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Forecasting Distribution of Body Mass Index in United States: Is there more room for growth?

Anirban Basu, PhD.

Section of Hospital Medicine, Department of Medicine, Center for Health and Social Sciences, University of Chicago, Chicago, IL, National Bureau of Economic Research, Cambridge, MA, 5841 S. Maryland Ave., MC-5000, AMD B226C, Chicago IL 60637, Tel: +1 773 834 1796, Fax: +1 773 834 2238

Anirban Basu: abasu@medicine.bsd.uchicago.edu

Abstract

Context—Much of the literature on obesity has consistently documented the unprecedented rise in body weight over the last two decades. Less attention is paid to future projections of the population distribution of body-mass index.

Objective—To forecast the distribution of body-mass index in children (6–17 years) and adults (>17 years) in the United States by age-group, sex and race over the period 2004–2014.

Design—Analysis of Medical Expenditure Panel Survey data (2001–2002 and 2004–2005) to estimate and compare the 1-year transitions across BMI categories for children and adults. Forecasting distributions of obesity over 2004–2014 using a probabilistic population-level simulation model and validate it with prevalence data from 2005–2006 NHANES.

Results—During 2004–2005, a majority of adults in each BMI category remained in the same category after one year, these estimates being not significantly different that the corresponding estimates in 2001–2002. Among children, stabilities within BMI categories are low during 2004–2005, and compared to 2001–2002, transition probabilities into Overweight Class 2 from other BMI categories increase substantially.

Forecasts reveal significant increases in the Risk of Overweight category among children 6–9 years old (5% to 14% in 5 years), with a greater increase anticipated in males; increases in overweight category for many years to come for adults, although the adult obesity prevalence remain at the current levels.

Conclusions—Although the absolute levels of obesity remain high among US adults, the growth in obesity appear to have stagnated. On the contrary, continued growth in the prevalence of the highest BMI category for children is anticipated.

Introduction

Last two decades have seen unprecedented growth in weights of US residents. Between 1976–1980 and 1999–2005, average body weight increased from 45.2 to 47.9 kgs among 7–16 year olds males; 78.7 to 85.5kgs among 18–65 years old males and 74.5 to 83.5 kgs among 65 years old males.[1] Increases in average body weight among females over the same period were even greater: 43.9 to 47.9 kgs, 65.5 to 74.6 kgs and 66.3 to 69.6 kgs respectively.[1] These changes in weights resulted in shifting the body mass index (BMI) distributions to the right for most age categories, with evidence that the upper tail of the BMI distribution shifting faster to the right than the lower tail, thus making the BMI distribution more right skewed over time.[2] At present, the US residents are fatter than ever before and are prone to a variety of chronic diseases due to the disruption of insulin regulation[3] that may be mediated via adipose tissue (AT) dysregulation brought about by higher fat content of the body.[4]

A vast literature documents this growth in weight and BMI categories in the United States and a complete review is beyond the scope of this paper. Some key findings include those that document the marked increase (12.8% to 22.5%) in the prevalence of obesity (BMI≥30.0) between 1976–80 and 1988–94 in the US.[5] This growth continued during the late 1990s.[6] More recently, using 1999–2000, 2001–2002 and 2003–2004 NHANES data, researchers have found that the prevalence of overweight among children and adolescents and obesity among men increased significantly during the 6-year period from 1999 to 2004; among women, no overall increases in the prevalence of obesity are observed.[7]

Despite the strong evidence regarding the increased prevalence of obesity in this country over the past two decades, there is lesser consensus on the question as to what extent such growth will continue into the future. Part of the ambiguity arises because changes in point prevalence of BMI categories that are estimated from the retrospective surveys fail to accurately forecast the future distribution of BMI. In fact, such an attempt can lead to misleading predictions. For example, a similar recent attempt to forecast obesity concluded that all Americans will become obese or overweight by 2048.[8] There are two contributing limitations to extrapolating annual point prevalence to future time periods: first, any model of extrapolation would heavily rely on the functional form used to fit the trends in point prevalence in previous years, and second, it fails to account for transitions across BMI categories that are essential to capture the curvature in the trends, which in turn could better serve to forecast future distributions of BMI categories.

As the literature documenting the growth of BMI grows, a parallel and large literature in economics, medicine and epidemiology demonstrates the roles of different system level factors such as food prices, activity reducing technologies and behaviors such as exercise levels and diet in determining BMI levels. See Philipson and Posner for a review.[9] Most, if not all, of these studies have tried to explain the retrospective growth in obesity in the United States using these factors. Based on this research, an alternative approach to forecast BMI levels of the future will be to understand how levels of each of the causative factors will change over time. Such an exercise, although theoretically appealing, will nevertheless be extremely challenging if not impossible. For example, can we really predict how eating habits of Americans would change over the next 10–15 years? Instead, what one can accomplish more reliably is to forecast the obesity rates holding constant the current micro-levels of change in all the causative factors for obesity. This in itself can be quite valuable from the policy perspective because first, it can help identify specific sub-groups in the population where the current rates of change in behavior and other causative factors of obesity will imply a further rise in obesity in the near future, so that proper resources can be diverted to those subgroups. Such information may also be valuable to physicians who play a crucial role in modifying patient behaviors. Second, these predictions can serve to be an integral component of policy and technology assessments that target one of the causative factors of obesity or obesity-related diseases, where the estimated trends will represent the baseline counterfactual trends under no policy.

In this paper, we present analysis that captures the transitions across BMI categories over time using the latest data available and then use them to forecast the BMI distribution for the next ten years. Specifically, we estimate the rate of transitions across BMI categories over a short time (e.g. one year) period, which is a manifestation of all the current micro-levels of changes in the causative factors that contribute to the changes in BMI distribution over this period. When we use these transition probability estimates to forecast the trends in obesity, the forecasts assume a static environment where the current short-term rates of change in system level factors and behaviors will persist in the future.

We also study whether the one-year transition rates across BMI categories were stable across a five year span on which the latest data are available. Stability of transition rates over time provides further evidence that these transition rates would provide meaningful basis for forecasting obesity prevalence in the future.

Using individual level longitudinal data from the Medical Expenditure Panel Survey, a nationally representative survey that is conducted by the Agency for Healthcare and Research Quality, we estimate the transitions across BMI categories that existed during 2000–2001 and compare them to those in 2004–2005 in order to examine whether such rates of change show signs of stability during this period. We then use the 2004–2005 rates to forecast BMI distribution over the next 10 years (up to 2014). Our forecasting model is unlike any other available thus far in that it is probabilistic in nature, thereby incorporating uncertainties in BMI-level transitions and obesity-related risk of mortality, to represent the most robust estimates BMI forecast we can have with current information. Furthermore, we account for these transitions starting from age 6 up to age 85 years as understanding changes in the distribution of childhood BMI levels is crucial for projecting distribution of adult obesity in the future. We also present forecast results by age-groups, sex and racial groups. Our main findings have important implications for the allocation of future resources in addressing the obesity epidemic, some of which is addressed in the discussion section.

Methods

Estimating transitions across BMI categories by year

We use panel 6 (2001–2002) and panel 9 (2004–2005) datasets from the Medical Expenditure Panel Survey. MEPS is a nationally representative longitudinal survey that collects detailed information on health care utilization and expenditures, health insurance, and health status, as well as a wide variety of social, demographic, and economic characteristics for the civilian non-institutionalized population. It is cosponsored by the Agency for Healthcare Research and Quality (AHRQ) and the National Center for Health Statistics (NCHS). Within each panel, MEPS interviews adult survey participants over 6 rounds spanning about 2 years. BMI information was collected from the same adult survey participants in the 3rd and the 5th rounds documenting the individual level longitudinal changes in BMI level over a one year period. Similarly, BMI information was collected from the same child survey participants in the 2^{nd} and the 4^{th} rounds documenting the individual level longitudinal changes in BMI level over a one year period. The longitudinal data in MEPS has full information across all 5 waves of data within each panel for over 90% of originally enrolled respondents. To compensate for the attrition, adjustments were made in the construction of the panel weight variable by MEPS. This weight variable can be used to produce national estimates for the two-year period.

In order to model transitions across BMI categories for adults (ages 18 – 85 years), we define 5 BMI categories as: Normal (BMI $<$ 25.0), Overweight (25.0 $\leq$ BMI $<$ 30.0), Obese Class 1 (30.0 $\leq$ BMI $<$ 35.0), Obese class 2 (35.0 $\leq$ BMI $<$ 40.0) and Obese Class 3 (BMI $\geq$ 40.0). Categories are defined in similar fashion in both rounds within a panel. Transitions from BMI categories in round 3 to those in round 5 are estimated using conditional ordered logit models where, besides round 3 BMI categories, additional covariates included race, sex, age and age-squared, duration between the midpoints of round 3 and round 5 for each subject and the interactions between these covariates and round 3 BMI categories. We run separate models for subjects in panels 6 and 9. In order to compare across these two panels, predictions of the transition probabilities in 2004–2005 are made conditional on the demographic distributions in Panel 6. Models account for survey sampling weights making the estimates nationally representative. Standard errors for transition probabilities and also the differences in the transitional probabilities between panels 6 and 9 are estimated via 1000 bootstrap replicates.

Similarly, for children (ages 6 to 17 years), 4 BMI categories are defined based on age and sex-specific percentiles as: Normal (BMI $< 85^{th}$ percentile), At risk for overweight ($85^{th} \leq$ BMI $< 95^{th}$ percentile); Overweight Class 1 ($95^{th} \leq$ BMI $< 99^{th}$ percentile), Overweight Class 2 (BMI $\geq 99^{th}$ percentile). Identical methods as reported above are implemented for the child cohorts. In addition to the above mentioned covariates, we also include indicator variables for age-groups 6–9 and 10–13 years and their interactions with round 2 BMI categories in order to improve goodness of fit for the models. Note that BMI categories defined for children are used as the 17-year olds transitions into the 18^{th} year. The children-specific BMI classification of normal, at risk of overweight, overweight classes 1 and 2 for 18 year olds corresponds very closely to the adult categories of normal, overweight, obese classes 1 and 2 respectively for 18 year olds, thereby providing a stitch across the children and adult transition matrices that is essential for forecasting.

Forecasting future distributions of BMI

In order to forecast the future distributions of BMI categories, we start from the baseline US population in 2004 stratified by 3200 cells defined by the cross classification of age (6–85 years), sex, race and ethnicity and BMI categories. The size of these cells are estimated using the 2003–2004 National Health and Nutrition Examination Survey (NHANES) that was conducted by the National Center for Health Statistics, Center for Disease Control and Prevention. Then, using the Panel 9 parameter estimates from the conditional logit models described above, we age each cell in cohort by one year along with transitioning them across BMI categories. A new cohort of 6 year olds with the current distribution of demographics and BMI categories are assumed to join the population every year. We account for mortality based on 2004 age, sex and race specific life tables after adjusting them to reflect age and BMI category related mortality risk ratios reported in the literature.[10] These adjustments are only done for the adult population. For children, mortality is assumed not to vary by BMI categories. In order to account for the uncertainty in the parameter estimates in both the conditional logit models and also the BMI category related risk ratios, we repeat our forecasts 10,000 times, each time drawing a random vector of parameter values using the corresponding mean and variance-covariance matrices of the parameter estimates from the conditional logit models and also the log risk ratios for mortality, assuming multivariate normality for the parameter distribution. Final forecasts reported are averaged over these 10,000 replicates.

All estimations are carried out in Stata 10.0. Simulations for forecasts are coded using the MATA language within Stata.

Results

Basic demographic characteristics and proportion in BMI categories in the 2004 MEPS and the 2003–2004 NHANES are presented in Table 1. Most of the estimates for demographics across these two nationally representative samples appear to conform to each other. There are small differences in the distribution of BMI prevalence especially among adults, NHANES reporting a higher percentage of obese subjects. It might be possible that the self reported nature of data in the MEPS is driving these differences. To what extent such biases would impact our analyses is not readily known. However, we overcome these biases by validating our model predictions with future NHANES data that the model has not seen.

Transitions across adult BMI categories

The estimated transition probabilities across adult BMI categories from Panel 6 (2000–2001) and Panel 9 (2004–2005) and differences between these estimates are reported in Table 2. Transitions from 2004 to 2005 reveal that about 82% (p-val <0.001) of normal weight adults continue to retain their normal BMI status after one year. Similar stabilities are found for other BMI categories: Overweight (72.5%), Obese Class 1 (62%), Obese Class 2 (51%) and Obese Class 3 (71%) all significant at the 5% level. Eighteen percent (p-val < 0.001) and 0.6% (p-val < 0.001) of normal weight adults transition into overweight and obese class 1 categories within a year, but none move to higher obesity classes within a year. More variability in transitions is observed at higher BMI categories. Twelve percent and 0.7% (both p-val < 0.0001) of overweight adults become obese class 1 and 2 respectively, where as 16% revert back to being normal weight. For obesity classes 1 and 2, we find that a greater percentage revert to a lower BMI category than moving to a higher one. Twenty nine percent (p-value < 0.0001) of class 3 obese people revert to a lower BMI category within a year.

Comparing these estimates to the 2000–2001 estimates reveal no statistically significant difference in any of the transitions. The biggest change appeared to be declines in the higher BMI categories, although these changes are small in magnitude and do not reach statistical significance.

Transitions across children BMI categories

The estimated transition probabilities across children BMI categories from Panel 6 (2000–2001) and Panel 9 (2004–2005) and differences between these estimates are reported in Table 3. Transitions from 2004 to 2005 reveal that about 71% (p-val <0.001) of normal weight children continue to retain their normal BMI status after one year. However, stabilities in other BMI categories, risk of overweight (16%) and overweight class 1 (22%), are much lower than the adult counterparts but are all significant at the 5% level. Stabilities in overweight class 2 category is also low (15%) and do not reach statistical significance. Forty four percent (p-val =0.004) of children at risk of overweight transition back to normal weight while 34% (p-val = 0.03) transition up to class 2 overweight within a year. For class 1 overweight children, majority continue to stay at the class 1 level (22%) or move to class 2 overweight (45%, p-val = 0.03).

Comparing these estimates to the 2000–2001 estimates reveal some statistically significant differences. Transition rate from each of normal, risk of overweight and class 1 overweight category to class 2 overweight increase, these changes being significant for transitions from risk of overweight categories (+30%) but not significant from normal (+5%) and overweight class 1 (+30%) categories. However, the probability of continuing to be in class 2 overweight category decline substantially (−70%, p-val < 0.001) with a significantly increased likelihood of transitioning back into the normal category (+53%, p-value = 0.02). Overall, the transition probabilities across children BMI categories appear to be larger than those for adults. We also found considerable heterogeneity in transition probabilities across specific age groups for children which will manifest themselves in the age-group-specific projections given below.

Forecasts of BMI categories in United States

Predicted changes in obesity categories across specific age-groups for the entire US population from 2004 up to 2014 are presented in Figure 1. The results suggest that we will expect to see substantial increases in the risk of class 2 overweight category for the 6–9 year age-group over the next four to five years (about 5% in 2004 up to 14% by 2009), accompanied by a decline in normal weight category, while the middle categories remain fairly stable. This rise in class 2 overweight among the younger cohort will have a carry-over effect on the BMI categories for 10–17 year olds. The declining trends in the risk of overweight and class 1 overweight categories among 10–17 year olds will flatten out (and possibly reverse among 10–13 year olds) by 2009/2010 (Figure 1). There will also be a slight increase in the prevalence of class 2 overweight category in this age range.

For 18–39 year olds, we will see slight increases in both the normal and the overweight groups until 2010. Most of these increases will come from transitions from the obese categories, which as a result show declines in prevalence in the future years. For 40 year and older population, the prevalence of obesity classes 1, 2 and 3 will remain constant. We also predict a decline in the overweight category among 60 years and older population with a contemporaneous increase in the prevalence of normal category in this age range.

These trends are found to be similar for males and females (with very subtle differences as highlighted in the Appendix) with perhaps the largest discrepancy being in the prevalence of class 2 overweight among 6–9 year olds that will increase by a much larger amount between 2004 and 2009 among males (5% to 17%) than among females (5% to 11%) (Figure A1). The trends, however, are much more dissimilar between blacks and whites across all age-groups (Figure 2 for children & Figure 3 for adults). Among 6–9 year olds, the prevalence of class 1 overweight will rise among blacks but not among whites, although both cohorts would show large increases in the prevalence of class 2 overweight. Among 10 – 17 years olds, the contrasts are even more striking. While the prevalence for the risk of overweight will decline for whites, exactly the opposite will happen among the blacks – an increase in the prevalence of the risk of overweight. Differences between adult whites and blacks are also evident but are less striking than in children and are shown in Figure 3.

Validation

In order to validate our predictions, we compare our predictions for the prevalence of BMI categories in 2005 for different age-groups to the estimates obtained from the 2005–2006 NHANES data. Since we use cross-sectional rather than longitudinal individual level data (which NHANES is not) to validate our results, we focus on calibration of our model predictions across different subgroups rather than individual-level discrimination for our model predictions. Note that we do not use the 2005–2006 NHANES data to generate our predictions. Rather our predictions are based on the baseline prevalence from the 2003–2004 NHANES data and the transitions probabilities estimated via 2004–2005 MEPS data. These comparisons are given in Table 4 and show that our predictions are quite accurate and lie within the 95% confidence intervals of the NHANES prevalence estimates on all BMI and age-categories except for the 6–9 year olds. In this young cohort, our model predicts a much higher prevalence of class 2 overweight (10%) than that reported in NHANES data (3%, 95%CI: 2% – 5%). Our predictions also report a lower prevalence (63%) of normal body weight in this age group compared to NHANES (75%, 95%CI: 68% – 81%).

Our model predictions will presumably be different from observed prevalence in the future. This is because, as discussed in the introduction, our predictions are conditional on holding constant the current rates of changes in all causative factors of obesity. However, in the short-run, i.e. say 1 year, we expect our predictions to tally with the observed trends. Our validation exercise is built on this principle and we find strong support to this end using the 2005–2005 NHANES data. Therefore, it is surprising to find this discrepancy for the 6–9year olds.

To further investigate this discrepancy, we look at the historical trends in these BMI categories among 6–9 year olds from 1999–2000, 2001–2002 and 2003–2004 NHANES data. Estimates for the prevalence of normal category trend from 70% (95%CI: 65%, 76%) in 1999–2000 to 66% (95%CI: 60%, 72%) in 2001–2002 to 68% (95%CI: 63%, 72%) in 2003–2004. The first two years do show a decline in the normal BMI category which is consistent with our predictions going forward to 2005. However, 2003–2004 show a slight increase in the normal category prevalence. Whether, this increase will sustain to generate a jump to a 75% prevalence (as 2005–2006 NHANES reports) in one year is uncertain. Our prediction model refutes this claim but the truth can only be sorted out with additional years of NHANES survey. Similarly, the trends in the prevalence of class 2 overweight category is 4% (95%CI: 1%, 7%) in 1999–2000, 9% (95%CI: 7%, 12%) in 2001–2002 and 5% (95%CI: 3%, 7%) in 2003–2004. If one looks at the first two years, our prediction of 10% in 2005 appear quite plausible, whereas if one looks at the last two years then 2005–2006 NHANES estimates of 3% is also plausible. This again will only be sorted as more years of NHANES data become available.

The 2006 MEPS full year data, which are also not used in our predictions, report the distribution of BMI categories of normal, risk of overweight, classes 1 and 2 overweight among 6–9 year old cohort to be 56.3% (95% CI: 53%–59%), 16.5% (95% CI: 14%–19%), 15.7% (95% CI: 13%–18%) and 11.6% (95% CI: 9%–14%), respectively and are more in line with our 2006 predictions of 61.3%, 13.3%, 12.8% and 12.6%, respectively.

Comment

We estimate transitions across BMI categories for both adults and children and compare these transition probabilities during 2000–2001 to those in 2004–2005. We find that in adults, transition probabilities across BMI categories do not change significantly during this period implying that we may have reached a steady state going forward. Among children, the transition probabilities are much more heterogeneous. We find an increased rate of transition into class 2 obesity categories in 2004–2005 compared to 2000–2001. These transitions are most pronounced in children of ages 6–9 years and they manifest into forecasting an increasing prevalence of class 2 overweight in this age range.

The study has several limitations. First, any attempt to forecast future prevalence of a chronic disorder is limited by being conditional on current rates of transitions between the chronic states. For example, we use the most current available estimates of individual level transitions across the BMI categories. Although these rates appear to have stabilized among adults, they continue to change in children and future changes in these rates may influence our results. Similarly, future changes in survival, especially obesity related survival, will influence the prevalence of the BMI categories. Another limitation of our analyses is that we base our calculations on transitions rates between BMI categories on MEPS data where weight and height data are self reported. However, we do not see any major violations of prevalence rates in 2004 between NHANES and MEPS (Table 1). Furthermore, the strongest validation of our methods and the data come from comparing the future predictions of our model to the 2005–2006 NHANES data, which mostly agreed with each other.

The forecast model we present is unique in that it is probabilistic in nature, thereby incorporating uncertainties in BMI-level transitions and obesity-related risk of mortality, to represent the most robust estimates BMI forecast we can have with current information. Such a model has several advantages besides forecasting future BMI categories. It can be used to form an integral part of modeling efforts for any disease where obesity plays a significant role in the incidence of the disease. For example, in a recent analysis on forecasting Medicare expenditures on diabetes, we have used a deterministic version of this model.[11]

Our results have several implications. Growth in obesity in most age, sex and race categories appear to have stagnated and therefore we do not expect that everyone in the population will be obese at some point in time, as another model suggested.[8] However, a large fraction remains and will continue to remain overweight and obese. More importantly, obesity in children still appears to be on the rise, especially in the youngest cohort of 6 – 9 years, which have follow-on consequences among older children that will be manifested in the coming years. This result is controversial and needs further support from future data but nevertheless implies that cautious monitoring of this population is needed and possibly calls for some tested and targeted interventions to curb the grown in class 2 overweight in this young population.

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Appendix

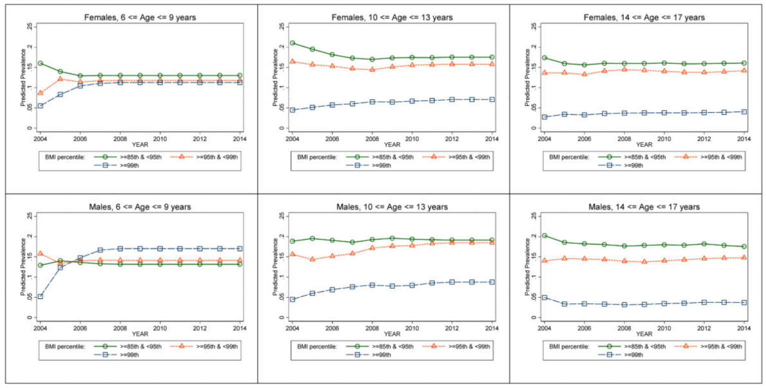

Figure A1.

Trends in BMI categories for children by age-group and sex over 2004 – 2014.

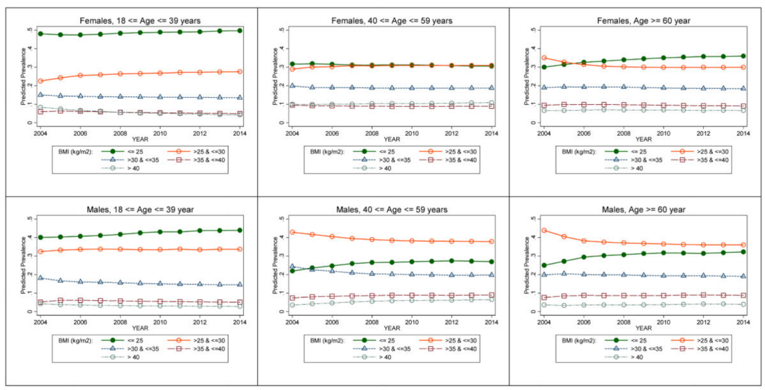

Figure A2.

Trends in BMI categories for adults by age-group and sex over 2004 – 2014.

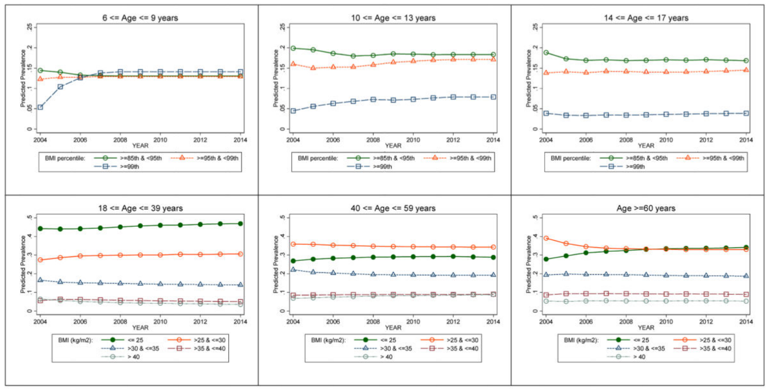

Figure 1.

Trends in BMI categories by age-groups for the overall US population over 2004 – 2014.

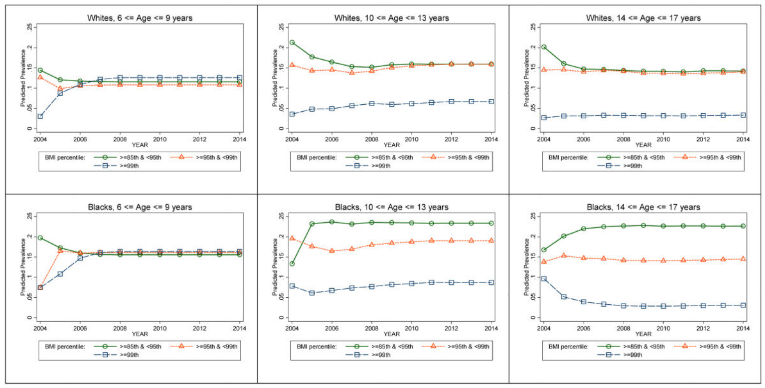

Figure 2.

Trends in BMI categories for children by age-group and race over 2004 – 2014.

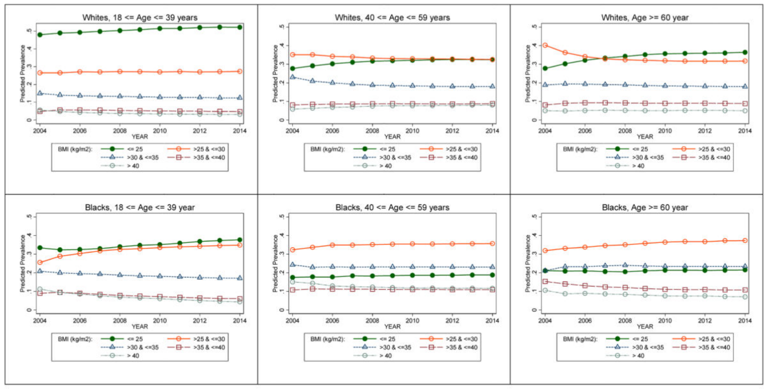

Figure 3.
Trends in BMI categories for adults by age-group and race over 2004 – 2014.

Table 1

Comparison of subject characteristics across different years and national surveys

	2004 MEPS	2003–2004 NHANES
Age:		
6 – 9 years	4.6%	6.3%
10 – 13 years	5.7%	6.3%
14 – 17 years	6.2%	6.4%
18 – 39 years	33.9%	33.8%
40 – 59 years	31.1%	30.6%
60 – 85 years	18.5%	16.6%
Sex:		
Females	50.9%	51.3%
Males	49.1%	48.7%
Race:		
Non Hispanic Whites	68.4%	69.5%
Non Hispanic Blacks	13.0%	12.1%
Hispanics	11.9%	12.9%
Other	6.8%	5.5%
Children BMI:		
Normal	63.4%	63.7%
At Risk of Overweight	15.8%	17.7%
Overweight Class 1	14.5%	14.0%
Overweight Class 2	6.2%	4.6%
Adult BMI:		
Normal	39.0%	34.3%
Overweight	35.0%	32.9%
Obesity Class 1	16.4%	19.2%
Obesity Class 2	6.1%	7.3%
Obesity Class 3	3.4%	6.3%
Mean Adult BMI (std. err.)	27.20 (0.06)	28.10 (0.15)

Table 2

Transitions probabilities (standard errors) across adult (18+ years) BMI categories.

	2001–2002 (Panel 6)						2004–2005 (Panel 9)						Difference between 2001–2002 & 2004–2005				
	Normal	Over-weight	Obese Class 1	Obese Class 2	Obese Class 3		Normal	Over-weight	Obese Class 1	Obese Class 2	Obese Class 3		Normal	Over-weight	Obese Class 1	Obese Class 2	Obese Class 3
Normal	0.795+ (0.014)	0.198+ (0.013)	0.007+ (0.002)	0.000 (0.000)	0.000 (0.000)	Normal	0.815+ (0.013)	0.179+ (0.012)	0.006+ (0.001)	0.000 (0.000)	0.000 (0.000)	Normal	−0.019 (0.019)	0.019 (0.018)	0.001 (0.002)	0.000 (0.000)	0.000 (0.000)
Over-weight	0.152+ (0.013)	0.716+ (0.017)	0.123+ (0.009)	0.008+ (0.003)	0.001 (0.001)	Over-weight	0.156+ (0.010)	0.715+ (0.008)	0.122+ (0.009)	0.007+ (0.001)	0.001 (0.000)	Over-weight	−0.004 (0.017)	0.001 (0.019)	0.001 (0.013)	0.002 (0.003)	0.000 (0.001)
Obese Class 1	0.010 (0.003)	0.255+ (0.018)	0.587+ (0.02)	0.133+ (0.013)	0.016+ (0.006)	Obese Class 1	0.009+ (0.001)	0.236+ (0.017)	0.622+ (0.014)	0.120+ (0.011)	0.013+ (0.002)	Obese Class 1	0.001 (0.003)	0.018 (0.025)	−0.035 (0.025)	0.013 (0.017)	0.002 (0.006)
Obese Class 2	0.001+ (0.000)	0.033+ (0.007)	0.324+ (0.032)	0.495+ (0.03)	0.146+ (0.041)	Obese Class 2	0.001+ (0.000)	0.024+ (0.004)	0.307+ (0.029)	0.511+ (0.023)	0.158+ (0.022)	Obese Class 2	0.000 (0.000)	0.009 (0.008)	0.017 (0.043)	−0.016 (0.038)	−0.011 (0.047)
Obese Class 3	0.000 (0.001)	0.003 (0.004)	0.037+ (0.016)	0.258+ (0.046)	0.702+ (0.059)	Obese Class 3	0.000 (0.000)	0.002+ (0.001)	0.040+ (0.012)	0.250+ (0.037)	0.708+ (0.047)	Obese Class 3	0.000 (0.001)	0.000 (0.004)	−0.003 (0.020)	0.009 (0.059)	−0.007 (0.075)

+ p-value < 0.05.

Table 3

Transitions probabilities (standard errors) across children (6 – 17 years) BMI categories.

	2001–2002 (Panel 6)					2004–2005 (Panel 9)					Difference between 2004–2005 & 2001–2002			
	Normal	Risk of Overweight	Overweight Class 1	Overweight Class 2		Normal	Risk of Overweight	Overweight Class 1	Overweight Class 2		Normal	Risk of Overweight	Overweight Class 1	Overweight Class 2
Normal	0.843+ (0.013)	0.109+ (0.009)	0.041+ (0.005)	0.007+ (0.001)	Normal	0.709+ (0.079)	0.157+ (0.04)	0.077+ (0.031)	0.056 (0.047)	Normal	−0.133+ (0.08)	0.048 (0.041)	0.036 (0.032)	0.049 (0.047)
Risk of Overweight	0.474+ (0.026)	0.288+ (0.015)	0.195+ (0.016)	0.043+ (0.006)	Risk of Overweight	0.440+ (0.151)	0.163+ (0.068)	0.057 (0.044)	0.34+ (0.158)	Risk of Overweight	−0.034 (0.153)	−0.125 (0.07)	−0.137+ (0.047)	0.296+ (0.150)
Overweight Class 1	0.211+ (0.019)	0.250+ (0.015)	0.388+ (0.020)	0.152+ (0.016)	Overweight Class 1	0.117 (0.143)	0.214+ (0.085)	0.218+ (0.106)	0.452+ (0.209)	Overweight Class 1	−0.094 (0.145)	−0.036 (0.087)	−0.170 (0.107)	0.300 (0.210)
Overweight Class 2	0.010 (0.015)	0.023 (0.023)	0.118+ (0.034)	0.849+ (0.062)	Overweight Class 2	0.534+ (0.210)	0.083+ (0.04)	0.232+ (0.074)	0.151 (0.189)	Overweight Class 2	0.525+ (0.211)	0.059 (0.046)	0.114 (0.081)	−0.698+ (0.199)

+ p-value < 0.05.

Table 4

Comparing 2006 model predictions with prevalence estimates from 2005–2006 NHANES (95% CI).

	Age 6–9 years		Age 10–13 years		Age 14–17 years	
	OUR MODEL	NHANES	OUR MODEL	NHANES	OUR MODEL	NHANES
Normal	**0.63**	**0.75 (0.68, 0.81)**	0.60	0.63 (0.57, 0.68)	0.65	0.68 (0.64, 0.72)
Risk of Overweight	0.14	0.13 (0.10, 0.17)	0.20	0.18 (0.14, 0.21)	0.17	0.14 (0.12, 0.16)
Overweight Class 1	0.13	0.09 (0.06, 0.12)	0.15	0.15 (0.11, 0.19)	0.14	0.12 (0.10, 0.15)
Overweight Class 2	**0.10**	**0.03 (0.02, 0.05)**	0.06	0.04 (0.03, 0.06)	0.03	0.05 (0.03, 0.07)

	Age 18–39 years		Age 40–59 years		Age 60+ years	
	OUR MODEL	NHANES	OUR MODEL	NHANES	OUR MODEL	NHANES
Normal	0.44	0.42 (0.38, 0.45)	0.28	0.28 (0.25, 0.31)	0.30	0.27 (0.24, 0.31)
Over-weight	0.29	0.3 (0.27, 0.32)	0.36	0.31 (0.28, 0.35)	0.36	0.37 (0.34, 0.39)
Obese Class 1	0.15	0.16 (0.14, 0.19)	0.21	0.21 (0.18, 0.23)	0.20	0.21 (0.19, 0.23)
Obese Class 2	0.06	0.07 (0.06, 0.09)	0.09	0.11 (0.09, 0.13)	0.09	0.08 (0.07, 0.09)
Obese Class 3	0.06	0.05 (0.04, 0.06)	0.07	0.09 (0.07, 0.11)	0.05	0.07 (0.05, 0.09)