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Multimorbidity Accumulation among Middle-Aged Americans: Differences by Race/Ethnicity and Body-Mass Index

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ABSTRACT

BACKGROUND: Obesity and multimorbidity are more prevalent among U.S. racial/ethnic minority groups. Evaluating racial/ethnic disparities in disease accumulation according to body-mass index (BMI) may guide interventions to reduce multimorbidity burden in vulnerable racial/ethnic groups.

METHODS: We used data from the 1998-2016 Health & Retirement Study on 8,106 participants aged 51-55 at baseline. Disease burden and multimorbidity (≥2 co-occurring diseases) were assessed using seven chronic diseases: arthritis, cancer, heart disease, diabetes, hypertension, lung disease, and stroke. Four BMI categories were defined per convention: normal, overweight, obese class 1, and obese class 2/3. Generalized estimating equations models with inverse probability weights estimated the accumulation of chronic diseases.

RESULTS: Overweight and obesity were more prevalent in non-Hispanic Black (82.3%) and Hispanic (78.9%) than non-Hispanic White (70.9 %) participants at baseline. The baseline burden of disease was similar across BMI categories, but disease accumulation was faster in the obese class 2/3 and marginally in the obese class 1 categories compared with normal BMI. Black participants across BMI categories had a higher initial burden and faster accumulation of disease over time, while Hispanics had a lower initial burden and similar rate of accumulation, compared with Whites. Black participants, including those with normal BMI, reach the multimorbidity threshold 5-6 years earlier compared with White participants.

CONCLUSIONS: Controlling weight and reducing obesity early in the lifecourse may slow the progression of multimorbidity in later life. Further investigations are needed to identify the factors responsible for the early and progressing nature of multimorbidity in Blacks of non-obese weight.

Key words: multimorbidity, disease accumulation, body-mass index, race/ethnicity

INTRODUCTION

Multimorbidity (i.e., two or more co-occurring chronic diseases) has been strongly associated with many outcomes of importance to aging adults—including disability, major health decline, self-rated health, institutionalization, and mortality—with the synergistic impact of these multiple, co-occurring diseases extending above and beyond the impact of individual component diseases.[1–4] The burden of multimorbidity among US middle-aged and older adults is high and has been steadily increasing over the past 25 years. Recent estimates show that 72% of adults ages 50-64 and 81% or more of those over the age of 65 have multimorbidity[5–7] and these numbers are even more stark for minority racial/ethnic groups, where Black and Hispanic adults consistently have greater burdens and rates of accumulation of multimorbidity relative to their White counterparts.[8–10] The U.S. Department of Health and Human Services has identified the prevalence of multimorbidity and associated consequences in the United States as a key health care concern and recommended a strong focus on multimorbidity as a target to improve care, particularly among vulnerable populations.[11,12] In this context, it is important to identify groups at risk for a more rapid accumulation of chronic diseases and thus with heightened vulnerability for adverse multimorbidity-related outcomes, which may benefit from targeted interventions based on patient-centered rather than disease-centered care.

Obesity is an important contributor to the development of chronic diseases and accumulation of greater multimorbidity burden, and may play a significant role in clarifying existing racial/ethnic disparities in multimorbidity.[13] Obesity is increasingly prevalent and strongly associated with a high chronic disease burden in mid- and late-life.[14–17] Previous studies have documented an increased prevalence and/or incidence of multimorbidity among individuals with excess weight and also a trend towards higher chronic disease burden and multimorbidity in high-weight groups over time.[17–19] However, only a few studies have

investigated whether the rate of accumulation of disease varies according to weight status. Two such studies found that starting in middle age, overweight/obese Australian women have a higher likelihood of following trajectories characterized by accumulating, rather than a stable or plateaued number of chronic diseases.[20,21] Further, long-standing racial/ethnic disparities in both the prevalence and secular trends in obesity and multimorbidity in the US have been widely documented,[5,6,14] and a recent study has shown that Blacks but not Hispanics enter middle age with a higher burden and accrue disease faster than Whites, thus reaching the multimorbidity threshold at substantial younger ages than their White counterparts.[8] Therefore, it is critical to characterize chronic disease accumulation early in midlife to identify individuals who may benefit from targeted clinical or behavioral intervention early in the disease process when such interventions may prove more effective in reducing disease burden and progression.[22] To our knowledge, no study to date has assessed the pattern of accumulation of chronic disease and development of multimorbidity according to race/ethnicity and weight status in a nationally-representative sample of middle age and older US adults.

The aim of this study is to estimate the burden of chronic disease in midlife and evaluate the long-term rate of accumulation of additional diseases according to racial/ethnic group and body-mass index (BMI) in a nationally-representative sample of US adults. Excess body-weight is potentially reversible.[15] Given the over-representation of overall obesity and of severe obesity among racial/ethnic minority groups in the US, identifying key intervention points according to body-weight and racial/ethnic group may inform preventive and management measures aimed at controlling the progression of multimorbidity among those most vulnerable to its consequences.

METHODS

Study Design and Analytic Sample

We evaluated up to 18 years (1998-2016) of longitudinal data from the Health and Retirement Study (HRS) (http://hrsonline.isr.umich.edu/). HRS is a nationally-representative survey of non-institutionalized middle- and older-aged adults, which assesses respondents and their partners every two years from the time of their entry into the study until death. The study protocol was approved by Oregon Health and Science University - Research Integrity Office Institutional Review Board (IRB #STUDY00017034).

To maximize our ability to capture chronic disease accumulation and multimorbidity onset in midlife and over an extended period, participants were followed starting from the earliest age of eligibility for study entry (51-55 years) until death or dropout. Proxy interviews were recorded when a respondent was unable to be interviewed due to physical or cognitive limitations. Of the 36,170 HRS respondents interviewed between 1998 and 2016 who were living in the community and age eligible for the study (i.e., respondents with a positive survey weight), 13,598 respondents were first interviewed at age 51-55. Of these, we excluded 808 respondents who had inconsistent chronic disease response patterns (see Chronic Disease section below for details), 40 respondents with missing chronic disease data at their first age-eligible interview, and 111 respondents with missing race/ethnicity information. Due to heterogeneous small subgroup size, 708 respondents who indicated American Indian, Asian or "other" race/ethnicity and 393 respondents who were underweight at baseline were also excluded. Lastly, we excluded 3,432 respondents with only one interview, which would have precluded the evaluation of change in chronic disease counts over time. The resulting analytic sample consisted of 8,106 respondents (45,675 observations;

5.6 mean number of observations per respondent). Sample selection flow is shown in Supplementary File S1.

Measures

Chronic Disease Burden and Multimorbidity

The main outcome variable was chronic disease burden, operationalized as the number of chronic diseases (summary index, range: 0-7). The following seven self-reported, physician diagnosed chronic diseases, each prompted by "Has a doctor ever told you that you have…" were included: heart disease (including myocardial infarction, coronary heart disease, angina, congestive heart failure, or other heart problems), hypertension (i.e., high blood pressure), stroke (but not TIA), diabetes, arthritis, lung disease (including chronic bronchitis or emphysema and excluding asthma), and cancer (including any malignant tumors with the exception of skin cancer). Multimorbidity was defined as the concomitant presence of two or more of these chronic diseases.

The conceptual model of chronic disease accumulation[23] proposes that once a respondent has developed a disease, the respondent continues to have the disease even if the disease symptoms are attenuated through lifestyle changes or medication. Inconsistencies in the self-reporting of chronic diseases across HRS waves (i.e., report of "yes" followed by "no" at the subsequent wave) were settled through a previously developed multistep adjudication method[24] using disease-specific questions considered to represent evidence of disease. Respondents with unresolved inconsistencies of disease reporting were excluded from the analysis (n=808, 5.9%).

Body Mass Index (BMI)

HRS respondents were asked to report their weight at each assessment. Beginning in 1996, respondents' height was only asked of new respondents. In 2006, all respondents were asked their height. After 2006, height was asked of new respondents at enhanced face-to-face re-interviews. We carried forward a respondent's height only if it was not updated in or after 2006. BMI was calculated according to the established formula (BMI = weight [pounds] x 703 / height^2 [inches]) using respondents' most recent self-reported height and self-reported weight at each interview. The BMI categories were defined per convention[25] as normal BMI (18.5 to <25.0), overweight (25 to <30.0), obese class 1 (30 to <35.0) and obese class 2/3 combined (≥35.0).

Race/Ethnicity

Race/ethnicity was ascertained through a sequence of two questions designed to ensure mutually-exclusive racial/ethnic categories: "Do you consider yourself Hispanic of Latino?" followed by "Do you consider yourself primarily white or Caucasian, Black or African American, American Indian, or Asian, or something else?" The three mutually exclusive groups were non-Hispanic White (White), non-Hispanic Black (Black), and Hispanic. American Indian, Asian or "other" race/ethnicity responses were excluded due to insufficient numbers.

Covariates

Sociodemographic covariates included sex (male/female), education (number of school years completed), and smoking status (ever smoker/never smoker).

Statistical Analysis

Descriptive statistics were calculated as frequencies and percentages for categorical variables and means and standard deviations or medians and interquartile ranges (IQR), as appropriate, for continuous variables.

We used a series of generalized estimating equation (GEE) models[26] with a first-order auto-regressive structure to evaluate the accumulation of chronic diseases within/between race/ethnicity groups and BMI categories, while accounting for intra-individual correlations over time. The observations for all participants were anchored such that the initial observation (time point) is at age 51-55 years old, with subsequent 2-year follow-ups. We considered linear and non-linear patterns of disease accumulation over time and determined that a quadratic order resulted in the best fit.

An extensive literature documents racial/ethnic disparities in mortality. To mitigate the potential for bias due to mortality and other attrition, we estimated models with inverse probability weights (IPW) for missingness.[27] Respondents were considered missing if they were deceased or lost to follow-up.[27] The final logistic model for IPW calculation included chronic disease diagnoses, sociodemographic covariates, lifestyle, healthcare utilization, and health status variables. The distribution of IPW values was right-tailed; to achieve a balanced distribution of IPWs, respondents with an IPW at or above the 98th percentile were set at the 98th percentile (n=170). Detailed description of IPW calculation is provided in Supplementary File S2. IPWs for missingness were then multiplied by HRS respondent-level weights as a way to account for the HRS complex sample design because variance adjustments for complex sampling design are not available for GEE analyses in STATA/SE 15.1

The GEE model included explanatory variables for BMI category, race/ethnicity, and linear and quadratic terms for time; we further adjusted this model by time-constant (sex and education) and time-varying (smoking) covariates. Interaction terms for BMI category by time and time-squared, and race/ethnicity by time and time-squared explicitly tested for differences in the accumulation (slope) of chronic diseases according to BMI category and race/ethnicity. We present the coefficients for the baseline number of chronic conditions (intercept), baseline disease accumulation (linear slope), direction and shape of disease accumulation (quadratic slope) and covariates. The coefficient for baseline disease accumulation represents the averaged and instantaneous slope at the start of follow-up, while the quadratic coefficient indicates the direction (acceleration or deceleration) and steepness in the curvature of disease accumulation.

Additionally, we tested for the overall effect of time on chronic disease burden, 2-way interactions for BMI category*time and race/ethnicity*time (to evaluate the overall difference in the accumulation of disease between BMI categories and racial/ethnic groups, respectively), as well as the 3-way interaction BMI category*race/ethnicity*time (to evaluate differences in the accumulation of disease between racial/ethnic groups within BMI categories).

A p-value of <0.05 indicated statistical significance. All analyses were conducted in STATA/SE 15.1 (StataCorp, College Station, TX). Figures were generated in RStudio version 1.1.456.

RESULTS

Descriptive characteristics of the study participants and information on participation (follow-up) are presented in Table 1, shown according to BMI category. Of the 8,106 participants at baseline, 25.4% were in the normal BMI category, 37.7% were overweight, 21.9% were obese class 1, and 14.9% were obese class 2/3. The median number of chronic conditions was higher overall in the obese categories compared with the normal and overweight BMI categories. Notably, there were significant differences in the racial/ethnic distribution of participants across the BMI categories (Table 2): higher proportions of Black participants were in the obese 1 and 2/3 categories (25.8% and 22.8%, respectively) compared with both White (20% and 12.1%, respectively) and Hispanic participants (24.3% and 15.8%, respectively).

[Tables 1 and 2 here]

Table 3 shows the estimated coefficients for the baseline count of diseases and the rate of accumulation (linear and quadratic change in counts of disease per wave), by BMI category (normal BMI as reference) and racial/ethnic group (White as reference) from the GEE model adjusted for covariates and weighted by IPWs.

[Table 3 here]

Trajectory of Chronic Disease Burden by BMI category

As shown by the baseline count of chronic diseases, there were no statistically significant differences in disease burden at baseline between the BMI categories (Table 3). The chronic disease burden increased with time in all the BMI categories (b=0.167, 95%CI [0.151, 0.184], P<0.001, as estimated for White participants with normal BMI). However, there was a faster

linear accumulation of disease in the obese 2/3 category (b=0.058, 95%CI [0.028, 0.087], P<0.001) with a small, but significant deceleration (negative quadratic slope) over time (b= -0.005, 95%CI [-0.009, -0.002], P=0.003) compared with the normal BMI category. The linear slope coefficient for the obese 1 category was marginally non-significant (b=0.022, 95%CI [-0.001, 0.045], P=0.058), but the quadratic slope coefficient for this category and the linear and quadratic rates of accumulation for the overweight category were not statistically different from those in the normal BMI category.

Trajectory of Chronic Disease Burden by Racial/Ethnic Group

The baseline count of chronic diseases was statistically different between the 3 racial/ethnic groups (Table 3), with a significantly higher count among Black participants (b=0.318, 95%CI [0.235, 0.401], P<0.001) but lower among Hispanic participants (b= -0.15, 95%CI [-0.252, -0.048], P=0.004) compared with the White reference group. The linear slope indicated a faster accumulation of disease among Black (b=0.035, 95%CI [0.008, 0.063], P=0.012) but not Hispanic participants (b= -0.001, P=0.965), compared with Whites. The quadratic slope coefficients were not statistically different between the 3 racial/ethnic groups.

Estimated Effect of Time on Chronic Disease Burden

Overall, there was a statistically significant effect of time (χ^2=4395.45, P<0.001); this applies to both the linear and the quadratic terms if assessed separately (respectively: χ^2=1513.17, p<0.001; χ^2=18.84, P=0.004). There was also a statistically significant effect for the interaction of BMI*time (χ^2=21.55, P=0.002) and race/ethnicity*time (χ^2=15.70, P=0.003), indicating that the rate of accumulation of chronic disease differed by BMI category and by racial/ethnic group, respectively. The 3-way interaction BMI*race/ethnicity*time was not significant and was not included in the fully-adjusted model (χ^2=17.49, P=0.13).

Figure 1 and Table 4 depict the trajectories of multimorbidity and the predicted chronic disease burden at each wave, by racial/ethnic group and by BMI category, derived from the fully-adjusted GEE model, including IPW adjustment for missingness, and the 2-way interaction terms. Notably, within each BMI category, Black participants, on average start with a higher chronic disease burden, reach the multimorbidity threshold (≥2 co-occurring diseases) 5-6 years earlier in the follow-up, and have a higher disease burden at the end of the follow-up compared with both Whites and Hispanic participants. Conversely, the predicted counts of diseases among Hispanic participants are similar to those of their White counterparts at most time points.

[Figure 1 here]

[Table 4 here]

DISCUSSION

This analysis of long-term longitudinal data from the nationally-representative HRS sample of middle-age and older US adults investigated the rate of accumulation of chronic diseases according to race/ethnicity and body-weight status. Our results show substantial differences in the baseline burden and rate of accumulation of chronic disease by race/ethnicity: compared with White adults, Black adults have a higher initial burden and a faster linear accumulation of chronic disease, while Hispanic adults have a lower initial burden but a similar rate of accumulation of disease over time. As starkly depicted in Figure 1, Black adults, including those with normal BMI, pass the multimorbidity threshold of two diseases at a much earlier age even when compared with Whites with obese 2/3 BMI. Interestingly, our findings indicate that overall, there are similar initial counts of chronic disease at age 51-55 across BMI categories and a faster accumulation of disease among participants with obese BMI, in particular in the obese 2/3 category, compared with those with normal BMI.

Participants with a BMI in the overweight range were statistically similar to those with normal BMI in both the baseline burden of chronic disease and the rates of accumulation over time.

There is substantial heterogeneity in the road to multimorbidity and in the pattern of disease accrual pre- and post- reaching the multimorbidity threshold among middle-age and older adults, with demonstrated variability according to sociodemographic characteristics.[28] Approximately 50% of Black and 40% of Hispanic participants in our sample had obese BMI, and a substantially lower representation in the normal BMI category, compared with White participants. These findings align with recent estimates from the general US adult population,[14] which show a high and increasing prevalence of overall and severe obesity in particular among Non-Hispanic Black and Mexican-American groups. In this context, our findings highlight the clinical and public health importance of identifying effective interventions aimed at preventing/reducing obesity, in particular among racial/ethnic minority adults vulnerable to obesity-related poor health.

In the United States, racial/ethnic disparities persist across most major chronic conditions.[29] Multimorbidity and obesity also disproportionately affect racial/ethnic minority groups.[5,14,22] In this study, we found substantial differences between the 3 racial/ethnic groups in both the initial burden of disease at age 51-55 and in the rate of accumulation of diseases over time. The 2-way interaction racial/ethnic group*time was significant, while the 3-way interaction (racial/ethnic group*BMI*time) was not significant, indicating that although the rate of accumulation of disease varies between the 3 racial groups, this pattern of variation is similar across the BMI categories. The results showed that Black adults start with a higher count of diseases at baseline and accumulate diseases faster over time, thus crossing the threshold of multimorbidity (2 or more diseases) at 4 to 6 years younger ages compared with their White peers (Figure 1 and Table 4) in all the BMI categories. The fact that the difference in disease

trajectory and in age at multimorbidity threshold between Blacks and Whites was preserved even in the normal BMI category reinforces the need to consider a constellation of health, social, and psychological factors - such as multiple domains of socio-economic status (aside from educational attainment, which was included in our analyses) and deprivation, cultural differences in health practices, psychological distress associated with perceived or experienced discrimination, and inequities in access to healthcare - that may contribute to racial disparities in multimorbidity starting prior to entering middle age.[22]

Conversely, Hispanics had a lower initial burden of disease and a similar rate of accumulation, resulting in trajectories that show a slightly later age at multimorbidity threshold compared with Whites. Previous studies documented a higher prevalence of one or more chronic conditions among Whites and Blacks compared with Hispanics[6] and higher rates of multimorbidity among Blacks, but not Hispanics, compared with Whites.[22,30,31] A recent analysis of the patterns of accumulation of chronic disease starting at age 51 found that Blacks, but not Hispanics, start with higher initial counts of disease and accrue diseases faster than their White age-counterparts.[8] We add to the existing literature by investigating the racial/ethnic variations in multimorbidity development according to body-weight status, a health risk with wide and persistent racial disparities, and by showing that the substantial difference in disease burden and accumulation is preserved even between Blacks and Whites with normal and overweight BMI. Taken together, the triangular relationship between race/ethnicity, BMI, and disease burden identified in our study argues for a lifecourse approach to reducing racial disparities in multimorbidity, focused on preventing or delaying the initiation of chronic diseases early in midlife and on slowing the accumulation of disease in later life, in particular among Black adults, including those with normal BMI, often overlooked as low-risk by clinical and public health efforts.

Prior studies have also documented a higher prevalence and incidence of several of the diseases considered here (e.g., hypertension, heart disease, diabetes, arthritis, stroke, and some cancers),[15,16,32,33] and of overall or cardiovascular multimorbidity,[17,21,34,35] in adults with overweight and obese BMI, but did not investigate differences in the initial burden and subsequent rate of accumulation of chronic conditions according to weight status starting in middle age. To our knowledge, the current study is the first to investigate the trajectories of accumulation of chronic diseases specifically by BMI category in a representative sample of middle-age and older US adults. We found a similar initial burden of chronic disease at ages 51-55 years old across all BMI categories, but a faster rate of disease accumulation among participants with obese BMI compared with participants with normal BMI (statistically significant in the obese 2/3 category and marginally non-significant in the obese 1 category); the overweight category was similar to the normal BMI category in both initial burden and rate of accumulation of diseases over the follow-up period. Our findings add to the existing literature by showing that the cumulative burden of chronic diseases increases more rapidly with age among those with severe obesity, but not among the overweight, as compared with those with normal weight. Correspondingly, the formal test of interaction between BMI and time indicated a significant difference in the rate of accumulation of disease over time between the four BMI categories. Taken together, the lack of an initial difference in the cumulative burden of disease at age 51-55 and the more rapid accumulation of diseases in the obese 2/3 category (and possibly obese 1 category) after this age suggests that, in the natural course of multimorbidity development, the divergence between BMI categories emerges later in the lifecourse and indicates an opportunity for intervention early in midlife (before or around age 50) to lower the subsequent burden of disease and the risk for multimorbidity and its functional, life expectancy, and economic consequences in later life.

Several explanations may account for the lack of baseline differences in disease burden between BMI categories. First, reverse causation due to overweight or obese individuals with one or more chronic conditions losing weight and dropping (due to poor health) to the normal BMI category at or prior to baseline may result in sicker individuals being included in the normal BMI category at baseline and thus reducing the difference in number of chronic conditions between the low and high BMI categories. Second, we considered differential death/attrition, which may result in healthy survivor bias due to resilient overweight/obese individuals being observed for longer periods of time (vs. sicker individuals who drop out or die sooner). We noted differences in death and lost-to-follow-up rates between the BMI categories, though the pattern was unclear due to small numbers, in particular among Hispanic participants. To mitigate healthy survivor bias and the likelihood of reverse causation, the modeling strategy used IPWs, calculated based on a wide range of sociodemographic, lifestyle, and health factors. Third, physical performance indicators, such as grip strength, and body composition indicators, were not included in the analysis because they were not available until 2006. These indicators show strong patterns of stratification according to race/ethnicity and body weight,[36,37] have high predictive value for several of the chronic diseases included in the calculation of multimorbidity,[38,39] and if included, may have allowed for a more refined differentiation between the trajectories of multimorbidity across the groups considered here. Fourth, it is possible that the rather narrow set of diseases available in HRS, although they represent the most prevalent leading causes of morbidity and mortality linked to obesity in the US population and were used as such in previous studies,[16,40] limited our ability to detect differences in counts of diseases between BMI categories. Future studies should include a wider range of chronic conditions, giving strong consideration to diseases recommended for inclusion in calculations of multimorbidity[23] and

that show disparities across body-weight status and racial/ethnic lines[16] (e.g., hyperlipidemia, liver disease, gallbladder disease, thromboembolic events).

The study has several strengths. First, the HRS is a large, robust, long-term, ongoing prospective study, including a wide range of health outcomes and sociodemographic parameters generalizable to the U.S. population of middle-aged and older adults, thus allowing us to model changes in participant reports of chronic disease burden and multimorbidity onset during the critical periods of entering middle age and into late adulthood. Second, the prospective design and oversampling of racial/ethnic minority populations in the HRS allows assessment of time-sequencing of chronic disease burden and accumulation in relation to BMI assessment, and enables the estimation of multimorbidity onset and progression between adults from the main BMI categories and racial/ethnic backgrounds. Third, this study contributes to the emerging literature on the epidemiology of multimorbidity and obesity by specifying the intra-individual age-based progression of multimorbidity burden over 18 years according to body-weight status. Fourth, by accounting for propensity to mortality and other non-random attrition using IPWs, our study mitigates the bias due to healthy survivorship and/or reverse causation to improve over previous work on differences in multimorbidity between body-weight categories and racial/ethnic groups.

Several limitations should also be noted. Weight and chronic disease diagnoses were self-reported, thus being subject to under-reporting or under-diagnosis, particularly among individuals who lack or experience suboptimal access to health care. However, several studies have shown adequate concordance between patient reports and objectively-validated weight and disease diagnoses.[41,42] Conventional anthropometric measures such as BMI, may not optimally capture the risk associated with cardiometabolic diseases and excess weight, and their stratification across race/ethnic groups. Physical performance measures, such as grip strength, were not included in the analysis because they first became available in 2006

for a subsample of the HRS population. Future studies including more refined measures of body-composition and objective physical performance may further describe the differences in disease burden and accumulation according to weight status. Additionally, because of their small number, participants with underweight BMI, potentially sicker and displaying distinct trajectories of disease accumulation, were not included in the analysis. Finally, a more refined and inclusive differentiation of racial/ethnic groups is needed, to better represent differences by ancestry and country of origin. Race/ethnicity embodies a range of life experiences and socioeconomic characteristics, representing diverse life course patterns that may elucidate some of the complexity in multimorbidity development in older ages.

In conclusion, we showed that Black adults enter middle-age with a higher burden of disease and accumulate diseases faster compared with Whites in all BMI categories. Consequently, even normal weight and overweight Black participants cross the multimorbidity threshold approximately 5-6 years earlier than White participants with obese 2/3 BMI. However, Hispanics have a lower initial burden but a similar rate of accumulation of disease compared with Whites. Further, our study found a more rapid accumulation of chronic conditions among individuals with obese, and in particular, severely obese BMI, compared with those in the lower BMI categories, despite no differences in initial disease burden at age 51-55. These findings highlight the importance of controlling weight and reducing obesity at early stages in the lifecourse to slow the progression of multimorbidity in later life and also call for investigations to identify the factors responsible for the early and progressing nature of multimorbidity in Blacks of non-obese weight.

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Table 1. Baseline and follow-up characteristics of study sample according to BMI category

	Normal BMI	**Overweight**	**Obese Class 1**	**Obese Class 2/3**	***P-value***
Total N=8,106 participants	N=2064 (25.4%)	N=3055 (37.7%)	N=1774 (21.9%)	N=1213 (14.9%)	
Baseline characteristics					
Age, years, mean (SD)	53.0 (1.38)	53.0 (1.41)	52.98 (1.38)	52.98 (1.38)	0.950
Sex, female, n (%)	1369 (66.3%)	1423 (46.6%)	984 (55.5%)	819 (67.5%)	<0.001
Education, years, median (IQR)	13.0 (12.0, 16.0)	13.0 (12.0, 16.0)	13.0 (12.0, 15.0)	12.0 (12.0, 14.0)	<0.001
Ever smoked, n (%)	1206 (58.7%)	1767 (58.1%)	1014 (57.3%)	630 (52.2%)	0.002
Race/Ethnicity, n (%)					
Non-Hispanic White	1512 (73.3%)	2017 (66.0%)	1043 (58.8%)	632 (52.1%)	<0.001
Non-Hispanic Black	310 (15.0%)	592 (19.4%)	452 (25.5%)	400 (33.0%)	
Hispanic	242 (11.7%)	446 (14.6%)	279 (15.7%)	181 (14.9%)	
BMI at 1st interview, mean (SD)	22.6 (1.6)	27.3 (1.4)	32.1 (1.4)	40.3 (5.4)	

Non-Hispanic White	22.5 (1.6)	27.2 (1.4)	32.1 (1.4)	40.1 (5.0)	
Non-Hispanic Black	22.8 (1.6)	27.5 (1.4)	32.3 (1.5)	40.8 (5.8)	
Hispanic	23.0 (1.5)	27.5 (1.4)	31.9 (1.4)	39.9 (5.4)	
Conditions at 1st interview, overall, median (IQR)	0.0 (0.0, 1.0)	1.0 (0.0, 1.0)	1.0 (0.0, 2.0)	2.0 (1.0, 3.0)	<0.001
Non-Hispanic White	0.0 (0.0, 1.0)	1.0 (0.0, 1.0)	1.0 (0.0, 2.0)	2.0 (1.0, 2.0)	<0.001
Non-Hispanic Black	1.0 (0.0, 1.0)	1.0 (0.0, 2.0)	1.0 (0.0, 2.0)	2.0 (1.0, 3.0)	<0.001
Hispanic	0.0 (0.0, 1.0)	1.0 (0.0, 1.0)	1.0 (0.0, 2.0)	1.0 (1.0, 2.0)	<0.001
Follow-up and attrition					
Total number of interviews, mean (SD)	5.9 (2.5)	5.8 (2.5)	5.4 (2.4)	5.2 (2.3)	<0.001
Participation, Non-Hispanic White					<0.001
Deceased	118 (7.8%)	136 (6.7%)	87 (8.3%)	68 (10.8%)	
Lost to follow-up	185 (12.2%)	188 (9.3%)	136 (13.0%)	55 (8.7%)	
Participation, Non-Hispanic Black					0.001

Deceased	40 (12.9%)	51 (8.6%)	35 (7.7%)	56 (14.0%)	
Lost to follow-up	20 (6.5%)	31 (5.2%)	24 (5.3%)	26 (6.5%)	
Participation, Hispanic					<0.001
Deceased	17 (7.0%)	23 (5.2%)	11 (3.9%)	11 (6.1%)	
Lost to follow-up	33 (13.6%)	40 (9.0%)	16 (5.7%)	5 (2.8%)	

Notes: BMI – body-mass index; BMI categories – normal (18.5 to <25.0), overweight (25.0 to <30.0), obese class 1 (30.0 to < 35.0), and obese class 2/3 (35.0 and above).

Table 2. Distribution of baseline BMI categories according to race/ethnicity

BMI **N (%)**	**Non-Hispanic White** **(n=5204)**	**Non-Hispanic Black** **(n=1754)**	**Hispanic** **(n=1148)**	***P-value***
Normal	29.1%	17.7%	21.1%	<0.001
Overweight	38.8%	33.8%	38.9%	
Obese, class 1	20.0%	25.8%	24.3%	
Obese, class 2/3	12.1%	22.8%	15.8%	

Notes: BMI – body-mass index; BMI categories – normal (18.5 to <25.0), overweight (25.0 to <30.0), obese class 1 (30.0 to < 35.0), and obese class 2/3 (35.0 and above).

Table 3. Model estimates: Initial burden and accumulation of chronic disease according to BMI category and racial/ethnic group

		Estimated Coefficient [95%CI]	*P-value*
Count of chronic diseases (baseline)	Normal BMI	ref	
	Overweight	0.011 [-0.023, 0.045]	0.52
	Obese Class 1	0.007 [-0.037, 0.051]	0.77
	Obese Class 2/3	0.012 [-0.045, 0.069]	0.68
	Non-Hispanic White	ref	
	Non-Hispanic Black	0.318 [0.235, 0.401]	<0.001
	Hispanic	-0.150 [-0.252, -0.048]	0.004
Linear accumulation of chronic disease	Linear Slope*	0.167 [0.151, 0.184]	<0.001
	Normal BMI	ref	

	Overweight	0.004 [-0.015, 0.023]	0.67
	Obese Class 1	0.022 [-0.001, 0.045]	0.06
	Obese Class 2/3	0.058 [0.028, 0.087]	<0.001
	Non-Hispanic White	ref	
	Non-Hispanic Black	0.035 [0.008, 0.063]	0.012
	Hispanic	-0.001 [-0.030, 0.029]	0.96
Quadratic accumulation of chronic disease	Quadratic Slope*	-0.000 [-0.002, 0.002]	0.76
	Normal BMI	ref	
	Overweight	-0.000 [-0.003, 0.002]	0.70
	Obese Class 1	-0.002 [-0.004, 0.001]	0.23
	Obese Class 2/3	-0.005 [-0.009, -0.002]	0.003
	Non-Hispanic White	ref	
	Non-Hispanic Black	-0.001 [-0.005, 0.002]	0.42
	Hispanic	0.003 [-0.001, 0.007]	0.19

Notes:

[a]BMI – body-mass index; BMI categories – normal [18.5 to <25.0], overweight [25.0 to <30.0], obese class 1 [30.0 to < 35.0], and obese class 2/3 [35.0 and above].

[b]Estimates derived from the fully-adjusted model, including two-way interaction terms between BMI*time [chi-square=21.55, P=0.002] and race/ethnicity*time [chi-square=15.70, P=0.003]. Three-way interaction BMI*race/ethnicity*time was not significant [chi-square=17.49, P=0.13] and not included in the fully adjusted model.

[c]The effect of time was statistically significant: overall [chi-square=4395.45, P<0.001] and for both the linear [chi-square=1513.17, P <0.001] and the quadratic [chi-square=18.84, P-value=0.004] coefficients if assessed separately.

[*]Linear and quadratic slope coefficients represent the respective rates of accumulation of diseases [per wave] for White participants within the normal BMI category.

Table 4. Predicted number of chronic diseases over time, according to BMI category and racial/ethnic group

Age at interview	*Normal BMI*			*Overweight*			*Obese class 1*			*Obese class 2/3*		
	White	**Black**	**Hispanic**	**White**	**Black**	**Hispanic**	**White**	**Black**	**Hispanic**	**White**	**Black**	**Hispanic**
51-55	0.97 (0.02)	1.29 (0.04)	0.82 (0.05)	0.98 (0.02)	1.30 (0.04)	0.83 (0.05)	0.98 (0.02)	1.29 (0.04)	0.83 (0.05)	0.98 (0.03)	1.30 (0.04)	0.83 (0.05)
53-57	1.14 (0.02)	1.49 (0.04)	0.99 (0.05)	1.15 (0.02)	1.50 (0.04)	1.00 (0.05)	1.16 (0.02)	1.52 (0.04)	1.02 (0.05)	1.20 (0.02)	1.55 (0.04)	1.05 (0.05)
55-59	1.30	1.69	1.16	1.32	1.70	1.18	1.35	1.73	1.21	1.41	1.79	1.27

	(0.02)	(0.04)	(0.05)	(0.02)	(0.04)	(0.05)	(0.02)	(0.04)	(0.05)	(0.02)	(0.04)	(0.05)
57-61	1.47 (0.02)	1.88 (0.05)	1.34 (0.05)	1.49 (0.02)	1.90 (0.04)	1.36 (0.05)	1.53 (0.02)	1.94 (0.04)	1.40 (0.05)	1.61 (0.03)	**2.02 (0.05)**	1.48 (0.05)
59-63	1.63 (0.02)	**2.07 (0.05)**	1.52 (0.06)	1.65 (0.02)	**2.09 (0.05)**	1.54 (0.06)	1.70 (0.02)	**2.14 (0.05)**	1.59 (0.06)	1.79 (0.03)	2.23 (0.05)	1.68 (0.06)
61-65	1.80 (0.02)	2.26 (0.05)	1.71 (0.06)	1.82 (0.02)	2.28 (0.05)	1.73 (0.06)	1.87 (0.02)	2.33 (0.05)	1.79 (0.06)	1.97 (0.03)	2.42 (0.05)	1.88 (0.06)
63-67	1.96 (0.03)	2.44 (0.05)	1.90 (0.07)	1.98 (0.02)	2.46 (0.05)	1.92 (0.06)	**2.04 (0.03)**	2.52 (0.05)	1.98 (0.06)	**2.13 (0.03)**	2.61 (0.05)	**2.07 (0.06)**
65-69	**2.12 (0.03)**	2.62 (0.06)	**2.10 (0.07)**	**2.14 (0.03)**	2.64 (0.06)	**2.12 (0.07)**	2.20 (0.03)	2.70 (0.06)	**2.18 (0.07)**	2.28 (0.03)	2.77 (0.06)	2.26 (0.07)
67-71	2.29 (0.03)	2.79 (0.07)	2.30 (0.09)	2.30 (0.03)	2.81 (0.07)	2.32 (0.08)	2.36 (0.03)	2.87 (0.07)	2.38 (0.08)	2.42 (0.04)	2.93 (0.07)	2.44 (0.09)
69-73	2.45	2.97	2.51	2.46	2.98	2.52	2.52	3.04	2.58	2.55	3.07	2.61

	(0.04)	(0.08)	(0.10)	(0.04)	(0.08)	(0.10)	(0.04)	(0.08)	(0.10)	(0.05)	(0.08)	(0.11)

Notes:

[a]BMI – body-mass index; BMI categories – normal (18.5 to <25.0), overweight (25.0 to <30.0), obese class 1 (30.0 to < 35.0), and obese class 2/3 (35.0 and above). NH – non-Hispanic.

[b]Columns represent the predicted mean number of chronic diseases (standard errors in parenthesis) at successive ages-at-interview.

[c]**Bolded/shaded** estimates correspond to the age-at-interview when the predicted mean burden of chronic disease crosses the multimorbidity threshold of 2 diseases.

Figure 1