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Research Article

Cardiometabolic Risk Trajectory Among Older Americans: Findings From the Health and Retirement Study

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Abstract

Background: Cardiometabolic risk (CMR) is a key indicator of physiological decline with age, but age-related declines in a nationally representative older US population have not been previously examined.

Methods: We examined the trajectory of CMR over 8 years of aging, from 2006/2008 to 2014/2016, among 3528 people older than age 50 in the Health and Retirement Study. We used growth curve models to examine change in total CMR as well as in individual cardiometabolic biomarkers to understand how baseline differences and rates of change vary across sociodemographic characteristics, by smoking status, and medication use.

Results: Total CMR did not change among respondents who survived over 8 years. Despite significant differences in CMR across demographic and education groups at baseline, the pace of change with age did not differ by these characteristics. Among individual biomarkers, risk levels of diastolic blood pressure, resting heart rate, and total cholesterol decreased over 8 years while glycosylated hemoglobin, waist circumference, and pulse pressure increased over that time. Both the statistical significance levels and the magnitudes of the reduction over time with age in diastolic blood pressure, resting heart rate, and total cholesterol in models adjusted for age, race/ethnicity, gender, smoking, and education were reduced after controlling for blood pressure and cholesterol medication.

Conclusions: The relatively constant total CMR level over 8 years occurred because some indicators improved with age while some deteriorated in this period. Medication use contributed to the improvement in blood pressure, resting heart rate, and total cholesterol.

Keywords: Cardiovascular risk, Change with age, Medication, Metabolism

Age is a major risk factor for poor health outcomes. Understanding how physiological status changes with age is an important addition to our understanding of aging health. Cross-sectional data have shown that biological dysregulation is higher at older ages, and that older people are more likely to have multisystem physiological dysregulation (1–5). Prior population-based studies have largely relied on cross-sectional data to examine differences in biological dysregulation across age groups, with relatively less attention to changes with age. Age differences observed in cross-sectional data can conflate cohort differences and mortality effects with age-related changes in health.

There are also limitations to prior studies with longitudinal analysis of changing physiological status. For instance, several studies used samples with limited representativeness or were based on a short time frame for studying change. Karlamangla et al. (6) found an increase over 2.5 years in allostatic load, a multisystem indicator of physiological functioning, in a study of "successful agers" from 3 communities in the United States. Merkin et al. (7) also found an increase in allostatic load over 7 years of aging in a sample recruited from 6 US counties, from 2000 to 2007, with the increase slower among those with the highest education.

Other examinations of change in physiological indicators have focused on younger age groups or specific demographic groups. Belsky et al. (8) quantified the pace of physiological deterioration in 18 biomarkers reflecting multiple systems among adults aged 28–35 using longitudinal data from the Dunedin Study in New Zealand. O'Keeffe et al. (9) found different trajectories in individual cardiovascular and metabolic measures by age at menopause among

middle-aged and older women in the United Kingdom: systolic blood pressure (SBP), waist circumference (WC), and high-density lipoprotein cholesterol increased with age, while low-density lipoprotein, triglycerides, and diastolic blood pressure (DBP) decreased with age. Mitchell et al. (10) examined race differences in 4-year CMR change in the nationally representative US Health and Retirement Study (HRS), finding that Blacks experienced an increase in risk over 4 years of aging while Whites and Hispanics experienced a decrease. Changes in physiological risk that characterize older Americans over a longer period are yet to be studied.

Both individual risk factors (5,11,12) and summary biological risk measures (10,11,13–15) vary across age, but also by race/ethnicity, gender, socioeconomic status (SES), and health behaviors. These factors may modify the trajectory of CMR with age. In recent decades, the increased usage and effectiveness of prescription drugs have driven improvement in some risk factors, particularly in blood pressure and cholesterol (11,12). So, medication use may affect changes over time in overall CMR by changing the prevalence of high risk of some biomarkers. All these factors need to be considered to understand the observed age/time trajectory.

In this study, we examine an 8-year change in an index of cardiometabolic risk (CMR), indicating dysregulation in the cardiovascular and metabolic systems (10). We use data from a nationally representative sample of Americans older than the age of 50. To better understand what drives the change in overall CMR, we also examine 8-year trajectories in each biomarker included in total CMR. We hypothesize that total CMR will increase over time with aging; however, individual biomarker components of the CMR may have different trends, and some of the trends may reflect the availability of medications. We also examine differences in trajectories of CMR for race/ethnic and SES groups and current smoking status. Our hypothesis is that racial/ethnic minorities, those with lower education level, and those who currently smoke will have higher CMR and experience a faster elevation in risk with age. Because the trajectories of some biomarkers may be affected by medication use, we also examine the effect of adopting or discontinuing medication use on specific markers.

Data and Methods

Data

The HRS is a nationally representative longitudinal study that surveys US adults older than age 50 every 2 years. In 2006, the HRS initiated an Enhanced Face-to-Face Interview where anthropometric measurements were taken, and dried blood spots (DBS) were collected and subsequently assayed. In 2006, this was done for a random half of the sample; the other half of the sample had the data collected in 2008. The first half sample had the measures collected again in 2010 and 2014, and the second half in 2012 and 2016 (16–19). Each respondent could have measures collected at 3 times. Hence, in this study, 2006/2008 is considered the baseline wave (Wave 1), Wave 2 includes the 2010/2012 interviews, and Wave 3 includes the 2014/2016 interviews. The 3 waves track individual trajectories for 8 years.

Among 12 000 people who participated in both the physical measurement and DBS biomarker collection at the baseline interviews, 9173 people had complete baseline data. We excluded 2142 people who died before the third wave and an additional 3503 people who had missing data for analysis variables. Our final analytical sample consisted of 3528 individuals who survived and had complete data for 3 waves. Most people with missing data were missing on glycosylated hemoglobin (HbA1c) and high-density lipoprotein cholesterol (HDL-C; missing 1139 and 1127, respectively) because of limited blood spot samples. Overall, those who had missing data (n = 3503) and those who did not have complete data due to death (n = 2142) had significantly higher baseline CMR, were older, and had lower education than our final analytical sample. We present differences between these subsamples in Supplementary Table 1, and we report results from sensitivity analysis including those who had some missing data after the main results. We also conducted analysis in the effect of medication on those in the sample with complete information on blood pressure medication (n = 3497) and cholesterol medication (n = 2694).

Measures

CMR is based on multiple indicators of cardiovascular and metabolic functioning including SBP, DBP, resting heart rate (RHR), WC, HbA1c, HDL-C, total cholesterol (TC), and C-reactive protein (CRP). Blood pressure and RHR were measured using an Omron HEM-780 N Monitor. SBP, DBP, and RHR were measured 3 times (20); we used the average of the nonmissing measures for this analysis. WC was measured at the level of the navel. The HRS biomarker values for CRP, TC, HDL-C, and HbA1c were assayed from DBS. DBS assay results can vary over time because of the assays used and across laboratories because of instrumentation differences. In order to make the DBS data comparable over time and to other population studies based on whole-blood assays, HRS DBS biomarker values have been converted into what are called NHANES (National Health and Nutrition Examination Survey) equivalent values. Because both NHANES and HRS are intended to represent the US population, the distributions of the biomarkers in HRS should be similar to those in NHANES within the appropriate age group. The conversion makes the distribution of the values for HRS DBS assays similar to that among NHANES respondents (16). For TC, HDL-C, and HbA1c, the equivalent values in the first wave of the HRS biomarker sample (2006/2008) were based on NHANES 2005–2006 and 2007–2008; values for HRS Wave 2 (2010/2012) were based on NHANES 2009–2010 and 2011–2012; and values for HRS Wave 3 (2014/2016) were based on NHANES 2011–2012 and 2013–2014 for HRS 2014 and 2013–2014 and 2015–2016 for HRS 2016 (19). This means that any time trend is similar to that observed in NHANES. Because NHANES did not provide CRP data from 2011 to 2014 and because there appeared to be a reduction in values of CRP in NHANES 2009–2010 with a high concentration at the lower end of detection which we believe resulted from assay changes, for this study, the NHANES equivalents for CRP for all waves were normed to NHANES 2005–2008. This means there is no time trend in the adjusted CRP measure in the HRS DBS sample, but values continue to reflect relative differences across the sample.

The summary CMR measure is a count of the number of biomarkers that exceeded the clinical high-risk thresholds for each biomarker (Supplementary Table 2). The high-risk thresholds are 140 mmHg for SBP and 90 mmHg for DBP, thresholds for hypertension (21,22). An RHR greater than 90 is normally defined as high risk (5,10,23–25). WC is an indicator of abdominal obesity and chronic metabolic dysregulation (9); and the thresholds defining high-risk WC are 88 cm (35 in.) for women and 102 cm (40 in.) for men (10,22). For HbA1c, an indicator of glucose metabolism and glycemic control over the past 2–3 months, a level higher than 6.5% is considered high risk (10). For TC, 240 mg/dL is the high-risk

cutoff (10,25). HDL-C lower than 40 mg/dL is used to indicate high risk (1,10,25). CRP is an indicator of systemic inflammation associated with cardiovascular and metabolic diseases (26). A CRP level higher than 3 mg/L is considered high risk (10,25).

In addition to the 8 high-risk indicators based on individual markers, we included one more risk factor to account for additional cardiovascular risk, high pulse pressure (PP). PP, the difference between SBP and DBP, is an indicator of arterial stiffness that gradually widens after middle age posing additional risk (22,27,28). If the SBP was greater than 140 mmHg (systolic hypertension) and the PP was greater than 70 mmHg, one additional risk was added to the total CMR. So, our CMR measure ranged from 0 to 9, with higher values indicating higher risk. When focusing on trends in individual markers, to facilitate comparison across biomarkers, each of the markers was standardized based on its mean and standard deviation at Wave 1, and values were expressed in *z*-scores.

At each wave of the survey, participants were asked whether they use medication to control blood pressure and cholesterol. For both blood pressure medication and cholesterol medication variables, we categorized people into 5 mutually exclusive and exhaustive groups: (a) those who never used medication during the study period, (b) those who started medication at Wave 3, (c) those who started medication at Wave 2, (d) those who used medication for all 3 waves, and (e) those who used medication at some point but stopped. While medication groups were based on 3 waves, we included them with the baseline characteristics. Because questions on medications were not asked at all waves, the *N* was lower when medication was included.

The covariates included age, race/ethnicity, gender, current smoking, and education. All of which were self-reported and assessed at baseline. Age was categorized into 4 groups: 50–59, 60–69, 70–79, and 80 and older. Racial/ethnic groups included non-Hispanic White, non-Hispanic Black, Hispanic, and non-Hispanic others. Education was classified as less than high school, high school, some college, and college degree or higher.

Statistical Analysis

We used growth curve models to examine CMR changes over time and differences in trajectories by sociodemographic characteristics. The linear multilevel equations are shown below.

(1) Level one:

$$Y_{it} = \pi_{0i} + \pi_{1i}T_{ti} + \varepsilon_{ti}$$

(2) Level two:

$$\pi_{0i} = \beta_{00} + \beta_{01}Z_i + \mu_{0i}$$

$$\pi_{1i} = \beta_{10} + \beta_{11}Z_i + \mu_{1i}$$

The subscript t indicates time and the subscript i indicates an individual respondent. Specifically, the models provided estimates of the average trajectory of CMR for the entire sample (Level one) as well as how baseline characteristics (noted by Z) were linked to variability in baseline CMR differences and CMR changes over 8 years over time (Level two). The coefficients on "the rate of change over time," noted as T in the equation, can be interpreted as the change with 1 year of aging. In the first model, we estimated the unadjusted intercept and slope in CMR. The second model was adjusted for age, gender, and race/ethnicity. Model 3 further controlled for education, and Model 4 further controlled for current smoking status.

The trajectories for each individual biomarker were graphed and compared descriptively using *z*-scores. Then the growth curve model was applied to each of the biomarker *z*-scores to further understand the direction and pace of its change over time. For some biomarkers (SBP, DBP, RHR, and TC), trajectories were also graphed by medication use during the study period to examine how medication use affected the changes, and then medication groups were controlled in individual marker models.

Survey weights for the DBS sample at baseline were used to adjust for initial sample selection and missing data. All analyses were performed using Stata version 16.

Results

Sample Characteristics

Supplementary Table 1 presents sample characteristics at baseline. The proportion with high-risk values varied across individual biomarkers in the CMR score. For some markers like SBP (26.4%), WC (35.5%), and CRP (34.8%), about one third of the participants were measured as high risk; the high-risk percentages of other markers were lower. The largest portion of the sample was aged 50–59 (41.9%), 35.1% were aged 60–69, 18.8% were aged 70–79, and 4.2% were aged 80 and older. More than four fifths of the sample were non-Hispanic Whites (83.7%). About 7.1% were non-Hispanic Blacks, 6.4% were Hispanics, and 2.8% were non-Hispanic others. Females were somewhat more than half the sample (54.0%). Only 13.2% of the participants were current smokers. In terms of education, 13.3% did not complete high school, while 32.2% completed high school, 24.3% had some college experience, and 30.2% had a college degree or more.

Change in Total CMR Over Time While Aging

Results from growth curve models of total CMR are presented in Table 1. Model 1 is an unadjusted growth model and shows an average baseline CMR score of 1.97 and no evidence that CMR increased over time. Model 2 added age, gender, and race/ethnicity. The oldest age group, aged 80 and older, had a significantly higher baseline CMR score ($\beta = 0.46$, $p < .001$) compared to those aged 50–59 (Model 2). There was no difference in the rate of change across age groups. Models 3 and 4 added education and current smoking status, respectively. The inclusions did not change the results on time trends. In the full model (Model 4), compared to those aged 50–59, those aged 80 and older had significantly higher baseline CMR score ($\beta = 0.35$, $p = .004$), and still, the rate of change did not differ across age groups.

The full model also suggests that both non-Hispanic Blacks ($\beta = 0.56$, $p < .001$) and Hispanics ($\beta = 0.29$, $p = .011$) had significantly higher CMR scores than non-Hispanic Whites. Current smokers had higher baseline CMR compared to their nonsmoking counterparts ($\beta = 0.22$, $p = .019$) but did not differ in time trends. Compared to those who did not complete high school, high school graduates ($\beta = -0.29$, $p = .001$), those who had some college experience ($\beta = -0.42$, $p < .001$), and those who had a college degree or more ($\beta = -0.72$, $p < .001$) had significantly lower baseline CMR. Despite the observed baseline differences within the previously mentioned variables, the rates of change over time were not significantly different across categories.

Change in Individual Cardiometabolic Biomarkers

We next examine change in the individual CMR biomarkers. Figure 1 shows the descriptive trajectory for the mean of each biomarker unadjusted for covariates; all biomarkers were *z*-scored for ease of

Table 1. Results of the Growth Curve Model Predicting Total CMR

N = 3528	Model 1	Model 2	Model 3	Model 4
Baseline CMR	1.972***	1.815***	2.332***	2.272***
Rate of change over time	−0.003	−0.004	−0.010	−0.009
Age groups—Reference: Ages 50–59				
Baseline				
60–69		0.093	0.056	0.066
70–79		0.108	0.024	0.050
80 and older		0.458***	0.325**	0.351**
Rate of change over time				
60–69		0.001	0.001	0.001
70–79		−0.006	−0.005	−0.005
80 and older		−0.031	−0.029	−0.029
Gender—Reference: Males				
Baseline				
Females		−0.001	−0.048	−0.042
Rate of change over time				
Females		0.008	0.009	0.009
Racial/ethnic groups—Reference: Non-Hispanic White				
Baseline				
Non-Hispanic Black		0.709***	0.572***	0.563***
Hispanic		0.519***	0.270*	0.286*
Others		0.079	0.053	0.034
Rate of change over time				
Non-Hispanic Black		−0.011	−0.009	−0.009
Hispanic		−0.018	−0.015	−0.015
Others		0.020	0.020	0.020
Education—Reference: Less than high school				
Baseline				
High school			−0.304***	−0.290***
Some college			−0.435***	−0.416***
College and higher			−0.754***	−0.722***
Rate of change over time				
High school			0.005	0.004
Some college			−0.000	−0.000
College and higher			0.011	0.011
Currently smoke—Baseline				0.215*
Currently smoke—Rate of change				−0.003
Log likelihood	−20 113.876	−20 035.495	−19 948.422	−19 940.118
Likelihood ratio test p		.000	.000	.000

Notes: CMR = cardiometabolic risk. The likelihood ratio test compares the current model with the previous model.
*p < .05, **p < .01, ***p < .001.

comparison. Most of the observed changes in biomarkers were statistically significant (p values are reported in Supplementary Table 3). Though the total CMR score did not change with age, individual biomarkers did change, but in different directions and with different magnitudes. For instance, PP, HbA1c, and WC increased, while RHR, DBP, and TC decreased. There were no statistically significant changes in SBP, HDL-C, and CRP.

To better understand the trajectories of individual markers with age, growth curve models adjusted for covariates were applied to each of the markers, and the results are given in Table 2. Over the 8 years, the increases in HbA1c (β = 0.04, p < .001), HDL-C (β = 0.02, p = .035), and PP (β = 0.04, p < .001, adjusted for high SBP) were statistically significant; this indicates worse levels of HbA1c and PP and improved levels of HDL. In contrast, DBP (β = −0.05, p < .001), RHR (β = −0.03, p = .002), and TC (β = −0.04, p < .001) decreased significantly over time indicating improvement in risk levels with increasing age.

Rates of changes in individual markers across subgroups differed. Older persons (aged 70–79 and 80 and older) had a faster decrease in blood pressures and a slower increase in WC and PP than the youngest age group (all p < .05). For non-Hispanic Blacks, blood pressures (SBP: β = −0.03, p = .011; DBP: β = −0.03, p = .003) dropped and HbA1c (β = 0.02, p < .021) increased faster, compared to non-Hispanic Whites. Women experienced slower decrease in both indicators of blood pressure (SBP: β = 0.03, p < .001; DBP: β = 0.02, p < .001), slower increase in HbA1c (β = −0.01, p = .029) and CRP (β = −0.02, p < .001), slower improvement in HDL-C (β = −0.03, p < .001), and faster increase in PP (β = 0.01, p < .001, adjusted for high SBP). Current smokers had a more rapid increase in WC compared to nonsmokers (β = 0.01, p = .006). Compared to those who did not complete high school, all the other education groups had less decline in RHR and faster WC increase (all p < .05). For those whose SBP was higher than 140 mmHg, PP increased significantly faster (β = 0.02, p < .001). Interestingly, the significant decrease in WC shown in Supplementary Table 3 was no longer significant after controlling for covariates in the growth curve model, indicating that the significant change in WC was the result of differential patterns across age groups, smoking behavior groups, and education groups.

Because DBP, RHR, and TC significantly decreased over time, and the values of these 3 markers can be regulated by medication, we further examined their trajectories by medication use.

The Impact of Medication Use

Figure 2 depicts the descriptive trajectories of SBP, DBP, RHR, and TC by medication use, unadjusted for covariates. The trajectories of SBP, DBP, and RHR were categorized by blood pressure medication groups (with a total sample size of 3497), and the trajectory of TC was categorized by cholesterol medication group (with a total sample size of 2694). The size of each medication group is given in Supplementary Table 4. Most people used medication during the study period; one third of the respondents never used blood pressure medication, and 45% used it at all 3 waves. Only around one fourth of the respondents never used cholesterol medication, while more than two fifths used it at all 3 waves. Figure 2 shows descriptively

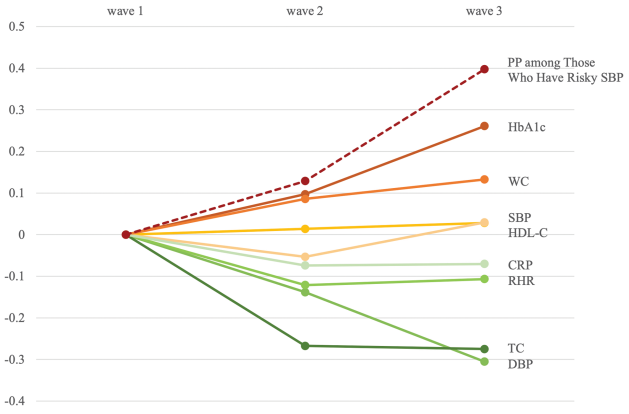

Figure 1. Biomarker *z*-score trajectories. *Notes:* Data at Wave 1 were collected in 2006/2008. Data at Wave 2 were collected in 2010/2012. Data at Wave 3 were collected in 2014/2016. Most of the changes are statistically significant. *p* values and significant stars are given in Supplementary Table 2. *N* = 3528. SBP = systolic blood pressure; DBP = diastolic blood pressure; PP = pulse pressure; RHR = resting heart rate; HbA1c = glycosylated hemoglobin; HDL-C = high-density lipoprotein cholesterol; TC = total cholesterol; WC = waist circumference; CRP = C-reactive protein. The dash line indicates the PP trajectory among those whose SBP is higher than 140 mmHg.

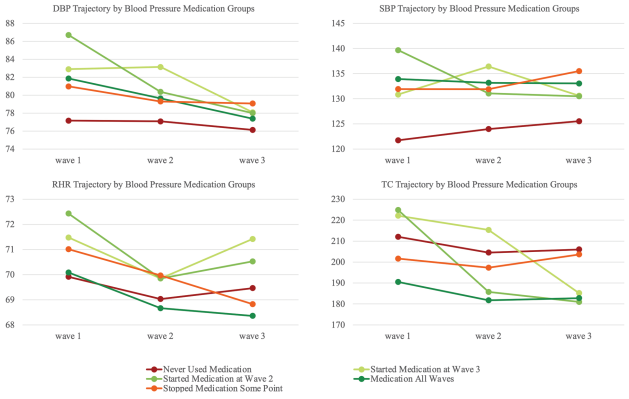

Figure 2. Trajectories of individual biomarkers by medication group. *Note:* Data at Wave 1 were collected in 2006/2008. Data at Wave 2 were collected in 2010/2012. Data at Wave 3 were collected in 2014/2016. SBP = systolic blood pressure; DBP = diastolic blood pressure; RHR = resting heart rate; TC = total cholesterol.

that, in general, biomarker values dropped with medication and were elevated without it. However, people who never used blood pressure medication had relatively low SBP, DBP, and RHR compared to the other medication groups; while people who never used cholesterol medication had a relatively high TC level. Overall, medication use seems to have explained the fluctuations in biomarker trajectories quite well.

Because Figure 2 shows that medication use may have affected some biomarkers' trajectories, we further controlled medication use in the growth curve models, where the *z*-scores of SBP, DBP, RHR, and TC were the dependent variables. Table 3 presents the comparison between the unadjusted and adjusted models. The magnitudes of declines with age in DBP, RHR, and TC were reduced after controlling for medication. Specifically, the coefficient of DBP (unadjusted: $\beta = -0.05$, $p < .001$; adjusted: $\beta = -0.02$, $p = .022$) and TC (unadjusted: $\beta = -0.04$, $p < .001$; adjusted: $\beta = -0.03$, $p = .047$) were cut in half, and the decrease in RHR (unadjusted: $\beta = -0.03$, $p = .002$; adjusted: $\beta = -0.02$, $p = .038$) was reduced by one third. Compared to those who never used medication, almost all other medication groups for SBP, DBP, and TC experienced faster decreases over time with aging (almost all $p < .05$). The rates of change did not differ a lot across medication groups for RHR, but clearly, those who took medication all the time had a faster decrease relative to those who never took medication ($\beta = -0.02$, $p = .004$).

Sensitivity Analysis

We noted above that people who died during the study period and those who survived but had missing data were not included in our analytic sample. We conducted additional analyses to determine whether limiting the sample to survivors observed in all 3 periods produces a different pattern of findings than using a sample that also includes those who were missing some data or died in the follow-up period. The comparison of total CMR models (Supplementary Table 5) as well as the biomarker *z*-score models (Supplementary Tables 6 and 7) across different samples shows that, the total CMR significantly decreased over time when including those who died ($\beta = -0.01$, $p < .001$) and when both the decedents and those who missed one wave were included ($\beta = -0.01$, $p < .001$). However, the decreases were no longer significant after controlling for covariates. The biomarker trajectories do not change much after using new samples (Supplementary Tables 6 and 7) except for that the overtime increase in HDL was no longer significant.

Discussion

In this representative national sample with a mean age of 63 at baseline, who survived and aged over 8 years from 2006/2008 to 2014/2016, we found no evidence of age-related change in total CMR and no difference in CMR rate of change across the population subgroups. Among the biomarkers included in CMR, risk from HbA1c, WC, and PP increased significantly over time with aging. In contrast, DBP, RHR, and TC decreased significantly over the 8 years. The mixed models on each of the biomarkers indicated that the decreases in DBP, RHR, and TC were still significant after controlling for age, race/ethnicity, gender, smoking, and education. The decreases were at least partially explained by medication use.

Although the aging rate of CMR appears relatively constant, it conceals differential aging in individual biomarkers.

Table 2. Results of the Growth Curve Model Predicting Biomarker *z*-Scores

N = 3528	SBP	DBP	CRP	TC	HbA1c	HDL-C	RHR	WC	PP Adjusted for SBP
Baseline CMR	0.126	0.216**	−0.054	−0.076	0.089	−0.536***	0.092	0.631***	−0.365***
Rate of change over time	−0.004	−0.049***	0.008	−0.043***	0.040***	0.021*	−0.032**	0.008	0.035***
Age groups—Reference: Ages 50–59									
Baseline									
60–69	0.207***	−0.075	0.020	−0.079	0.089	0.014	−0.131**	0.024	0.322***
70–79	0.423***	−0.241***	−0.027	−0.294***	0.080	−0.039	−0.294***	−0.039	0.702***
80 and older	0.869***	−0.231**	0.212	−0.398***	0.066	−0.084	−0.344***	−0.183*	1.111***
Rate of change over time									
60–69	−0.002	−0.006	−0.003	−0.008	−0.012*	0.000	0.004	−0.009*	−0.002
70–79	−0.018*	−0.016*	0.007	−0.002	−0.009	0.004	0.009	−0.019***	−0.012*
80 and older	−0.049**	−0.027*	−0.031	0.001	−0.013	0.013	0.034*	−0.031***	−0.032**
Gender—Reference: Males									
Baseline									
Females	−0.353***	−0.142***	0.170***	0.288***	−0.058	0.634***	0.129**	−0.601***	−0.290***
Rate of change over time									
Females	0.026***	0.019***	−0.021***	0.000	−0.011*	−0.028***	−0.007	0.001	0.013***
Racial/ethnic groups—Reference: Non-Hispanic White									
Baseline									
Non-Hispanic Black	0.342***	0.273***	0.145**	−0.017	0.438***	0.042	0.197*	0.213***	0.162***
Hispanic	0.143	0.042	−0.011	0.065	0.371**	−0.049	−0.040	−0.075	0.113*
Others	0.118	0.168	−0.047	−0.107	0.500**	−0.062	0.057	−0.226*	0.030
Rate of change over time									
Non-Hispanic Black	−0.028*	−0.033**	−0.002	−0.010	0.022*	−0.017	0.000	−0.004	−0.005
Hispanic	−0.002	−0.003	0.002	−0.013	0.000	−0.012	0.004	−0.002	0.000
Others	0.005	−0.003	0.010	0.014	0.003	0.021	0.014	−0.009	−0.002
Education—Reference: Less than high school									
Baseline									
High school	−0.123*	−0.071	−0.044	−0.046	−0.127	0.102	−0.103	−0.176**	−0.150***
Some college	−0.228***	−0.105	−0.039	0.032	−0.264***	0.197***	−0.157*	−0.264***	−0.169***
College and higher	−0.292***	−0.180**	−0.178***	−0.031	−0.258***	0.373***	−0.179**	−0.491***	0.000
Rate of change over time									
High school	0.000	0.009	−0.008	0.013	0.010	−0.005	0.029***	0.020***	−0.006
Some college	0.004	0.015	−0.009	0.000	0.002	−0.002	0.017*	0.012*	−0.008
College and higher	0.011	0.017	−0.004	0.024*	−0.005	0.000	0.019*	0.020***	0.000
Currently smoke—Baseline	0.168**	0.169**	0.057	−0.052	−0.027	−0.115	0.331***	−0.214***	0.017
Currently smoke—Rate of change	−0.016	−0.010	0.007	0.012	0.009	0.000	−0.015	0.013**	−0.007
High SBP—Baseline	—	—	—	—	—	—	—	—	1.166***
High SBP—Rate of change	—	—	—	—	—	—	—	—	0.019***
Log likelihood	−16 053.984	−16 174.462	−15 544.130	−16 861.539	−15 316.554	−16 225.407	−16 443.457	−11 139.088	−12 599.278

Note: CMR = cardiometabolic risk; SBP = systolic blood pressure; DBP = diastolic blood pressure; PP = pulse pressure; RHR = resting heart rate; HbA1c = glycosylated hemoglobin; HDL-C = high-density lipoprotein cholesterol; TC = total cholesterol; WC = waist circumference; CRP = C-reactive protein.

*$p < .05$, **$p < .01$, ***$p < .001$.

Table 3. The Growth Curve Model Predicting Biomarker *z*-Scores Controlling for Medication

	No Medications				With Medications			
	SBP*	DBP*	RHR*	TC*	SBP†	DBP†	RHR†	TC‡
Baseline CMR	0.126	0.216**	0.092	−0.076	−0.233***	−0.103	0.027	−0.023
Rate of change over time	−0.004	−0.049***	−0.032**	−0.043***	0.017	−0.024*	−0.021*	−0.026*
Age groups—Reference: Ages 50–59								
Baseline								
60–69	0.207***	−0.075	−0.131**	−0.079	0.142***	−0.126**	−0.136**	−0.058
70–79	0.423***	−0.241***	−0.294***	−0.294***	0.344***	−0.305***	−0.302***	−0.226***
80 and older	0.869***	−0.231**	−0.344***	−0.398***	0.769***	−0.316***	−0.349***	−0.365***
Rate of change over time								
60–69	−0.002	−0.006	0.004	−0.008	0.001	−0.002	0.007	−0.003
70–79	−0.018*	−0.016*	0.009	−0.002	−0.016*	−0.012	0.013	0.001
80 and older	−0.049**	−0.027*	0.034*	0.001	−0.048**	−0.024	0.038**	0.005
Gender—Reference: Males								
Baseline								
Females	−0.353***	−0.142***	0.129**	0.288***	−0.343***	−0.133***	0.136***	0.273***
Rate of change over time								
Females	0.026***	0.019***	−0.007	0.000	0.024***	0.017**	−0.008	−0.001
Racial/ethnic groups—Reference: Non-Hispanic White								
Baseline								
Non-Hispanic Black	0.342***	0.273***	0.197*	−0.017	0.222**	0.173*	0.189*	0.012
Hispanic	0.143	0.042	−0.040	0.065	0.113	0.006	−0.046	0.101
Others	0.118	0.168	0.057	−0.107	0.106	0.164	0.063	−0.117
Rate of change over time								
Non-Hispanic Black	−0.028*	−0.033**	0.000	−0.010	−0.022*	−0.025*	0.003	−0.014
Hispanic	−0.002	−0.003	0.004	−0.013	−0.001	0.000	0.003	−0.014
Others	0.005	−0.003	0.014	0.014	0.002	−0.006	0.014	0.015
Education—Reference: Less than high school								
Baseline								
High school	−0.123*	−0.071	−0.103	−0.046	−0.081	−0.032	−0.085	−0.021
Some college	−0.228***	−0.105	−0.157*	0.032	−0.160**	−0.042	−0.147*	0.019
College and higher	−0.292***	−0.180**	−0.179**	−0.031	−0.197***	−0.095	−0.153*	−0.066
Rate of change over time								
High school	0.000	0.009	0.029***	0.013	−0.003	0.006	0.026**	0.011
Some college	0.004	0.015	0.017*	0.000	0.002	0.011	0.014	−0.005
College and higher	0.011	0.017	0.019*	0.024*	0.005	0.011	0.015	0.016
Currently smoke—Baseline	0.168**	0.169**	0.331***	−0.052	0.176**	0.169**	0.327***	−0.072
Currently smoke—Rate of change	−0.016	−0.010	−0.015	0.012	−0.016	−0.010	−0.016	0.021
Medication—Reference: Never used medication								
Baseline								
Started medication at Wave 3					0.555***	0.584***	0.094	0.406***
Started medication at Wave 2					0.811***	0.771***	0.184*	0.241**
Medication at all waves					0.549***	0.450***	0.044	−0.445***
Stopped medication at some point					0.357***	0.342***	0.148	−0.178*

Table 3. Continued

	No Medications				With Medications			
	SBP*	DBP*	RHR*	TC*	SBP†	DBP†	RHR†	TC‡
Rate of change while aging								
Started medication at Wave 3					−0.026*	−0.041***	0.005	−0.094***
Started medication at Wave 2					−0.083***	−0.083***	−0.017	−0.114***
Medication at all waves					−0.027***	−0.035***	−0.017**	−0.005
Stopped medication at some point					0.006	−0.004	−0.022	0.026*
Log likelihood	−16 053.984	−16 174.462	−16 443.457	−16 861.539	−15 681.778	−15 860.050	−16 309.364	−11 755.672

Note: CMR = cardiometabolic risk; SBP = systolic blood pressure; DBP = diastolic blood pressure; RHR = resting heart rate; TC = total cholesterol.
*The models do not control for medication. $N = 3528$.
†The models control for blood pressure medication. $N = 3497$.
‡The models control for cholesterol medication. $N = 2694$.
$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$ (2-sided t test).

Examining the trajectory of each cardiometabolic biomarker in addition to the CMR summary measure provided us with a more nuanced understanding of how CMR changes with aging over time. Risks of individual biomarkers did not all change in the same direction or by the same magnitude. This suggests complex associations among physiological systems included in CMR.

Our study design allowed us to contribute to the existing literature. In the past, studies using cross-sectional data (1,3) were not able to differentiate observed age differences from cohort effects or mortality effects, and studies using longitudinal data were limited either by representativeness (6–8) or by a short time frame (10). However, we showed how CMR changed with age longitudinally over 8 years of aging in a sample representative of older Americans who survived.

The estimated total CMR was relatively constant over 8 years among people with an initial average age of 63 in this period, a conclusion that differs from the increase by age observed in a nationally representative cross-sectional sample in an earlier period (1). Due to the longitudinal nature of our data, we were able to assess the within-person changes while aging, and by only including the participants who responded in all 3 waves, our results were not influenced by mortality selection out of the sample. Our results also differ from the increase in risk with aging found by previous longitudinal studies using nonrepresentative samples (6–8). This may reflect differences between the national sample we used and less representative community samples. Moreover, our results reflect a more recent time period when the use of efficacious medications was spreading rapidly through the population.

Our results also showed that despite the decrease in blood pressures, heart rate, and cholesterol with aging, the constant total CMR resulted from increases in metabolic markers like HbA1c and WC. Medication use has reduced the CMR and balanced out the changes linked to metabolism and obesity in a relatively short period of time. Medication can be recognized as slowing the aging process in terms of cardiometabolic health during this period.

We should note that by limiting our sample to those who had complete data for all 3 waves, we analyzed a slightly healthier and younger sample compared to those who were in the sample at baseline, those who died, and those who were missing data at later waves (Supplementary Table 1). Including those who died or were missing for a wave resulted in baseline CMR difference across age groups becoming more significant, likely due to the fact that those who died or who failed to complete the 3 waves of the survey were older. Also, when these persons were included, the total CMR decreased over time in unadjusted models as, in general, it was people with higher CMR who died and were missing (Supplementary Table 5). But the decreases were no longer significant after controlling for age, gender, race/ethnicity, education, and smoking status, and the pattern of the results of the full models did not change much. So, we believe that including factors related to mortality and data missing in the models has partially accounted for the sample selection, and our results should be seen as representative of the US community-dwelling older population who survived for 8 years.

Our growth curve models reveal how baseline characteristics were associated with initial levels and rates of change. The results indicated relatively higher baseline risk among older age groups, racial/ethnic minorities, current smokers, and people with lower education level, which were consistent with previous studies (5,10,13,14). Our findings confirmed the effectiveness of medication in regulating blood pressure, heart rate, and cholesterol in reducing CMR (11,12).

While we found that non-Hispanic Blacks and Hispanics had higher baseline CMR, our results indicate that the rates of change across racial/ethnic groups did not differ. Our findings differed from those reported in a study by Mitchell et al. (10), which also used the HRS, but found an increase in CMR over a 4-year period (2006–2010/2008–2012) among non-Hispanic Blacks. There are 2 key study design differences that account for our discrepant findings. First, Mitchell et al. used a different CMR summary score from ours. Our CMR score included PP as well as SBP and DBP, while the CMR score in the study of Mitchell et al. only included PP. While PP is a good indicator of arterial stiffness, we believe that using PP alone to reflect blood pressure in a summary CMR is not sufficient (29–32). Recent literature has suggested treating high PP as an additional risk under the condition of high SBP (22,33–35). So, in this article, we included both the traditional hypertension indicators (SBP higher than 140 and DBP higher than 90) and added 1 point to the CMR index if the SBP is higher than 140 mmHg and the PP is higher than 70 mmHg. We believe the new CMR measure better reflects CMR. Second, our sample is limited to those who had complete data for all 3 waves rather than just 2 waves, as in the study of Mitchell et al., resulting in a somewhat healthier sample in our analysis that is likely to have experienced slower cardiometabolic deterioration.

When we replicated our analysis using the CMR measure employed in the work of Mitchell et al., we found an increased CMR over the 8-year study period, but this increase did not differ by race/ethnicity and the final model with all controls did not indicate an increase over time similar to our results (Supplementary Table 8). We attribute the difference in the overall time change results to the difference in the trends in the blood pressure-related indicators: increase in PP, lack of change in SBP, and decrease in DBP. In the supplemental analysis using methods similar to Mitchell et al. which allowed us to compare both the measures and the samples in the 2 studies (Supplementary Figures 1 and 2), we found that the slopes of racial/ethnic trajectories did not differ much based on CMR measures, but the increasing trend for Blacks was attenuated when we only included those who had complete data for all 3 waves. This leads us to believe that the differential results on the racial change between the 2 articles are primarily due to sample selection and the requirement for longer survival.

Our study has limitations. First, though we included a longer period of observation than had been available previously, we were not able to study trajectories over more than 8 years of aging. It will be useful to extend this analysis to a longer time period in the future. Second, the number of biomarkers collected from the DBS assays was limited. However, in 2016, HRS started collecting venous blood from respondents, allowing a wider range of biomarkers in the future. It means that the future study informed by new data may provide a fuller picture of the trajectory of physiological deterioration.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series A: Biological Sciences and Medical Sciences* online.

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Conflict of Interest

None declared.

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