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25-Year Weight Gain in a Racially Balanced Sample of U.S. Adults: The CARDIA Study

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Abstract

Objective—To examine 25-year trends in weight gain, partitioned by time-related and aging-related changes, during early and middle adulthood.

Methods—Coronary Artery Risk Development in Young Adults (CARDIA), a prospective, non-nationally representative cohort study conducted at four urban field centers that began in 1985-86 with 5,109 black (B) and white (W) men (M) and women (W) aged 18-30 years, has followed participants for 25 years (aged 43-55 years in 2010-11). Time-related and aging-related components of weight change were estimated to construct longitudinal models of linear and nonlinear trends.

Results—There were non-linear trends in time-related weight gain in women, with larger weight gains early that attenuated at subsequent exams. Time-related trends were linear in men. There were non-linear trends in aging-related weight gain in BM, BW, and WM, with the greatest weight gains at younger ages. Aging-related trends were linear in WW. Participants with overweight or obesity in early adulthood had greater attenuation of aging-related weight gain during middle adulthood.

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Conclusions—These findings partially support recent surveys indicating slower increases in obesity prevalence in recent years. Findings further suggest that aging-related weight gain is greatest in the 20s and may begin attenuating as early as the mid-30s among some groups.

Keywords

weight gain; obesity; adults; race; longitudinal

Introduction

Recent estimates indicate that nearly 38% of U.S. adults are affected by obesity,[1] and these proportions are even greater among certain demographic groups. For instance, 35% of White women (WW) are affected by obesity compared to 57% of Black women (BW).[1] There were recent indications that the increasing prevalence of obesity observed for several decades may be leveling off,[2-4] and similar trends were observed in other developed countries as well.[5] However, a recent report questions this conclusion by demonstrating a significant increase in the prevalence of obesity among U.S. adults between 1999-2000 and 2013-2014.[1] While these serial cross-sectional surveys provide valuable information regarding population-level changes in weight over time, these studies only capture time-related trends and do not address aging-related changes among the same individuals over time.

By following the same sample longitudinally, studies such as the Coronary Artery Risk Development in Young Adults (CARDIA) provide an opportunity to examine both time-related and aging-related weight change. In this case, time-related weight gain is conceptualized as change in weight at different calendar times that is independent of age, while aging-related weight gain refers to change in weight at different ages that is independent of calendar time. Previous analyses with this cohort indicated that time- and aging-related weight gain was experienced by Black and White men and women over a 10-year period in early adulthood, although the magnitude of weight change differed between demographic groups.[6] For instance, BW and participants who were initially overweight demonstrated the greatest weight gains. In contrast, other studies have shown that initially heavier individuals gained less weight over time than participants who were leaner at baseline.[7,8] In CARDIA, aging-related weight gain was greatest in the early to mid-20s for most groups, which is consistent with other epidemiological studies in the U.S.[8,9] and other countries that have demonstrated the greatest adult weight gains in early adulthood.[7,10-12]

However, most of this previous research has examined weight gain over time periods ranging from 5-10 years, [6,7,9,11,13-15] although two studies, including one in the U.S.[8] and one in the Philippines[10] followed the same participants for 20 years. In the U.S. study, weight gain was most pronounced in early adulthood (aged 25-35 years), and this was consistent for men and women as well as Blacks and Whites.[8] These results also demonstrated nonlinear trends, such that weight gain leveled off by age 60. The study conducted in the Philippines included only women who were initially pregnant at baseline. Nonlinear aging- and time-related trends in weight gain were observed, and similar to other studies, younger women gained more weight than older women.[10] Finally, a Norwegian study documented 22-year changes in weight by examining three cross-sectional samples between 1984-86 and 2006-08.[16] In this study, weight gain was observed across all weight categories, although increased prevalence of obesity was most pronounced among younger adults.

The current study extends previous work by examining trends in weight among black and white adults over a 25-year period from 1985-86 to 2010-11 in the CARDIA cohort.[6,14] This extended follow-up provides particularly useful information regarding time- and aging-related changes in weight over the course of early and middle adulthood in this racially- and sex-balanced sample. Participants ranged in age from 18-30 years at baseline to 43-55 years at the most recent follow-up, providing comparisons of weight trends by race and sex.

Methods

Sample

The CARDIA study is a longitudinal, epidemiological investigation examining the development and determinants of clinical and subclinical cardiovascular disease.[17,18] The CARDIA study began in 1985-86 with a sample of 5,115 Black and White men and women aged 18-30 years from four affiliated field centers located in Birmingham, AL; Chicago, IL; Minneapolis, MN; and Oakland, CA. Participants were recruited primarily by telephone (with limited door-to-door recruitment at one site) via random-digit dialing and/or use of local census tracts. Further, the recruitment scheme was designed to achieve balanced representation based on race, sex, and educational attainment at each of the field centers. A brief screening interview was conducted to establish eligibility, and eligible individuals were invited to participate in the baseline clinic exam. The response rate among individuals invited to participate was 50%. However, this sample was not representative of the U.S. adult population.

This sample has been followed for the past 25 years, with follow-up examinations occurring during 1987-1988 (Year 2), 1990-1991 (Year 5), 1992-1993 (Year 7), 1995-1996 (Year 10), 2000-2001 (Year 15), 2005-2006 (Year 20), and 2010-2011 (Year 25). A majority of the group has been examined at each of the follow-up examinations (91%, 86%, 81%, 79%, 74%, 72%, and 72%, respectively, among survivors). Approximately 88% of participants have attended ≥4 CARDIA examinations. For the current investigation, data from five-year exam intervals (i.e., Years 0, 5, 10, 15, 20, and 25) were included in analyses. Of the 5,115 participants initially assessed in 1985-86, three had no available anthropometric information at any exam, two identified as transgendered, and one revoked consent over the course of the study. In addition, 258 individuals were underweight (BMI<18.5 kg/m^2) at baseline and were excluded from analyses. Therefore, 4,851 participants who had available anthropometric data at one or more exams were included in this analysis.

Measures

Anthropometry—At each exam, body weight was measured in light clothing to the nearest 0.2 kg using a calibrated balance beam scale. Height without shoes was measured to the nearest 0.5 cm with a stadiometer. These values were used to calculate body mass index (BMI; kg/m^2).

Self-reported variables—Sociodemographic characteristics (race, sex, and educational attainment), medical history, and tobacco use were obtained from self-report questionnaires at each exam. This included self-reported history of bariatric surgery.

Statistical Analyses

Repeated measures regressions were used to construct longitudinal models of 25-year weight change (i.e., body weight, kg) for each of the four race-sex groups: Black men (BM), Black women (BW), White men (WM), and White women (WW). Women's data from a particular exam were excluded if pregnant at that exam, although other exam data were retained in analyses. Data of participants reporting bariatric surgery (n=59) were excluded for all exams following the surgery. In addition, underweight participants were excluded from the analysis. This resulted in 4,851 participants contributing 22,685 unique data points across all exams for these analyses. For the sample overall, this corresponded to a median of 5 exams completed by participants. For each race-sex group, the median number of exam visits completed was 5 for Black men, 5 for Black women, and 6 for White women and White men.

Since race-sex interactions were significant for both time and aging related trends, analyses were stratified and conducted separately for BM, BW, WM, and WW. Analyses estimated and partitioned time- and aging-related components of change in weight for each group by regressing weight (kg) at each examination on year of examination and age at examination.[19] Thus, age-related weight gain is the change from age to age and is independent of when in calendar time that age is achieved. It is estimated from a pooling determined within PROC MIXED of the age slopes across the serial cross-sections, taking into account the within-person correlation. Time-related weight gain is the difference between the predicted dependent variable at fixed age achieved at different calendar times. A time-related or period effect occurs across calendar time independent of age. Participants' height and field center location served as covariates in analyses. Additional models also adjusted for baseline weight, smoking status, and educational attainment. However, inclusion of these additional covariates produced similar patterns of results. Thus, the results presented controlled for height and field center only.

Both linear and non-linear (quadratic) terms for time- and aging-related weight changes were examined to determine the best fit for the longitudinal trends within each race-sex group. We have previously shown that if there is no time × age effect (i.e., birth cohort or simply cohort effect), the age coefficient is always the amalgamation of the serial cross-sectional age effects, and if time and baseline age are in the model, then the time coefficient is total cohort change and if time and current age are in the model, then the time coefficient is the period effect (i.e., secular trend).[19]

To determine whether inflection points could be identified in the non-linear time and aging related change in weight, we constructed a series of one-knot spline models to assess the slope change occurring at year of examination (break point at exam years 5, 10, 15, and 20) or age of examination (break point at ages 19, 22, 25, 28, 31, 34, 37, 40, 43, 46, 49, 52, and 55 years). These break points represent the median ages after participants were grouped into 3-year age categories (e.g., 21-23 years, 24-26 years) for these analyses. The best fit of each spline model was chosen based on the lowest Akaike information criterion (AIC) value. The estimated linear coefficients prior to and after the inflection point were represented along with difference in slopes between the two estimates.

The sensitivity analyses using Little's test ($p > 0.05$)[20] and multiple imputation method using SAS PROC MI and MIANALYZE were used to address the missing data, and these analyses produced stable estimates. In addition, baseline BMI was not associated with exam non-attendance over time (OR=0.996, 95% CI 0.98-1.01, p=0.625) or at Year 25 specifically (OR=0.998, 95% CI 0.99-1.01, p=0.742). Among BM, BW, and WM, there were no differences in baseline weight (kg) or BMI (kg/m^2) between participants who attended at Year 25 compared to those that did not attend the final follow-up. Compared to non-attenders, WW who attended at Year 25 had slightly lower weights and BMI at baseline, ps=0.008 (Table S1). Given all of these findings, we proceeded with repeated measures analyses in all available participants at each exam. All analyses were conducted using SAS version 9.4 (SAS institute, Cary, NC).

Results

Sample Characteristics and Observed Weight Gain

Of the 4,851 participants initially assessed in 1985-86 and contributing data to these analyses, 3,260 (67.2%) had weight measured at Year 25 (2010-11). The demographic characteristics of this sample, stratified by race and sex, at baseline and Year 25 are summarized in Table 1. All four race-sex groups demonstrated increases in weight and BMI from baseline to Year 25. Based on available data from each exam, observed mean 25-year weight gain was 18.8±15.7 kg for BM, 20.8±15.6 kg for BW, 14.0±11.5 kg for WM, and 13.8±14.2 kg for WW. Observed mean 25-year increase in BMI was 5.8±4.8 kg/m^2 for BM, 7.6±5.7 kg/m^2 for BW, 4.5±3.5 kg/m^2 for WM, and 5.2±5.3 kg/m^2 for WW. Figure 1 illustrates these observed total weight changes across each 5-year exam interval, and Figure 2 summarizes the proportion of participants in each BMI category at baseline and Year 25. As demonstrated in Table S2, nearly all participants who entered the study with obesity remained in this BMI category at Year 25. In contrast, most participants who began CARDIA in the normal-weight range transitioned to overweight or obesity by Year 25.

Time-Related Weight Gain

Modeled estimates of time-related weight gain adjusted for aging-related gains indicated non-linear (quadratic) trends for BW and WW (ps<0.01). For women, trends in weight gain were more pronounced at earlier exams but attenuated at more recent exams (Figure 3A). Linear spline analyses were also conducted to provide estimates for changes in the slope of weight gain at various exam years to determine at which exam the slope divergence was greatest (Table 2). These analyses indicated an inflection point at Year 10 (i.e., 1995) provided the best data fit for BW (AIC=46316.2), while the inflection point for WW occurred later at Year 15 (i.e., 2000; AIC=41698.3). In contrast to these non-linear trends in women, time-related weight gain was linear for BM (p<0.0001 for linear term; p=0.078 for quadratic term) and WM (p<0.0001 for linear term; p=0.241 for quadratic term) across the 25-year period.

Analyses further stratifying participants by baseline BMI status (i.e., normal weight, overweight, obesity) indicated that patterns of time-related weight gain were generally consistent across these sub-groups (Figure 3A). While participants with overweight or obesity at baseline demonstrated heavier weights at each follow-up exam, their slope of weight gain was similar to that of normal-weight participants. Thus, baseline weight status was not associated with time-related weight gain over the 25-year follow-up.

Because of the potential association between smoking status and weight gain, additional analyses also stratified participants into four categories of smoking status, including those who reported: 1) never smoking at any exam (N=2943), 2) smoking at all exams (N=726), 3) smoking at baseline and unsuccessfully attempting to quit at some point (N=177), and 4) smoking at baseline and successfully quitting at some point (N=483). As observed in Figure S1, patterns of weight gain did not substantively differ by smoking status in any race-sex group, with the potential exception of Black men.

Aging-Related Weight Gain

The quadratic term for aging-related weight gain was significant for BM, BW, and WM, indicating non-linear trends for these groups (*p*s<0.0001). In each of these three groups, weight gain was more pronounced at younger ages but attenuated at older ages (Figure 3B). Spline analyses provided supplemental information about the ages at which changes in the slopes of weight gain were most pronounced (Table 3). These analyses indicated inflection points in the slope of aging-related weight gain at 31 years for BM (AIC=33548.0), 37 years for BW (AIC=46297.3), and 43 years for WM (AIC=38831.8). In contrast to the non-linear aging trends observed for these three groups, WW demonstrated a linear trend in aging-related weight gain ($p<0.05$ for linear term; $p=0.836$ for quadratic term).

Analyses stratifying participants by baseline BMI status indicated that patterns of aging-related weight gain during adulthood differed for those with normal weight, overweight, or obesity in early adulthood. Compared to participants already with overweight or obesity in early adulthood, those who were initially normal weight demonstrated a more persistent pattern of continued weight gain throughout later adulthood. In contrast, those with initial overweight or obesity showed greater attenuation in weight gain at later ages (Figure 3B).

Discussion

Findings from the current investigation offer some support for national and international cross-sectional surveys suggesting that time-related trends in weight gain among adults in the U.S. and other developed countries may be slowing in recent years after several decades of pronounced increases.[2-5] In the current cohort, this modest attenuation of time-related weight gain was sex-specific and observed for women but not men. For BW and WW in this sample, weight gain was most pronounced during the first 10-15 years of observation (i.e., 1985 through 1995/2000) but slowed in the past 10-15 years. For BM and WM, time-related weight gain continued to occur in a linear fashion over the 25-year period. However, it is important to note that weight gain continued to occur during that time for all race-sex groups, but the patterns differed slightly for men and women. It is also important to interpret time-related breakpoints with some caution, as analyses are based on only five follow-up exam years during the overall 25-year study period.

By following the same group of individuals over time, this study provides novel information on the aging-related trends in weight over the past 25 years in this cohort. Similar to the non-linear time trends, aging-related weight gain seems to slow somewhere between the early to mid-30s (for BM and BW) and early 40s (for WM). Again, aging-related weight gain continued to occur in these groups but at a slower pace than what was observed earlier in the life course. These observations are consistent with prior studies that suggested weight gain was most pronounced in early adulthood [8-12] with non-linear trends observed as participants aged.[8] WW demonstrate a somewhat different pattern of weight gain; as they moved from young adulthood (i.e., late teens to early 20s) to middle adulthood (i.e., late 40s to mid-50s), there was no statistically significant slowing of weight gain attributable to aging.

These data further provide important information on whether trends in weight gain differ for individuals already with overweight and/or obesity compared to those with normal-weight at the beginning of the study. In this cohort, the slope for time-related weight gain was very consistent for those with normal weight, overweight, and obesity initially. Thus, there was no indication that initial overweight or obesity was related to greater escalation of weight gain over time. However, there was more variability in the patterns of aging-related weight gain for different baseline BMI categories. In general, those already with overweight or obesity in early adulthood evidenced greater attenuation of weight gain at older ages than those who were normal-weight in early adulthood. This is an encouraging finding for adults who experience overweight or obesity at younger ages, and it is consistent with some past work demonstrating that subsequent weight gain is less pronounced for those with excess body weight initially.[7,8]

It is unclear why the four race-sex groups demonstrated somewhat different trends for aging- and time-related weight gain over the 25-year period. In this study, BW were the only race-sex group to demonstrate a slowing in both time-related and aging-related weight gain, which is important since BW have some of the highest prevalences of obesity and weight-related conditions such as type 2 diabetes.[1,2,21] With that said, visual inspection of these results (see Figures 3A and 3B) suggests that the four groups may be more similar than different in overall patterns of weight gain over the 25-year period. Perhaps WW appear most distinct from the other three race-sex groups, as WW generally entered the study at a lower body weight, evidenced a lower slope to their weight gain, and subsequently had a lower weight at study end as well. They also had the highest prevalence of normal weight values at the beginning and end of the study period, yet they were the only sub-group to demonstrate a linear trend in aging-related weight gain.

In addition to the extended length of follow-up available with this cohort, other strengths include an objective measure of weight as well as the ability to examine weight gain attributable to both time and aging, which was further stratified by baseline weight status. While recent time trends in weight gain have been documented,[1-5] these data reflect cross-sectional snapshots with different samples over time. A strength of CARDIA is the available cohort that allows for examination of within-person phenomena.

Although this investigation followed the same cohort over time, some limitations of the current study deserve mention. First, the sample was recruited in early adulthood and followed through middle adulthood. Therefore, these results do not address weight gain during adolescence and older adulthood, both of which represent important time frames for understanding changes in body weight and obesity risk. Second, the sample was limited to white and black adults, so weight gain for other racial groups is lacking. While random samples (stratified for race, sex, and education) were obtained at each study site and 50% of eligible individuals elected to participate, the CARDIA sample is not representative of the U.S. adult population. Third, as with any longitudinal study, attrition can be a challenge. However, given the extended time frame of follow-up, this study demonstrated high retention, with 72% of the original, surviving sample completing the Year 25 examination, and we used all available data in analyses. Fourth, these data relate to total body weight and BMI, but changes in body composition are unknown. To some extent, changes in body composition may help explain the observed attenuations in weight gain, as aging-related declines in muscle mass may become apparent beginning around age 45.[22] Finally, the CARDIA participants were recruited in 1985-86 and the experiences, environment, and cultural milieu prevailing at that time may not reflect those of similarly-aged people now or at another calendar time.

Conclusion

The current results suggest that time-related weight gain may be attenuating in more recent calendar years for women, and aging-related weight gain attenuated in the early 30s to 40s, at least among some groups. Further, these overall patterns are relatively consistent by race-sex. The reasons for these observed trends, including biological factors and/or public policy initiatives, warrant further investigation. Future research will also be important for determining whether attenuations in weight gain continue or even increase into older adulthood and whether more substantial race and/or sex differences emerge over time.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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What is already known about this subject?

- The increasing prevalence of obesity in the U.S. may have slowed in recent years.
- Among adults, aging-related weight gain is most pronounced in early adulthood.
- Existing epidemiological evidence is limited on the unique contribution of time-related and aging-related weight gain in the same cohort over time.

What does this study add?

- The extended, 25-year follow-up of this study provides novel information regarding time-related and aging-related weight gain over the course of early and middle adulthood.
- Results suggest that time-related weight gain has slowed in the past 10-15 years for women, while aging-related weight gain slowed as early as the mid-30s to mid-40s for some groups in the CARDIA cohort.
- Those with overweight or obesity in early adulthood showed greater attenuation of weight gain during middle adulthood in the CARDIA cohort.

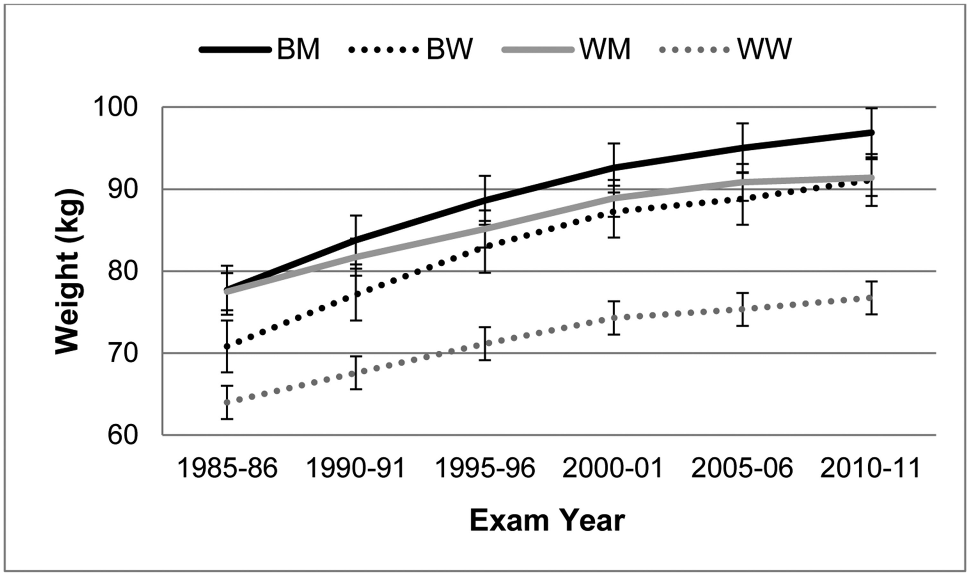


Figure 1.
Observed mean changes in weight (kg) between 1985-86 and 2010-11, by race and sex

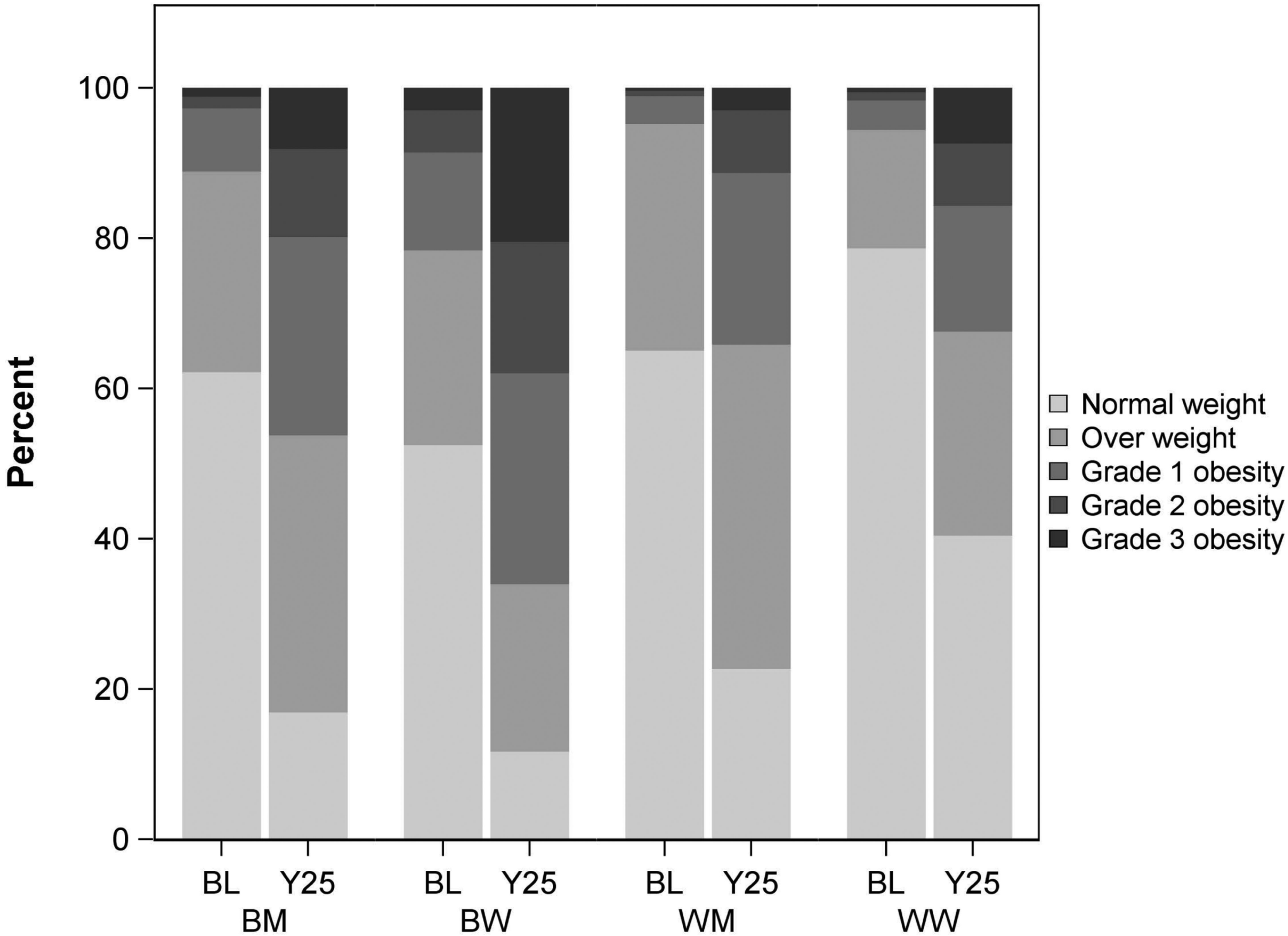
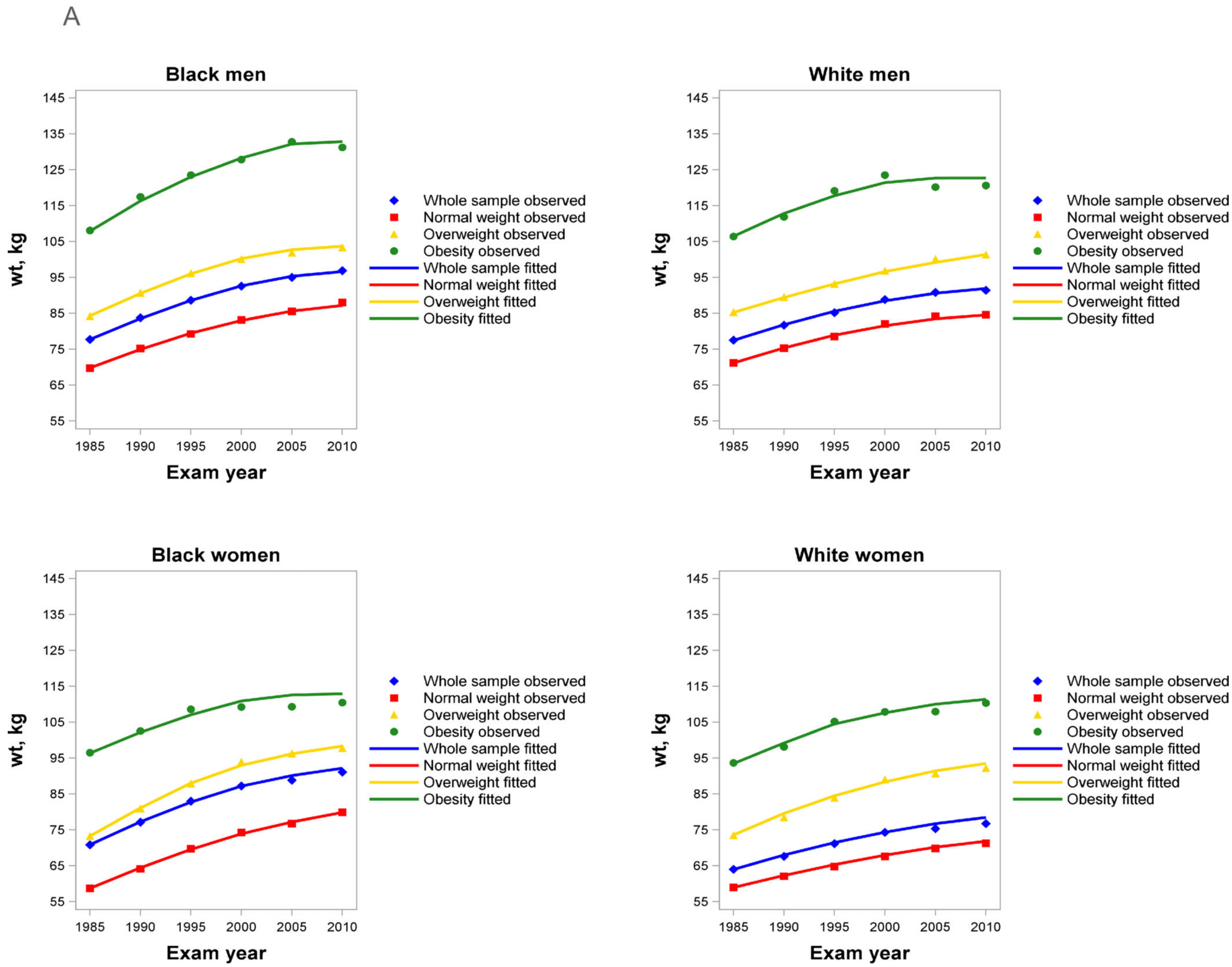


Figure 2.
Proportions of participants with normal weight, overweight, and obesity at baseline and follow-up, by race and sex


A
Black men
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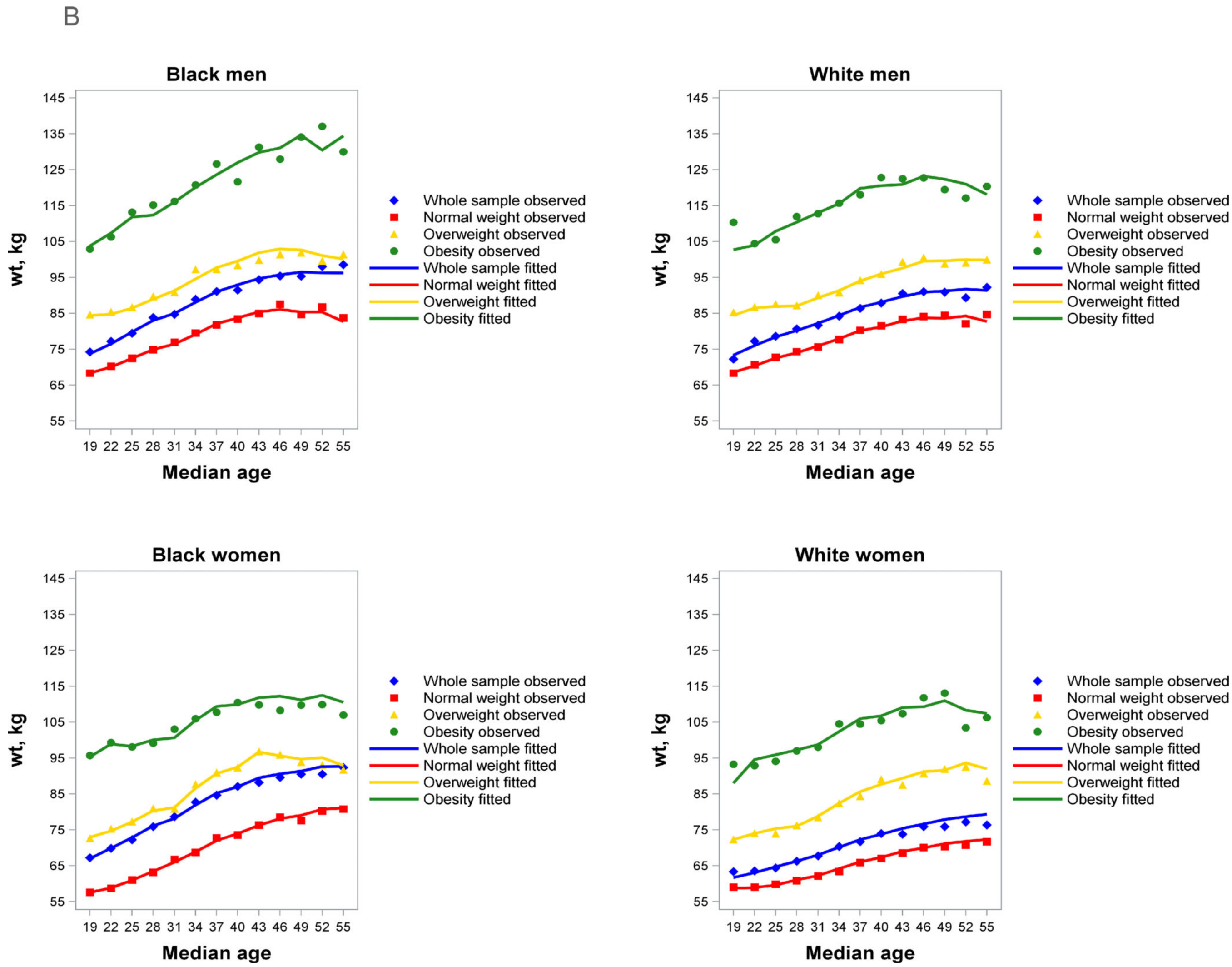

Figure 3.
Observed and fitted model-based time and aging trends in weight (kg), overall and by baseline BMI status, in each race-sex group

3A. Time-related weight change

3B. Aging-related weight change

Observed and fitted models for time (A) and aging (B) trends in weight in CARDIA, 1985-2010, based on mixed models. Time trends are adjusted for aging, while aging trends are adjusted for time. Fitted models were obtained with linear and quadratic term of age and time; averaged over time (A) or age (B) with equal weights in each case. Models include participants' height and field center location as covariates. Marks indicate observed means for race-sex; lines indicate fitted linear or quadratic models.

Table 1

Sample characteristics (M±SD) at baseline (BL; 1985-86) and Year 25 (Y25; 2010-2011)

	Black men (BM) N=632		Black women (BW) N=876		White men (WM) N=845		White women (WW) N=907	
	BL	Y25	BL	Y25	BL	Y25	BL	Y25
Age, years	24.4 ± 3.8	49.4 ± 3.8	24.6 ± 3.8	49.6 ± 3.8	25.6 ± 3.3	50.7 ± 3.3	25.7 ± 3.3	50.8 ± 3.4
Education, years	13.1 ± 1.9	13.8 ± 2.5	13.2 ± 1.8	14.4 ± 2.4	14.9 ± 2.4	15.9 ± 2.7	14.8 ± 2.2	16.0 ± 2.4
Current smoker, %	32.4	26.9	27.6	18.7	22.5	12.4	23.3	11.2
Weight, kg[a]								
Overall	78.1 ± 15.0	96.9 ± 23.3	70.3 ± 17.1	91.1 ± 22.0	77.3 ± 12.0	91.4 ± 17.1	63.0 ± 10.9	76.8 ± 19.6
NW	70.1 ± 7.2	88.0 ± 16.2	58.9 ± 6.9	79.9 ± 16.1	71.5 ± 7.4	84.6 ± 12.2	59.0 ± 6.4	71.3 ± 14.8
OW	84.3 ± 7.4	103.3 ± 17.1	73.2 ± 7.0	97.7 ± 20.0	85.5 ± 7.8	101.3 ± 16.1	73.0 ± 6.1	92.2 ± 18.5
OB	108.1 ± 15.5	131.2 ± 31.4	94.5 ± 16.3	110.5 ± 20.3	106.3 ± 13.7	120.6 ± 19.0	91.4 ± 12.4	110.4 ± 25.7
BMI, kg/m^2 [a]								
Overall	24.8 ± 4.3	30.6 ± 6.8	26.2 ± 5.8	33.8 ± 7.8	24.3 ± 3.3	28.8 ± 4.9	23.1 ± 3.8	28.3 ± 7.1
NW	22.3 ± 1.6	27.9 ± 4.6	21.9 ± 1.7	29.5 ± 5.3	22.5 ± 1.6	26.7 ± 3.4	21.6 ± 1.7	26.2 ± 5.2
OW	26.9 ± 1.4	32.8 ± 4.9	27.2 ± 1.4	36.1 ± 6.8	26.9 ± 1.4	31.9 ± 4.3	26.7 ± 1.3	33.9 ± 6.4
OB	33.9 ± 4.1	41.0 ± 8.8	35.1 ± 4.8	41.2 ± 7.2	33.3 ± 3.5	37.6 ± 5.2	34.3 ± 4.0	41.7 ± 9.5

NW=normal weight (BMI<25 kg/m^2); OW=overweight (BMI=25-29.9 kg/m^2); OB=obesity (BMI≥30 kg/m^2)

[a] Categorization as NW, OW, or OB is based on baseline BMI values.

Table 2

Summary of time-related break points with best fit (lowest AIC) based on single breakpoint linear spline models [a]

Race-Sex	Time of break point	Slope before break point	Slope after break point	Change in slopes	p-value	Fit statistic (AIC)
Black women	Year 10	0.55	0.02	−0.53	<.0001	46316.21
White women	Year 15	0.44	0.14	−0.30	<.0001	41698.27

[a] Results are presented for race-sex groups with significant quadratic trends for time-related weight gain.

Table 3

Summary of age-related break points with best fit (lowest AIC) based on single breakpoint linear spline models [a]

Race-Sex	Age of break point	Slope before break point	Slope after break point	Change in slopes	p-value	Fit statistic (AIC)
Black men	31 years	0.67	−0.01	−0.68	<.0001	33548.02
Black women	37 years	0.70	0.10	−0.59	<.0001	46297.29
White men	43 years	0.54	0.04	−0.50	<.0001	38831.08

[a] Results are presented for race-sex groups with significant quadratic trends for age-related weight gain.