The Income Gradient and Distribution-Sensitive Measures of Overweight in the U.S.

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Abstract: This paper considers alternate measures of overweight in the U.S. that are sensitive to changes in the body-mass index (BMI) distribution, more robust to measurement error and continuous in the body-mass index (BMI) at the overweight threshold. The measures suggest that standard prevalence rates may be understating the severity of the problem. Since 1971, overweight prevalence has increased by 40% while the distribution-sensitive measure has increased by 174%. They also provide some useful insight into socioeconomic differences in overweight. For example, overweight prevalence rates for the poor and the rich have been very similar over the last 30 years, with the rich have a slightly higher rate in the most recent 2001-2002 data. In contrast, the distribution sensitive measures reveal that overweight rich people exceed the overweight threshold by 23% while the overweight poor exceed the threshold by a much greater amount (31%) on average.

Classification: I1, I18, I32
Key Words: Overweight, Obesity, Body Mass Index, Robust Measurement, Foster-Greer-Thorbecke Poverty Measures, NHANES

[*] The views and opinions expressed in this paper do not necessarily reflect the views of the Economic Research Service of the U.S. Department of Agriculture.

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1. **Introduction**

National Center for Health Statistics (2004) estimates that 65 percent of U.S. adults were overweight (including those who were obese) between 1999 and 2002.[1] The list of potential negative health consequences from being overweight or obese is long and includes being at increased risk of morbidity from hypertension, stroke, type 2 diabetes, osteoarthritis, respiratory problems, and breast, prostate, and colon cancers.[2] Himes (2000) finds that for elderly women, there is a clear association between being overweight and having difficulties with essentially all activities of daily life such as bathing and dressing. Similarly, there appear to be significant negative economic consequences of being overweight. Cawley (2004), Pagan and Davila (1997) and Register and Williams (1990) find that overweight women receive significantly lower wages than not overweight women with otherwise similar characteristics. In terms of the public costs of this health issue, the U.S. Department of Health and Human Services (2000) estimates that in 1995 the economic costs from medical expenses and lost productivity were $99 billion.

While it appears that there are numerous potential negative consequences of the growing prevalence of overweight (i.e. the proportion of the population that is overweight) in the U.S., there has been relatively little scientific discussion of how we measure overweight and obesity. The purpose of this paper is to show that examining measures other than prevalence rates can reveal more information about the U.S. overweight public health problem in general as well as more information about the nature of the income gradient in this dimension of health.

The decision to discuss overweight in terms of prevalence rates requires that the continuous Body Mass Index (BMI) be converted into discrete outcomes indicating whether it is above or below some threshold. Converting this continuous measure into discrete outcomes for

[1] This estimate is "age-adjusted" based on 2000 Census data and five age categories.

overweight and obese has the important advantage that it is easy for the general public to understand prevalence rates and this presumably helps the public health debate on this issue.

Nonetheless, there are several disadvantages to measuring overweight status in this manner. First, research indicates that the risks of health problems for adults associated with being overweight are increasing in BMI (Willett, Dietz and Colditz, 1999). For example, the risk of heart failure increases 5 percent in adult men and 7 percent in adult women with a unit increase in BMI (Kurth et al., 2002). Similarly, a one-unit increase in BMI is associated with a 6 percent increase in the relative risks of total, ischemic and hemorrhagic stroke for men (Kenchaiah et al., 2002). The decision to convert BMI to a dichotomous outcome for overweight, is a decision to ignore the case that someone whose BMI is twice the overweight threshold is likely to be at higher risk of negative health outcomes than someone whose BMI is 5 or 10 percent greater than the overweight threshold.

A second, and related issue, is that when the outcome is dichotomous; the selection of the threshold value becomes more important. There is no research that literally argues that there is some razor's edge at a BMI of 25 (the current overweight threshold). That is, there is no evidence indicating that someone with a BMI of 24.9 is in significantly better health than someone whose BMI is 25.1; yet the discontinuity at the threshold implies this is the case. When the measurement methodology imposes assumptions such as discontinuity at an important public health threshold, the public health debate may well place unnecessary emphasis on the threshold points at the expense of discussion about the shifting distribution of BMI.

For example, when the U.S. government changed the threshold in 1998, numerous reports in the popular press reported on the 30 million Americans who had been reclassified from "healthy

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[2] See National Heart, Lung, and Blood Institute (1998, Chapters 1 and 2) for a more complete list of health problems associated with being overweight and for citations for each of the listed health problems.

weight" to "overweight" by this decision. The shift in the discontinuous threshold produced a significant change in the measured levels of overweight in the U.S. With a continuous measure and a shift of the threshold, the re-classification would have been sensitive to the situation that the new "overweight" were only marginally over the threshold. Similarly, stories of highly muscular (and typically low fat mass) athletes or celebrities who are classified as overweight are also easy to find in the popular press. In this case, the issue is measurement error but again the discontinuity at the threshold is important. Highly muscular are frequently mis-measured as being overweight because BMI doesn't distinguish between types of high weight individuals. If it is the case though, that most of these cases of measurement error are occurring near the overweight threshold, then continuous measures will be more robust to this type of mis-classification.

These issues of the discontinuity of the welfare measure, measurement error, and disagreement about the appropriate threshold are also faced in the measurement of poverty and the general solution to these measurement issues is to consider distribution-sensitive measures. This paper draws from the poverty-measurement literature and considers alternate measures of the overweight problem that: 1. Treat BMI as a continuous variable, 2. Are sensitive to changes in the bodyweight distribution of the overweight population, and 3. Are less sensitive to measurement error for those persons whose BMI is near the threshold.

2. Overweight Measurement[3]

2.1 NHANES Data, 1971- 2002

The data used in this paper are from five rounds of the National Health and Nutrition

[3] Parts of this section are drawn from Jolliffe (2004).

Examination Survey (NHANES), which is conducted by the National Center for Health Statistics of the Centers for Disease Control. The NHANES samples are representative of the U.S. civilian, non-institutionalized population and observations were selected following a stratified, multi-stage design.[4] Measures of overweight and obesity are estimated for six points in time: 1971-1974 (NHANES I), 1976-1980 (NHANES II), 1988-1991 (NHANES III, Phase I), 1991-1994 (NHANES III, Phase II), 1999-2000, and 2001-2002 NHANES files. Body weight and height measures were obtained by trained health technicians, and effective sample sizes of those persons between 20 and 75 years of age range from 3,647 in the 1999-2000 cycle to 12,901 from NHANES I.

2.2 Overweight and Obesity Measures

Current medical research indicates that excess accumulation of body fat, as a percent of total body weight, is the primary source of health concerns associated with being overweight. Federal guidelines use BMI as an approximation for measuring body fat, and the National Heart, Lung, and Blood Institute (part of the National Institutes of Health) asserts that it provides an acceptable approximation for large groups.[5]

In order to identify the overweight and obese, it is necessary to establish overweight and obese thresholds based on the BMI. Prior to 1998, many U.S. studies used the 85th percentile from the 1983 Metropolitan Life Insurance tables, resulting in an overweight BMI threshold of 27.8 for men and 27.3 for women. In 1995, a World Health Organization Expert Committee (1995) recommended defining a person as overweight if they had a BMI greater than or equal to

[4] For all rounds I report standard errors based on the pseudo-strata and pseudo-PSUs.
[5] See National Heart, Lung and Blood Institute (1998, Chapter 4) for more details. This view is supported by the American Society for Clinical Nutrition (1998) and the World Health Organization (1995). Nagaya *et al*. (1999) also show that BMI is well correlated with body fat.

25, and obese at 30.[6] The U.S. Federal Government adopted this lower threshold in 1998 (National Heart, Lung, and Blood Institute, 1998), thereby bringing the U.S. in line with much of the rest of the world and also reclassifying millions of individuals as overweight.

For children, there is less international consensus. In the U.S., A child or adolescent is considered at "risk of being overweight" if their BMI is at or above the 85th percentile of the revised 2000 Center for Disease Control (CDC), sex-specific BMI for age growth charts. The CDC growth charts for children and adolescents are based on U.S. nationally representative data obtained from 5 surveys conducted between 1963 and 1994 (cycles II and III of the National Health and Examination Survey and rounds I, II, III of the National Health and Nutrition Examination Survey).

These thresholds identifies the overweight and the next step is to aggregate this information into an overweight index. Drawing from the poverty literature, I use a family of indices introduced by Foster, Greer and Thorbecke (1984, hereafter referred to as FGT) to measure poverty. Slightly modifying the FGT index, one can express a class of overweight indices, OW_α, as:

$$OW_\alpha = 1/n \sum_i I(BMI_i > f)[(BMI_i - f)/f]^\alpha \qquad (1)$$

where n is the sample size, i subscripts the individual, f is the cutoff point identifying who is overweight, and I is an indicator function which takes the value of one if the statement is true and zero otherwise. When α=0 the resulting measure, OW_0, is the proportion of the population that is overweight, or the overweight *prevalence*. When α=1, the FGT index results in the

[6] BMI is body weight in kilograms divided by the square of height in meters. The English approximation,

overweight-gap index, or OW_1, which can be described as revealing the *depth* of the problem. One interpretation of the overweight-gap index is that it is equal to the product of the prevalence rate and the average value of excess BMI of the overweight (expressed as a fraction of the overweight cutoff point). When $\alpha=2$, the resulting measure is the average of the squared values of the individual overweight-gaps and is sensitive to (mean-preserving) changes in the bodyweight distribution of the overweight. Due to its distribution sensitivity, and using the poverty semantics, OW_2 can be described as reflecting the *severity* of the overweight problem.

The usefulness of these measures can be illustrated by considering an overweight person who gains weight. This weight gain has no effect on the overweight prevalence, but the health of this person has changed and this change is reflected in the overweight-gap and squared overweight-gap indices. As another example, consider a mean-preserving, increasing spread of the bodyweight distribution of the overweight (and assume there is no change in the prevalence). In this case the overweight-gap index will not reflect a change in the overall welfare of the population, but the squared overweight-gap index will be sensitive to this change in the distribution. In terms of shaping public-health policy, OW_1 and OW_2 provide important information. Policies that focus on helping the extremely overweight to loose some weight would likely have no effect on OW_0, yet could possibly have very important public-health benefits.

Another reason why considering the overweight-gap and squared overweight-gap indices is useful is linked to the issues of measurement error and the choice of the overweight threshold. Consider someone whose BMI is just marginally less than the cutoff point for being overweight and assume that they gain a small amount of weight (thereby increasing their BMI). The prevalence measure, OW_0, for this person is discontinuous at the cutoff point, changing in value

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provided by the CDC is (weight in pounds/inches^2)*703.

from zero to one. In contrast, the overweight-gap index, OW_1, is continuous at the cutoff point and a small BMI gain around this point results in a change in the index that is proportional to the BMI gain. Similarly OW_2 is continuous and differentiable at the cutoff point, and the partial derivative of OW_2 with respect to BMI evaluated at the threshold is zero.[7] Small BMI changes around the threshold value have small effects OW_2 and OW_1, but large effects on OW_0. For more on this point, see Lipton and Ravallion (1995).

The implication of this difference is that misclassifying persons can be more problematic for OW_0 for two reasons. First, OW_1 and OW_2 are more robust to measurement error near the threshold. Second, from the viewpoint of the policy debate, persons just over the threshold are classified as being just slightly overweight by OW_1 and OW_2 (rather than completely 'overweight' by OW_0), a distinction that may help the public to be less doubtful of the overweight estimates.

2.3 Sampling Variance of the Measures

To test whether changes in OW_α over time or across demographic characteristics are reflective of true changes in the population, it is necessary to estimate the sampling variance of (1). FGT show that their index is additively decomposable. This characteristic greatly simplifies the derivation of design-corrected estimates of the sampling variance. To illustrate this, consider any BMI vector, broken down into M subgroups, $BMI^{(1)}, \ldots, BMI^{(M)}$. Because OW_α is additively decomposable with population share weights, it can be written as:

$$OW_\alpha(BMI;f) = \sum_{j=1}^{M} (n_j / n)\, OW_{\alpha,j}(BMI^j; f) \qquad (2)$$

[7] OW_α is continuous in BMI for $\alpha>0$ and differentiable for $\alpha>1$.

where n is the sample size, n_j is the size of each subgroup, and f is again the overweight threshold. By extension, each observation can be treated as a subgroup and then the overweight index is the weighted mean of the individual-specific measures, or: $OW_\alpha = \sum OW_{\alpha,i}/n$. Following Kish (1965) and noting that OW_α can be considered a sample mean, the estimated sampling variance of the FGT indices from a weighted, stratified, clustered sample is given by:

$$V(OW_{\alpha,w}) = \sum_{h=1}^{L} n_h (n_h - 1)^{-1} \sum_{i=1}^{n_h} \Big(\sum_{j=1}^{m_{h,i}} w_{h,i,j}\ OW_{\alpha,h,i,j} \ - \ \sum_{i=1}^{n_h} \sum_{j=1}^{m_{h,i}} w_{h,i,j}\ OW_{\alpha,h,i,j} \Big)^2 \qquad (3)$$

where the h subscripts each of the L strata, i subscripts the cluster or primary sampling unit (PSU) in each stratum, j subscripts the ultimate sampling unit (USU), so w_{hij} denotes the weight for element j in PSU i and stratum h. The number of PSUs in stratum h is denoted by n_h, and the number of USUs in PSU (h, i) is denoted by m_{hi}.[8]

3. Results

3.1 Examining the Alternate Measures

Panel A of Table 1 presents the three overweight indices for each round of the NHANES, starting with estimates from 1971-1974 and ending with the recently released 2001-2002 two-year cycle data. The prevalence of overweight adults from the ages of 20 to 75 increased by 40 percent during this time; with most of this increase occurring during the 1990s. The most recent estimate from the 2001-2002 data indicate that 65 percent of the population is overweight. While the rapid increase during the 1990s and the currently high prevalence is typically considered sufficiently alarming to describe this as an overweight epidemic, the OW_1 and OW_2 measures provide more compelling reason for concern.

Whereas the prevalence measure, OW_0, simply informs how many persons are overweight, OW_1 describes the average percent by which the population exceeds the BMI threshold. This measure has been increasing much more quickly than the rate of the prevalence increase, more than doubling from 7.9 in the 1970s to 16.3 by the early 2000s. When divided by the prevalence rate, OW_1, reveals the average percent by which the overweight population exceeds the BMI threshold. This too steadily increased from 17 percent in the 1970s to 25 percent throughout 1999-2002. OW_0 indicates that the number of persons who are overweight has been rising, and OW_1 indicates that the overweight have become heavier.

The most rapid increase across the three indices considered occurs for the measure that is sensitive to the distribution of the overweight population, OW_2. This measure increased by more than 2½ times during the 30-years examined. From OW_1 it is clear that on average the overweight have been getting heavier, OW_2 tells us that much of this weight gain is coming from a worsening (increasing spread on the right-hand tail) of the BMI distribution. The most overweight are the ones disproportionately gaining more weight.

[INSERT TABLE 1 APPROXIMATELY HERE]

Panel C provides the same information except the BMI cutoff of 30 is used to identify the

[8] The indices and sampling variance estimates are documented in more detail in Jolliffe and Semykina (1999) who also provide a program to estimate equations (1) and (3) in the *Stata* software for the FGT

obese (rather than overweight). As stated above, we learn that the tails of the BMI distribution are getting thicker and shifting out. The obesity measures reinforce this finding. The growth rate of the prevalence of obesity is much greater (115%) than the growth rate of the overweight prevalence (40%) between 1971 and 2002. Furthermore, even when considering the more extreme threshold of 30, the fastest growing measure is the distribution-sensitive OW_2 index. This measure increased at more than twice the rate as the prevalence index. The patterns are similar whether one considers a BMI threshold of 25 or 30. The prevalence measures mask important information about the changing BMI distribution of the overweight and obese. For both the overweight and obese, not only are their numbers growing, they are becoming heavier on average and experiencing an increasing mass in the right tail of their BMI distribution.

Figure 1 graphically displays the change over time by plotting BMI density estimates from the 1971-1974 and the 2001-2002 rounds. The figure clearly shows that BMI in 2001-2002 has significantly more mass in the part of the distribution where BMI is greater than 25. It also reveals that the 2001-2002 distribution is less-peaked indicating greater spread in the tails.

[INSERT FIGURE 1 APPROXIMATELY HERE]

The estimates in Panel C of Table 1 are aimed at addressing the concern that BMI measures body-fat composition with error. The National Institutes of Health asserts that BMI provides an accurate average assessment of the overweight population, or that it incorrectly misses as many high-body-fat individuals as it improperly classifies low-body-fat individuals as overweight. The primary concern expressed in the popular press though, appears to be over the highly muscular body shapes that have been misclassified as overweight.

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poverty indices.

[ADD MATERIAL ON BIOELECTRICAL IMPEDANCE ANALYSIS (BIA)]

I currently explore this issue of measurement error in terms of skinfold measures. I hope to be able to expand on this by complimenting the analysis with BIA data.

BIA measures the electrical impedance of body tissues and can be used to assess fat-free body mass. A small alternating current is passed through surface electrodes placed on the right hand and foot and the impedance to the current flow is measured by different electrodes placed adjacent to the injection electrodes. The voltage drop between electrodes provided a measure of impedance, or opposition to the flow of the electric current. The electrical conductivity of muscle is greater than that of adipose or bone due to the greater electrolyte content (2), and a leaner individual will provide less of an impedance to this current. I'm currently trying to locate factors to convert the NHANES impedance data to measures of body fat.

Measures from the 2001-2002 data are taken on individuals between the ages 8-49. Measures were not taken in the case of: Pregnancy, Amputations other than fingers or toes, Artificial joints, pins, plates, or other types of metal objects in the body, Pacemaker or automatic defibrillator Coronary stents or metal suture material in the heart, or weight over 300 pounds.

I address this measurement-error issue with data on tricep and subscapular skinfold measures. Both of these measures provide alternate measures of body fat and are useful for distinguishing within the set of high-BMI persons those who have too much body fat from those who are high-muscle, low-body-fat persons (Dietz, 2002). To identify low-body-fat individuals, I use the weighted median values of these two measures from the NHANES I (1971-1974) for six age-sex categories.[9] For all persons who are classified as overweight, but have tricep and subscapular skinfold measures that are below these median values, I re-classify them as not overweight.[10]

After re-classifying low-skinfold-measure persons as not overweight, the prevalence measure

[9] Weighted median values are separately estimated for males and females in the following age groups: 20-40, 40-60, 60-75 years.

[10] I use these cutoffs simply as a screen to identify a subpopulation of those individuals with a greater probability of having a low level of bodyfat and a high BMI, or in other words, of having a greater probability of being improperly classified as overweight.

in 1999-2000 drops by 5 percent and re-classifies 5 million persons from overweight status to a healthy-weight status. The median BMI of these re-classified individuals is 26 indicating that most of the measurement error (as assessed by this skinfold adjustment) is very near the overweight threshold. Given this result, it is then not surprising that the OW_1 measure only drops by 2 percent and the OW_2 by less than half a percent.

This example of reclassifying low-skinfold-measure persons is not intended to produce more accurate measures of overweight and obesity prevalence, but rather it is intended to illustrate the potential impact of measurement error on the overweight measures. The skinfold-adjusted measures reported in Panel C may well identify some high-BMI, low-body-fat individuals but they may also incorrectly reclassify individuals and furthermore they make no attempt to correct for the misclassification of low-BMI, high-body-fat persons. Nonetheless, the results are useful in that they shed light on the sensitivity of the various overweight measures to the misclassification of lean, high-BMI persons, which has been the focus of the public doubt over the overweight estimates. In particular, the OW_1 and OW_2 indices reveal that they are much more robust than the prevalence measure to measurement error around the threshold.

Table 2 provides the three measures for children considered to be at risk of being overweight (i.e. BMI greater than the 85^{th} percentile of the 2000 CDC growth charts). The findings are qualitatively similar to those for adults. The prevalence of being at risk of overweight has increased significantly over the last thirty years. Twenty-three percent of children between two and five years of age are deemed to be at risk of being overweight. This represents and increase of 46 percent over the last thirty years. When considering older children, those who have had more time to accumulate body fat, both the prevalence and the rate of increase are greater. More than thirty percent of children six years and older are at risk, and this represents an increase of more than 100 percent.

[INSERT TABLE 2 APPROXIMATELY HERE]

As with adults, Table 2 reveals that the prevalence measures understate the magnitude of the growth in BMI. Across three age groups considered (2-5, 6-11 and 12-19 years), the OW1 and OW2 measures have increased by much larger amounts than the prevalence measure. For example, for the oldest age group (12-19 years), the distribution sensitive measure OW2 increased by 224 percent moving from 0.8 to 2.6 over the last thirty years.

Perhaps the most significant changes are happening to children between 6 and 11 years of age. In the early 1970s, children of this age were noticeably different from teenagers with significantly lower levels of all three overweight measures. Thirty years later, this was no longer the case—there are no significant differences across these two age categories for any of the measures. This can also be seen by noting that the fastest growth rates have occurred for children between 6 and 11 years of age, with the OW1 measure increasing by more than 300 percent and OW2 by well over 500 percent. The ratio of OW1 to OW0 reveals that in the early 1970s, mid-aged children who were at risk of being overweight exceeded their "at risk" threshold by 11 percent. By 2001-2002 these children at risk of being overweight now exceed the cutoff by 20 percent. Children are accumulating more excess body fat in much shorter time periods which has allowed this health concern to become a problem for increasingly younger children.

3.2 Income and Overweight

Conventional wisdom suggests that the poor comprise a disproportionate share of the overweight population. [I need to find and add citations on this. This will be largely from the popular press, but I'll aim to find some academic articles that also assert this. Associated Press, May 2, 2005. Obesity, Income Linked? "The poor are most likely to be fat …"] This view also conforms well to more general findings of correlation between income and negative health outcomes (Deaton, 1999; Deaton and Paxson, 1999; Deaton, 2001). Yet, whenever overweight in the U.S. is discussed, it is in terms of prevalence rates; and there is no empirical evidence that the poor a greater prevalence than the nonpoor.

Table 3 lists the overweight measures for the poor (income less than 130 percent of the poverty line), mid-income (greater than 130 and less than 300 percent of the poverty line), and upper-income (greater than 300 percent of the poverty line). The data indicate that there have been no statistically significant differences between prevalence rates across these income categories over the last thirty years.[11] In fact, from 1991 until now, the overweight prevalence for the poor has been lower (though not statistically significant) than for the nonpoor (income greater than 130 percent of the poverty line).

[INSERT TABLE 3 APPROXIMATELY HERE]

[INSERT FIGURE 2 APPROXIMATELY HERE]

Despite the lack of empirical evidence to support the conventional wisdom that the poor comprise a disproportionate proportion of the overweight population, Table 3 provides some indications to a potential reason for this misperception. A candidate explanation is that our ability to visually identify someone who has a BMI of 25 or greater is limited. As the modal BMI

[11] This is based on 95 percent confidence interval, comparison of prevalence rates across two income categories.

is between 25 and 27 (comprising about 15 percent of the adult population), conventional wisdom might be based on visual identification of the overweight as those who look heavier than the median value of BMI (27).

Regardless of the potential explanation for the misperception, the OW1 and OW2 measures in Table 3 indicate that there are important differences between the poor and nonpoor in terms of the BMI distribution. Both of these measures are significantly higher for the poor than for the mid-income and high-income groups. The OW2 measure is 85 percent higher for the poor than for the upper income group. Further, while the average BMI for the upper income overweight is 30.8, the average for the poor is much higher at 32.7. This is a difference of approximately 13 pounds for a person 5 foot 9 inches in height. Figure 2 displays BMI density estimates for the poor and nonpoor (all persons with income greater than 130 percent of the poverty line) using the 2001-2002 data. Over the range of BMI less than 25, the distributions are fairly similar. They diverge though quite significantly for the overweight. The nonpoor distribution is much more peaked and has more mass between 25 and 33, while the BMI distribution of the poor has much more mass between 35 and 55.

Gender adds an additional and important dimension to the income gradient in BMI. Table 4 compares the OW measures for the poor and upper income by gender. Controlling for gender provides a stark difference in the prevalence rates. Over the last 30 years, upper income men had much higher overweight prevalence rates than poor men. In the last round of the data, 73 percent of upper income men were overweight as compared to 62 percent of poor men. For women, the story is the opposite. Fifty-six percent of upper income women are overweight, while this figure is 65 percent for lower income women. In terms of the distribution sensitive measures, both OW1 and OW2 are higher for poor men and women, indicating that the right tails of the BMI distribution are thicker for poor men and women.

[INSERT TABLE 4 APPROXIMATELY HERE]

Table 5 examines the overweight measures for children by income, and presents a contrasting picture to the estimates for adults. During the 1970s and early 1980s, the overweight prevalence was quite similar for poor and upper-income children. This changed in the late 1980s and continues through 2002. One third of all poor children are at risk of being overweight, which contrasts to 26 percent of upper-income children. Similarly, the OW1 and OW2 measures of child overweight are higher for poor children.

Though the evidence is limited, it is a fairly commonly held view that an overweight child has a higher probability of being overweight as an adult (relative to a health weight child). [Search literature on this point.] Similarly, the empirical evidence suggests that children growing up poor are more likely to be poor during their adult years (Borjas and Sueyoshi, 1997; Case, Fertig and Paxson, 2003; Corcoran et al. 1992; Solon, 1992). If poverty and overweight are transmitted from childhood to adulthood, then the estimates in Table 5 indicate that in the near future we might see a more marked relationship between income and the prevalence of overweight.

[INSERT TABLE 5 APPROXIMATELY HERE]

4. Conclusion

This paper is motivated by discussing two measurement issues associated with treating overweight status as a dichotomous outcome. The first is that when measuring overweight as a dichotomous outcome, there is an unwarranted emphasis placed on the overweight threshold. For many diseases, where an individual is either free of the disease or infected, it may well be sensible to treat the outcome as dichotomous. In the case of being overweight though, there is little reason to believe that a marginal change in BMI around the cutoff point of 25 results in a discrete change in the true health status of the individual. The second issue is that a dichotomous measure of overweight is completely insensitive to the changing BMI distribution of the overweight. Once someone is overweight, a dichotomous measure is unaffected by whether they lose or gain weight. For example, a severely obese individual could lose several pounds and most likely improve their true health status, but a dichotomous outcome measure would fail to capture this improvement in wellbeing.

This paper considers a modified version of the Foster-Greer-Thorbecke (FGT) class of poverty indices as alternate measures of the overweight epidemic which are sensitive to changes in the BMI distribution of the overweight. The robustness of these indices to measurement error near the threshold is illustrated by considering an exercise of reclassifying as not overweight a large subpopulation of high BMI, but low-skinfold-measure individuals. The result is that the standard prevalence measures are greatly affected by this reclassification, but the distribution-sensitive measures are largely unaffected. The implication is that even if a lot of people whose BMI is near 25 are mis-classified as overweight, the distribution-sensitive measures are robust to this mis-classification and continue to indicate a high level and high growth rate in the overweight epidemic.

Most all of the discussion about the increasing rates of overweight in the U.S. are based on measures of overweight prevalence. By considering measures of the overweight epidemic that are sensitive to changes in the BMI distribution, this paper finds that the growth rate of this health problem appears to be much greater than the well-publicized increases in prevalence rates. The FGT measures reveal that the overweight have been getting heavier and the BMI distribution has become more extreme in the tails. In particular, the measures indicate that in 1971-1974, the overweight were on average 17 percent in excess of the threshold and this increased to 25 percent by 2001-2002. These findings, in combination with the medical research indicating the health risks are increasing in BMI, suggest that the negative public health effects of the overweight epidemic may be much greater than we currently believe.

The distribution-sensitive measures are also used to shed some light on some of the misperceptions surrounding the correlation between income and overweight. The commonly held belief is that the prevalence of overweight is higher for the poor than for the rich. The NHANES data indicate that this is not at all the case. In fact the most recent estimates indicate that the poor have a slightly lower prevalence of overweight relative to the nonpoor. In contrast, the OW1 and OW2 measures are greater for the poor than the nonpoor, indicating greater depth and severity of overweight for the poor. The value of the distribution sensitive measures is that they readily reveal that while there aren't substantial differences in prevalence rates by income, there is significantly greater mass in the in the right-hand tail of the BMI distribution for the poor.

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Table 1: Indices of Overweight and Obesity, Ages 20-75

OW_α	Indices of Overweight	1971 - 1974	1976 - 1980	1988 - 1991	1991 - 1994	1999 - 2000	2001 - 2002	% Change 1971-2002
Panel A: BMI Threshold at 25 (Overweight)								
OW_0	Prevalence	46.6	46.1	51.6	57	63.7	65.4	40%
		(0.77)	(0.81)	(1.00)	(1.00)	(1.70)	(0.69)	
OW_1	Depth	7.9	7.9	10.7	12.4	16.2	16.3	105%
		(0.19)	(0.18)	(0.37)	(0.45)	(0.81)	(0.56)	
OW_2	Severity	2.7	2.7	4.2	5.1	7.3	7.3	174%
		(0.13)	(0.11)	(0.24)	(0.39)	(0.57)	(0.52)	
Avg. Overweight gap (percent)		17	17	21	22	25	25	
Overweight population (millions)		55.9	60.8	83.7	95.4	111.2	114.8	
Panel B: Low Skinfold Measures Evaluated as Not Overweight								
OW_0	Prevalence	42.2	43.3	49.3	54.8	59.5	62.4	48%
		(0.72)	(0.82)	(0.98)	(1.04)	(1.78)	(0.80)	
OW_1	Depth	7.6	7.8	10.6	12.3	15.9	16.0	110%
		(0.18)	(0.18)	(0.37)	(0.45)	(0.84)	(0.56)	
OW_2	Severity	2.6	2.7	4.2	5.1	7.2	7.3	177%
		(0.13)	(0.11)	(0.24)	(0.38)	(0.58)	(0.52)	
Avg. Overweight gap (percent)		18	18	21	22	27	26	
Overweight population (millions)		50.7	57.1	79.9	91.6	103.9	109.6	
Panel C: BMI Threshold at 30 (Obese)								
OW_0	Prevalence	14.3	14.5	20.6	24	30.3	30.6	115%
		(0.42)	(0.39)	(0.82)	(01.05)	(01.55)	(01.1)	
OW_1	Depth	1.9	2	3.2	4	5.8	5.6	190%
		(0.09)	(0.08)	(0.19)	(0.26)	(0.43)	(0.38)	
OW_2	Severity	0.6	0.6	1	1.3	2.0	2.0	253%
		(0.05)	(0.05)	(0.09)	(0.17)	(0.21)	(0.23)	
Avg. Overweight gap (percent)		14	14	15	16	19	18	
Overweight population (millions)		17.1	19.1	33.5	40.2	52.9	53.8	

Notes: Indices are multiplied by 100 and estimated with the exam sample weights. Standard errors, in parentheses and also multiplied by 100, are corrected for sample-design effects. All years excludes pregnant women. Overweight gap is the average amount by which the overweight population exceeds the BMI threshold, expressed as a percent of the threshold.

Table 2: Children at Risk of Overweight by Age

OW_α	Indices of Overweight	1971 - 1974	1976 - 1980	1988 - 1991	1991 - 1994	1999 - 2000	2001 - 2002	% Change 1971-2002
Panel A: Ages 2-5 years								
OW_0	Prevalence	15.5	14.1	18.1	17.7	20.6	22.7	46%
		(1.01)	(0.66)	(1.56)	(1.25)	(2.07)	(2.42)	
OW_1	Depth	1.0	1.0	1.5	1.9	2.1	2.6	153%
		(0.09)	(0.09)	(0.2)	(0.56)	(0.28)	(0.51)	
OW_2	Severity	0.2	0.1	0.3	0.7	0.5	0.7	294%
		(0.03)	(0.02)	(0.08)	(0.44)	(0.1)	(0.21)	
Panel B: Ages 6-11 years								
OW_0	Prevalence	13.9	15.4	20.9	29.2	30.3	32.3	131%
		(1.02)	(1.07)	(1.51)	(1.78)	(2.61)	(2.16)	
OW_1	Depth	1.6	2.4	3.4	5.1	5.1	6.5	315%
		(0.16)	(0.22)	(0.35)	(0.6)	(0.61)	(0.72)	
OW_2	Severity	0.4	0.7	1.0	1.7	1.6	2.6	571%
		(0.07)	(0.11)	(0.15)	(0.29)	(0.25)	(0.42)	
Panel C: Ages 12-19 years								
OW_0	Prevalence	16.2	14.5	20.2	29.5	30.4	31.4	93%
		(0.93)	(0.77)	(1.43)	(1.61)	(1.42)	(1.38)	
OW_1	Depth	2.5	2.2	3.8	5.6	6.5	6.8	172%
		(0.19)	(0.19)	(0.34)	(0.69)	(0.36)	(0.44)	
OW_2	Severity	0.8	0.7	1.3	2.6	2.5	2.6	224%
		(0.1)	(0.1)	(0.18)	(0.79)	(0.24)	(0.22)	

Note: See note above. At risk children are defined as a BMI greater than the 85^{th} percentile of the CDC growth charts. The label for age in years is truncated, so for example, Panel A (2-5 years) includes all children less than six years (72 months) of age.

Table 3: Adult Overweight by Income

OW_α	Indices of Overweight	1971 - 1974	1976 - 1980	1988 - 1991	1991 - 1994	1999 - 2000	2001 - 2002	% Change 1971-2002
Panel A: Income < 130% poverty line								
OW_0	Prevalence	48.3	46.5	55.6	55.8	64.1	63.5	32%
		(01.54)	(1.40)	(2.18)	(1.74)	(2.57)	(1.45)	
OW_1	Depth	10.4	10.2	14.4	13	17.7	19.7	89%
		(0.46)	(0.48)	(01.1)	(0.77)	(0.66)	(1.15)	
OW_2	Severity	4.4	4.3	6.6	5.7	8.6	10.7	144%
		(0.35)	(0.39)	(0.79)	(0.57)	(0.59)	(1.04)	
Panel B: Between 130 & 300% poverty								
OW_0	Prevalence	47.8	46.9	51.3	59.9	67	66.5	39%
		(0.96)	(1.05)	(1.69)	(2.10)	(2.26)	(1.97)	
OW_1	Depth	8.2	8.1	10.6	14.5	18.1	16.2	98%
		(0.3)	(0.25)	(0.43)	(0.98)	(1.31)	(0.76)	
OW_2	Severity	2.6	2.6	4	6.4	8.3	7.2	176%
		(0.18)	(0.13)	(0.31)	(0.90)	(0.94)	(0.53)	
Panel C: Income > 300% poverty line								
OW_0	Prevalence	45.2	44.7	50.6	54.6	63	65.2	44%
		(1.12)	(1.00)	(1.62)	(1.17)	(2.23)	(1.11)	
OW_1	Depth	6.8	6.7	9.5	10.4	14.6	14.7	116%
		(0.27)	(0.22)	(0.58)	(0.46)	(1.26)	(0.57)	
OW_2	Severity	2.1	2.1	3.5	3.8	6.1	5.8	183%
		(0.19)	(0.15)	(0.42)	(0.31)	(0.91)	(0.50)	

Note: See note Table 1.

Table 4: Adult Overweight by Sex and Income

OW_α	Indices of Overweight	1971 - 1974	1976 - 1980	1988 - 1991	1991 - 1994	1999 - 2000	2001 - 2002	% Change 1971-2002
Panel A: Low Income Men (<130% poverty)								
OW_0	Prevalence	43.8	42.8	52.2	50.9	62.9	62.1	42%
		(2.18)	(1.99)	(3.45)	(2.74)	(2.67)	(3.17)	
OW_1	Depth	7.0	6.8	11.4	9.1	14.8	16.4	133%
		(0.5)	(0.44)	(1.41)	(0.79)	(1.18)	(1.48)	
OW_2	Severity	2.2	2.1	4.4	3.0	6.4	8.7	303%
		(0.3)	(0.27)	(0.92)	(0.42)	(0.91)	(1.60)	
Panel B: Low Income Women (<130% poverty)								
OW_0	Prevalence	51.7	49.0	58.2	59.7	65.1	64.7	25%
		(1.94)	(1.75)	(2.37)	(2.24)	(3.40)	(2.09)	
OW_1	Depth	12.9	12.5	16.7	16.1	20.0	22.3	72%
		(0.64)	(0.79)	(1.08)	(1.26)	(0.98)	(1.25)	
OW_2	Severity	6.0	5.8	8.3	7.8	10.3	12.3	103%
		(0.51)	(0.67)	(0.86)	(0.90)	(0.82)	(1.19)	
Panel C: High Income Men (>300% poverty)								
OW_0	Prevalence	55.3	53.3	59.3	62.2	68.5	73.0	32%
		(1.73)	(1.1)	(1.96)	(1.65)	(1.81)	(1.4)	
OW_1	Depth	7.5	6.7	9.6	10.1	14.4	14.7	95%
		(0.39)	(0.23)	(0.63)	(0.62)	(1.24)	(0.67)	
OW_2	Severity	2.0	1.6	3.3	3.3	5.7	5.2	158%
		(0.31)	(0.1)	(0.59)	(0.49)	(1.10)	(0.72)	
Panel D: High Income Women (>300% poverty)								
OW_0	Prevalence	34.4	34.9	41.4	46.6	57.1	56.1	63%
		(1.17)	(1.52)	(2.35)	(1.80)	(3.77)	(1.68)	
OW_1	Depth	6	6.7	9.4	10.7	14.7	14.8	144%
		(0.36)	(0.46)	(0.87)	(0.68)	(1.57)	(0.94)	
OW_2	Severity	2.1	2.6	3.8	4.5	6.5	6.6	211%
		(0.23)	(0.32)	(0.52)	(0.46)	(1.03)	(0.60)	

Note: See note Table 1.

Table 5: Children at Risk of Overweight by Income

OW_α	Indices of Overweight	1971 - 1974	1976 - 1980	1988 - 1991	1991 - 1994	1999 - 2000	2001 - 2002	% Change 1971-2002
Panel A: Low Income Children (<130% poverty)								
OW_0	Prevalence	13.5	14.9	22.8	29.6	31.3	33.3	146%
		(1.03)	(1.09)	(1.63)	(2.11)	(1.93)	(1.67)	
OW_1	Depth	1.9	2.3	3.9	5.3	5.8	6.8	268%
		(0.18)	(0.27)	(0.42)	(0.63)	(0.37)	(0.56)	
OW_2	Severity	0.6	0.8	1.3	2.1	2.0	2.8	408%
		(0.07)	(0.14)	(0.23)	(0.41)	(0.28)	(0.35)	
Avg. Overweight gap (percent)		14	16	17	18	19	20	
Overweight population (millions)		2.5	2.8	3.9	6.2	7.4	7.2	
Panel B: High Income Children (>300% poverty)								
OW_0	Prevalence	14.1	14.3	17.4	20.5	24.0	26.0	84%
		(01.18)	(01.16)	(01.94)	(02.03)	(01.56)	(01.95)	
OW_1	Depth	1.5	1.6	2.3	3.8	4	5	233%
		(0.19)	(0.21)	(0.41)	(01.5)	(0.49)	(0.57)	
OW_2	Severity	0.4	0.3	0.6	2.1	1.3	1.7	377%
		(0.08)	(0.07)	(0.15)	(01.47)	(0.24)	(0.25)	
Avg. Overweight gap (percent)		11	11	13	19	16	19	
Overweight population (millions)		2.2	2	2.9	3.5	5.1	6	

Note: See note Table 2.

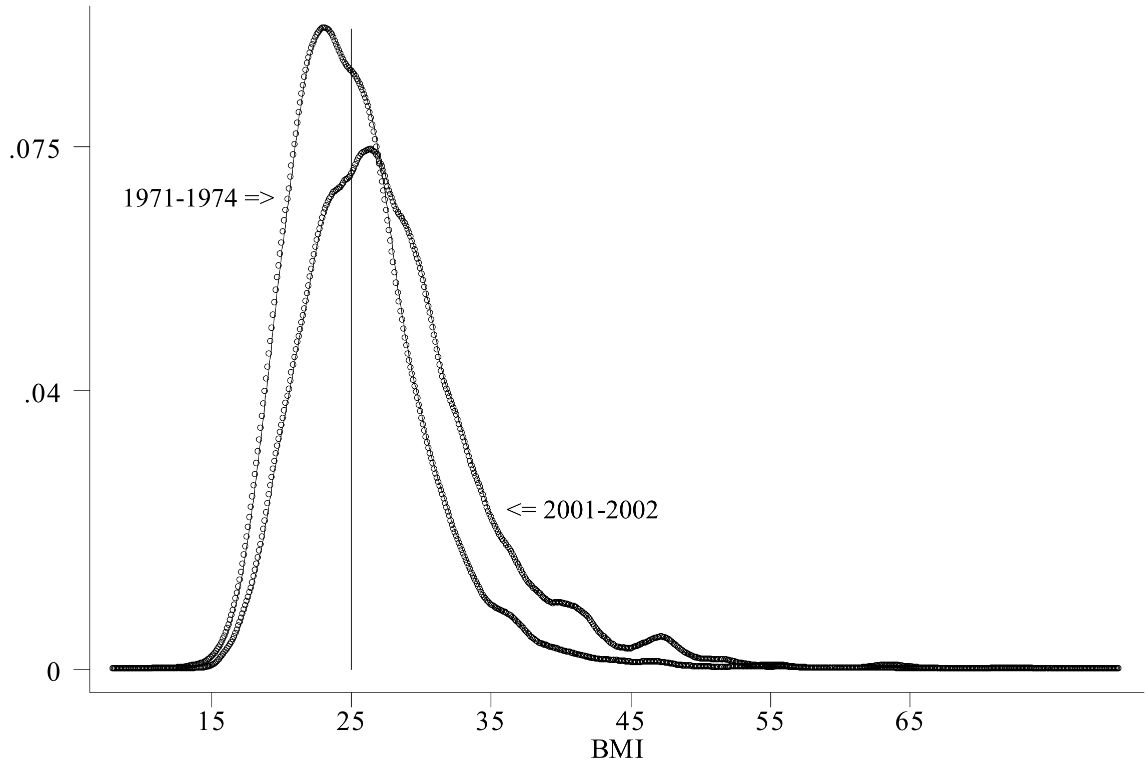

Figure 1: Density estimates of BMI from NHANES I (1971-1974) and NHANES 2001-2002

Notes: The Epanechnikov kernal is used to estimate the density functions with the smoothing parameter set to 0.75.

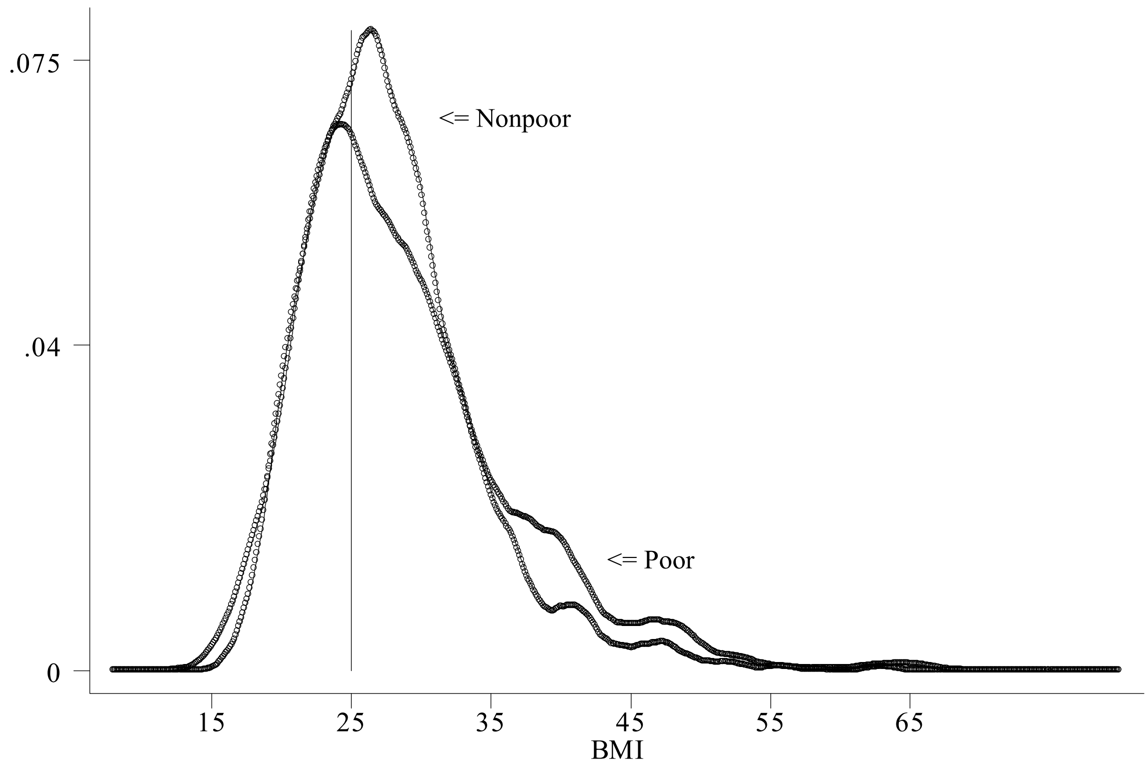

Figure 2: BMI density estimates from NHANES 2001-2002 by income

Notes: Poor persons are those with incomes less than 130 percent of the poverty line, nonpoor are those with incomes greater than 130 percent. The Epanechnikov kernal is used to estimate the density functions with the smoothing parameter set to 0.75 for the nonpoor and 1.5 for the poor.