Obesity and Mortality Risk: New Findings from BMI Trajectories

Abstract

Little research has addressed the heterogeneity and mortality risk of BMI trajectories among older populations. Applying latent class trajectory models to 9,538 adults aged 51 to 77 from the Health and Retirement Survey (1992-2008), we capture six latent BMI trajectories: normal weight downward, normal weight upward, overweight upward, overweight-obesity, Class I obese upward, and Class II/III obese upward. Survival analysis finds that people in the “overweight upward” trajectory have the highest survival rate, followed by “overweight-obesity”, “normal weight upward”, “class I obese upward”, “normal weight downward”, and “class II/III obese upward” trajectories. Results are robust after controlling for demographic and socioeconomic characteristics, smoking status, ADL limitations, a wide range of chronic illnesses, and self-rated health. Further analysis suggests BMI trajectories are more predictive of mortality risk than static BMI status. Attributable risk analysis finds about 7.6% of deaths after age 51 among the 1931-1941 birth cohort are due to obesity upward trajectories. This suggests trajectories of increasing obesity past age 51 pose a substantive threat to future gains in life expectancy.

The rising prevalence of obesity has emerged as a potential threat to future increases in life expectancy. The extent of this threat, however, is still uncertain, and estimates of the percentage of total deaths due to obesity vary widely, from 5%[1] to 13%[2-4]. Though these estimates are all based on measuring the mortality consequences of baseline BMI (BMI measured at one point in time), other studies have found that a dynamic measure of weight status (weight or BMI change) is more predictive of mortality than a static measure of weight status (i.e., baseline BMI), especially among older adults[5, 6]. In other words, we should expect obesity to increase the risk of mortality more profoundly when it persists over the life course. Therefore, in order to better assess the rising threat of obesity, it is essential to examine the mortality consequences of BMI trajectories.

Prior studies based on dynamic measures have yielded mixed findings about the mortality consequences of weight change [5-21]. Several factors contribute to the mixed findings. First, the effect of weight change depends on baseline BMI status. Weight gain leads to excess death among overweight/obese individuals but lowers mortality risk among underweight or normal weight people[7]. Second, the effect differs by the magnitude of weight change. Modest weight gains are associated with a decreased mortality risk, but excessive weight gains predict an increased mortality risk[8, 9]. Studies that simultaneously take both initial weight and the magnitude of change into account find that, among 50-70 year old Americans, small weight gains (1.0-2.9 BMI units) are not associated with excess mortality risk regardless of the initial BMI level; while large weight gains (3.0-5.0 units) increase death risk only among people with an initial BMI greater than 35. Moreover, both small weight loss (1.0-2.9 units) and large weight loss (3.0-5.0 units) are associated with an increase in mortality risk among people who are normal, overweight, or mildly obese at baseline[10].

In advancing beyond a static measure of baseline BMI, prior studies nevertheless have suffered from several limitations. First, most studies only consider mortality consequences of weight change between two time points, either over the short term[10] or the long term[7]. This approach obscures heterogeneity in weight changes that occur after the second time point, as well as weight fluctuations between the two time points. Second, although differentiation between small and large weight changes is important, the specified cutoffs are necessarily arbitrary and may inadequately represent true variation in the magnitude of weight change. Third, when estimating the interaction effect between weight change and BMI on mortality risk, some studies assume a linear functional effect; that is, they expect the effect of weight gain or weight loss on mortality to be linear across initial BMI status. This functional assumption, however, is arbitrary and may distort the interrelation of weight change and initial weight status.

The objectives of this study are to capture heterogeneity in the entire BMI trajectory after age 51; examine the mortality consequences of this heterogeneity; and calculate the mortality risk attributable to each trajectory using data from the U.S. Health and Retirement Survey. We use a semiparametric group-based trajectory model or the latent class trajectory model[11-14] to capture heterogeneity in weight changes without specifying artificial cut-off points or a strong functional assumption. This strategy can straightforwardly depict how BMI may increase, decrease, or remain stable among various groups with different initial BMI statuses.

MATERIALS AND METHODS

Data and participants

We use data from the Health and Retirement Study (HRS), a nationally representative survey of Americans born between 1931 and 1941. HRS respondents and their spouses were initially interviewed in 1992, and re-interviewed at two-year intervals since then. We use nine waves of data, spanning 1992-2008. We restrict the analysis to respondents aged 51-61 in the original 1992 HRS sample. Our analytic sample consists of 9,538 respondents aged 51 to 61 in 1992 who were followed until death, exit from the study, or censoring at the 2008 interview. HRS matches respondents to the National Death Index to ascertain vital status after respondents exit the survey. As of September 2011, 2,010 respondents from our analytic sample have been confirmed as deceased by the HRS. The HRS supplies the month and year of death, allowing us to compute time spent at risk. For the 2,010 respondents known to have died, exposure to mortality risk is calculated as duration from age 51 till the date of death, in months. For the 7,528 surviving respondents, we can similarly compute exposure to mortality risk as duration from age 51 till December 2009 if they are known alive or presumed alive as of the 2010 wave.

Predictors of mortality

BMI trajectory. Upon entry into the study, respondents contribute data on self-reported height and weight, and contribute further data on self-reported weight at every successive interview. We use these data to calculate body mass index (BMI). BMI is defined as the ratio of weight in kilograms to the square of height in meters. In waves where a respondent was not interviewed or did not report their weight, we treat BMI as missing. The latent class trajectory model we use allows for individuals to have incomplete BMI data over the course of follow-up, so they can be retained in the analytic sample. The youngest respondents in the sample are 51 years old in 1992, and the oldest respondents in the sample are 77 in 2008, so we are able to construct BMI trajectories from age 51 to 77.

Social-demographic and behavioral factors. At the 1992 baseline, HRS records respondents' gender; race/ethnicity (non-Hispanic White, non-Hispanic Black, or Hispanic); marital status (never married, married, separated, divorced, widowed, or living with a partner); and education (years completed). We use imputed data files provided by RAND to determine respondents' income, in dollars. Respondents also reported whether they have ever smoked, and if so, whether they currently smoke. We collapse these questions into a single measure of smoking, distinguishing never-smokers, former smokers, and current smokers. We include a binary measure of physical activity, distinguishing among respondents who engage in vigorous physical activity three or more times per week and those who do not.

Health and medical history. HRS data include a battery of 5 questions measuring difficulty with activities of daily living (ADLs), including dressing oneself, eating, bathing and showering, getting in and out of bed, and walking across a room[15]. The original response categories for each activity consisted of a four-point scale, from "not at all difficult" to "very difficult/can't do," with an additional category: "don't do." We recoded each ADL item to one if the respondent reported any difficulty or that he or she didn't do the task, and zero if the respondent reported no difficulty. We then summed the items to create a 0-5 scale of ADL limitations. Finally, respondents reported if they had ever been diagnosed with each of seven conditions: angina, heart failure or heart attack; arthritis; bronchitis or emphysema; cancer; diabetes; stroke; or bone fracture. We also include a measure of self-rated general health (SRH) on a five-point scale: 1 "excellent", 2 "very good", 3 "good", 4 "fair" or 5 "poor."

Statistical analysis

We use a semiparametric group-based trajectory model to capture unobserved heterogeneity in the BMI trajectories after age 51. This model uses a multinomial mixture modeling strategy and is designed to identify relatively homogeneous clusters of trajectories of development or change over time in the presence of repeated observations on analytic units[11, 13]. In other words, this model assumes the population consists of a mixture of underlying trajectories[16]. Online supplement I explains the technical details for this model. We use SAS Proc Traj package to estimate the model. Given that the distribution of BMI is right-skewed, we model the logarithm of BMI (log(BMI)) instead of a linear specification of BMI. After obtaining trajectories of log(BMI), we apply a multivariate Cox proportional hazard model to calculate the relative mortality risk of each trajectory, using age (months elapsed since age 51) to parameterize the baseline hazard function[17]. The analyses were performed using SAS Proc Phreg program.

After obtaining the hazard ratios associated with BMI trajectories from Cox model, we calculate the population attributable mortality risk fraction based on the formula

$\frac{\sum_j (C_j RR_j - C_j^* RR_j)}{\sum_j (C_j RR_j)}$ where *j* indexes the category of BMI trajectories; C_j refers to the proportion of j_{th} BMI trajectory in the population; and RR_j refers to the relative mortality risk of j_{th} BMI trajectory compared to the reference trajectory, which can be obtained from the hazard ratios in the proportional hazard model[18]. C_j^* is the counterfactual proportion of the j_{th} BMI trajectory in the population when all the respondents in the corresponding j_{th} trajectory are assigned to the reference trajectory.

RESULTS

Table 1 describes the analytic sample. At baseline, the mean BMI is 27.2, in the middle of the "overweight" range. The average age is 56, with non-Hispanic Whites constituting 73% of the sample, non-Hispanic Blacks—17%, and Hispanics—10%. Men account for 47% of the sample and women account for 53%. Health and disease characteristics reveal a population beginning to experience the maladies of old age: 38%, 12%, and 11% have been diagnosed with arthritis, circulatory problems, and diabetes, respectively. Yet the average respondent reports fewer than one ADL limitation, and the average self-rated health is halfway between the "very good" and "good" categories.

[Table 1 about here]

Figure 1 portrays the six trajectories obtained from latent class trajectory model. Six linear latent trajectories fit the data better than other possibilities with regard to the number of trajectories and their functional form. We defined four BMI groups based on World Health Organization guidelines: normal weight (BMI of 18.5 to 24.9 kg/m^2), overweight (BMI of 25 to 29.9 kg/m^2), class I obese (BMI of 30 to 34.9 kg/m^2), class II/III obese (BMI greater than or equal to 35 kg/m^2). As we model trajectories based on log(BMI), we transform the cutoff points to 2.92, 3.21, 3.4, and 3.56, respectively. Trajectory 1, consisting of 22.8% of sample, starts with overweight at age 51 and then linearly increases and enters class I obese status at age 77. This is the "overweight-obesity" trajectory. Trajectory 2 starts with overweight at age 51 and slowly increases afterwards, but remains within the overweight category by age 77. We call this trajectory "overweight upward," consisting of 29.5% of sample. Trajectory 3, accounting for

24.2% of the sample, starts with normal weight at age 51 and slowly increases afterwards. We call this the “normal weight upward” trajectory. Trajectory 4, including 3.4% of the sample, starts with class II/III obesity at age 51 and then linearly increases. We refer to this as the “class II/III obese upward” trajectory. Trajectory 5, including 8.4% of the sample, starts with normal weight status at age 51 and slowly declines afterwards. We refer to this as the “normal weight downward” trajectory. Trajectory 6, including 11.7% of the sample, starts with class I obese status at age 51 and increases afterwards, entering class II/III obese status at age 77. We refer to this as the “class I obese upward” trajectory.

[Figure 1 about here]

Figure 2 portrays the Kaplan-Meier survival curve for these six BMI trajectories. “Overweight upward” trajectory, shown as a solid line, is more rectangular and extends further to the right than other trajectories. This means individuals on this trajectory are more likely to survive to older ages. Close to this survival curve are the curves for “overweight-obesity” and “normal weight upward” trajectories, with the former extending further to the right. “Class I obese upward” and “normal weight downward” are less rectangular than the above three trajectories, implying that individuals on these two trajectories die earlier. The survival curve on the far left is for “Class II/III obese upward” trajectory, which means individuals on this trajectory die even earlier than those in the other five. Log-Rank statistics indicate the survival curves are significantly different across these six trajectories.

[Figure 2 about here]

Table 2 presents the adjusted hazard ratios of BMI trajectories from a Cox proportional hazard model with “overweight upward” trajectory as the reference group. As expected from

Figure 2, the other five trajectories are associated with excess death risk compared to the "overweight upward" trajectory. Adjusted for socio-demographic factors, "normal weight downward" is significantly associated with 107% (*P* < .001, two-sided here and in what follows) increase in mortality risk. "Normal weight upward" is associated with an excess risk of 20% (*P* < .01). "Overweight-obesity" is associated with 1% increase in hazard but this increase is not significant. "Class I obese upward" increases the mortality hazard by 27% (*P* < .001). "Class II/III obese upward" increases the mortality hazard to an even larger extent, by 137% (*P* < .001). Adjusted for behavioral factors, including smoking status and vigorous physical activity, the excess mortality risks associated with "overweight-obesity", "class I obese upward" and "class II/III obese upward" increase to 4% (*P* > .05), 33% (*P* < .001) and 153% (*P* < .001), respectively, while the excess risks associated with "normal weight downward" and "normal weight upward" decrease to 73% (*P* < .001) and 12% (*P* >.05).

The next two models adjust for ADL status, seven chronic illness measures, and self-rated health, and the effects of the five trajectories remain significant and in the same direction. Stratifying the analyses by gender returns comparable findings, presented in online supplement II. Finally, we calculate the population attributable mortality risk fraction using hazard ratios from the model adjusted for behavioral factors. We do not use the fully adjusted model, as obesity affects mortality risk through the measures of disability, chronic disease, and chronic conditions[1, 19]. In our sample, the mortality risks attributable to "class I obese upward trajectory" and "class II/III obese upward trajectory" are 3.2% and 4.4%, respectively, when compared to the "overweight upward" trajectory.

[Table 2 about here]

In Table 3, we constrain the analysis to the healthiest subsamples (no preexisting illness or excellent/very good/good self-rated health), as we may get more accurate estimates of the obesity effect among healthy people who experience few comorbid illnesses and competing mortality causes[19, 20]. We find that the deleterious effects of “class I obese upward” and “class II/III upward” trajectories are greater among the healthiest individuals than when estimated for the whole sample; excess mortality risks associated with these two trajectories are 44% ($P < .05$) and 130% ($P < .01$), respectively, among people with no preexisting chronic illness; and 27% ($P < .05$) and 145% ($P < .001$), respectively, among people reporting good or better health. Thus, the onset of disability and chronic illnesses at midlife appears to mask some of obesity’s contribution to a greater mortality risk.

[Table 3 about here]

DISCUSSION

Little research has addressed the heterogeneity and mortality risk of BMI trajectories in older populations. This paper focuses on BMI trajectories past age 51 of the original respondents in the Health and Retirement Study, born between 1931 and 1941. Using the latent class trajectory model to capture heterogeneity in weight changes without specifying artificial cut-off points or a strong functional assumption on the effect of weight changes, we obtain six latent BMI trajectories: normal weight downward, normal weight upward, overweight upward, overweight-obesity, Class I obese upward, and Class II/III obese upward. People who are overweight at age 51 and remain overweight through age 77 have the lowest mortality risk. People who are obese II/III at age 51 and gain weight through age 77 have the highest mortality risk. Compared to “overweight upward” trajectory, “class I obesity upward” and “class II/III obese upward” trajectories are significantly associated with 33% and 153% increase in mortality risk without controlling for confounding health factors. The numbers decrease after controlling for these confounding factors. The deleterious effects of these two trajectories, however, are even bigger among people with no preexisting chronic illness or those who report "good" or better health at baseline. This is consistent with several studies[20-22] that have found obesity leads to a higher mortality risk among healthy people.

Statistical significance tests show the differences among "overweight upward" and "overweight-obesity" trajectories are not significant. These findings suggest that among overweight people at age 51, small weight gains do not entail a lower probability of survival. By contrast, weight gain among obese people, in either Class I or Class II/III, increases their mortality risk. These findings indicate the effects of weight gain depend on baseline BMI status. Many previous studies find weight gain is associated with higher mortality risk among overweight/obese individuals[7], whereas we find weight gain does harm obese individuals but not overweight individuals. These inconsistencies may result from prior studies using arbitrary cut-off points on weight change or assuming a linear function of weight change effect across BMI status, which may yield over-deterministic results. Weight loss, even small weight loss, among people at "normal" weight at age 51, carries a significant deleterious effect on health. Many previous studies find even small weight losses can exert a harmful effect on survival regardless of the initial BMI level[10].

These effects are caused by BMI trajectory more so than by initial BMI status alone. Online supplement III presents mortality risk of baseline BMI status. Underweight and class II/III obese increase subsequent mortality risk compared to the reference category, "overweight". "Normal weight" and "class I obese" are not associated with significant increases in mortality risk. These findings are consistent with Mehta and Chang's analysis[19]. The effect size of these BMI statuses is smaller than those of BMI trajectories in Table 2. BIC statistics suggests BMI trajectories fit model better than BMI status. This is consistent with studies concluding that a dynamic measure of weight status (e.g., weight or BMI change) is more predictive of mortality than static measure of weight status (e.g., baseline BMI)[5, 6].

This study has several limitations. First, BMI measures were constructed from self-reported weight and height, and are subject to potential bias. But self-reported and clinically measured height and weight are strongly correlated[10, 19, 23]. Therefore, using self-reported weight and height should not have introduced substantial bias to our analysis. Second, we are not able to trace the BMI trajectories to earlier periods in the life course. It would be interesting to extend the current study by investigating whether BMI trajectories in early and middle adulthood display similar heterogeneity, and whether this heterogeneity has similar implications for mortality risk. In other words, the findings in this study may not be generalizable to adults younger than 51. Third, we are not able to differentiate between intentional and unintentional weight changes, particularly weight losses. On the other hand, prior studies have found intentional weight loss has, at best, weaker detrimental effects on mortality, and not the anticipated protective effect[24, 25]. Moreover, we have controlled for a wide range of underlying health problems and functional limitations that may lead to unintentional weight change, thereby estimating the net effect of weight change. Fourth, although BMI is the most commonly used measure of adiposity, it has been criticized as not being able to directly measure body fat and muscle composition, or distinguish between central and peripheral adiposity[26]. Although some data sets (e.g., NHANES IV 1999-2004) have more accurate and direct measures of body composition, such as Dual Energy X-ray Absorptiometry, they do not track long-term changes in these measures.

Improving upon prior studies, we investigate the effect of dynamic BMI trajectories on mortality risk. We find people in the “overweight upward” trajectory have the lowest mortality risk, followed by “overweight-obesity”, “normal weight upward”, “class I obese upward”, “normal weight downward”, and “class II/III obese upward” trajectories. Mortality risks attributable to “class I obese upward trajectory” and “class II/III obese upward trajectory” are 3.2% and 4.4%, respectively, compared to the “overweight upward” trajectory. In total, about 7.6% of deaths after age 51 in the 1931-1941 birth cohort are due to obesity upward trajectories. These estimates are larger than Mehta and Chang’s estimates[19] (5.1% and 4.7% for obese females and males, respectively), which use baseline BMI measures with reference to overweight status in the same dataset and same cohort of respondents. This comparison again demonstrates BMI trajectories are more predictive of mortality risk than initial BMI status. Further, our numbers are possibly underestimated, as about 79% of respondents were censored at the end of the survey. We might have observed an even larger detrimental effect of obesity upward trajectories if we had a longer mortality follow-up period. Our estimates are not directly comparable to those obtained by Allison and colleagues[2], Mokdad and colleagues[3, 4] or Flegal and colleagues[1] due to different age groups of the sample. Their studies include adults of all age groups, while ours focus on people 51 years and older. Due to the age-dependent nature of the BMI-mortality link (i.e., a stronger correlation among younger adults[27-30]), we might have observed an even larger effect for the 1931-1941 birth cohort if we could take into account the risk of dying before age 51. Our study suggests trajectories of increasing obesity past age 51 pose a substantive threat to future life expectancy increases.

Online Supplement:

I. Technical Details for Latent Class Trajectory Models.

Suppose vector $Y_i = \{y_{i1}, y_{i2}, y_{i3}, ..., y_{iT}\}$ represents a longitudinal sequence of outcome variable on an individual *i* over T periods, the latent class trajectory model can be specified as below[16]

$$P(Y_i) = \sum_j \pi_j P^j(Y_i),$$

where *j* denotes the underlying trajectory *j*, $P(Y_i)$ denotes the probability of Y_i, π_j denotes the probability of trajectory *j*, and $P^j(Y_i)$ is the probability of Y_i given membership in trajectory *j*. Trajectory membership probabilities, π_j, *j*=1,…,J, are estimated by a multinomial logit regression. This model assumes that, conditional on membership in trajectory *j*, y_{it}, t=1,…, T, are independent, thus $P^j(Y_i) = \prod^T p^{jt}(y_{it})$[16]. As the outcome variable in this study is log(BMI), $p^{jt}(y_{it})$ is assumed to follow a censored normal distribution. For the censored normal distribution, the linkage between time (age in our study) and the outcome variable is established by means of a latent variable, y_{it}^{*j}, that is a function of age[13].

II. Adjusted Hazard Ratios of BMI Trajectories with Reference to “Overweight Upward” Trajectory from Cox Proportional Hazard Model by Gender, 1931-1941 HRS Cohort.

Covariate	Men		Women	
	HR	95% CI	HR	95% CI
Normal weight downward	1.66	1.32, 2.09	1.63	1.32, 2.03
Normal weight upward	1.16	0.99, 1.37	1.10	0.91, 1.34
Overweight-obesity	1.10	0.93, 1.30	0.87	0.70, 1.08
Class I obese upward	1.26	1.02, 1.56	1.07	0.85, 1.34
Class II/III obese upward	1.83	1.26, 2.67	1.88	1.45, 2.45
Sample Size	4483		5055	
Number of Deaths	1101		909	
BIC	17277		14293	

Abbreviations: BIC, Bayesian information criterion; BMI, body mass index; CI, confidence interval; HR, hazard ratio; HRS, Health and Retirement Study.

Note: All models fully adjust for demographic, socioeconomic, behavioral, diseases, and health indicators.

III. Adjusted Hazard Ratios of Baseline BMI Status from Cox Proportional Hazard Model, 1931-1941 HRS Cohort.

Covariate	Fully adjusted	
	HR	95% CI
Underweight	1.47	1.08, 1.99
Normal weight	1.09	0.97, 1.21
Class I obese	1.13	0.99, 1.28
Class II/III obese	1.65	1.41, 1.93
BIC	34273	

Abbreviations: BIC, Bayesian information criterion; BMI, body mass index; CI, confidence interval; HR, hazard ratio; HRS, Health and Retirement Study.

Note: Model fully adjusts for demographic, socioeconomic, behavioral, diseases, and health indicators.

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Table 1. Baseline Characteristics of Participants in the Health and Retirement Study, United States, 1992.

	Total		Men		Women	
	Mean (SD)	%	Mean (SD)	%	Mean (SD)	%
Sample size	9538		4483		5055	
No. of deaths	2010		1101		909	
BMI	27.2 (5.1)		27.3 (4.4)		27.1 (5.7)	
Demographics						
Age, years	55.7 (3.2)		55.7 (3.2)		55.7 (3.2)	
Non-Hispanic white		73.1		75.2		71.2
Non-Hispanic black		17.4		15.6		19.0
Hispanic		9.5		9.2		9.8
Socioeconomic factors						
Income	46390 (50394)		52059 (55363)		41362 (44946)	
Years of schooling	12.0 (3.2)		12.2 (3.4)		11.9 (3.0)	
Married		73.5		80.6		67.2
Partner		2.5		3.5		1.7
Separated		3.2		2.6		3.6
Widowed		6.2		1.6		10.3
Never married		3.7		3.6		3.7
Divorced		11.0		8.1		13.4
Full time employment		49.2		65.7		34.5
Part time employment		16.7		9.6		23.0
Retired		7.1		8.2		6.2
Unemployed		17.1		5.6		27.3
Behavioral factors		9.9		10.9		9.0
Current smoker		27.4		29.6		25.4
Former smoker		36.3		45.0		28.6
Never smoker		36.3		25.4		46.0
Vigorous physical activity (>=3 times per week)		22.3		21.4		23.0
Health and disease factors						
ADL	0.2 (0.7)		0.2 (0.7)		0.2 (0.7)	
Bone fracture		13.8		13.3		14.3
Arthritis		38.1		31.0		44.5
Angina, heart failure or heart attack		12.9		14.9		11.1
Bronchitis or emphysema		8.2		7.7		8.6
Cancer		5.6		3.3		7.6
Diabetes		10.8		10.7		10.8
Stroke		2.9		3.3		2.6
Self-rated health	2.6 (1.2)		2.6 (1.2)		2.6 (1.2)	

Abbreviations: ADL, activities of daily living; BMI, body mass index; SD, standard deviation.

Table 2. Adjusted Hazard Ratios of BMI Trajectories with Reference to "Overweight Upward" Trajectory from Cox Proportional Hazard Model, 1931-1941 HRS Cohort.

Covariate	Total		Adjusted for Sociodemographic Factors [a]		Adjusted for Behavioral Factors [b]		Adjusted for Disease Factors [c]		Fully adjusted [d]	
	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Normal weight downward	1.83	1.58, 2.13	2.07	1.77, 2.41	1.73	1.48, 2.01	1.68	1.44, 1.96	1.62	1.39, 1.89
Normal weight upward	1.15	1.02, 1.30	1.20	1.06, 1.35	1.12	0.99, 1.27	1.13	1.00, 1.28	1.14	1.01, 1.29
Overweight-obesity	1.03	0.91, 1.18	1.01	0.89, 1.15	1.04	0.92, 1.19	1.02	0.90, 1.17	1.01	0.88, 1.15
Class I obese upward	1.29	1.11, 1.50	1.27	1.09, 1.48	1.33	1.14, 1.55	1.23	1.05, 1.43	1.17	1.01, 1.37
Class II/III obese upward	2.34	1.91, 2.86	2.37	1.92, 2.91	2.53	2.05, 3.11	2.10	1.70, 2.59	2.00	1.62, 2.47
BIC	34985		34766		34507		34335		34251	

Abbreviations: ADL, activities of daily living; BIC, Bayesian information criterion; BMI, body mass index; CI, confidence interval; HR, hazard ratio; HRS, Health and Retirement Study.

[a] Adjusted for gender, race-ethnicity, marital status, education, income.

[b] Adjusted for gender, race-ethnicity, marital status, education, income, smoking status, physical activities.

[c] Adjusted for gender, race-ethnicity, marital status, education, income, smoking status, physical activities, ADL, angina, heart failure or heart attack, arthritis, bronchitis or emphysema, cancer, diabetes, stroke, bone fracture.

[d] Adjusted for gender, race-ethnicity, marital status, education, income, smoking status, physical activities, ADL, angina, heart failure or heart attack, arthritis, bronchitis or emphysema, cancer, diabetes, stroke, bone fracture, and self-rated health.

Table 3. Hazard Ratios of BMI Trajectories with Reference to “Overweight Upward” Trajectory from Cox Proportional Hazard Model among Healthier Sample within 1931-1941 HRS Cohort.

Covariate	No Preexisting Chronic Illness Sample		Excellent/Very Good/Good Self-Rated Health Sample	
	HR	95% CI	HR	95% CI
Normal weight downward	1.81	1.36, 2.40	1.80	1.48, 2.20
Normal weight upward	1.13	0.90, 1.40	1.06	0.91, 1.24
Overweight-obesity	1.16	0.91, 1.46	1.07	0.91, 1.25
Class I obese upward	1.44	1.06, 1.94	1.27	1.03, 1.56
Class II/III obese upward	2.30	1.38, 3.81	2.45	1.83, 3.29
Sample Size	3901		7389	
Number of Deaths	593		1226	
BIC	9087		20333	

Abbreviations: BIC, Bayesian information criterion; BMI, body mass index; CI, confidence interval; HR, hazard ratio; HRS, Health and Retirement Study.

Note: All models fully adjust for demographic, socioeconomic, behavioral, diseases, and health indicators.

Figure 1. Six Latent Body Mass Index (BMI) Trajectories over Age 51, 1931-1941 HRS Cohort.

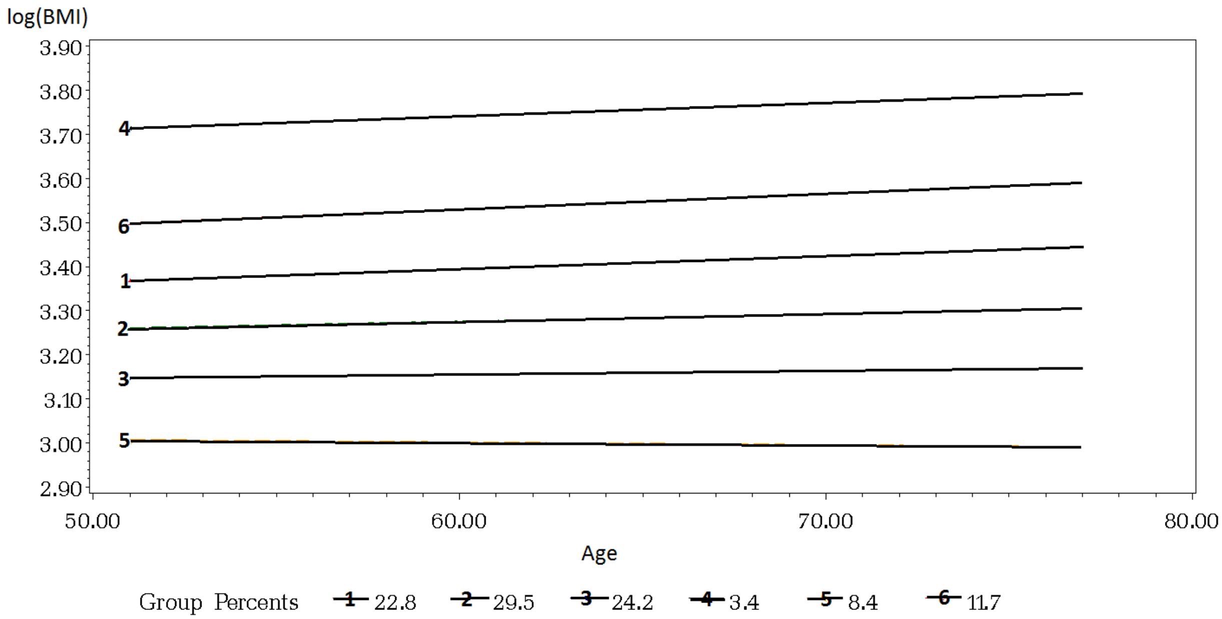

Figure 2. Kaplan-Meier Survival Curve among 6 Body Mass Index (BMI) Trajectories, 1931-1941 HRS Cohort.