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ABSTRACT

In our opinion, the trend in the BMI values of US children has not been estimated accurately. We use five models to estimate the BMI trends of non-Hispanic US-born black and white children and adolescents ages 2-19 born 1941-2006 on the basis of all NHES and NHANES data sets. We also use some historical BMI values for comparison. The increase in BMIZ values during the period considered was on average 1.3σ (95% CI: 1.16σ; 1.44σ) among black girls, 0.8σ for black boys, 0.7σ for white boys, and 0.6σ for white girls. This translates into an increase in BMI values of some 5.6, 3.3, 2.4, and 1.5 units respectively. While the increase in BMI values started among the birth cohorts of the 1940s among black females, the rate of increase tended to accelerate among all four groups born in the mid-1950s to early-1960s with the contemporaneous spread of TV viewing. The rate of increase levelled off somewhat thereafter. There is some indication that among black boys and white girls born after c. 1990 adiposity has remained unchanged or perhaps even declined. The affects of the IT revolution of the last two decades of the century is less evident. Some regional evidence leads to the speculation that the spread of automobiles and radios affected the BMI values of boys already in the interwar period. We infer that the incremental weight increases are associated with the labor-saving technological developments of the 20th century which brought about many faceted cultural and nutritional revolutions.

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Introduction

While the descriptive statistics pertaining to the increasing prevalence of overweight and obesity of US children and adults have been very extensively reported (Freedman et al. 1997; Hedley et al. 2004; Ogden et al. 2002; Ogden et al. 2004; Strauss and Pollack 2001), trends have been less clearly identified. For example, Troiano and Flegal (1998) suggest that "Overweight prevalence increased over time, with the largest increase between NHANES II and NHANES III," surveys, that is to say between those measured in the 1980s and early 1990s. Subsequent NHANES surveys, beginning in 1999 substantiate the direction of trend. Ogden et al. (2006) conclude that "The prevalence of overweight among children and adolescents and obesity among men increased significantly during the 6-year period from 1999 to 2004." Freedman et al. (2006) suggest that "the secular increases among black girls began during the 1970s, whereas increases among other children were not evident until the 1980s." Troiano and Flegal (1998) did not find systematic variation of overweight with "race-ethnicity, income, or education," while Freedman et al. (2006) report that "Overall, black children experienced much larger secular increases in BMI, weight, and height than did white children." In contrast, Anderson, Butcher and Levine (2003) suggest that "the increase in obesity began between 1980 and 1988." Hence, there is considerable disagreement on just when the epidemic increase began as well as on its rate of change, and all papers refer to measurement cohorts rather than birth cohorts.

Data

We estimate for the first time the long-term trends in the BMI values (kg/m^2) of children aged 2-19 years continuously for the birth cohorts 1941-2004 stratified by gender and ethnicity on the basis of surveys collected between 1959 and 2006 by the National Center for Health Statistics (NCHS). The following surveys were concatenated: National Health Examination Surveys: (NHES I: 1959-62, NHES II: 1963-65, NHES III: 1966-70) and the National Health and Nutrition Examination Surveys (NHANES I: 1970-74, NHANES II: 1976-80, NHANES

III: 1988-94, and Current NHANES 1999-2006). Heights and weights in the surveys are actual measurements. In order to ensure comparability both over time and with studies on other countries and to reduce uncontrolled heterogeneity[1] (Rosenbaum 2005) we confine our analysis to non-Hispanic blacks and non-Hispanic whites born in the United States. (Henceforth, we drop the designation non-Hispanic for the sake of brevity.) We limit the analysis to individuals aged 24 – 240 months with information on body height and weight.[2] While whites constitute the majority of observations well into the early 1970s, the ethnicity composition is more balanced in the second half of the period considered due to oversampling of minority groups (Figure 1) (N = 6,653 Black girls, 14,326 white girls, = 6,611 black boys, and 14,972 white boys).

Figure 1 about here

We use birth cohorts as the basis of our estimates insofar as BMI at a particular measurement reflects the accumulated weight gains during the life course. Birth cohorts experienced similar social, economic and technological changes whereas the same cannot be said of measurement cohorts. For example, those measured in 1960 have been exposed to television viewing for a different length of time in their lives. In contrast, all those born in 1955 regardless of when they were measured have been exposed to television viewing throughout their lives.

We analyse three dependent variables: 1) the body mass index (BMI), 2) the standardized BMI-for-age z-scores using the CDC 2000 reference values standardized for age and gender (Kuczmarski et al., 2002)[3] (BMIZ) and 3) a binary variable for overweight, defined as a BMI-for-age value above the 85th percentile of the reference value. In addition, the BMIZ results are calculated two ways: 2a) with and 2b) without sampling weights.[4] We use a Bayesian approach (discussed below) for all of these four dependent variables. In addition, we use ordinary least squares regression (OLS) on the BMIZ values with dummy variables for age in order to explore the sensitivity of the results to the use of the Bayesian approach. Each of the five dependent variables is estimated four times, i.e., separately by gender and ethnicity.

Admittedly, all dependent variables have some limitations: 1) and 5) assume that a one unit increase in BMI has similar implications for nutritional balance at all ages. Similarly, 2a) and 2b) treat a one standard deviation (σ) change at all ages identically, whereas in actuality children's BMIZ values may not be uniformly responsive to environmental effects at all ages. The obesity prevalence pertains, in the main, to the right tail of the distribution.[5] Nonetheless, using these various approaches should enable us to provide a sufficient overview of the trends in BMI values among children and adolescents during the course of the second half of the 20th century.

A Bayesian approach

A Bayesian regression framework avoids superimposing a parametric structure upon the data. Thus, there is no need to assume, for example, that the BMI values increased linearly or as a polynomial. In other words, the functional relationship is flexibly determined by the data rather than being determined ex ante. The changes in BMI as well as in the BMIZ values are composed of an age and a birth cohort trend effect. That is to say, in addition to a trend that pertains to all ages, children in some ages might have experienced greater (or less) increases in BMI values perhaps because of earlier maturation. We estimate these effects using a non-parametric additive regression model that enables us to estimate these two components by means of penalized cubic spline functions, thus smoothing the functional form at adjacent values of the independent variables. We use BayesX, a "freeware" computer program (Brezger, Kneib, Lang, 2005; Brezger, Lang, 2006; Lang, Sunder 2003). BayesX estimates an intercept term[6] (γ) as well as the functional relationships between the dependent and independent variables. The latter are flexible functions of age (f_1) and of the year of birth (f_2):

(Eq. 1) $$BMIZ_i = \gamma + f_1(AGE_i) + f_2(BYEAR_i) + \varepsilon_i$$

where *AGE* is the age of the subject at the examination in months, *BYEAR* is the year of birth, f_1 and f_2 are functions to be estimated, and ε is a random error term. The age effect captures the impact of earlier maturation (earlier onset of puberty) on the BMIZ values (Hermanussen et al. 2007). We estimate this model three ways: with and without survey weights[7] (Models 2a and 2b) as well as with BMI as the dependent variable (unweighted) (Model 1).

In addition, we also estimate a logit model specification that uses a binary indicator variable for being overweight ($Y_i = \{0;1\}$), defined as an age-specific BMI value above the 85th percentile of the reference values[8] (Model 3). The probability of being overweight is assumed to be a non-linear function of age and year of birth:

(Eq. 2) $$\Pr(Y_i = 1) = \frac{1}{1 + e^{-(\gamma + f_1(AGE_i) + f_2(BYEAR_i))}}$$

With this model we obtain the predicted probability of being overweight.

We present the estimated trends with the four models above (Equations 1 and 2) and three dependent variables in Figures 2-5. The estimates are calibrated for a child (arbitrarily chosen for illustrative purposes) at the age of 150 months (12.5 years) (which implies out-of-sample predictions for some cohorts). However, the trends themselves reflect averages (of particular the dependent variables) of all ages of children in our sample.[9] (The trend is estimated so that the year-to-year fluctuations are smoothed.) The bottom panel of the figures displays year-to-year changes implied by the estimated trends. The trends are themselves derived from the Bayesian procedure and their rate of change is then calculated. The slopes of the trend estimates fluctuate quite a bit even though the trend itself appears quite smooth.[10]

The fifth model is an OLS regression using dummy variables for age and cohort groups presented in the appendix.

Results

We do not report the estimated values of the function f_1 in Eq. 1 insofar as the age effects are not the focus of this paper. The three secular trends estimated by function f_2 in Eq. 1 and the trend in prevalence estimated by Eq. 2 are presented in Figure 2-5. Models 2a and 2b are almost identical for three of the ethnic/gender groups, diverging somewhat from one another only among black boys. The use of the sampling weights makes little difference because of stratification.[11]

Among white girls the four trends are quite similar for the period under consideration until c. 1990 when the trend in the raw BMI values diverges substantially from the other three trends (Figure 2 top panel). The prevalence trend also flattens out somewhat compared to the BMIZ values (both weighted and unweighted) during the final decade considered. The increase in weight was already under way at the very onset of the period considered, i.e., in the 1940s. The relatively high rate of change of BMI values at the outset tended to decelerate during the 1950s reaching nearly zero by circa 1960 (Figure 2 bottom panel). Thereafter it increased according to all four models reaching a plateau in the 1970s. After c. 1980 the rate of increase decreased, but the estimates diverge from one another somewhat. The rate of change of BMI and of the prevalence decreased most rapidly. The BMIZ values show the least decrease after 1980 while the rate of change of the raw BMI values actually become negative in the early 1990s.

Figure 2 about here

Among black girls the two BMIZ estimates (models 2a and 2b) are virtually indistinguishable as among white girls. The trends for black girls also point to an early start in the increase in weight (Figure 3 top panel) with the raw BMI values showing the largest rate of change in the 1940s (Figure 3, bottom panel). Thereafter there are some fluctuations in the rate of change in the raw BMI values as well as the BMIZ values with peaks in the mid-1960s, and mid 1980s. There was a tendency for the rate of change to decrease until the mid

1990s when it began to increase again slightly as among white girls. However, the rate of change of the prevalence peaked in the late-1960s and then declined but very slightly thereafter, not showing the cycles evinced by the other three estimates. It also does not indicate a decrease after 1990. The raw BMI values alone indicate a negative rate of change after c. 1993.

Figure 3 about here

The BMI values of white boys began to increase later than that of the girls. There were no meaningful changes until the late-1950s except for a slight increase in the prevalence (Figure 4 top panel). However, by 1960 an upswing began for all of the indicators. The rate of change in the BMI and BMIZ (unweighted) values peaked in the mid-1960s and then declined slightly with the BMIZ values (weighted) showing a bit of a rebound in the mid-1980s (Figure 4 bottom panel). For the overweight prevalence estimates the acceleration that began in the late-1950s continued until the late 1970s. The estimate for the raw BMI value alone declines after c. 1990.

Figure 4 about here

The four estimates for black boys differ among themselves in the beginning of the period under consideration, with BMIZ values changing very little while BMI and overweight prevalence increasing (Figure 5, top panel). But the rate of change in all indicators increased by the 1950s and peaked in the mid-1960s (Figure 5, bottom panel). The rate of change began to decrease by the late 1960s with a slight rebound in the mid 1980s. In the early 1990s the four indicators diverged from one another again with the BMI and the BMIZ values (weighted) decreasing while the overweight prevalence continued to increase. Two of the rate of change indicators even reached negative values (BMI and BMIZ weighted).

Figure 5 about here

Weight increased substantially between 1941 and 2004. Calibrated for 150 month old youth (12.5 years) the BMI values for white girls increased by 2.4, those of black girls by 5.6, those of white boys by 1.5 and of black boys by 3.3 (without the age effects). In terms of prevalences the increase was 24 percentage points among white girls, 43 percentage points among black girls, 28 percentage points among white boys and 34 percentage points among black boys. In terms of BMIZ values the increase for black girls was 1.3σ (95% CI: 1.16σ; 1.44σ) for black boys 0.8σ, among white girls 0.7σ, and among white boys 0.6σ. The 95% confidence intervals around the point estimates of the BMIZ values are approximately 0.05σ for whites and about 0.07σ for blacks except at the ends of the period under consideration on account of the smaller number of observations. The "fit" of the models is low, considering that we do not control for genetic components (e.g. with BMI of parents), eating habits, or level of physical activity.[12]

Figure 6 about here

The BMIZ trends seem most plausible as the estimates based on the raw BMI values appear to be influenced by the unbalanced nature of the sample in the beginning and end of the period. Moreover, the overweight prevalences pertain to information in the right tail of the distribution. The comparison of the BMIZ scores for the four ethnic-gender groups shows how much more the weight of black girls increased compared to the other groups (Figure 6). The annual rate of increase was almost consistently above 0.02σ per annum and it did not fluctuate as much as for the other groups (Figure 6 bottom panel). The rate of change of BMIZ values of black females and white boys experienced an acceleration from the late-1950s to the mid-1960s, while that of black boys started somewhat earlier and that of white girls a bit later. After the mid-1960s the rate of increase tended to be generally somewhat slower with a slight increase among white boys after the mid-1980s. After 1990 the rate of increase was slower among white girls and black boys than among black girls and white boys. The fluctuation in the rate of change was the greatest among black boys increasing from near zero to 0.03σ per annum in the 15 year period 1950-1965 and then declining back to zero again by 1999. The model using OLS regression with dummy variables for age and birth cohort groups reported in the appendix yield qualitatively similar results to the Bayesian approach (see Appendix).

There are no national samples prior to the ones analysed above, but there is some regional evidence on BMI values of white male youth going back to the birth cohorts of the 1850s in case of the West Point Cadets (Cuff 1993, Komlos 1987). These indicate that average BMI values were quite low in the middle of the 19th century and increased very little during the course of the second half of the century even among military cadets who were surely among the better situated members of the society (Figure 7). In fact, about 90% of the cadet sample was below today's median reference value (Figure 8). Another regional sample from The Citadel Military Academy in Charleston, S.C. supports the notion that BMI values continued to be low for the remainder of the 19th century. In fact, BMI values tended to decline slightly until the turn of the 20th century[13] (Coclanis and Komlos 1995). Not until the birth cohorts of the 1910s - 1920s did BMI values increase substantially, at least in the South, but in the main still remained within the normal range (Figure 9). The next substantial increase in BMI values began among boys in the mid-1950s. The increase in the 20th century occurred not only by shifting the distribution to the right, but also by increasing the right tail of the distribution substantially (Figure 8).

Figures 7 - 9 about here

Discussion

Our goal has been to identify the long-run trends in adiposity of native-born children and youth born 1941-2004 (net of effects that are due to earlier maturation) rather than to analyze in detail their proximate determinants. Such a long-run perspective has not yet been provided as the various NHANES samples have not been concatenated as in this analysis. In addition, this is the first time that BMI data are analyzed by birth cohorts. This is useful for interpreting the path of the obesity pandemic insofar as so ordered data exist for every year in the second half of the 20th century whereas analysis by measurement years provide cross-sectional observations for only a handful of years that conceals important turning points. Hence, using birth cohorts the trend can be estimated with more clarity and its association with the major technological changes and increasing affluence which contributed to a sedentary life style and to excessive nutrient consumption of the US population can be identified more credibly (Anderson, Butcher, and Levine, 2003; Bleich et al. 2007; Lakdawalla, Philipson, and Bhattacharya 2005; Popkin, 2004).

That the BMI level of blacks has been increasing by more than that of whites has been known.[14] Yet, that the increase in BMIZ values among black females and possibly also among white females was already under way to some extent among the 1940s birth cohorts has not been noted. Why the effect was greatest among black females in the 1940s is unclear (Figure 6). To be sure, it is uncertain just when during the life cycle the weight gain took place among those born, for example, in 1942 and measured as 19-year-olds in 1961. Moreover, the small number of observations as well as the unbalanced age composition of the sample in the 1940s render the results for this decade quite tentative.[15] To be sure, the increase in the 1940s might be associated with the war, insofar as those cohorts were born into limited nutritional circumstances, but then why did the war not affect the boys at all?[16] And why did the increase in BMI values continue among black girls after the war? Thus, it would be premature to suppose that increase in the BMI values among the 1940s female birth cohorts was brought about by the war effort.

To what extent are the weight gains associated with the major labor saving technological, cultural and life-style changes of the 20th century? To mention only the most obvious ones, they include (inter alia) the industrial processing of food, the spread of fast-food culture, the use of automobiles, the introduction of radio and television broadcasting,[17] the increasing labor-force participation of women, and the IT revolution which led to social and cultural transformations associated with the post-industrial nutritional revolution and a much more sedentary lifestyle (Cutler, Edwards, and Shapiro, 2003; Philipson and Posner, 2003). For example, the share of food expenditures spent on eating outside of the home increased from 24% in 1950 to 45% in 1995 (Offer 2001, 2006, pp. 147, 149). “The per-capita number of fast-food restaurants doubled between 1972 and 1997” (Chou et al. 2004, 568), and the calories available for consumption increased by some 20% in the late 1980s and 1990s. In turn, the consumption of such energy-dense foods was associated with the increase in the number of hours worked by mothers (Anderson, Butcher and Levine 2003).

It is quite evident that all four (gender/ethnic) groups of children considered here were affected by the introduction and spread of TV-viewing in the 1950s as this was a time when TV sets in US households increased very quickly[18] (Chou, Rashad, Grossman, 2007) (Figure 10). This was also the time when the weight gain was consistently most rapid among the four groups with black boys being affected the most. The rate of increase peaked in the mid-1960s and then decelerated somewhat although staying at a high level throughout the 1970s. Insofar as the trends in the BMI values of the four groups considered here are distinct to some extent, the technological changes mentioned above seems to have affected them somewhat differently. Nonetheless, this is the first time to our knowledge that the effect of the introduction of television on the contemporaneous acceleration in children’s weight has been so vividly identified.

Figure 10 about here

On the other hand, the association of the IT revolution of the 1980s and 1990s on the rate of increase of BMI values was not as consistent as the spread of TV sets, only making a slight impact on white boys and to a limited extent also on black boys (of short duration). This is consistent with the fact that fewer black households own computers than white ones (black: 46%; white: 83%) (US Bureau of the Census, 2001). There might have been a substitution from one leisure activity to another both of which contributed to a sedentary life style without having a net effect. After c. 1990 the rate of change of BMI values was slowing among white girls and black boys but remained higher among black girls and white boys. Ogden et al (2006) also report that the prevalence of overweight children ages 2-5 among white females remained unchanged between measurement years 1999 and 2004 and among black males between 2001 and 2004. We thereby corroborate this finding.

To be sure, the results are somewhat sensitive to the dependent variables used: BMI (kg/m^2), BMIZ and overweight prevalence, primarily at the two ends of the period discussed probably because of the uneven age coverage in the sample. At the beginning of the period the increase in BMI values and in prevalence tend to be faster among boys than those estimated by the BMIZ values, while at the end of the period the BMI values tend to decline faster in contrast to the results obtained by the other methods. Nonetheless, the five models basically do corroborate the substantial increase in adiposity during the period considered and the impact of TV viewing. However, all methods indicate that the weight of black girls increased faster than those of the other groups and all of the estimates tend to corroborate the acceleration in weight gain in the mid-1950s and early-1960s when in most cases the greatest changes are found. This was also the time when the height of children tended to stagnate or decline implying that there might have been an association between these two phenomena (Komlos and Breitfelder, 2008). The rate of increase in the weight gain tended to decline after c. 1970. As the results in the appendix indicate, the estimated time trends remain essentially unchanged if we use an OLS model instead of the Bayesian ones above.

Nationally representative data on BMI values were not collected prior to the samples reported above. However, regional evidence indicates that at least among a sample of Southern white boys the increase in BMI values actually began among the 1910s and 1920s birth cohorts (Figure 7-9). According to this evidence, the transition between early-industrial and post-industrial BMI values could well have begun with the cohorts born around World War I. The transition would have occurred at least among US white boys in two steps of approximately equal size: in the 1910s-1920s which was actually a healthy jump, i.e., an improvement in biological well being, and then another shift began among the mid-1950s birth cohorts which brought too many BMI values into the danger zone (Figure 8).[19]

The inference appears plausible even if somewhat speculative that the incremental effects of changes in lifestyle associated with the labor saving technological developments of the 20th century might well have been already underway in the 1920s with the introduction of radio broadcasting and the rapid spread of automobiles (Figure 10). The obesity pandemic among US-born children and youth can be seen as the outcome of the combined incremental effects of the continuous and multifaceted technological, cultural, and nutritional changes of the 20th century.[20]

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Appendix

In order to explore the extent to which the Bayesian technique used above influences the results reported above we also analyzed the data using OLS regressions with dummy variables for age and for quinquennium of birth with BMIZ values as the dependent variable (Figure 1A). Circles indicate the estimates of the cohort effects and are compared to the estimates obtained with the Bayesian models. Admittedly, the construction of the dummy variables can influence the timing of peaks.[21] This is, in fact, the reason why we prefer not to rely on ad-hoc dummy-variable specification in which, e.g., the definition of cohort start and end points of the dummy variable determine whether one detects a peak or not.[22] Hence, we favor the Bayesian framework, as we believe that the assumption of a "smooth" trend is quite plausible in this application.

Figure 1A about here

However, the OLS method does have the advantage of being able to calculate standard errors that that account for clustering within the primary sampling units (PSU).[23] These are reported in Figure A1 along with the usual OLS standard errors (i.e. under the random sampling assumption). To be sure, the PSU-adjusted confidence intervals are not meaningfully larger than the "standard" ones on average, so that we believe that this design effect does not play a major role in our context. Nonetheless, we can test if successive BMIZ-scores estimates are statistically significant from one another (using PSU-adjusted standard errors). In several cases we find a significant (at the 10% level) difference between the cohorts born in the early 1960s and the late 1960s, and between the late 1970s and the early 1980s among all four sex/race groups. These are indicated by filled circles in Figure A1.

In sum, the OLS method does not affect the conclusions crucially. However, the fluctuations are greater with the OLS model. Moreover, the OLS estimates provide some evidence that the BMI values of white girls declined during the final quinquennium under consideration. Changes in the BMI of US children over the 20th century are a real phenomenon of both statistical and medical significance and not simply artefacts of survey design or details of the statistical analysis.

Figure 1: Number of observations by birth cohort. Combined NHES and NHANES Samples 1941-2004

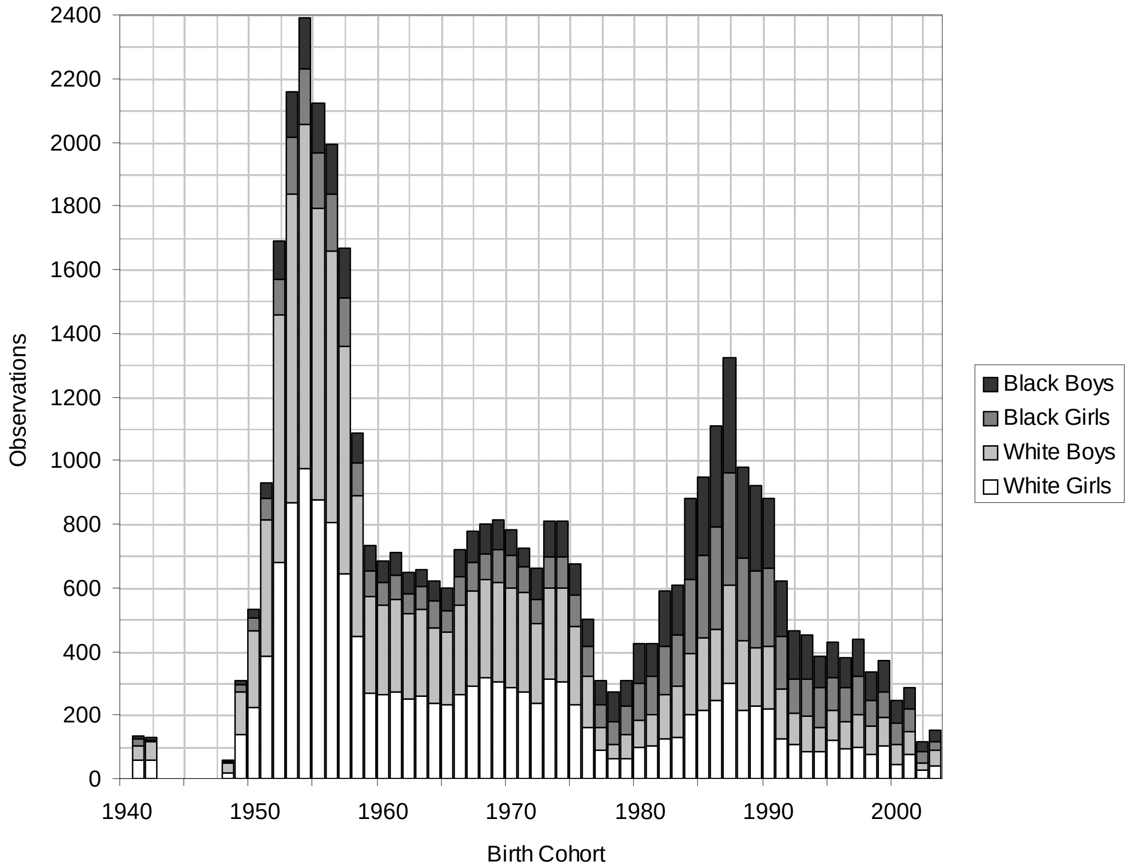


Figure 2: Top panel: Trend in BMI and BMIZ values: function f_2 from Eq. 1; overweight prevalences estimated from Eq. 2; pertains to non-Hispanic US-born white girls ages 2-19 born 1941-2004. Bottom Panel: rate of change of the functions estimated in the top panel.

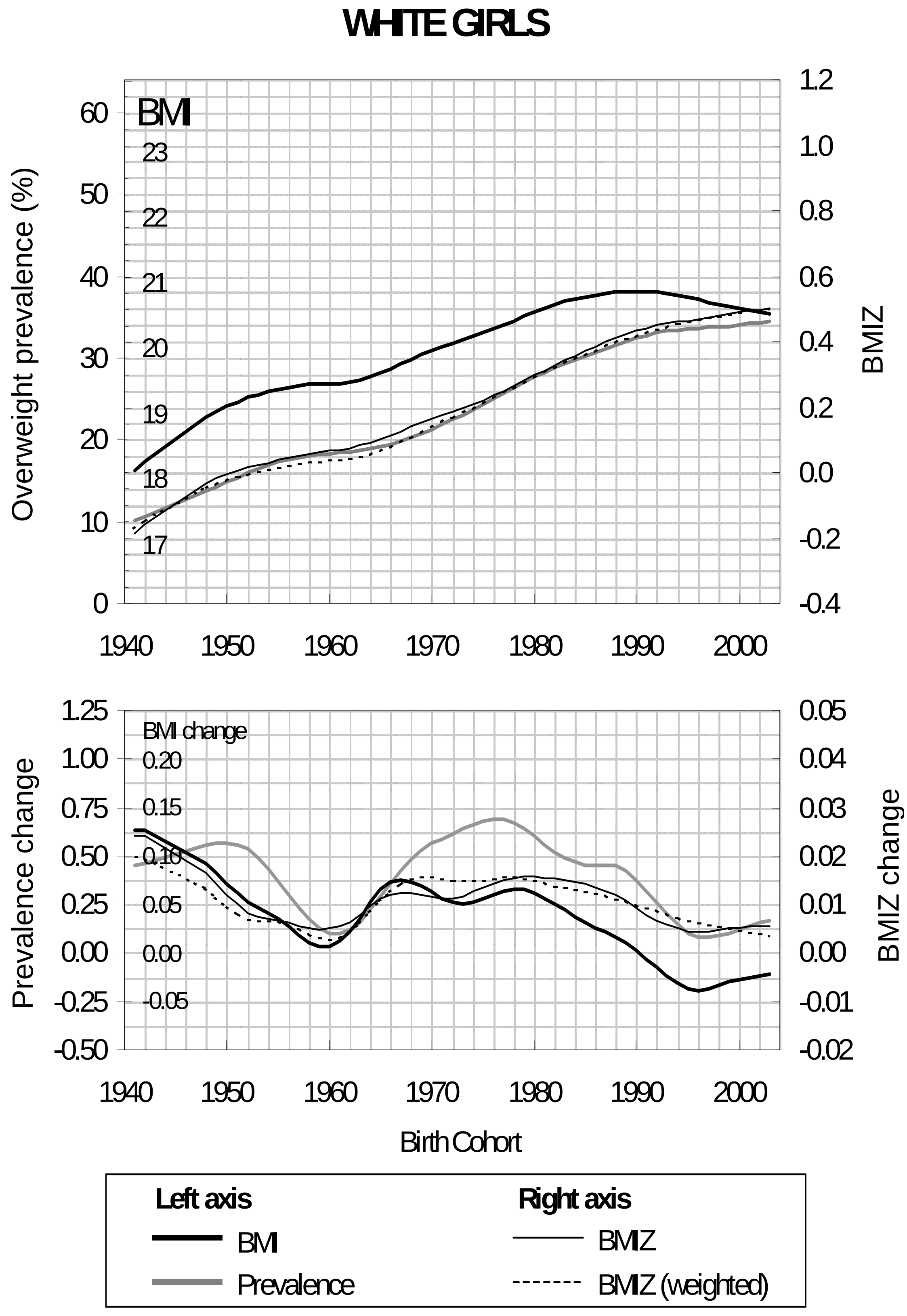


Figure 3: Top panel: Trend in BMI and BMIZ values: function f_2 from Eq. 1; overweight prevalences estimated from Eq. 2; pertains to non-Hispanic US-born black girls ages 2-19 born 1941-2004. Bottom Panel: rate of change of the functions estimated in the top panel.

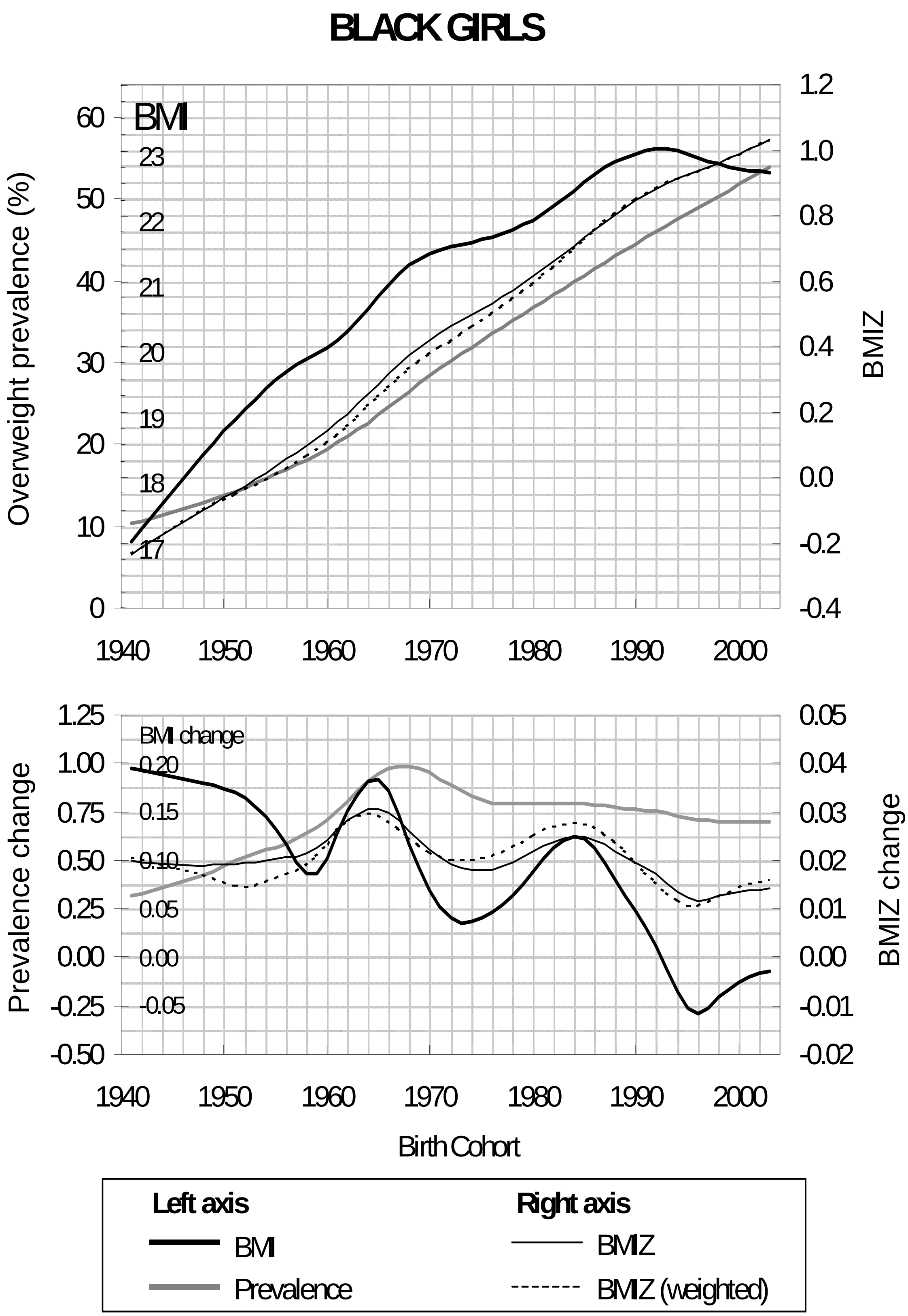


Figure 4: Top panel: Trend in BMI and BMIZ values: function f_2 from Eq. 1; overweight prevalences estimated from Eq. 2; pertains to non-Hispanic US-born white boys ages 2-19 born 1941-2004. Bottom Panel: rate of change of the functions estimated in the top panel.

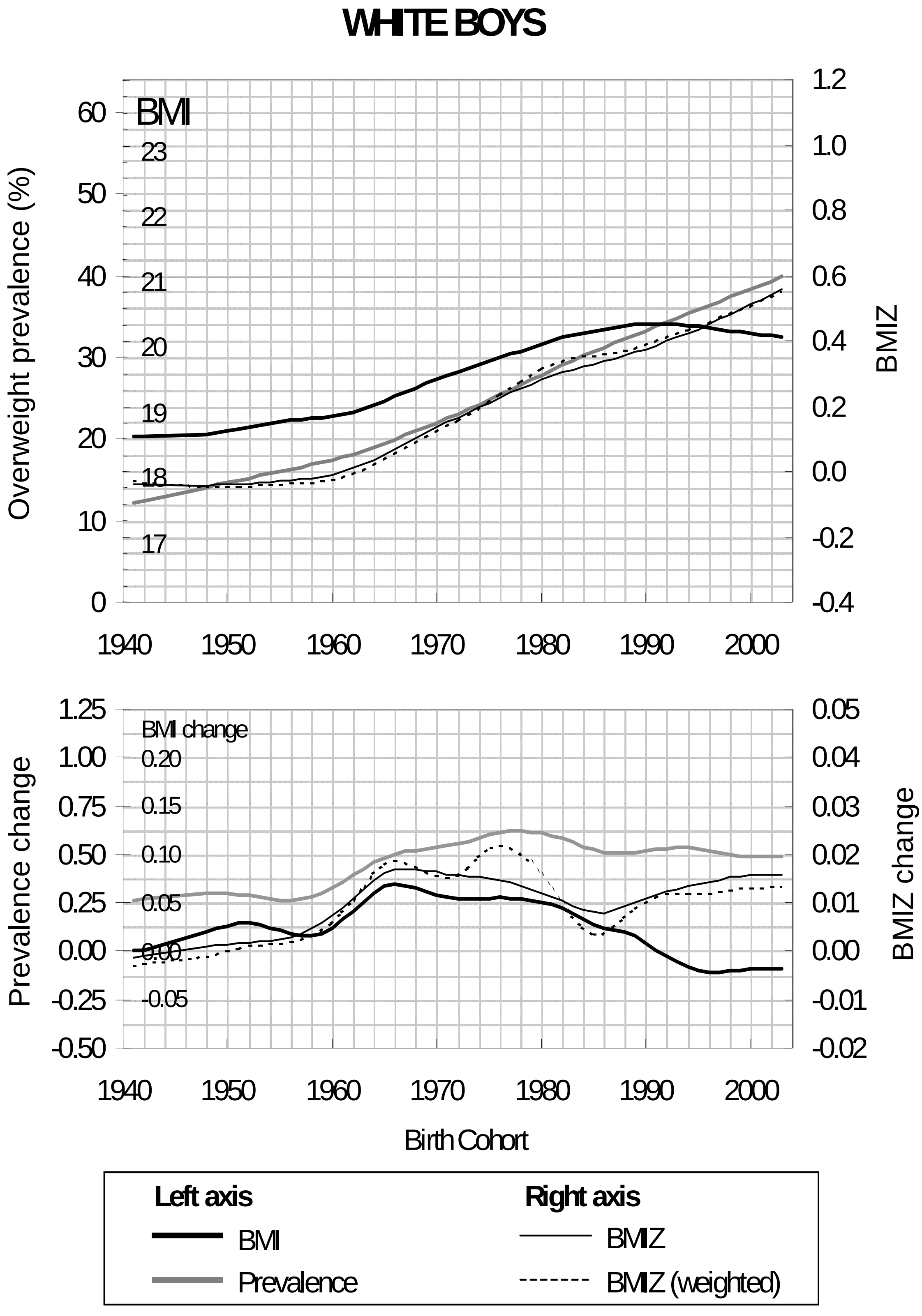


Figure 5: Top panel: Trend in BMI and BMIZ values: function f_2 from Eq. 1; overweight prevalences estimated from Eq. 2; pertains to non-Hispanic US-born black boys ages 2-19 born 1941-2004. Bottom Panel: rate of change of the functions estimated in the top panel.

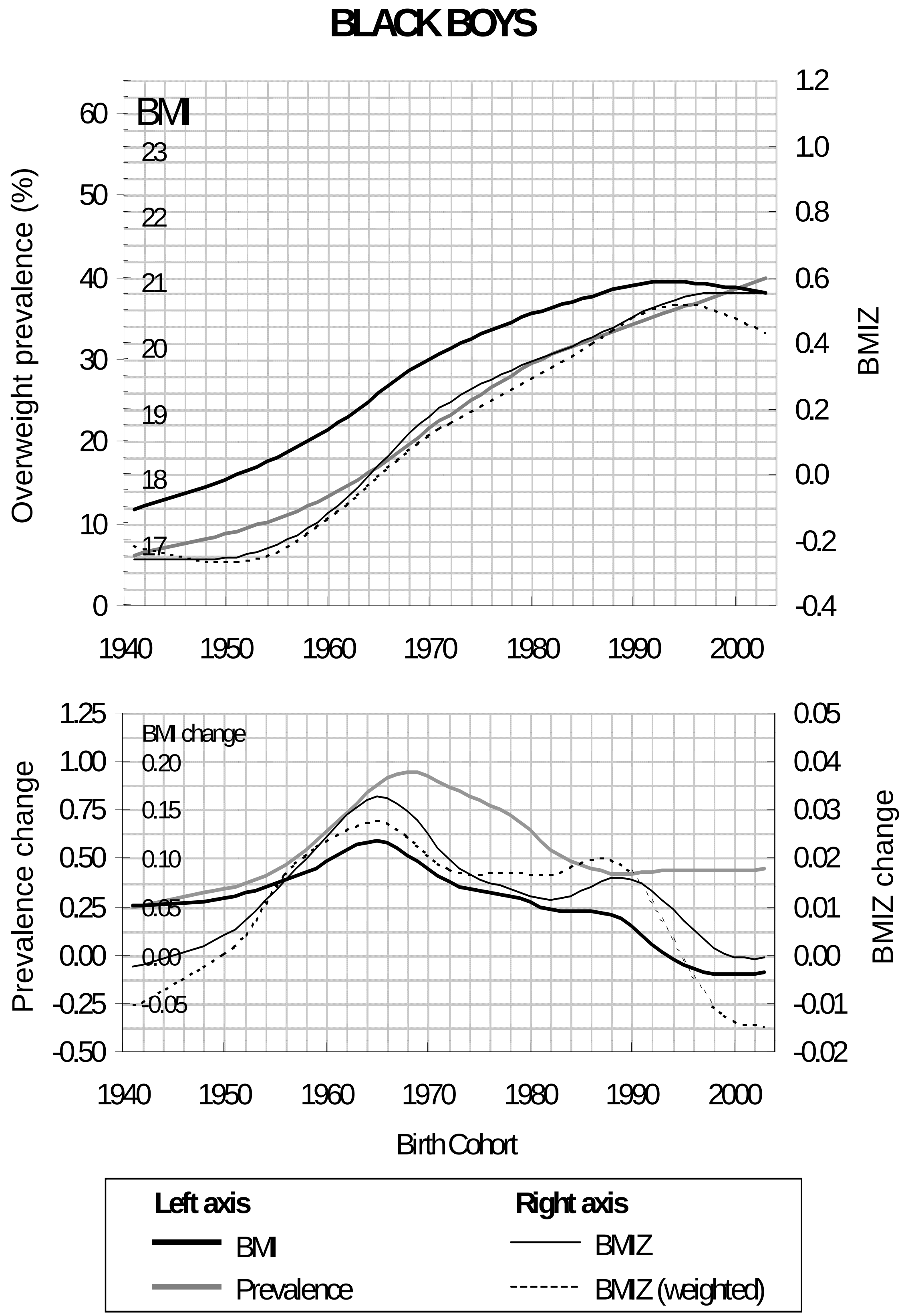


Figure 6. Top panel: Trend in BMIZ values: function f_2 from Eq. 1; of non-Hispanic US-born black and white boys and girls ages 2-19 born 1941-2004 (Model 2b); Bottom Panel: rate of change of the functions estimated in the top panel.

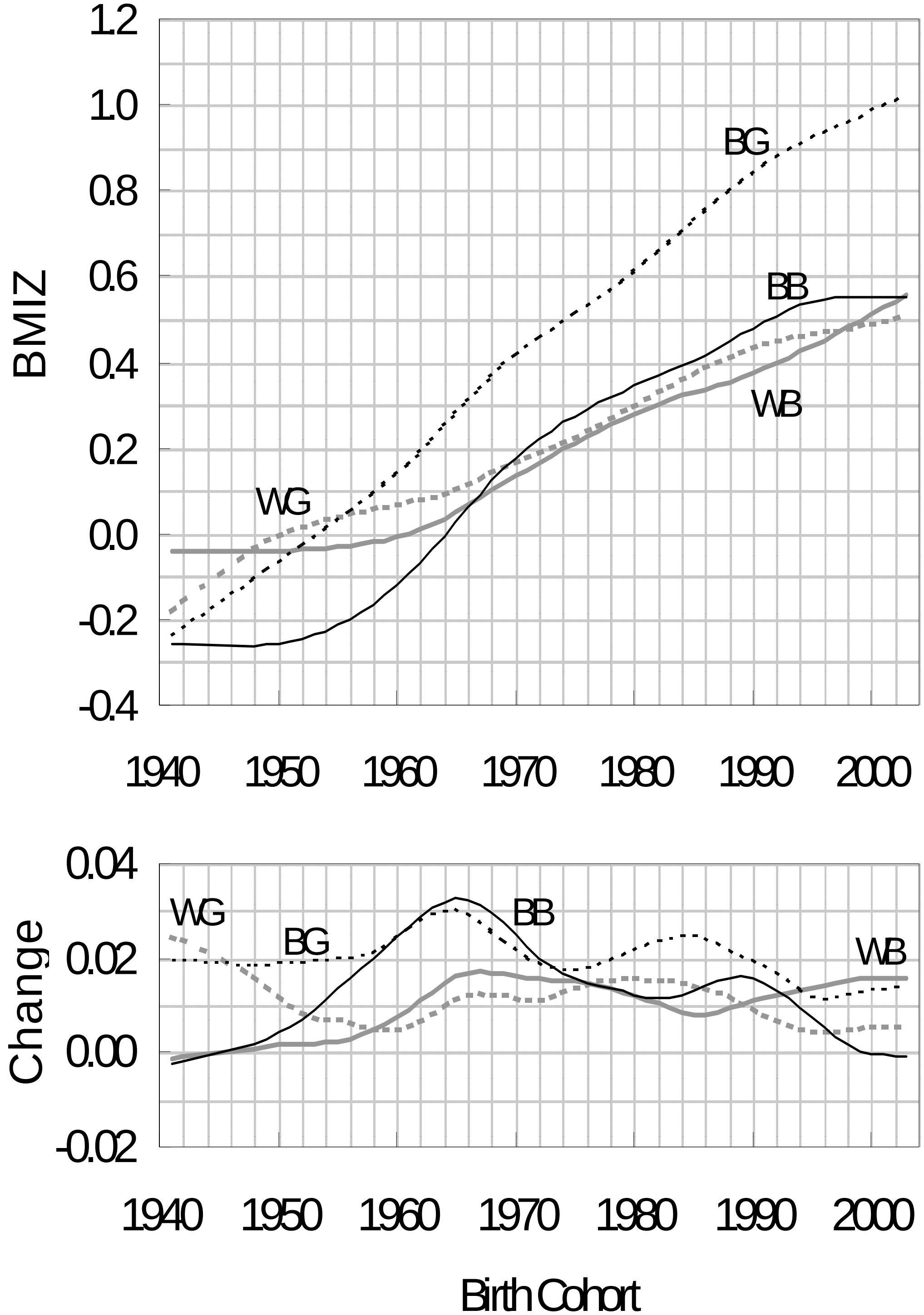
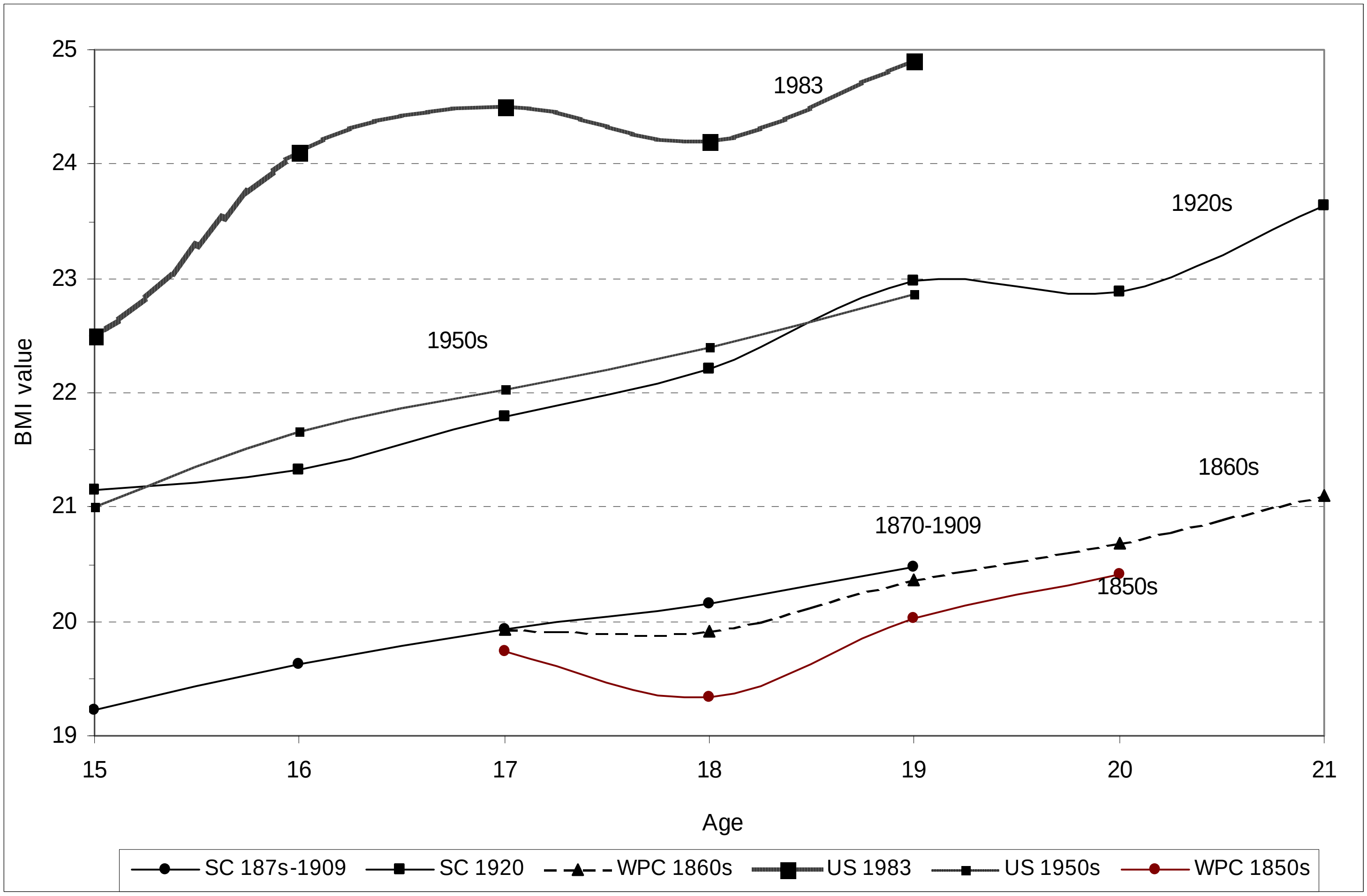
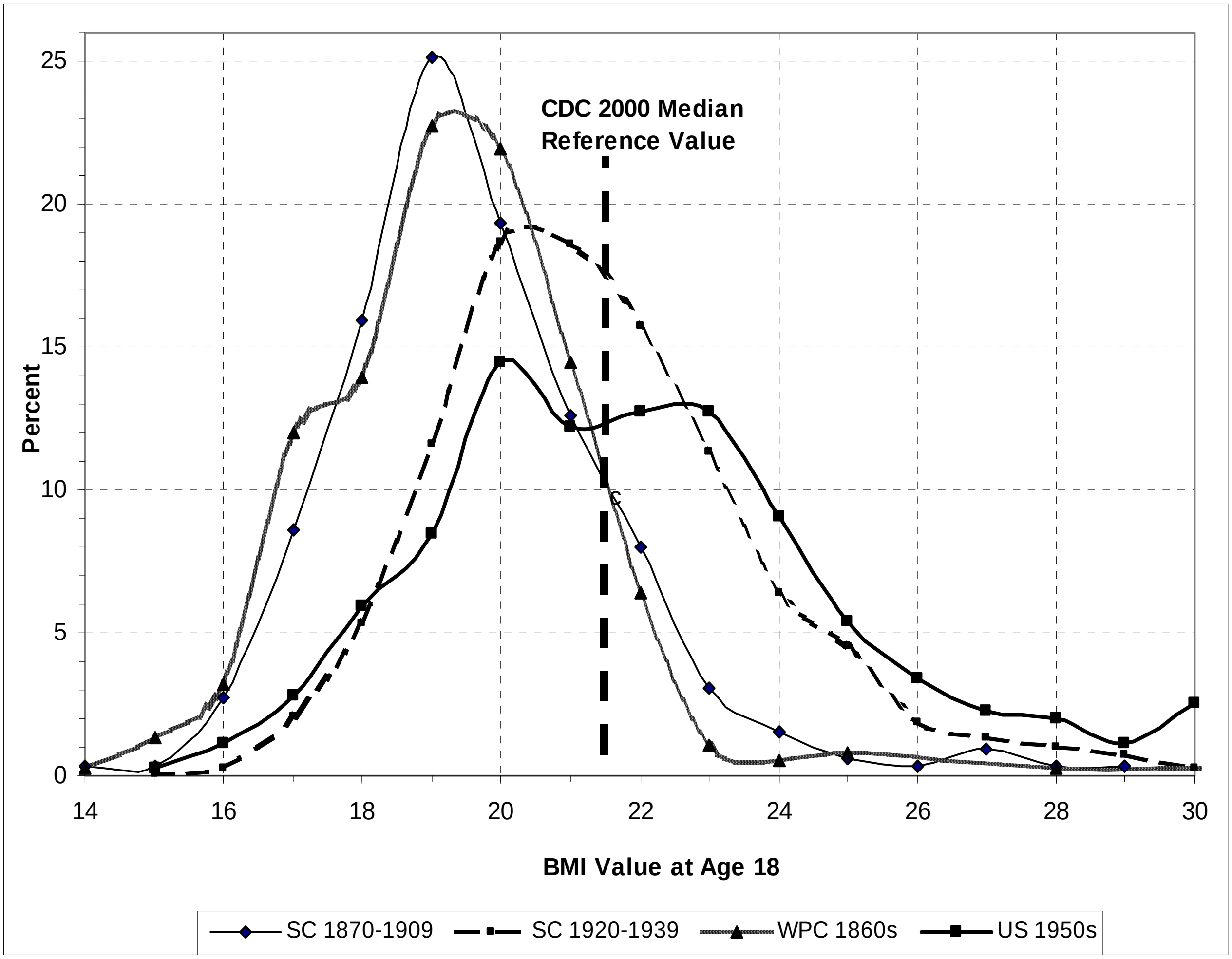


Figure 7. BMI values of US-born white male youth, born c. 1850-1983



Note: SC = Cadets at The Citadel Military Academy in Charleston, SC; WPC = Cadets at the West Point Military Academy.

Figure 8. Distributions of BMI Values of White US 18-year-olds, 1860s-1950s



Note: SC = Cadets at The Citadel Military Academy in Charleston, SC; WPC = Cadets at the West Point Military Academy.

Figure 9. BMI values of students attending The Citadel Military Academy in Charleston, SC.

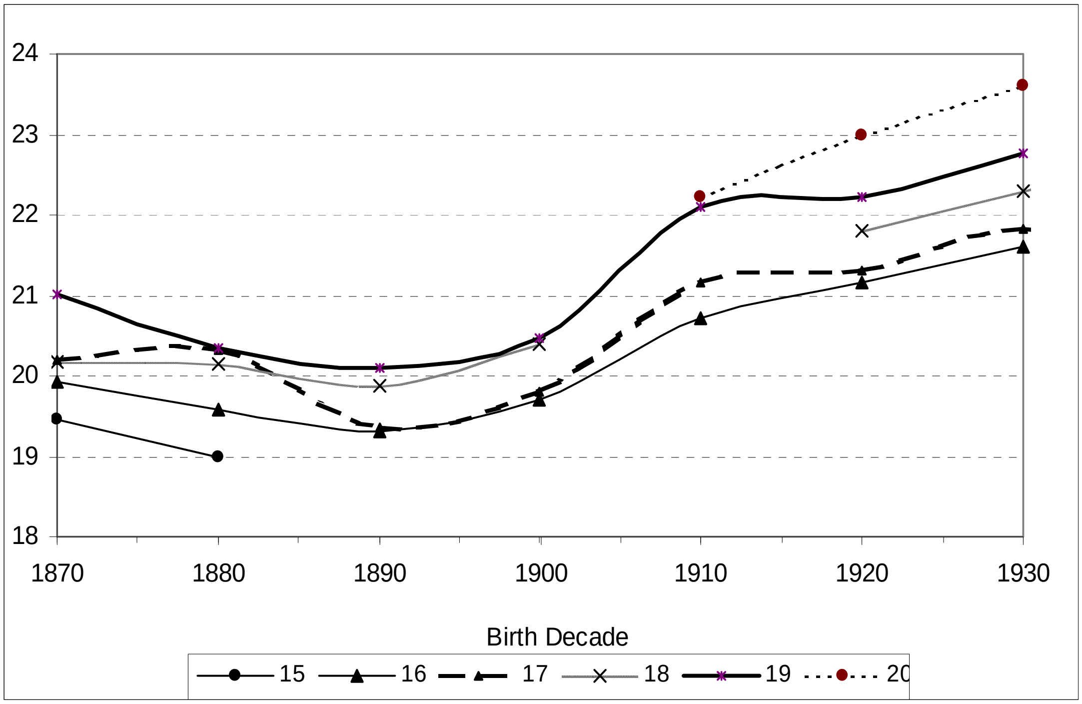
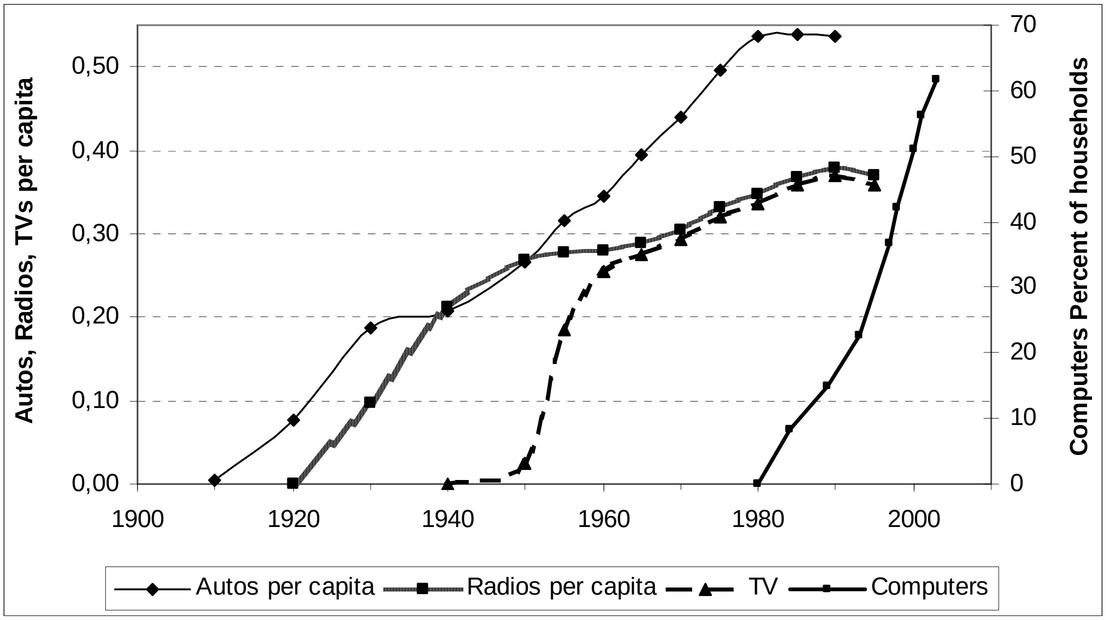
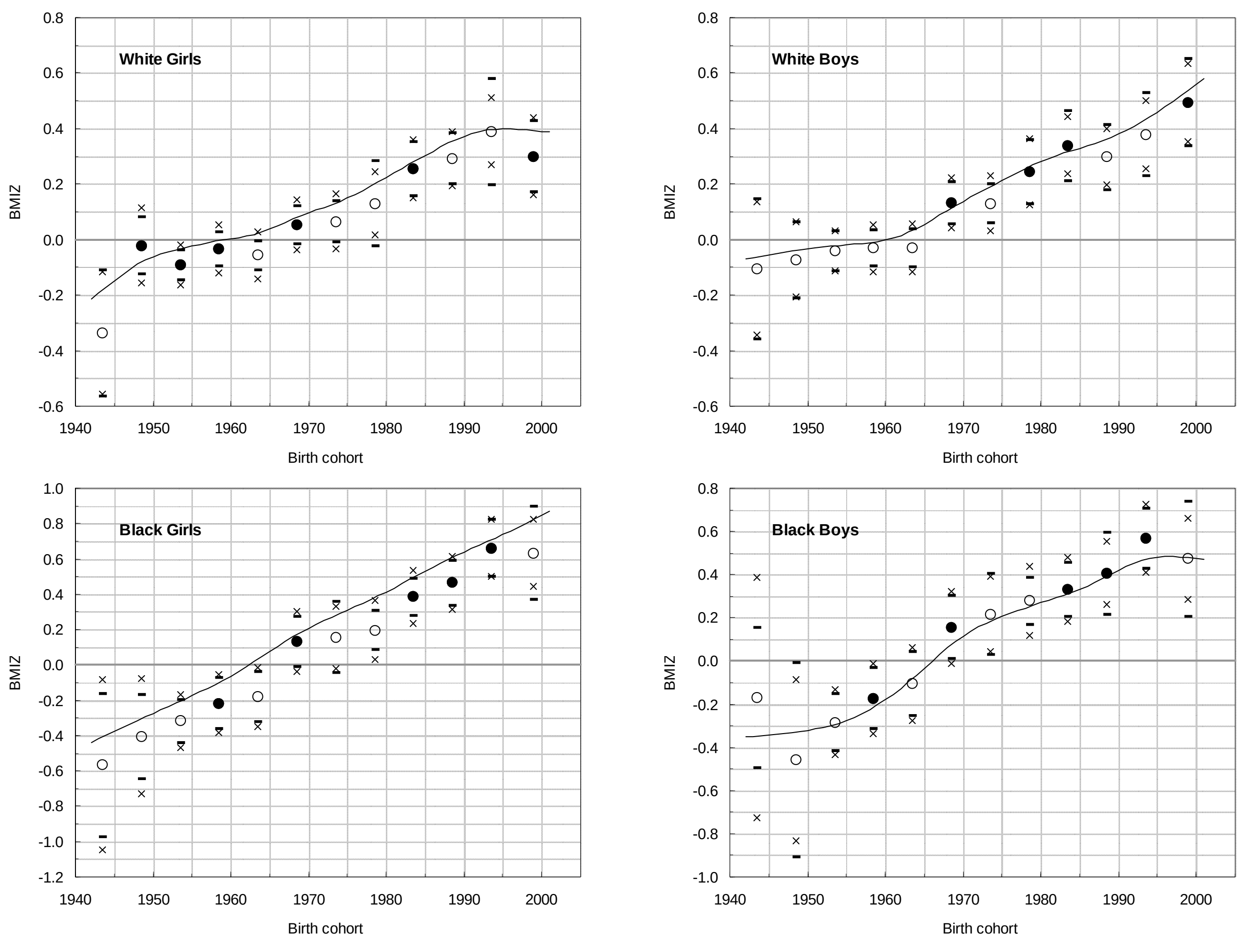


Figure 10. The Spread of major technologies in the 20th century, contributing to a sedentary lifestyle in the US



Source: US Bureau of the Census, Statistical Abstract of the United States 2000, Washington D.C. Bureau of the Census, 2000.

Figure A1: Supplemental estimated trends of BMI-z score of US-born youth by sex, race, and birth cohort based on OLS regression



Remarks: The continuous curves represent our estimated spline functions (calibrated at age 126 months), whereas the circles are taken from an OLS regression with dummy variables for birth cohort groups and ages in years (calibrated at age 10). The 95% confidence intervals for the mean BMI z-score are calculated on the basis of standard OLS standard errors ("x" symbol) and adjusted for grouping by PSU ("–" symbol). A filled circle indicates that a cohort's z-score differs significantly from the previous one (significance level 10%).

Endnotes

[1] The US-born criterion cannot be applied for NHES I. For NHES II and III we assume that those with a birth certificate were US-born. Information on Hispanic ethnicity is only available for NHANES III and Current NHANES. Lack of information in earlier surveys does not constitute a major problem, though, inasmuch as Hispanics were not intentionally oversampled before NHANES III.

[2] For some surveys we had to calculate age in months at examination and birth year as in NHES I, only age in years is available. We have subjects only aged 18 or 19 years in our sample from this survey and assume that these individuals are 222 and 234 months old, respectively. Year of birth cannot be exactly determined for NHES I (only up to a c. 4-year interval), NHANES III (c. 3-year interval), and Current NHANES (c. 2-year interval). In these cases we assumed that all subjects were measured at the midpoint of the examination interval.

[3] The BMIZ values were calculated using the *EpiInfo* software (Kuczmarski et al., 2002).

[4] Theoretically one does not need sampling weights if the sample is stratified by gender and ethnicity insofar as age is controlled for (DuMouchel, W., Duncan, G.J., 1983). Nonetheless, we do this part of the analysis with and without weights in order to demonstrate this point.

[5] The reference values pertain to the whole US population of children including Hispanics as well as legal immigrants. There is a problem with the reference values themselves (used with dependent variables 2 and 4) in as much as up to age six they include values measured in 1988-94 by which date BMI values have increased, whereas for ages 7-19 they were constructed on the basis of data from 1963 to 1980. Thus, the reference values are not time-consistent as BMI values were increasing during that time period.

[6] In order to identify the intercept term, the two spline functions are restricted to have an average value of zero.

[7] The final sample weight for our effective sample (all four groups combined) was adjusted such that it had a mean of 1 within each underlying survey.

[8] Or BMIZ-value larger than 1.04

[9] In each case we added the constant, γ, and the effect of an age of 150 months to the estimated values of f_2.

[10] The considerable fluctuations in the first derivatives are not caused by over fitting as this graph is not derived directly from the Bayesian regression.

[11] The secular trends estimated here are in addition the age effects which affect all ages and are available from the authors upon request.

[12] The squared correlation between predicted and actual BMI-z-scores ranges from 0.02 (white boys) to 0.10 (black girls). This might seem like a small amount but note that the proximate determinants of bmi values are omitted. Nonetheless the trends are significant.

[13] Evidence from the military corroborates the decline in BMI values toward the end of the 19th century (Costa and Steckel 1997, p. 55).

[14] BMI values of black men exceeded that of whites also among Union Army soldiers (Costa 2004).

[15] The results for the black females is slightly more convincing for this decade insofar as the rate of change in BMI remains similar for the rest of the century while that for white females first declines temporarily in the 1950s before rising again.

[16] Cindy Fitch was kind enough to point out that the National School Lunch Program started in 1946 and could have improved the nutritional status of girls.

[17] Television viewing has an additional affect through food and drink advertising that also affects food intake and obesity rates (Chou et al., 2007; Powell et al., 2007).

[18] Germaine Cornelissen-Guillaume has pointed out that exposure to magnetic fields of TV could be associated with hormonal imbalances in the body (Salti et al. 2006).

[19] However, there is also contradictory evidence: the BMI values of a sample of Union Army soldiers was the same as of those measured just after World War II (Costa 2004). Yet, this evidence is difficult to reconcile with data on the BMI values of West Point cadets who were to a considerable degree underweight (Figures 8 and 9). Gould (1869, vol 2, p. 403) gives the BMI values of native soldiers as 21.8 which is more in line with the values reported for the West-Point Cadets and the Citadel (Figures 7 and 9).

[20] Admittedly we are unable to explain many of the patterns found. For example, we do not know why the rate of change of white girls weight decreased in the early 1950s or why the weight trend among white girls was more similar to that of black boys than to that of the other groups after 1990.

[21] Age is in completed years. One could have defined these dummy variables in narrower or broader categories. It is clearly not desirable to have “too many” categories, as this would overfit the data and result in unrealistically abrupt changes; “too few” categories would also be a problem inasmuch as this might average out interesting patterns. This trade-off between flexibility and smoothness also exists with higher-order spline functions, so that one would have to specify a number of inner knots that determine the flexibility of the function (e.g. with the “GAM” routine available for STATA). If there is more than one such function, there is no straight-forward method to obtain an optimal combination of degrees of freedom or an optimal amount of smoothing for each function. An alternative to choosing a number of knots is to specify a relatively large number of inner knots in the first place (20 in our models) and to impose a penalty for abrupt changes of the slope of the function (Eilers and Marx 1996). BayesX allows the joint estimation of coefficients for the spline basis functions and a term that governs the smoothness of the spline – modeled as the variance of the second derivative with weakly informative inverse gamma hyperpriors (with both parameters set to 0.001). As a result of the smoothing process, the effective degrees of freedom used range from 4.7 (black

boys) to 7.0 (white girls) for the age spline function and from 4.2 (black girls) to 5.0 (white girls) for the birth year spline function. Hence, this specification could be considered more parsimonious than the approach with dummy variables in Figure A1. Brezger and Lang (2006) provide details on Bayesian inference with penalized splines.

[22] If the number of observations had been greater we could have used single year dummy variables for the birth cohort effects.

[23] We use the “SVYREG” routine in STATA. PSU numbers were changed such that each PSU number in the combined dataset can originate only from one of the constituent surveys.