*	0.63*
BMI = 30	0.78	0.75	0.70	0.75	0.52**	0.59*	0.39**	0.38**
BMI = 31	0.87	0.86	0.93	1.00	0.89	0.99	0.44**	0.44**
BMI = 32	0.93	1.00	0.83	0.99	0.86	1.00	0.41**	0.42**
BMI = 33	0.75	0.86	0.80	0.92	0.33**	0.39**	0.24**	0.26**
BMI = 34	0.38	0.40	0.70	0.84	0.51*	0.65	0.26**	0.29**
BMI = 35, 36	0.41*	0.47	0.56	0.70	0.29**	0.36**	0.26**	0.31**
BMI = 37-39	0.48	0.52	0.47	0.60	0.49*	0.64	0.14**	0.16**
BMI >= 40	0.28**	0.31**	0.54	0.72	0.27**	0.35**	0.16**	0.21**
Age	0.97**	0.98**	0.94**	0.95**	0.96**	0.97**	0.96**	0.97**
High School Grad	1.02	1.02	1.51**	1.40**	1.57**	1.41**	1.39**	1.24
Wealth Quintile 2	1.13	1.09	1.77**	1.52**	1.26	1.14	1.36*	1.23
Wealth Quintile 3	1.26	1.14	1.85**	1.54*	1.60**	1.44**	1.32	1.15
Wealth Quintile 4	1.41	1.34	2.29**	1.79**	1.98**	1.76**	2.10**	1.81**
Wealth Quintile 5	1.18	1.01	2.34**	1.81**	1.94**	1.64**	1.85**	1.54**
Female	1.04	1.08	1.18	1.43**	0.65**	0.69**	0.56**	0.59**
Hispanic	0.99	1.01	1.37	1.26	1.34	1.21	1.62**	1.44*
Black	0.78	0.77	1.20	1.16	1.00	1.00	1.43*	1.49**
Other Race	0.62	0.66	1.26	1.31	1.08	1.07	0.94	0.93
In Couple	1.19	1.20	0.70**	0.73*	1.07	1.06	1.08	1.08
Diabetes		0.62**		0.69*		0.65**		0.58**
Heart Disease		1.04		0.77*		0.66**		0.72**
Psychiatric Illness		0.85		0.62**		0.82		0.73*
Arthritis		0.86		0.72**		0.49**		0.44**
Regular Exercise		1.49**		1.64**		1.41**		1.50**
Observations	1447		2582		6485		7080	
* significant at 5%; ** significant at 1%.								

TABLE 5: Relationship Between Functional Status (1998) and Weight Change (1998-2004)			
	Change in Weight (kg)		
ADL Difficulty (1998)	-1.006**	-0.663	-0.721*
IADL Difficulty (1998)	-0.113	-0.170	-0.163
Upper Body Limitation (1998)	-0.240	-0.161	-0.232
Lower Body Limitation (1998)	-0.255	0.133	0.103
Age	-0.159**	-0.179**	-0.179**
High School Grad	-0.338	-0.371	-0.338
Wealth Quintile 2	-0.490	-0.505	-0.474
Wealth Quintile 3	0.111	0.006	0.044
Wealth Quintile 4	-0.226	-0.382	-0.348
Wealth Quintile 5	-0.154	-0.359	-0.318
Female	0.134	0.010	-0.018
Hispanic	-0.164	-0.191	-0.197
Black	-0.630*	-0.339	-0.314
Other Race	-0.116	-0.057	-0.033
In Couple	-0.178	-0.131	-0.120
Underweight		1.585*	1.624*
Overweight		-0.821**	-0.837**
Obese, Class I		-1.750**	-1.779**
Obese, Class II		-2.487**	-2.540**
Obese, Class III		-6.160**	-6.281**
Diabetes			0.572**
Heart Disease			-0.174
Psychiatric Illness			0.648*
Arthritis			0.238
Regular Exercise			0.323*
Constant	0.727*	1.441**	1.073**
Observations	12704	12704	12704
R-squared	0.04	0.06	0.07
* significant at 5%; ** significant at 1%.			

TABLE 6: Relationship Between Weight Change (1998-2000) and Disability Onset (2000-2004)		
	Lower Body Limit (Relative Odds)	
	Onset	**Recovery**
Change in Weight (kg), 1998-2000	1.00	0.99
Underweight (1998)	0.71	0.37
Overweight (1998)	1.21	0.86
Obese (1998)	2.13**	0.41**
Age	1.05**	0.97**
High School Grad	0.93	1.39*
Wealth Quintile 2	1.14	1.53*
Wealth Quintile 3	0.93	1.04
Wealth Quintile 4	0.86	1.85**
Wealth Quintile 5	0.75	1.54
Female	1.48**	0.57**
Hispanic	1.41	1.54
Black	0.77	1.43
Other Race	1.11	0.82
In Couple	0.95	1.19
Diabetes	1.65**	0.64*
Heart Disease	1.40*	0.77
Psychiatric Illness	1.92**	0.72
Arthritis	1.33**	0.47**
Regular Exercise	0.77**	1.40**
Observations	3957	5469
* significant at 5%; ** significant at 1%.		

TABLE 7: Relationship Between Functional Status Change (1998-2000) and Weight Change (2000-2004)		
	Change in Weight (kg)	
	Onset Model	Recovery Model
Onset of Lower Body Limit	-0.063	
Recovery form Lower Body Limit		0.416
Underweight	-0.706	-1.084
Overweight	-0.110	-0.704**
Obese	-0.273	-1.427**
Age	-0.111**	-0.134**
High School Grad	-0.309	-0.496
Wealth Quintile 2	0.338	-0.010
Wealth Quintile 3	0.620	0.242
Wealth Quintile 4	0.532	0.555
Wealth Quintile 5	0.493	0.582
Female	0.407*	0.198
Hispanic	-0.681	0.282
Black	-0.435	-0.112
Other Race	0.540	0.217
In Couple	-0.060	-0.088
Diabetes	-0.016	0.674
Heart Disease	0.668*	-0.868**
Psychiatric Illness	0.332	0.206
Arthritis	0.035	-0.008
Regular Exercise	0.465*	0.234
Constant	-0.789	-0.063
Observations	5764	7080
R-squared	0.030	0.030
* significant at 5%; ** significant at 1%.		

TABLE 8: Interaction of BMI and Disease in Predicting Disability Onset (1998-2004)								
	Relative Odds of Disability Onset							
	ADL Disability		IADL Difficulty		Upper Body Limit		Lower Body Limit	
BMI_{under}	0.87	0.82	0.83	0.81	0.99	0.99	1.02	1.02
BMI_{normal}	0.98	0.96	0.96*	0.95*	1.01	1.00	1.08**	1.08**
BMI_{over}	1.08**	1.08**	1.04**	1.03	1.06**	1.04**	1.10**	1.08**
Age	1.07**	1.06**	1.07**	1.06**	1.05**	1.04**	1.06**	1.06**
High School Grad	0.78**	0.85*	0.65**	0.68**	0.85*	0.87	0.89	0.93
Wealth Quintile 2	0.79*	0.86	0.85	0.90	0.93	0.95	0.99	1.01
Wealth Quintile 3	0.59**	0.65**	0.67**	0.73**	0.84	0.87	0.92	0.92
Wealth Quintile 4	0.47**	0.55**	0.62**	0.69**	0.71**	0.75*	0.79	0.82
Wealth Quintile 5	0.47**	0.56**	0.68**	0.78*	0.62**	0.65**	0.64**	0.67**
Female	1.09	0.97	0.58**	0.55**	1.51**	1.47**	1.66**	1.60**
Hispanic	0.97	1.04	1.15	1.22	1.02	1.10	1.08	1.16
Black	1.20	1.23	0.96	0.98	0.98	1.02	0.80	0.82
Other Race	0.97	1.00	1.24	1.23	0.78	0.80	1.04	1.01
In Couple	0.85	0.85	1.12	1.14	1.05	1.04	0.98	0.98
Diabetes		2.00**		1.58**		2.00**		1.37
Diabetes*BMI_{over}		0.98		0.99		0.94*		1.01
Heart Disease		1.21		1.38**		1.19		1.17
Heart*BMI_{over}		1.00		0.99		1.04		1.09
Psychiatric Illness		1.59**		1.56**		1.71**		1.93**
Mental*BMI_{over}		1.02		0.99		0.99		0.95
Arthritis		2.00**		1.21*		0.53**		1.49**
Arthritis*BMI_{over}		0.98		1.01		1.03		1.02
1998 phys3wk		0.62**		0.71**		0.85*		0.72**
Observations	11367		10232		6329		5734	
* significant at 5%; ** significant at 1%.								

APPENDIX

TABLE A1: Relationship Between Obesity Status (adjusted) and Disability Status								
	Relative Odds of Disability							
	ADL Disability		IADL Difficulty		Upper Body Limit		Lower Body Limit	
Underweight	1.87**	1.97**	2.38**	2.35**	1.66**	1.78**	1.35*	1.41**
Overweight	1.06	0.97	0.87**	0.85**	1.09**	0.98	1.44**	1.33**
Obese, Class I	1.50**	1.25**	0.86**	0.81**	1.60**	1.31**	2.64**	2.27**
Obese, Class II	2.54**	1.94**	1.07	0.98	2.46**	1.84**	5.23**	4.20**
Obese, Class III	5.32**	3.65**	1.80**	1.52**	4.60**	2.95**	12.57**	8.65**
Age	1.06**	1.06**	1.06**	1.06**	1.05**	1.04**	1.06**	1.05**
High School Grad	0.73**	0.83**	0.63**	0.67**	0.67**	0.75**	0.72**	0.81**
Wealth Quintile 2	0.49**	0.54**	0.54**	0.59**	0.63**	0.71**	0.61**	0.68**
Wealth Quintile 3	0.43**	0.49**	0.47**	0.52**	0.57**	0.66**	0.53**	0.60**
Wealth Quintile 4	0.36**	0.43**	0.43**	0.48**	0.48**	0.58**	0.45**	0.53**
Wealth Quintile 5	0.31**	0.38**	0.40**	0.46**	0.41**	0.49**	0.37**	0.45**
Female	1.16**	1.02	0.55**	0.52**	1.76**	1.65**	1.76**	1.67**
Hispanic	0.94	1.07	0.97	1.01	0.83**	0.96	0.77**	0.88*
Black	1.03	1.15**	0.95	1.03	0.89**	0.98	0.78**	0.85**
Other Race	1.14	1.25*	1.12	1.16	0.90	0.99	0.88	0.95
In Couple	0.92*	0.94	1.17**	1.20**	1.01	1.01	1.02	1.02
Year 2000	0.94	0.86**	0.65**	0.63**	0.95*	0.86**	0.96	0.87**
Year 2002	0.94*	0.81**	0.74**	0.70**	1.04	0.90**	1.10**	0.96
Year 2004	0.86**	0.71**	0.77**	0.72**	1.02	0.85**	1.11**	0.94*
Diabetes		1.46**		1.21**		1.45**		1.60**
Heart Disease		1.62**		1.28**		1.75**		1.91**
Psychiatric Illness		2.51**		2.23**		2.30**		2.21**
Arthritis		2.79**		1.10**		3.15**		2.98**
Observations	53956							
* significant at 5%; ** significant at 1%.								

TABLE A2: Relationship Between BMI (adjusted) and Disability Status								
	Relative Odds of Disability							
	ADL Disability		IADL Difficulty		Upper Body Limit		Lower Body Limit	
BMI < 19	1.80**	1.85**	2.09**	2.06**	1.51**	1.57**	1.32*	1.35**
BMI = 19	1.33**	1.32*	1.41**	1.40**	1.03	1.02	1.12	1.13
BMI = 20	1.13	1.11	1.05	1.04	0.87	0.83*	0.94	0.91
BMI = 21	1.00	1.01	1.08	1.10	1.00	1.01	1.03	1.05
BMI = 23	0.93	0.92	0.88	0.88	0.93	0.91	1.06	1.05
BMI = 24	0.91	0.90	0.92	0.92	0.89	0.86*	1.11	1.10
BMI = 25	0.90	0.83*	0.85*	0.84*	0.95	0.88*	1.22**	1.16*
BMI = 26	1.05	0.99	0.87*	0.87*	1.00	0.91	1.36**	1.29**
BMI = 27	1.05	0.96	0.91	0.89	1.06	0.93	1.54**	1.39**
BMI = 28	1.16	1.03	0.86*	0.84*	1.09	0.94	1.69**	1.52**
BMI = 29	1.27**	1.11	0.84*	0.81**	1.10	0.92	1.99**	1.78**
BMI = 30	1.21**	1.04	0.75**	0.72**	1.31**	1.10	2.13**	1.87**
BMI = 31	1.45**	1.20	0.88	0.82*	1.43**	1.16*	2.46**	2.11**
BMI = 32	1.80**	1.48**	0.89	0.83*	1.69**	1.38**	3.39**	2.98**
BMI = 33	1.68**	1.33**	0.96	0.90	1.77**	1.38**	3.50**	2.93**
BMI = 34	1.83**	1.45**	0.92	0.86	1.66**	1.22*	4.06**	3.24**
BMI = 35, 36	2.24**	1.69**	1.08	0.99	2.27**	1.69**	4.83**	3.89**
BMI = 37-39	3.03**	2.31**	1.06	0.97	2.41**	1.75**	6.73**	5.33**
BMI >= 40	5.41**	3.67**	1.79**	1.52**	4.37**	2.75**	13.34**	9.16**
Age	1.06**	1.06**	1.06**	1.06**	1.05**	1.04**	1.06**	1.05**
High School Grad	0.74**	0.83**	0.64**	0.67**	0.68**	0.75**	0.72**	0.81**
Wealth Quintile 2	0.49**	0.54**	0.54**	0.59**	0.64**	0.71**	0.61**	0.68**
Wealth Quintile 3	0.43**	0.50**	0.47**	0.52**	0.57**	0.66**	0.53**	0.60**
Wealth Quintile 4	0.36**	0.43**	0.43**	0.49**	0.49**	0.58**	0.45**	0.53**
Wealth Quintile 5	0.31**	0.39**	0.40**	0.46**	0.41**	0.50**	0.38**	0.45**
Female	1.15**	1.02	0.54**	0.51**	1.76**	1.64**	1.77**	1.68**
Hispanic	0.95	1.07	0.97	1.02	0.83**	0.96	0.77**	0.88*
Black	1.02	0.15**	0.95	1.03	0.89**	0.98	0.77**	0.84**
Other Race	1.14	1.25*	1.12	1.16	0.90	0.98	0.89	0.95
In Couple	0.93	0.94	1.18**	1.21**	1.01	1.02	1.02	1.02
Year 2000	0.94*	0.86**	0.65**	0.63**	0.95*	0.86**	0.95*	0.87**
Year 2002	0.93*	0.80**	0.74**	0.70**	1.04	0.90**	1.09**	0.96
Year 2004	0.86**	0.71**	0.77**	0.72**	1.01	0.85**	1.10**	0.94*
Diabetes		1.46**		1.22**		1.45**		1.57**
Heart Disease		1.62**		1.28**		1.75**		1.91**
Psychiatric Illness		2.51**		2.23**		2.30**		2.21**
Arthritis		2.78**		1.10**		3.15**		2.97**
Observations	53956							
* significant at 5%; ** significant at 1%.								

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