CURRENT AND FUTURE PREVALENCE OF OBESITY AND SEVERE OBESITY
IN THE UNITED STATES

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ABSTRACT

The prevalence of obesity has increased rapidly since the mid-1970s, following a period of relative stability. This study examines past patterns and projects future prevalence rates of obesity and severe obesity among US adults through 2020. Trends in body mass index (BMI), overweight (BMI 25), obesity (BMI 30), class 2 obesity (BMI 35), class 3 obesity (BMI 40) and class 4 obesity (BMI 45) of 20-74 year olds are obtained using data from the first National Health Examination Survey and the Nutrition Health and Nutrition Examination Surveys. Quantile regression methods are then used to forecast future prevalence rates through 2020. By that year, 77.6% of men are predicted to be overweight and 40.2% obese, with class 2, 3 and 4 obesity prevalence rates projected at 16.4%, 6.3% and 3.1%. The corresponding forecasts for women are 71.1%, 43.3%, 25.3%, 12.8% and 5.8%. The large growth predicted for severe obesity represents a major public health challenge, given the accompanying high medical expenditures and elevated risk of mortality and morbidity. Combating severe obesity is likely to require strategies targeting the particularly large weight gains of the heaviest individuals.

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Americans are gaining weight. The average adult added 9 to 12 pounds during the 1990s (Freeman et al., 2002). Persons with a body mass index (BMI) of 25 kg/m^2 or more are classified as overweight (World Health Organization, 1997; National Heart, Lung and Blood Institute, 1998). Using this criterion, almost two-thirds of Americans 20 and older weighed too much in 1999-2000, compared to 46 percent in 1976-80 (Flegal et al., 1998, 2002). The prevalence of overweight and obesity is particularly high in the US but is growing rapidly throughout much of the world (World Health Organization, 1997; International Obesity Task Force, 2005).

The rise in excess weight in the US has been widely documented (Flegal et al., 2002; Mokdad et al., 2001; Hedley et al., 2004). However, because the BMI distribution has both shifted to the right and become increasingly skewed (Flegal and Troiano, 2000), severe obesity has increased especially quickly. Based on self-reported data, the 10th percentile of the adult BMI distribution rose 0.6 kg/m^2 between 1990-91 and 2000, compared to 1.2 kg/m^2 at the median and 3.2 kg/m^2 at the 95th percentile (Freedman et al., 2002). Examination data reveal that median adult BMI rose 9.5 percent between 1976-80 and 1999-2000, versus 15.2 percent at the 95th percentile (Anderson et al., 2003). The prevalence of obesity (BMI $\geq$ 30) doubled between 1986 and 2000, based on self-reported data, while class 3 obesity (BMI $\geq$ 40) quadrupled and BMI $\geq$ 50 quintupled (Sturm, 2003).

The growth of obesity, particularly in its most extreme forms, is a major current public health issue and is likely to become even more problematic in the future. Compared to normal weight or overweight but non-obese individuals, the severely obese have substantially elevated

mortality (Allison et al., 1999; Calle et al., 1999; Engeland et al., 2003; Fontaine et al., 2003;

Peeters et al., 2003; Flegal et al., 2005) and much higher rates of diabetes, high blood pressure,

asthma and other diseases (Must et al., 1999; Mokdad et al., 2001; Okoro et al, 2004). Extreme

obesity raises medical expenditures, stresses the health care system and results in productivity

losses due to disability, illness and premature mortality (Quesenberry, 1998; Thompson et al.,

2001; Finkelstein et al., 2003; Andreyeva et al., 2004). Olshansky et al., (2005) raise concern

that growing obesity may limit or even reverse historical gains in life expectancy. Since their

analysis did not account for the effects of excess weight beyond a BMI of 35 kg/m^2, it may

understate the decline in lifespan associated with the rapid increases in severe adiposity.

This study begins by detailing trends in adult body weight since the 1960s. Compared to

earlier research, it supplies unusually detailed information on changes over the entire BMI

distribution, which is important for the second stage of analysis – forecasting the future

prevalence of overweight, obesity and severe obesity. Predictions, through 2020, are obtained

assuming a continuation of recent trends and using quantile regression techniques that provide a

flexible method of allowing increases in BMI to differ across the distribution (e.g. to be larger at

the 90th than the 50th percentile) in ways that closely align with observed patterns. The

investigation next decomposes obesity trends into the portions due to population-wide increases

in BMI and those resulting from particularly large growth among the heaviest individuals. For

ease of exposition, these will often be referred to as "general" versus "concentrated" weight

gains.

The study yields three major findings. First, it confirms previous evidence that rapid

increases in overweight and obesity date from the middle 1970s and followed a period of relative

stability. Although this partially reflects shifts in the entire BMI distribution, disproportionately

large growth occurred at the highest BMI levels. Second, a continuation of these trends implies

that the prevalence of all forms of excess weight will rise in the future, but with particularly

rapid increases in severe and extreme obesity.[1] Third, future growth in overweight and mild

forms of obesity is predicted to largely result from overall shifts in the BMI distribution and

might therefore be effectively addressed by efforts achieving modest but widely distributed

reductions in weight. By contrast, previous and expected future increases in severe obesity are

dominated by the particularly large weight growth in the right tail of the distribution. Reducing

these prevalence rates is therefore likely to require new medical and behavioral interventions

targeted at extremely obese adults and high risk youths.

1. Data and Outcomes

Baseline information was obtained from the first National Health Examination Survey

(NHES 1, 1960-1962), the first, second and third National Health and Nutrition Examination

Surveys (NHANES 1, 1971-1974; NHANES 2, 1976-1980; NHANES 3, 1988-1994), and from

the first six years (1999-2004) of the most recent NHANES survey (hereafter referred to as

NHANES 99), which is continuously conducted and with data publicly released at two year

intervals.[2] Each of these is a cross-sectional nationally representative survey conducted by the

National Center for Health Statistics, Centers for Disease Control and Prevention. They were

designed to provide prevalence estimates for selected diseases and risk factors, monitor trends in

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[1] Of course, recent trends may not continue, in part because of public health campaigns and policy initiatives aimed at slowing or reversing future increases in body weight. The success of these efforts remains uncertain, however, and it is useful to understand the patterns predicted by current trends.

[2] Additional information on these data sets is available from National Center for Health Statistics (1965, 1994); Miller (1973); McDowell et al. (1981), and at the website: http://www.cdc.gov/nchs/nhanes.htm.

risky behaviors and environmental exposures, and to study the relationship between diet, nutrition, and health.

The NHES/NHANES data have several features that are particularly useful for this project. Most importantly, almost all respondents complete health and laboratory examinations that include clinical measurements of height and weight obtained using standardized procedures and equipment.[3] Such clinical data are helpful because self-reports of height and weight contain errors that generally lead to an underestimate of BMI, with most evidence suggesting a bigger downwards bias for heavier individuals.[4] Sample sizes are also reasonably large – although bigger samples would be desirable when measuring low-prevalence conditions such as severe obesity – and minorities and senior citizens are oversampled. Finally, sufficient information is provided on the geographic location and sampling strategy to permit standard errors to be corrected for complex survey design.

Analysis is restricted to 20-74 year olds because different weight classification criteria are used for persons under 20 and individuals older than 74 are excluded from NHANES 2. Pregnant women are retained in the primary analysis sample because larger than anticipated differences in reported pregnancy rates across NHANES surveys raised the possibility of classification errors. Sensitivity analysis conducted after omitting pregnant women yielded virtually identical estimates to those presented below.

BMI is calculated as weight in kilograms divided by height in meters squared. Following national and international standards (World Health Organization, 1997; National Heart, Lung

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[3] For the NHES, two pounds were subtracted from measured weight, because the examinee was partially dressed (unlike the other surveys where individuals wore only underwear) and the remaining clothing was estimated to weigh approximately two pounds (National Center for Health Statistics, 1981).

[4] Specifically, there is a tendency over-report height and understate weight (Strauss, 1999; Goodman et al., 2000; Kuczmarski et al., 2001). A number of (not entirely satisfactory) regression-based procedures have been proposed for correcting the self-report errors.

and Blood Institute, 1998), overweight is defined as BMI $\geq$ 25, obesity as BMI $\geq$ 30, class 2

obesity as BMI $\geq$ 35 and class 3 obesity as BMI $\geq$ 40.[5] No standards have been established for

obesity beyond class 3. This analysis categorizes "class 4" obesity as BMI $\geq$ 45, to illustrate

growth of a more extreme form of excess weight.

2. Empirical Methods

Trends in BMI and the prevalence of overweight and alternative classes of obesity were

ascertained for all 20-74 year olds and for subsamples stratified by sex. Total changes and

annual growth rates were calculated for the period from NHES 1 (1960-1962) to NHANES 2

(1976-1980) and from NHANES 2 to NHANES 99 (1999-2004), as well as for some subperiods.

Annual percent changes were based on years elapsed between the midpoints of the specified

surveys (i.e. a 17-year time difference between 1960-1962 and 1976-1980; a 13-year difference

between 1976-1980 and 1988-1994; and a 10.5-year difference between 1988-1994 and 1999-

2004). All statistical and econometric analysis was conducted using the STATA statistical

software (StataCorp, 2005). Sampling weights were incorporated to allow for unequal selection

probabilities and standard errors were computed using Taylor series linearization methods to

account for complex survey design.

Future prevalence rates were projected as the fraction of the population, in the specified

year, predicted to have BMI at or above the threshold level (e.g. $\geq$ 30 kg/m^2 for obesity).

Traditional regression methods are useful for estimating relationships between covariates and

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[5] BMI is the favored method of assessing excess weight since it is simple, rapid, and inexpensive to calculate.
However, it is less accurate than laboratory measures of body composition because it does not account for variations
in muscle mass or the distribution of body fat (e.g. intra-abdominal versus overall adiposity). Some researchers
prefer alternative anthropometric measures such as waist circumference (Sönmez et al., 2003), waist-hip ratio
(Dalton et al., 2003), or waist-height ratio (Cox and Whichelow, 1996). Cawley and Burkhauser (2006) have
recently recommended the use of Bioelectrical Impedance Analysis (BIA).

mean values of the dependent variable but, without strong parametric assumptions, will not

accurately indicate changes at other points in the distribution. Such restrictions are unlikely to

be justified since, as shown below, BMI increased more over time (in both absolute and

percentage terms) at high than low values.

As an alternative, future outcomes were forecasted using a series of quantile regressions

that allowed BMI growth trends to vary across the distribution.[6] The projections were based on

time trends using data from NHANES 2, 3 and 99, covering the period 1976-1980 to 1999-2004.

Data from NHES 1 and NHANES 1 were excluded because the BMI distribution changed little

during these periods. The dependent variable in the quantile regressions was body mass index.

Covariates included dummy variables for race/ethnicity (non-Hispanic Black, Hispanic, other

nonwhite) and age (25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69 and 70-74

years old), as well as linear time trends showing years elapsed since 1975.[7]

Quantile regressions were estimated for each of the 1st through 99th BMI percentiles (a

total of 99 estimates). Projected BMI, at the specified percentile, was obtained by setting the

time trend to its value in the forecast year of interest (2001, 2010 or 2020), with other

explanatory variables evaluated at the NHANES 99 averages.[8] The forecasts were therefore

based on the race/ethnicity and age characteristics of the 1999-2004 population.[9]

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[6] Quantile regression minimizes the weighted sum of the absolute deviations of the error term, unlike standard regression that minimizes the sum of the squared residuals (Manning et al., 1995; Koenker and Hollack, 2001). At quantile q, the weights q and (1-q) are applied to positive and negative residuals. In the special case of median regression, q and (1-q) are both 0.5, implying that estimates minimize the unweighted sum of the absolute residuals.

[7] The survey year was not specified in the public-use versions of NHANES 3 and 99 but the data sets do indicate whether measurements occurred in 1988-1991, 1991-1994, 1999-2000, 2001-2002 or 2003-2004. The year was set to the midpoint of the range in these cases (1989.5, 1992.5, 1999.5, 2001.5 and 2003.5).

[8] Sampling weights were incorporated throughout.

[9] The same procedure, but with the explanatory variables set to the NHANES 2 means, was used when predicting 2001 values based on 1976-1980 population characteristics.

Overweight and obesity prevalence rates were calculated by linear interpolation between adjacent percentiles where expected BMI spanned the threshold. For instance, if BMI was predicted to be 34.75 kg/m^2 at the 87th percentile and 35.25 kg/m^2 at the 88th percentile, the estimated prevalence of class 2 obesity at 12.5 percent (since 35.0 kg/m^2 is half way between the two estimates). These interpolations will be quite accurate when the difference in BMI is across adjacent percentiles is small but less so in tails of the distribution, where the changes are often quite large. Therefore, forecasts of class 3 or class 4 obesity involved the additional step of estimating quantile regressions for each 0.1 percentile within the BMI percentile spanning the threshold value and then using linear interpolation for the adjacent 0.1 percentiles above and below it. To illustrate, if predicted BMI at the 95th and 96th percentile was 44.05 kg/m^2 and 45.83 kg/m^2, estimates would be obtained for the 95.1st through 95.9th percentiles. If these indicated that BMI was 44.95 kg/m^2 and 45.05 kg/m^2 at the 95.4th and 95.5th percentile, the prevalence of class 4 obesity was forecasted to be 4.55 percent.

Prevalence rates were estimated separately for males and females. Rates for the combined (male and female) sample were calculated as a weighted average of the sex-specific prevalence rates, with weights corresponding to NHANES 99 population shares. Median BMI was forecasted as the predicted value at the 50th percentile in the specified year, using the methods just described, except that the value for the combined sample of men and women was obtained from a single (full sample) median regression.

Ninety-five percent confidence intervals were constructed in two steps. First, prevalence rates at each BMI percentile were forecasted (for the specified year) after subtracting or adding 1.96 times the associated standard error to the trend regression coefficient. Next, upper and

lower bounds on the 95 percent confidence interval were obtained using these forecasts and the linear interpolation procedures described above.

Secular increases in obesity may reflect a combination of a general rise in body weight and disproportionate growth at the top of the distribution. The contribution of population-wide growth is BMI was obtained by the following procedure: 1) quantile regression was used to estimate annual growth in sex-specific median BMI; 2) the increase in median BMI predicted to occur between the baseline and forecast periods was then calculated and added to the BMI of each respondent in the baseline NHANES survey; 3) median BMI and overweight/obesity prevalence rates were computed using the transformed data and differences between these and corresponding statistics from the untransformed data were attributed to general growth in body weight. To illustrate, assume that median BMI was predicted (in step one) to increase by 0.110 kg/m^2 per year. This implies projected growth of 2.035 kg/m^2 (18.5 x 0.110 kg/m^2) between 2001.5 – midpoint of NHANES 99 – and 2020. If adding this amount to the BMI of each NHANES 99 sample member raises obesity prevalence from 30 to 35 percent, then a 5-percentage point increase is attributed to general weight gains. Assuming that the obesity rate was forecasted to be 38 percent in 2020 (using the quantile regressions), the residual 3-point rise, corresponding to 37.5 percent (3 out of 8 percentage points) of the total increase, would be attributed to larger than typical BMI growth in the right tail of the distribution.

3. Trends in Obesity and Severe Obesity

The average BMI of 20-74 year olds changed little between 1960-1962 and 1976-1980 (rising just 0.26 kg/m^2) but increased much more rapidly thereafter: by 1.26 kg/m^2 between 1976-1980 and 1988-1994 and 1.61 kg/m^2 from 1988-1994 to 1999-2004 (see Table 1). On an

annualized basis, body mass index grew over 50 percent faster from 1988-1994 to 1999-2004

than between 1976-1980 and 1988-1994 (0.56 percent versus 0.37 percent per year).

Obesity and severe obesity have increased even more. The prevalence of overweight

rose 43 percent between 1976-80 and 1999-2004, while obesity more than doubled and class 2, 3

and 4 obesity tripled, quadrupled and quintupled.[10] To place this in perspective, class 2 obesity

was nearly as prevalent in 1999-2004 as obesity had been two decades earlier; class 3 obesity

was more frequent than class 2 obesity had been at that time; and class 4 obesity rose from a

clinical rarity to affecting over two percent of the population.

Figure 1 demonstrates that the particularly large rise of severe obesity reflects a shift in

the overall BMI distribution, combined with increasing skewness, resulting in a much thicker

right tail. This provides preliminary evidence of the roles of both general and concentrated

weight gains in explaining the growth in extreme obesity. Figure 2 shows that the height of U.S.

adults changed little during the period of rapidly rising obesity: in 1976-1980, the 10th, 50th, 90th

and 99th percentiles of the height distribution were 156.0, 167.8, 181.2 and 190.0 cm, compared

to 156.7, 168.8, 182.8, and 191.5 cm in 1999-2004. By contrast, weight rose 4.1 kg (from 53.3

to 57.4 kg) at the 10th percentile, and 8.3 kg (from 70.2 to 78.5 kg), 15.5 kg (from 91.9 to 107.3

kg) and 27.3 kg (from 116.4 to 143.6 kg) at the 50th, 90th and 99th percentiles.

The overall pattern of stable weight prior to NHANES 2 and rapid increases thereafter

was observed for both sexes (see Table 2) but two differences are noteworthy. First, as

previously recognized, males were somewhat more likely than women to be overweight but were

much less frequently obese or severely obese (Flegal et al., 1998; Hedley et al, 2004; Must et al.,

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[10] Results for 1971-1975 are very similar to 1976-1980 and so are not displayed on this or future tables. For instance, average BMI was 25.30 kg/m², overweight prevalence was 46.56 percent and obesity and class 3 obesity prevalence were 14.30 and 1.29 percent respectively.

1999): in 1999-2004, the prevalences of class 3 and 4 obesity were 6.9 and 2.9 percent for

women compared to 3.3 and 1.2 percent for men. Second, weight increased faster over time for

females than males. Between 1976-1980 and 1999-2004, average BMI rose 12.7 percent for

women compared to 9.9 percent for men. This reflected larger growth for females at all points of

the BMI distribution except the very highest: BMI rose 6.2, 9.0, 12.6, 16.2 and 16.9 percent at

the 10th, 25th, 50th, 75th and 90th percentile for women, compared to 4.3, 7.1, 8.8, 10.8 and 14.4

percent for men.[11]

Age-adjusting the data to the 2000 Census population, using the age groups 20-39, 40-59

and 60-74, slightly increases BMI and obesity prevalence but does not change the basic trends.

For instance, age-adjusted BMI averaged 25.16, 25.58 and 28.29 kg/m^2 in 1960-62, 1976-1980

and 1999-2004 (results not shown on a table). The corresponding prevalence of obesity was

13.8, 15.4 and 31.9 percent and that of class 3 obesity was 0.9, 1.4 and 5.2 percent.

4. Future Forecasts of Obesity and Severe Obesity

Table 3 displays forecasts of median BMI and the prevalence of overweight and various

classes of obesity in 2001, 2010 and 2020. Projections for 2001 are similar to actual 1999-2004

rates (shown in the first column), indicating that the prediction procedures work well within the

sample period: the actual value is outside the forecast 95 percent confidence interval in only one

of 18 cases (obesity prevalence of females) and the differences are generally small. For

example, 65.5 percent of 20-74 year olds were overweight and 31.5 percent were obese in 1999-

2004, compared to the 2001 predictions of 65.2 and 30.0 percent. The projected prevalences of

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[11] Median height rose 0.8 cm for males and 1.1 cm for females between 1976-1980 and 1999-2004. This was
accompanied by rapid weight gains of 7.4, 11.6, 15.1 and 19.4 kg at the 50th, 75th, 90th and 95th percentile for men
and 8.3, 12.5, 16.9 and 19.4 kg for women.

class 2, 3 and 4 obesity in 2001 (12.1, 4.8 and 1.9 percent) were all slightly below the rates observed in NHANES 99 (13.0, 5.2 and 2.1 percent). A likely reason is that the predictions are based on a linear time trend, while the evidence indicates that the secular increase in weight is accelerating. This suggests that the point forecasts for moderate and severe obesity prevalence in 2010 and 2020 may be slightly understated.[12]

Body weight is projected to grow rapidly during the first two decades of the 21st century. Median male BMI is expected to be 1.8 percent (0.5 kg /m^2) greater in 2010 than in 1999-2004, while the median BMI of females is predicted to rise 2.2 percent (0.6 kg /m^2). By 2020, median BMI is anticipated to be 5.1 percent (1.4 kg/m^2) higher than in 1999-2004 for men and 6.3 percent (1.7 kg /m^2) greater for women. Based on current trends, 78 percent of men and 71 percent of women will be overweight in 2020.

Severe forms of excess weight are expected to rise much more. Obesity is forecasted to grow from 28.7 (34.1) percent of males (females) in 1999-2004 to 40.2 (43.3) percent in 2020. Class 2 obesity is estimated to climb over 70 percent for men (from 9.6 to 16.4 percent) and 57 percent for women (from 16.1 to 25.3 percent). Class 3 obesity is anticipated to rise more than 80 percent for both males (from 3.3 to 6.3 percent) and females (from 6.9 to 12.8 percent), with class 4 obesity more than doubling (from 1.2 to 3.1 percent for men and from 2.9 to 5.8 percent for women).

As mentioned, the preceding estimates assumed a linear time trend and so did not adjust for the accelerating growth in body weight occurring at the end of the 20th century. Accounting

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[12] An additional downwards bias is likely due to changes in population characteristics that will occur between 1999-2004 and 2020 but are not accounted for. Consistent with this, corresponding 2001-year forecasts, based on 1976-1980 population characteristics, are always below the actual results for the NHANES 99 period – e.g. predicted obesity and class 3 obesity prevalence is 28.8 and 4.67 percent, versus observed rates of 31.5 and 5.17 percent. The understatement is largely due to not accounting for rapid growth in the population share of Hispanics – rising from 5.2 to 13.6 percent between 1976-1980 and 1999-2004 – who are relatively often obese.

for such nonlinearities yields still higher estimates of future obesity. For instance, in a second

set of projections using the same methods but measuring trends over the shorter period covered

by NHANES 3 and 99 only (1988-94 through 1999-2004), 45.1 percent of men and 48.6 percent

of women are forecasted to be obese in 2020, with class 2, 3 and 4 obesity predicted for 19.2, 7.9

and 3.3 percent of men and 29.3, 13.8 and 6.4 percent of women (see Appendix Table A.1).

Even larger future obesity rates are obtained using other specifications, such as including a

quadratic time trend for the NHANES 2 through 99 period.

5. General Versus Concentrated Weight Gains

Class 3 obesity quadrupled and class 4 obesity quintupled between 1976-80 and 1999-

2004. This was mostly due to abnormally large weight increases at the top of the BMI

distribution, rather than a general rise in body weight, and contrasts with the more dominant role

of dispersed changes in explaining the corresponding growth in overweight and mild obesity.

These findings are documented in Table 4. Median BMI and overweight/obesity prevalence

during the NHANES 2 period are shown in column (a). Column (b) displays corresponding

statistics predicted for 1976-1980, assuming the race/ethnicity and age characteristics of the

1999-2004 population.[13] Column (c) indicates expected values in 2001, using 1976-1980

population characteristics but adjusted for predicted sex-specific median growth in BMI

occurring between 1978 (the midpoint of NHANES 2) and 2001.[14] Actual 1999-2004 median

BMI and prevalence rates are displayed in column (d). Column (e) shows the estimates of

secular increases attributed to concentrated (rather than general) weight gains. These are

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[13] These are obtained using the previously described quantile regression methods for the NHANES 99 sample but with the time trend variable set to 1978.

[14] Median BMI is predicted to rise 0.0844 (0.1027) kg/m^2 per year for men (women).

calculated by subtracting from the total growth (column d – column a), the proportions due to

changing population characteristics (column b – column a) and rising median BMI (column c –

column a). To illustrate, obesity prevalence increased 17.0 percentage points (from 14.5 to 31.5

percent) between 1976-1980 and 1999-2004, with -0.4 points of this due to changing population

characteristics and 9.8 points reflecting growth in median BMI. The remaining 7.6 percentage

points are therefore attributed to concentrated weight gains and this accounts for 44.4 percent of

the total rise in obesity.[15]

General growth in body weight accounted for around 90 percent of the increase in

median BMI, between 1976-1980 and 1999-2004, and more than 100 percent of the rise in

overweight. The importance of dispersed weight gains for these outcomes is unsurprising, since

more than half of males and two-fifths of females were overweight at the beginning of the

analysis period.

Conversely, increases in severe obesity prevalence mainly resulted from concentrated

weight gains: these are responsible for 65, 79 and 77 percent of the growth in class 2, class 3 and

class 4 obesity. This is particularly true for men but increases in the right tail of the BMI

distribution explain at least three-fifths of the growth for both sexes.[16]

Table 5 details corresponding decompositions of the increases in prevalences of

overweight and obesity forecasted to occur between 1999-2004 and 2020. Column (a) shows

actual statistics for the NHANES 99 period and column (c) provides projections for 2020

previously obtained from the quantile regressions. Column (b) indicates rates expected in 2020

under the assumption that the BMI of all adults will increase at the predicted sex-specific median

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[15] The statistics were calculated to six significant digits, with some differences in the table due to rounding error.

[16] Median BMI increased faster for women than men and so explains a greater portion of rising prevalence rates of
females. Concentrated weight growth also accounts for 23 percent (20 percent for men and 27 percent for women)

(1.85 kg/m^2 for males and 2.37 kg/m^2 for females), rather than using the larger growth anticipated in the right tail of the BMI distribution. The proportion of the change due to concentrated weight gains, shown in column (d), is then calculated as the difference between the total predicted increase (column c – column a) and that resulting from median BMI growth (column b – column a).[17]

Predicted increases in severe obesity are again dominated by weight gains in the right tail of the BMI distribution: these account for half the predicted growth in class 3 obesity and two-thirds of the rise in class 4 prevalence, with even higher contributions for males. By contrast, the increase anticipated for overweight and mild obesity entirely results from general weight gains. This occurs because a large majority of adults are overweight in 1999-2004 and so these prevalences are less affected by experiences at the extremes of the distribution.

6. Discussion

Obesity became ubiquitous during the last quarter of the 20th century – prevalence rates for 20-74 year olds rose from 15 percent in 1976-1980 to 32 percent in 1999-2004 – following a period of relatively stable weight. If these trends continue, 33 percent of men and 38 percent of women will be obese in 2010, with predicted prevalences of 40 and 43 percent in 2020. To provide perspective, the *Healthy People 2010* target is to lower the prevalence of adult obesity to 15 percent (US Department of Health and Human Services, 2000).

Even more significant are the increases forecasted for severe forms of excess weight. Class 3 obesity, sometimes referred to as "morbid" obesity, was unusual in the late 1970s –

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of the growth in class 1 obesity (BMI: 30.0-34.9).

[17] Since the 2020 forecasts were obtained using 1999-2004 population characteristics, no additional correction is included for changes in the age and race/ethnicity characteristics of the population.

affecting just over one percent of 20-74 year olds – but prevalence surpassed 3 percent of men and 6 percent of women at the turn of the 21st century, and is predicted to exceed 6 percent of males and approach 13 percent of females in 2020.

There are currently no generally accepted US or international standards for excess weight beyond class 3 obesity but the rapid growth in BMI suggests the importance of classifying and monitoring such extremes. To illustrate, the prevalence of "class 4" obesity, defined as $BMI \geq 45$, increased from 0.4 percent of 20-74 year olds in 1976-1980 to 2.1 percent in 1999-2004, and is forecasted to reach 4.4 percent in 2020. For women, the prevalence of class 4 obesity was 2.9 percent in 1999-2004 and is predicted to be 5.8 percent in 2020.

Extreme obesity represents a particular public health risk. In 2000, approximately nine million 20-74 year olds had class 3 (or higher) obesity, making them potential candidates for extreme interventions, such as antiobesity surgery (National Institutes of Health Consensus Development Conference, 1992). The projections above indicate that the corresponding number will exceed 17 million in 2020, even abstracting from future population growth.   Some (but not all) negative health consequences of obesity may be declining over time but the risks remain much higher for obese than non-obese individuals and a portion of the reduction is probably due to medical interventions that raise health care costs (Gregg et al., 2005; Henderson, 2005). Moreover, the medical problems associated with high BMI may be larger for women than men (Flegal, 2006), raising additional concern about the particularly high prevalence of severe obesity among females.

Between 1976-80 and 1999-2004, class 3 obesity quadrupled and class 4 obesity quintupled. This was mostly due to especially large weight increases at the top of the BMI

distribution, rather than to more general growth in body weight. To illustrate, if BMI had

increased at the sex-specific median for all adults, the prevalences of class 3 and 4 obesity would

have been 2.2 and 0.7 percent in 1999-2004, rather than 5.2 and 2.1 percent. Projecting forward

from the actual rates in NHANES 99, BMI growth at the projected sex-specific median across all

individuals (rather than at the higher amounts expected for heavier persons) would imply class 3

and class 4 obesity rates of 7.4 and 2.8 percent in 2020, substantially below the forecasted

prevalences of 9.6 and 4.4 percent.

Some analysts suggest that interventions designed to reverse the obesity epidemic should

"focus on the population rather than solely on the heaviest individuals" (Flegal and Troiano,

2000, p. 818). Others believe this can be accomplished with "small behavior changes that fit

relatively easily into most people's lifestyles" (Hill et al., 2003, p. 855). By contrast, this

analysis suggests that such population-wide changes may reduce the future growth in overweight

and mild obesity but will be less effective in combating the rise in severe obesity. Doing so is

likely to require additional strategies targeting the especially large weight gains of the heaviest

individuals, probably involving substantial behavior modifications or medical interventions.

Additional monitoring of extreme obesity represents an important first step. Even the

analysis of class 4 obesity presented above may be inadequate, given the rapid growth of the

highest levels of body weight. For instance, 1.0 percent of 20-74 year old women had BMI$\geq$50

in 1999-2004 but 2.4 percent were projected (using quantile regression techniques) to exceed

this threshold in 2020 . Future research also needs to examine whether there are differences in

the energy balance of normal weight or overweight and mildly obese individuals, compared to

those who are severely obese. For example, evidence that class 3 or 4 obesity primarily results

from high levels of energy intake would suggest the importance of reducing calories consumed

or absorbed, although presumably accompanied by efforts to raise energy expenditure.

These findings should be evaluated in light of several methodological limitations. First

this study examines BMI rather than more accurate measures of body composition. However,

the resulting errors are likely to be quite small when considering severe obesity. To illustrate,

note that waist circumference exceeding 102 (88) cm for men (women) represents a separate

obesity risk factor (Freedman et al, 2000; Janssen et al., 2002; Sönmez et al., 2003; Dalton,

2003). By this standard, 39.1 percent of males and 58.5 percent of women were at risk in 1999-

2004, compared to projections (using the quantile regression methods) of 56.2 and 72.4 percent

in 2020. Moreover, while 52 percent of overweight but non-obese (BMI: 25.0-29.9) adults in

NHANES 3 and 99 had waist sizes below the threshold, the same was true of less than 8 percent

of the class 1 obese (BMI: 30.0 – 34.9) and 0.3 percent of those with class 2 or higher obesity.

Second, the forecasts of future obesity and severe obesity prevalence were based on

characteristics of the 1999-2004 population and so did not account for anticipated demographic

changes, the most important of which are probably population aging and growth in the share of

Hispanics. Accounting for these would probably result in an additional increase in future

prevalence forecasts, although it is not obvious by how much.[18]

Third, the future obesity projections used extrapolations of prior trends but without

identifying the sources for them. It is possible that the factors increasing obesity during the last

quarter of the 20th century will be ameliorated over the next two decades. Indeed, an important

goal of public health policies and medical interventions is to do precisely this. However,

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[18] Projecting future population trends is always difficult. In addition, Hispanics have relatively high rates of obesity but not class 3 obesity (Ogden et al., 2006), while obesity and severe obesity reach their highest levels during late middle-age (Freedman et al., 2002; Flegal et al., 2002).

evidence of the recent success of these efforts is mixed at best. Ogden et al. (2006), using data from NHANES 99, find that the overweight and obesity prevalence of adult females did not increase by statistically significant amounts between 1999 and 2004; however, male obesity continued to rise and the sample sizes for the time periods examined were too small to reject the possibility that large increases occurred. Using much larger samples, but self-report data, Sturm (forthcoming) indicates that the growth of moderate and severe obesity continued to accelerate after the turn of the century, which is consistent with available evidence analyzing longer time periods. This suggests that future rates of obesity and severe obesity may be even higher than those predicted by this analysis. Subsequent research is likely to arrive at more sophisticated forecasts by examining how obesity trends vary with population characteristics, across geographic locations, and by accounting more fully for lifecycle changes in body weight, variations in specific components of the energy balance across types of individuals, and personal decisions relating to energy intake and expenditure.

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Table 1. Trends in Body Mass Index and Excess Weight for 20-74 Year Olds

Time Period (Data Source)	Body Mass Index (BMI)	Over-weight (BMI ≥ 25)	Obese (BMI ≥ 30)	Obese: Class 2 (BMI ≥ 35)	Obese: Class 3 (BMI ≥ 40)	Obese: Class 4 (BMI ≥ 45)
Average/Prevalence Rate						
1960-1962 (NHES 1)	25.05 (0.08)	45.27% (0.80)	13.41% (0.53)	3.35% (0.22)	0.88% (0.13)	0.28% (0.09)
1976-1980 (NHANES 2)	25.31 (0.07)	45.91% (0.83)	14.48% (0.41)	4.42% (0.16)	1.30% (0.13)	0.42% (0.09)
1988-1994 (NHANES 3)	26.57 (0.12)	54.59% (0.92)	22.39% (0.72)	8.12% (0.54)	2.91% (0.25)	1.02% (0.14)
1999-2004 (NHANES 99)	28.18 (0.11)	65.45% (0.65)	31.51% (0.77)	12.95% (0.51)	5.17% (0.32)	2.07% (0.20)
% Change						
1960-1962 to 1976-1980	1.06%	1.43%	7.98%	32.16%	48.72%	48.16%
1976-1980 to 1988-1994	4.95%	18.90%	54.59%	83.46%	123.45%	143.67%
1988-1994 to 1999-2004	6.07%	19.90%	40.75%	59.60%	77.56%	103.42%
Annual Growth Rate						
1960-1962 to 1976-1980	0.06%	0.08%	0.45%	1.65%	2.36%	2.34%
1976-1980 to 1988-1994	0.37%	1.34%	3.41%	4.78%	6.38%	7.09%
1988-1994 to 1999-2004	0.56%	1.74%	3.31%	4.55%	5.62%	7.00%

Note: NHES 1 indicates the first National Health Examination Survey and NHANES the National Health and Nutrition Examination Surveys. Sample sizes for NHES 1 and NHANES 2, 3 and 99 are 6,257, 1,1864, 14,756 and 12,025. BMI is weight in kilograms divided by height in meters squared. The data are weighted to provide nationally representative estimates and standard errors, displayed in parentheses, are corrected for complex survey design. Annual percent changes are calculated assuming a 17-year time difference between 1960-62 and 1976-80, a 13-year difference between 1976-80 and 1988-94, and a 10.5-year difference between 1988-94 and 1999-2004.

Table 2. Trends in Body Mass Index and Excess Weight for 20-74 Year Olds, By Sex

Time Period	Body Mass Index (BMI)	Over-weight (BMI ≥ 25)	Obese (BMI ≥ 30)	Obese: Class 2 (BMI ≥ 35)	Obese: Class 3 (BMI ≥ 40)	Obese: Class 4 (BMI ≥ 45)
Males						
1960-1962	25.15	49.42%	10.66%	1.49%	0.29%	0.15%
	(0.09)	(1.13)	(0.73)	(0.23)	(0.11)	(0.10)
1976-1980	25.48	51.06%	12.07%	2.30%	0.40%	0.06%
	(0.07)	(0.95)	(0.55)	(0.20)	(0.08)	(0.04)
1988-1994	26.63	59.10%	19.64%	5.31%	1.80%	0.53%
	(0.11)	(1.07)	(0.71)	(0.55)	(0.33)	(0.17)
1999-2004	28.00	69.09%	28.74%	9.61%	3.34%	1.23%
	(0.10)	(0.76)	(0.77)	(0.59)	(0.36)	(0.19)
Females						
1960-1962	24.95	41.51%	15.90%	5.03%	1.41%	0.40%
	(0.11)	(1.07)	(0.59)	(0.41)	(0.19)	(0.11)
1976-1980	25.16	41.23%	16.68%	6.35%	2.13%	0.75%
	(0.11)	(1.00)	(0.56)	(0.28)	(0.24)	(0.17)
1988-1994	26.50	50.37%	24.96%	10.75%	3.95%	1.47%
	(0.17)	(1.14)	(1.05)	(0.78)	(0.34)	(0.22)
1999-2004	28.35	62.01	34.14%	16.12%	6.91%	2.88%
	(0.14)	(0.95)	(1.00)	(0.66)	(0.44)	(0.29)

Note: See note on Table 1. Sample sizes for NHES 1 and NHANES 2, 3 and 99 are 2,895, 5,604, 6,916 and 5,696 for males and 3,362, 6,260, 7,840 and 6,329 for females.

Table 3. Projected Future Prevalence of Excess Weight for 20-74 Year Olds,
Based on 1999-2004 Population

Outcome	1999-2004 (Actual)	Projected:		
		2001	**2010**	**2020**
Males				
Median BMI	27.3	27.1 [26.8 – 27.3]	27.8 [27.5 – 28.1]	28.7 [28.3 – 29.0]
Overweight	69.1%	69.0% [67.0 – 70.8]	73.9% [71.3 – 76.2]	77.6% [75.3 – 80.5]
Obese	28.7%	27.4% [25.5 – 29.4]	33.0% [30.2 – 36.2]	40.2% [35.9 – 42.7]
Obese: Class 2	9.61%	8.97% [7.49 – 10.2]	12.8% [11.2 – 14.1]	16.4% [14.6 - 18.9]
Obese: Class 3	3.34%	3.15% [2.45 – 3.87]	4.77% [3.84 – 5.52]	6.27% [5.07 – 8.07]
Obese: Class 4	1.23%	1.15% [0.44 – 1.55]	2.01% [1.03 – 2.51]	3.10% [2.31 – 3.99]
Females				
Median BMI	26.9	26.6 [26.3 – 26.9]	27.5 [27.1 – 28.0]	28.6 [28.0 – 29.1]
Overweight	62.0%	61.5% [59.7 – 63.5]	66.0% [64.2 – 68.2]	71.1% [68.1 – 73.2]
Obese	34.1%	32.4% [30.7 – 33.9]	37.8% [35.8 – 40.2]	43.3% [40.6 – 46.3]
Obese: Class 2	16.1%	15.0% [13.3 – 16.3]	19.2% [17.0 – 20.9]	25.3% [21.9 – 27.8]
Obese: Class 3	6.91%	6.40% [5.46 – 7.37]	9.12% [7.34 – 10.6]	12.8% [10.3 – 14.5]
Obese: Class 4	2.88%	2.52% [1.82 – 3.15]	3.68% [2.82 – 4.66]	5.77% [4.08 – 7.19]
Males and Females				
Median BMI	27.1	26.9 [26.7 – 27.1]	27.8 [27.5 – 28.0]	28.7 [28.4 – 29.0]
Overweight	65.5%	65.2% [63.3 – 67.0]	69.9% [67.7 – 72.1]	74.3% [71.6 – 76.7]
Obese	31.5%	30.0% [28.2 – 31.7]	35.5% [33.1 – 38.3]	41.8% [38.3 – 44.6]
Obese: Class 2	13.0%	12.1% [10.5 – 13.3]	16.1% [14.2 – 17.6]	21.0% [18.4 – 23.5]
Obese: Class 3	5.17%	4.82% [4.00 – 5.67]	7.00% [5.66 – 8.12]	9.60% [7.75 – 11.4]
Obese: Class 4	2.07%	1.86% [1.15 – 2.37]	2.87% [2.13 – 3.61]	4.37% [3.22 – 5.63]

Note: Table shows predicted prevalence rate in the specified year obtained from quantile regressions that include covariates for race/ethnicity, age and linear time trends showing years elapsed since 1975; 95 percent confidence intervals are shown in brackets. Projections are based on time trends for the period covered by the NHANES 2, 3 and 99 surveys, using methods described in the text, with race/ethnicity and age set to the average characteristics of the 1999-2004 population.

Table 4. BMI and Obesity in 1976-80 and 1999-2004 Under Alternative Assumptions

Outcome	1976-1980: Actual	1976-1980: at 1999-2004 Characteristics	2001: Projected at Median BMI Growth	1999-2004: Actual	Increase From Concentrated Weight Gains
	(a)	(b)	(c)	(d)	(e)
Males					
Median BMI	25.1	25.1	27.1	27.3	9.8%
Overweight	51.1%	51.4%	72.5%	69.1%	-20.8%
Obese	12.1%	11.3%	22.4%	28.7%	42.7%
Obese: Class 2	2.30%	2.17%	4.45%	9.61%	72.5%
Obese: Class 3	0.40%	0.47%	0.67%	3.34%	88.1%
Obese: Class 4	0.06%	0.21%	0.13%	1.23%	80.5%
Females					
Median BMI	23.9	24.2	26.3	26.9	9.5%
Overweight	41.2%	43.2%	62.2%	62.0%	-10.7%
Obese	16.7%	16.8%	26.1%	34.1%	45.6%
Obese: Class 2	6.35%	6.38%	10.2%	16.1%	60.2%
Obese: Class 3	2.13%	1.97%	3.57%	6.91%	73.1%
Obese: Class 4	0.75%	0.78%	1.26%	2.88%	74.4%
Males & Females					
Median BMI	24.6	24.7	26.7	27.1	11.5%
Overweight	45.9%	47.2%	67.1%	65.5%	-15.1%
Obese	14.5%	14.1%	24.3%	31.5%	44.4%
Obese: Class 2	4.42%	4.33%	7.47%	13.0%	65.4%
Obese: Class 3	1.30%	1.24%	2.19%	5.17%	78.7%
Obese: Class 4	0.42%	0.51%	0.72%	2.07%	76.5%

Note: Projections are based on time trends for the period covered by NHANES 2, 3 and 99 and are obtained from gender-specific estimates that control for race/ethnicity and age. Those projected at "median BMI growth" assumed the same trend increase in BMI for all persons as for the median individual of the same gender. Those "projected for 1976-1980 at 1999-2004 characteristics" allow for variations across the distribution, using the methods described in the text, and are evaluated with the time trend set to the year 1978. "Increases from concentrated weight gains" are calculated as the proportion of the total change (column (d – column a) not explained by changes in population characteristics (column b – column a) or increases projected at median BMI growth (column c – column a).

Table 5. BMI and Obesity in 2020 Under Alternative Assumptions

Outcome	1999-2004: Actual	2020: Projected at Median BMI Growth	2020: Projected at Distribution-Specific BMI Growth	Increase From Concentrated Weight Gains
	(a)	(b)	(c)	(d)
Males				
Median BMI	27.3	28.9	28.7	-15.0%
Overweight	69.1%	81.2%	77.6%	-42.6%
Obese	28.7%	40.6%	40.2%	-3.3%
Obese: Class 2	9.61%	13.8%	16.4%	37.8%
Obese: Class 3	3.34%	4.62%	6.27%	56.4%
Obese: Class 4	1.23%	1.67%	3.10%	75.9%
Females				
Median BMI	26.9	28.8	28.6	-14.6%
Overweight	62.0%	74.5%	71.1%	-36.6%
Obese	34.1%	43.4%	43.3%	-1.5%
Obese: Class 2	16.1%	22.0%	25.3%	36.1%
Obese: Class 3	6.91%	9.99%	12.8%	47.2%
Obese: Class 4	2.88%	3.92%	5.57%	61.2%
Males & Females				
Median BMI	27.1	28.9	28.7	-10.3%
Overweight	65.5%	77.7%	74.3%	-39.4%
Obese	31.5%	42.1%	41.8%	-2.4%
Obese: Class 2	13.0%	18.0%	21.0%	36.8%
Obese: Class 3	5.17%	7.38%	9.60%	50.2%
Obese: Class 4	2.07%	2.82%	4.37%	67.1%

Note: Projections are based on time trends for the period covered by NHANES 2, 3 and 99 and are obtained from gender-specific estimates that control for race/ethnicity and age. Those projected at "median BMI growth" assume the same trend increase in BMI for all persons as for the median individual of the same gender. Those projected at "distribution-specific BMI growth" allow for variations across the distribution, using the methods described in the text. "Increases from concentrated weight gains" are calculated as the proportion of the total change (column c – column a) not explained by increases projected at median BMI growth (column b – column a).

Table A.1. Projected Future Prevalence of Excess Weight, Based on 1999-2004
Population and Using Shorter Time Trends

Outcome	1999-2004 (Actual)	Projected: 2001	2010	2010
Males				
Median BMI	27.3	27.2 [26.5 – 27.8]	28.2 [27.4 – 29.1]	29.4 [28.3 – 30.5]
Overweight	69.1%	69.6% [64.2 – 75.0]	75.1% [69.7 – 79.9]	78.9% [73.9 – 84.9]
Obese	38.7%	27.9% [23.9 – 32.0]	36.2% [29.0 – 43.2]	45.1% [38.4 – 55.1]
Obese: Class 2	9.61%	9.25% [5.57 – 12.0]	13.9% [9.87 – 18.2]	19.2% [13.8 – 25.3]
Obese: Class 3	3.34%	3.23% [0.42 – 5.10]	4.99% [2.39 – 7.22]	7.88% [4.12 – 11.5]
Obese: Class 4	1.23%	1.24% [0.23 – 2.21]	2.01% [0.20 – 3.93]	3.34% [0.19 – 5.78]
Females				
Median BMI	26.9	26.8 [26.1 – 27.5]	28.1 [27.2 – 29.0]	29.6 [28.4 – 30.8]
Overweight	62.0%	62.6% [58.1 – 67.0]	68.2% [63.3 – 73.8]	74.1% [68.0 – 80.0]
Obese	34.1%	33.4% [27.9 – 37.8]	40.8% [35.7 – 44.8]	48.6% [41.7 – 52.5]
Obese: Class 2	16.1%	15.1% [11.7 – 17.8]	20.8% [15.0 – 26.8]	29.3% [21.0 – 35.8]
Obese: Class 3	6.91%	6.53% [4.46 – 9.07]	9.66% [6.15 – 13.7]	13.8% [8.61 – 17.7]
Obese: Class 4	2.88%	2.72% [0.28 – 3.89]	4.14% [0.27 – 6.58]	6.37% [3.01 – 9.87]
Males and Females				
Median BMI	27.1	27.0 [26.6 – 27.5]	28.2 [27.6 – 28.8]	29.6 [28.8 – 30.3]
Overweight	65.5%	66.0% [61.1 – 70.9]	71.5% [66.4 – 76.8]	76.4% [70.9 – 82.4]
Obese	31.5%	30.8% [25.9 – 35.0]	38.6% [32.5 – 44.0]	46.9% [40.1 – 53.8]
Obese: Class 2	13.0%	12.3% [8.72 – 15.0]	17.4% [12.5 – 22.6]	24.4% [17.5 – 30.7]
Obese: Class 3	5.17%	4.92% [2.49 – 7.14]	7.39% [4.32 – 10.6]	10.9% [6.43 – 14.7]
Obese: Class 4	2.07%	2.00% [0.25 – 3.07]	3.10% [0.24 – 5.30]	4.89% [1.64 – 7.88]

Note: Predicted prevalence is calculated using the same methods as in Table 4, except that projections are based on time trends for the period covered by the NHANES 4 and 99 surveys only.
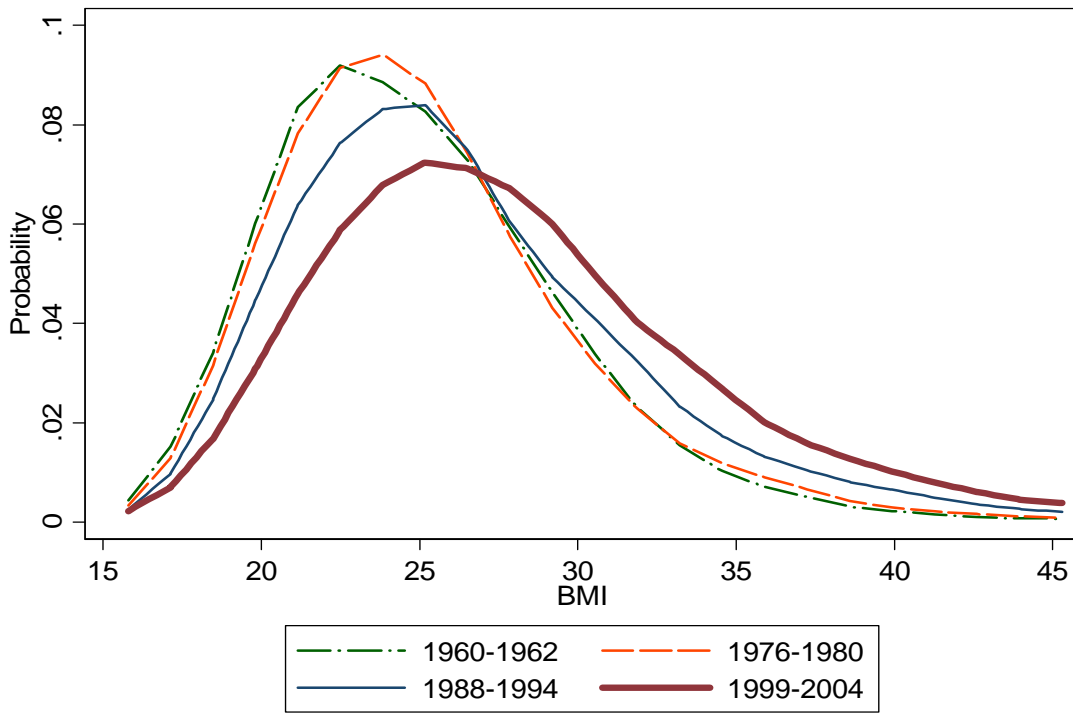
Figure 1. Trends in the Body Mass Index Distribution of 20-74 Year Olds. Data are weighted so as to be nationally representative.
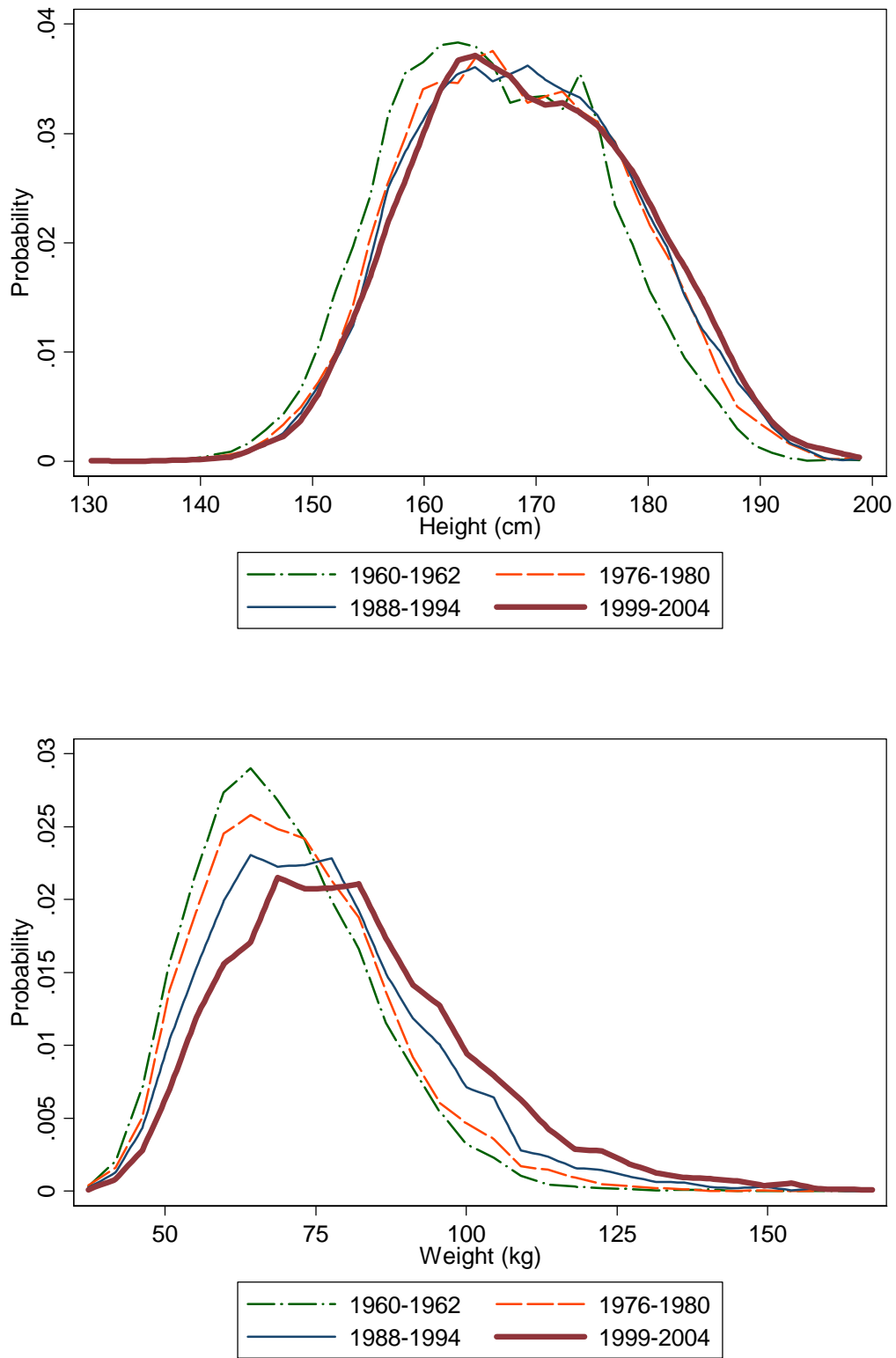
Figure 2. Trends in the Height and Weight of 20-74 Year Olds. Data are weighted so as to be nationally representative.