

Trajectory Classes of Body Mass Index in a Representative Elderly Community Sample

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Background. It is unclear whether distinct weight-related trajectory classes, differing in course, demographics, and health characteristics, exist in the elderly population.

Methods. Data came from the 10-year (1986–1996) Duke Established Populations for Epidemiologic Studies of the Elderly study of 3,861 black (54%) and white (46%) participants aged 65–105 years. Latent-class trajectories of body mass index (BMI: kg/m²) based on self-reported weight and height at baseline, 3, 6, and 10 years later were determined using generalized mixture models. Polytomous logistic regression was used to identify baseline demographic and health characteristics that distinguished the trajectories, and 10-year postbaseline data to confirm the findings.

Results. We identified three trajectories: normal weight (BMI ~24, 27.6% of the sample), overweight (BMI ~26, 65.1%), and obese (BMI ~31, 7.3%). Demographic characteristics distinguished the three trajectories: highest odds of blacks, women, and less education in the obese trajectory, lowest in the normal-weight trajectory. Obese and overweight differed adversely from normal-weight trajectories, but not significantly from each other on cognitive impairment, hypertension, and diabetes. Depressive symptomatology was more prevalent in the obese; they were also younger. There was no association with cancer or heart disease.

Conclusion. Distinct trajectories and course of BMI were present in this older population. Weight loss increased with increase in BMI class. Although demographic characteristics distinguished all trajectory classes, adverse health characteristics distinguished the overweight and obese classes from the normal-weight class, but not from each other. Problems associated with education and health are present at study entry and should be addressed earlier in life.

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ALTHOUGH increase in obesity in adults may have plateaued (1), obesity has been occurring at successively younger ages (2), and its impact remains to be fully felt in the older population (3). Obesity is a risk factor for many adverse health conditions (including diabetes, cardiovascular disease, hypertension, stroke, and certain cancers [4]), which are already more prevalent in the older population (5), functional disability (6,7), increased health service use and cost (8), and possibly reduced longevity (9). The extent to which these associations hold in the older population and how weight changes over time in persons aged 65 years and older remain unclear (10–13).

Longitudinal studies have typically used a population averaging approach, which may conceal notable differences within the population. Recently, more sophisticated analytic procedures, such as generalized growth mixture models

(GMM [14]), have been used to identify the presence of distinct latent-class trajectories within a population. Such analyses identify classes with unique characteristics, classes that might not otherwise be noticed, and classes that may merit different types of attention. Regarding examination of obesity, latent-class trajectory analyses have only been applied to data from young-to-late middle-aged samples (15–18), but the findings indicate what may be expected in older age. All these studies (sample sizes from ~5,000 to 90,000 participants), used self-reported height and weight to determine body mass index (BMI: weight (kg)/height/[m²]). They followed ages 12–23 (17), 18–49 (18), 19–35 (15), and 25–59 (16), typically identifying four latent-class trajectories, from normal weight to obese, each increasing in BMI over time. An exception was the study of 19- to 35-year-old persons (15), which yielded two classes, and

the 25- to 59-year-old persons, where one trajectory (with small representation) showed gain and then loss. In all studies except the latter, which did not look at this issue, heavier weight was associated with poorer health status or adverse outcome. Overall, in these young-to-late middle age representative samples, several latent classes of increasing BMI were present. In only one instance, and for only a small proportion, was decline in BMI found.

Here, we examine BMI over a 10-year period in a community-representative sample of whites and blacks aged 65 and older. We anticipate that multiple latent-class trajectories of BMI will be found. Given conflicting prior findings, we did not predict trajectory direction (BMI increase or decrease), but we did predict that classes reflecting higher BMI would be associated with more adverse circumstances.

METHODS

Sample

Data come from the Duke site of the Established Populations for Epidemiologic Studies of the Elderly, a 10-year longitudinal study of a stratified random sample of community-based residents aged 65 years and older, in five adjacent counties in the Piedmont area of North Carolina (19). At baseline (1986/87), 4,162 sample members (80% of those contacted) enrolled (black: 54% [oversampled to improve statistical precision for this group]; white: 45%; <1% "other race"); 65% were women. We excluded persons of "other race" ($N = 26$) with proxy respondents at baseline ($N = 162$) or with BMI missing at all time points ($N = 113$), yielding an analysis sample of 3,861 participants. The study was approved by the Institutional Review Board of Duke University Medical Center. Consent forms were signed by all participants.

Data Gathering

Sample members were interviewed in-person at home at baseline, 3, 6, and 10 years later. Using structured questionnaires, trained interviewers gathered information at baseline on demographic characteristics, and at each in-person wave on self-reported height, weight, and mental and physical health condition, and survival status. At the third in-person interview, height and weight were also measured.

Dependent variable.—Our dependent variable is BMI, obtained from self-reported height and weight at each of the four in-person waves. In this sample, there was good agreement between self-reported and measured height, weight, and BMI (intraclass correlation coefficients 0.85, 0.97, and 0.91, respectively [20]). BMI was imputed when information on height or weight was missing to maintain the sample (Statistical Analysis section).

Independent variables.—*Demographic characteristics* included race (black and white), age (continuous), sex, and years of education curtailed at 17 years.

Health status.—For baseline and 10-year postbaseline analysis, we noted self-reported, doctor-diagnosed stroke, heart disease, hypertension, diabetes, and cancer (excluding skin cancer). Cognitive status was measured using the Short Portable Mental Status Questionnaire (21). An error score ≥ 4 (possible range 0–10) indicated cognitive impairment. A modified Center for Epidemiologic Studies-Depression (CES-D) scale (19,22) measured depressive symptomatology. Each item was scored 0 or 1 (scoring range 0–20 symptoms), and the summed score dichotomized between 8 and 9 (recoded as 0 and 1), corresponding to the original CES-D cut-point of 15 and 16, in agreement with previous work (19).

Statistical Analysis

Imputation for height and weight.—Depending on wave, missing values ranged from 8.8% to 14.8% for height and from 4.4% to 9.5% for weight. Initial analyses indicated that a respondent's values of height and weight were highly correlated across waves. First, systematic discrepancy between self-reported and measured height was adjusted by adding to measured height the mean of the difference between measured and self-reported height determined separately by gender within quintiles of measured height (self-reported height tends to be higher than measured height). All available measures of height were then averaged to yield the imputed value for height. Evaluation of this approach by regressing wave 1 height on an imputed height variable yielded $R^2 = 0.78$. A similar procedure was used for weight. First, mean difference in weight between successive waves (by gender within weight quintiles) was determined, and it was used to adjust upwards available data on weight. It was then averaged to yield imputed weight ($R^2 = 0.82$). When only height (weight) was absent on all waves, stochastic regression was used to impute height (weight), based on race, gender, education, income, baseline weight (height), and health status (and smoking status in estimating weight). These predictors yielded $R^2 = 0.50$ for baseline height, and $R^2 = 0.29$ for weight. The manner of imputation (23) was designed to maximize accuracy at each wave. However, because information from other waves was used to impute missing data at a particular wave, the imputed data to some extent overestimate stability across waves. BMI was estimated for 199 participants (5.15%).

Basic descriptive statistics (N , %, mean, and standard deviation [SD]) were used to characterize the sample, and χ^2 was used to examine bivariate differences using SAS 9.2.

The number of trajectory classes of BMI using GMM (24) was determined using M-plus version 5.2 (14). GMM determines subgroups of trajectories in the data set. To determine the form of the curve, we fit the intercept only, linear (ie, with intercept and slope), and quadratic (ie, with intercept, slope, and squared) model to the data. The number of latent classes was determined by sequentially increasing

the number of classes and examining fit statistics (Akaike information criteria, Bayesian information criteria [BIC], sample size-adjusted BIC, entropy, and condition number). Lo–Mendell–Rubin sequential test was used to determine if the decrease in likelihood ratio with increase in classes was statistically significant. Model convergence was tested with a number of start values to ensure proper solution. In addition to the Lo–Mendell–Rubin test, bootstrap-based testing, together with theoretical and substantive considerations, was also used to determine the number of classes. Participants were included in the trajectory they best fit, that is, there is no “crisp” separation of people.

Polytomous logistic regression was used to compare the trajectories in controlled multivariable models. Baseline characteristics were used to identify differences for all participants present at baseline. To check whether these differences held throughout the years of the study, we repeated the analyses with 10-year postbaseline survivors and 10-year postbaseline data.

RESULTS

The analysis sample consisted of 3,861 participants (65% women, 54% black, and median education 8 years). Details are given in Table 1. Mean (*SD*) of BMI was 26.04 (4.94). The 199 participants for whom BMI was imputed were, on average, older, more likely to be black, women, with less education, cognitively impaired (each $p < .0001$), having high depressive symptomatology ($p = .008$), and reporting stroke ($p < .0001$) and diabetes ($p = .025$) (Supplementary Table 1).

Analysis indicated that three trajectories of BMI best fit the data (Figure 1). They were a high normal class (baseline BMI = 23.8, $n = 1,066$, and 27.6% of the sample), consistent over time (BMI 23.7, 23.7, 23.6; 3, 6, and 10 years later; $p < .094$); a mildly overweight class (baseline BMI = 26.3, $n = 2,514$, and 65.1%), which declined by 1.4 BMI units over 10 years (BMI 25.8, 25.4, 24.9; 3, 6, and 10 years later; $p < .000$); and an obese class (baseline BMI = 31.1, $n = 281$, and 7.3%), which declined by 2.7 BMI units over 10 years (BMI: 30.2, 29.4, 28.4; 3, 6, and 10 years later; $p < .000$). We compared the distribution across the three trajectory classes of those for whom BMI was immediately calculable with those for whom it was imputed. Specifically (nonimputed BMI precedes imputed BMI): normal-weight class—28.1% (18.1%), overweight—64.5% (76.4%), and obese class—7.4% (5.5%). The differences in distribution reflect the health characteristics of the imputed group and were appropriate to class assignment (characteristics of the latent-class trajectories are described later). These health characteristics were not included in the imputation procedure, suggesting that imputation was appropriate.

Unadjusted comparison of the three trajectories (Table 1) indicated a higher proportion of blacks, women, and younger persons in the obese class and higher proportion of whites and men in the normal-weight class. Cognitive impairment

Table 1. Descriptive Characteristics of the Sample at Baseline.

	Total sample (<i>N</i> = 3,861)	Normal (<i>N</i> = 1,066) (27.6%)	Overweight (<i>N</i> = 2,514) (65.1%)	Obese (<i>N</i> = 281) (7.3%)
	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)	<i>N</i> (%)
Demographic characteristics				
Age (y)				
65–74	2,437 (63.1)	700 (65.7)	1,535 (61.1)	202 (71.9)
75–84	1,173 (30.4)	301 (28.2)	799 (31.8)	73 (26.0)
85+	251 (6.5)	65 (6.1)	180 (7.2)	6 (2.1)
Race				
White	1,762 (45.6)	630 (59.1)	1,073 (42.7)	59 (21.0)
Black	2,099 (54.4)	436 (40.9)	1,441 (57.3)	222 (79.0)
Sex				
Male	1,366 (35.4)	439 (41.2)	870 (34.6)	57 (20.3)
Female	2,495 (64.6)	627 (58.8)	1,644 (65.4)	224 (79.7)
Education (y)				
0–8 y	2,020 (52.3)	418 (39.2)	1,409 (56.1)	193 (68.7)
9–12 y	1,285 (33.3)	421 (39.5)	795 (31.6)	69 (24.6)
>12 y	556 (14.4)	227 (21.3)	310 (12.3)	19 (6.8)
Mental health				
Cognitive impairment*	422 (11.0)	87 (8.2)	303 (12.1)	32 (11.5)
Depression†	357 (9.5)	79 (7.6)	231 (9.4)	47 (17.0)
Physical health conditions				
Stroke	324 (8.4)	63 (5.9)	230 (9.2)	31 (11.0)
Heart attack	581 (15.1)	151 (14.2)	391 (15.6)	39 (14.0)
Hypertension	2,220 (57.5)	521 (49.0)	1,498 (59.6)	201 (71.5)
Diabetes	773 (20.1)	145 (13.6)	545 (21.7)	83 (29.5)
Cancer (excluding skin)	362 (9.4)	101 (9.5)	234 (9.3)	27 (9.6)

Note: Percentages may not total 100 because of rounding.

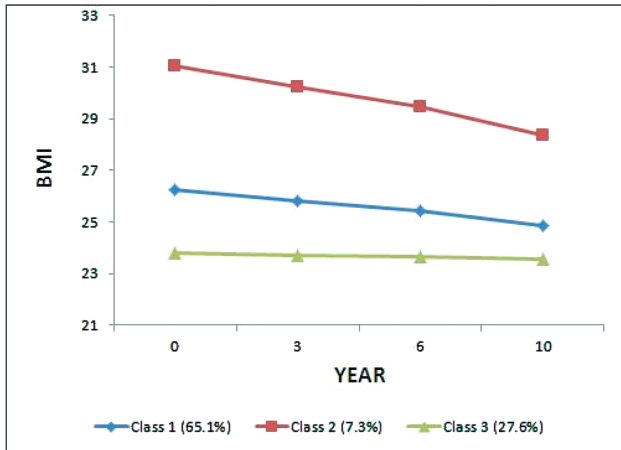
*Cognitive impairment indicated by Short Portable Mental Status Questionnaire error score ≥ 4 .

†Depression indicated by modified Center for Epidemiologic Studies–Depression scale score ≥ 9 .

was more common in the overweight and least common in the normal-weight trajectory, whereas depression was most common in the obese class. Heart attack and cancer were comparable across classes, but stroke, hypertension, and diabetes were most prevalent in the obese class and least prevalent in the normal-weight class.

Fully controlled polytomous logistic regressions (reference: normal-weight group) (Table 2) found that with increase in weight class, there was an increased representation of blacks, women, and people with less education. There was a fourfold increased odds of blacks and a threefold increased odds of women in the obese trajectory compared with 64% increase and 37% increase, respectively, in the overweight trajectory. Members of both the obese and overweight trajectories had less education than those in the normal-weight trajectory, with the difference between the obese and overweight trajectories just missing significance. Uniquely, members of the obese trajectory were more likely to be younger (5% for each year of age) than those in the normal-weight trajectory.

Members of both obese and overweight trajectories were more likely than normal-weight trajectory members



	Normal weight (N =1 066; 27.6%)	Overweight (N =2514; 65.1%)	Obese (N = 281; 7.3%)
Intercept (BMI at baseline) (standard error)	23.79 (0.34)	26.26 (0.68)	31.06 (0.71)
Slope (standard error)	-0.02 (0.01)	-0.14 (0.04)	-0.27 (0.05)

Figure 1. Latent class trajectories of BMI.

Table 2. Fully Controlled Polytomous Logistic Regression (Reference: Normal-Weight Trajectory Class), Baseline Data.

	Overweight		Obese	
	OR (95% CI)	p value	OR (95% CI)	p value
Age	1.01 (0.99, 1.02)	0.243	0.95 (0.92, 0.97)	<.0001
Race (black)	1.57 (1.34, 1.84)*	<0.0001	4.05 (2.88, 5.70)*	<.0001
Sex (female)	1.35 (1.15, 1.58)*	0.001	3.14 (2.23, 4.42)*	<.0001
Education (y)	0.93 (0.91, 0.95) [†]	<0.0001	0.88 (0.85, 0.92) [†]	<.0001
Cognitive impairment [‡]	1.52 (1.14, 2.04) [†]	0.005	1.77 (1.08, 2.91) [†]	0.023
Depression [§]	1.02 (0.77, 1.34)	0.916	1.77 (1.16, 2.70) [†]	0.008
Stroke	1.28 (0.93, 1.75)	0.132	1.44 (0.87, 2.40)	0.158
Heart	1.02 (0.82, 1.27)	0.835	0.92 (0.61, 1.39)	0.692
Hypertension	1.32 (1.13, 1.54) [†]	0.001	1.74 (1.28, 2.38) [†]	0.001
Diabetes	1.57 (1.27, 1.93) [†]	<0.0001	1.75 (1.25, 2.46) [†]	0.001
Cancer (excluding skin)	1.02 (0.78, 1.32)	0.909	1.28 (0.80, 2.06)	0.303

Note: Unmarked values = not significantly different from normal-weight class.

*Overweight and obese trajectory classes are significantly different from each other and from normal-weight class.

[†]Overweight and obese trajectory classes differ significantly from normal-weight class, but not from each other.

[‡]Cognitive impairment indicated by Short Portable Mental Status Questionnaire error score ≥4.

[§]Depression indicated by modified Center for Epidemiologic Studies-Depression scale score ≥9.

to be cognitively impaired, but only members of the obese trajectory were more likely to have substantial depressive symptomatology. Only hypertension and diabetes discriminated the normal weight from the overweight and obese trajectories. Although odds for each condition were higher for the obese class, the differences between the overweight and obese trajectory classes were not statistically significant.

The characteristics that distinguished the trajectories at baseline held 10 years later for 10-year postbaseline data, except that for the obese trajectory, stroke was now significant but depression lost significance (on average, members were now overweight).

Overall, 49.3% of participants died during the study. Death was most likely in the overweight class (53.8%) and least likely in the normal weight (40.8%) and obese (41.3%) classes (chi square, 2 *df* = 58.34, *p* < .0001). At the final wave, 9.3% of the survivors dropped out (refusals, lost, moved, etc.): normal weight: 9.4%; overweight: 9.4%; obese: 8.5% (chi square, 2 *df* = 7.71, *p* < .025).

DISCUSSION

The vast majority of longitudinal studies of BMI have used a population-averaging approach which, while identifying general trends over time, conceals potential differences within the population examined. To our knowledge, this is the first longitudinal study of BMI in an older population that, using a latent-class trajectory approach, determines whether there are notable differences within an elderly sample, their distinguishing characteristics, and differences in course.

Using a GMM approach, we identified three latent-class trajectories of BMI—normal weight, overweight, and obese—in a biracial, representative community-resident sample aged 65 and older. The characteristics of these classes were shown to be comparable 10 years later. The presence of distinct trajectories of BMI in the older population complements findings of multiple trajectories for younger adults: two latent-class trajectories were identified in one analysis (15) and four latent-class trajectories in three others (16–18). However, whereas the studies of young adults typically showed increase in BMI over time, this study of an older sample showed stability (the normal-weight class), minor decline (overweight class), or more marked decline (the obese class). So, unlike previous studies that used a population-averaging approach and identified general weight decline in older age (10–12), this study, which identifies three classes within this sample, indicates that weight decline is focused and is more likely for the overweight and particularly for the obese. Weight decline is unlikely to have been due to dropout or

death. Dropout was least in the obese class, which had death rates comparable to the normal-weight class.

Although previous reports suggest a gradation of demographic, mental, and physical health characteristics with increase in BMI (3,15,18,25–28), in our study, this was found uniformly only for demographic characteristics. It did not hold for mental or physical health characteristics. Stroke (possibly because of low prevalence), heart disease (the definition of which may have been too restrictive), and cancer (where only certain cancers have been found to be associated with BMI) did not distinguish among the three latent-class trajectories. Agreeing with some studies, but not with others (29–31), there was a greater odds of cognitive impairment in the overweight and the obese classes, which did not differ significantly from each other. The same held for hypertension and diabetes, although point estimates suggested increased odds of disadvantage in the obese class. Depressive symptomatology was an exception, distinguishing only the obese class from the normal-weight class. Interestingly, depression, which may have a bidirectional association with obesity (32,33), was no longer associated with the obesity trajectory 10 years later, when the level of obesity had declined. Unlike previous studies (34), we did not find that overweight was protective for mortality, perhaps because this was the oldest class.

Latent-class trajectory analysis offers a more nuanced approach and a more accurate depiction of obesity in this population, providing an opportunity to better design and in particular target interventions to classes at risk. We agree with previous findings on the association of demographic and health characteristics with BMI (indicating the validity of present findings), while providing information not previously presented and highlighting information to which too little attention has been paid. First, older people are not uniform—three different trajectory classes of BMI are present in this older, community representative sample. Second, change in weight is not uniform. Weight is stable over 10 years in older people of normal weight and declines minimally in the overweight and more markedly in the obese. Although most studies indicate that the overweight have the lowest mortality, in this study this was not the case, perhaps because the overweight were the oldest. Although the overweight did not have increased depressive symptomatology, their morbidity was otherwise not significantly different from that of the obese class—*any additional weight appears to have health consequences*. Finally, we must remain aware of the interrelationships among and between BMI, and the demographic, mental, and physical health characteristics examined (31,33,35–40). This provides alternative opportunities to intervene with the intent of improving health. Because this is an integrated system, any particular intervention may affect multiple potential outcomes.

This study has limitations. Most information is self-reported, although self-report is reasonably reliable (41).

Information on cognition and depressive symptomatology was gathered using validated, reliable measures, but are not clinical diagnoses. The accuracy of self-reported height and weight, and hence BMI, has been determined for this sample and is substantial (20). To maintain sample characteristics and size, BMI was imputed where relevant, the procedure used could have increased the stability of the trajectory classes that were found. Imputation, however, appears to have been appropriate. Although health characteristics were not included in the BMI imputation procedures, those for whom imputation was needed had health characteristics in common with the overweight (and obese) class trajectories to which they were disproportionately assigned, suggesting that imputation was reasonably accurate. Imputation allowed inclusion of participants who were more demographically challenged and sicker and so increased the representativeness of the findings. Our data come from the south-eastern United States, where obesity is highest. In consequence, our findings may indicate the status of older persons in other geographical areas which are now reaching the levels of additional weight found here. Finally, present findings need to be replicated.

People enter older age with the impact of the demographic characteristics and health conditions accumulated up to that time. Their weight does not have a uniform course, which has implications for well-being (42). As the present analysis shows, we need to understand the diversity present, so that we can tailor response accordingly.

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SUPPLEMENTARY MATERIAL

Supplementary material can be found at: <http://biomedgerontology.oxfordjournals.org/>.

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