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Research paper

Life's simple 7 and its association with trajectories in depressive symptoms among urban middle-aged adults

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ABSTRACT

Background: The American Heart Association Life's Simple 7 (LS7) is a composite metric assessing cardiovascular health on a scale of 0–14 comprised of nutrition, physical activity, cigarette use, body mass index, blood pressure, cholesterol and glucose.

Methods: Using data from the Healthy Aging in Neighborhoods of Diversity across the Life Span study [$n = 1465$, Age at visit 1 (v1: 2004–2009): 30–66 y, 41.7 % male, 60.6 % African American], we investigated associations of trajectories in depressive symptoms (2004–2017) with Life's simple 7 scores after ~8.6 years follow-up (2013–2017). Analyses used group-based zero-inflated Poisson trajectory (GBTM) models and multiple linear or ordinal logistic regression. GBTM analyses generated two classes of depressive symptoms trajectories ("low declining" and "high declining"), based on intercept and slope direction and significance.

Results: Overall, "high declining depressive symptoms" vs. the "low declining" group was associated with −0.67 ± 0.10 lower scores on LS7 total score ($P < 0.001$) in analyses adjusted for age, sex, race and the inverse mills ratio. This effect was markedly attenuated to −0.45 ± 0.10 score-points ($P < 0.001$) upon adjustment for socioeconomic factors and to −0.27 ± 0.10 score-points ($P < 0.010$) in fully adjusted analyses, with a stronger association detected among women (β ± SE: −0.45 ± 0.14, $P = 0.002$). An association between elevated depressive symptoms over time ("high declining" vs "low declining") and LS7 total score was detected among African American adults (β ± SE: −0.281 ± 0.131, p = 0.031, full model). Moreover, the "high declining" vs. "low declining" depressive symptoms group was associated with a lower score on LS7 physical activity (β ± SE: −0.494 ± 0.130, $P < 0.001$).

Conclusions: Poorer cardiovascular health was linked to higher depressive symptoms over time.

1. Introduction

Although cardiovascular disease (CVD) mortality has been declining over the past decade (Benjamin et al., 2017; Wilmot et al., 2015), it remains the leading cause of death and morbidity among adult men and women. Efforts targeted at traditional risk factors may have reduced CVD rates to similar extents among men and women. Improving cardiovascular health was related to reduced risk of inpatient encounters in old age as well as lower inpatient and outpatient healthcare expenditure (Aaron et al., 2017). However, non-traditional risk factors including psychosocial stressors may have affected men and women's CVD rates to different extents (McKibben et al., 2016). Among psychosocial stressors,

Abbreviations: AHA, American Heart Association; CES-D, Center of Epidemiologic Studies-Depression; CVD, Cardiovascular Disease; CVH, Cardiovascular Health; GBTM, Group-based trajectory Model; HANDLS, Healthy Aging in Neighborhoods of Diversity Across the Life Span; LS7, Life's Simple 7; MRV, Medical Research Vehicle; V1, Visit 1; V2, Visit 2; V3, Visit 3.

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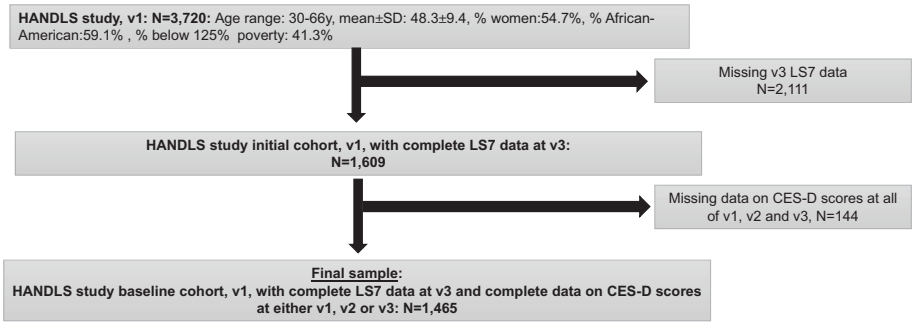


Fig. 1. Participant flowchart.
Abbreviations: CES-D = Center for Epidemiologic Studies-Depression; LS7 = Life's Simple 7; HANDLS = Healthy Aging in Neighborhoods of Diversity Across the Life Span; v_1 = visit 1; v_2 = visit 2; v_3 = visit 3.

elevated depressive symptoms are associated with faster development of CVD (Rosengren et al., 2004; Rozanski et al., 2005) as well as worse health outcomes (Richardson et al., 2012; Stewart et al., 2017; Xu et al., 2015).

Furthermore, behavior and lifestyle are affected adversely by chronic stress, whereby stress may trigger health risk behaviors such as poor diet, sedentary lifestyles and smoking leading to various biological sequelae including obesity, hypertension, type 2 diabetes and dyslipidemia (McEwen, 2008). The prevalence of stress-associated psychiatric conditions among women is double to that among men, including anxiety and depression, particularly during women's menopausal transition (Georgakis et al., 2016; Vaccarino and Bremner, 2017). Stress affects men and women differentially (McEwen, 2017; Oyola and Handa, 2017; Samad et al., 2014; Vaccarino and Bremner, 2017) particularly in its effect on CVD risk (Rooks et al., 2016; Vaccarino and Bremner, 2017; Xu et al., 2015). In fact, the regulation of the hypothalamic–pituitary–adrenal axis depends on sex hormones, which may explain why stress response differs in men and women (Oyola and Handa, 2017). Hence, interventions targeting depressive symptoms among psychosocial stress responses may reduce sex disparities in CVD morbidity and mortality.

In 2010, the American Heart Association (AHA) defined health behaviors and indicators that would achieve maximal cardiovascular health (CVH) of all Americans, with the goal to reduce deaths from CVD by 20 % by 2020 (Lloyd-Jones et al., 2010). "Life's Simple Seven" (LS7) were deemed easily obtained metrics for monitoring the prevalence of ideal CVH. The metrics include diet, smoking status, physical activity, body mass index (BMI), cholesterol, fasting blood glucose and blood pressure (BP). Poor LS7 was shown to predict mortality from both cardiovascular and non-cardiovascular disease (Aaron et al., 2017; Egan et al., 2020; Han et al., 2019; Hasbani et al., 2022; Ogunmoroti et al., 2016). Studies have explored the sex differences in the relationship between depressive symptoms and CVH and a few have examined the differential influence of psychosocial factors on CVD risk in White and African American adults (Capistrant et al., 2013; Lewis et al., 2009; Lewis et al., 2011; Mwendwa et al., 2013; O'Brien et al., 2015; Sims et al., 2016; Weinstein et al., 2011). Studies have also uncovered racial and socio-demographic differences in LS7 at one point in time or over many years of follow-up (Brown et al., 2018; Egan et al., 2020; Gonzalez et al., 2016; Lassale et al., 2022).

However, no studies have specifically tested associations of depressive symptoms with ideal CVH, as measured by the AHA LS7, across sex and race groups. A more thorough investigation of depressive symptom trajectories over time and how it may influence CVH is warranted, particularly among African American adults considering their greater exposure to stressors from life circumstances and discrimination (Beydoun et al., 2017). This is particularly important since chronic occurrence of depressive symptoms may alter lifestyle factors which could lead to biological sequelae related to poor cardiovascular health after a specific follow-up time. Moreover, according to the Research Domain Criteria (RDoC) approach, "which encourages studies to focus on the neurobiological mechanisms and core aspects of behavior rather than to rely on traditional diagnostic categories" (such as major depressive disorders or elevated depressive symptoms), examining domains of depressive symptoms in relation to various health outcomes is of great importance (Katahira and Yamashita, 2017).

We investigated whether self-reported depressive symptoms were related to inadequate CVH as determined by the AHA LS7 measures and whether these associations differed by sex or by race. We hypothesized that the association of depressive symptoms and their domains therein, over time, with CVH measures would be greater among women and African American adults in a sample of urban middle-aged adults.

2. Materials and methods

2.1. Database

Initiated in 2004, HANDLS is a prospective cohort study that focuses on disparities pertaining to physical and psychological health including cardiovascular disease. HANDLS recruited a sample of urban adults using an area probability sampling strategy. Middle-aged African American and White urban adults (baseline age: 30-64y) were selected from thirteen Baltimore city neighborhoods who had widely ranging household incomes (above and below poverty) (Evans et al., 2010). The current study analyzed data from visits 1 (v_1: 2004–2009), 2 (v_2: 2009–2013) and 3 (v_3: 2013–2019) of HANDLS, yielding an average follow-up time between v_1 and v_3 of 8.58 ± 1.66 y. Data were collected on depressive symptoms during all 3 visits, and on several measures that allowed us to score participants on the LS7 at v_3. Written informed consent was obtained from all study participants who were provided with a booklet and a video explaining key study procedures. The study protocol was approved by the National Institute on Environmental Health Sciences Institutional Review Board of the National Institutes of Health.

2.2. Study sample

The HANDLS study is comprised of $N_1 = 3720$ African American and White adults (30–66 years, Phase I, v_1). During Phase II of v_1 (Medical Research Vehicle (MRV) baseline visit), in-depth examinations included a fasting blood draw, a DXA scan, a physical examination, an EKG, a 24-hour dietary recall and an assessment of depressive symptoms severity. For most participants who had one 24-h recall during the MRV visit, a second 24-hour dietary recall telephone interview was completed, 3–10 days later. To evaluate dietary intakes, the average nutrient and food intakes were estimated between the two dietary recalls. Subsequently, LS7 was measured at v_3 for a sub-sample of individuals with complete data on the measure's components. The final sample included

participants with LS7 scores at v_3 and complete CES-D scores at any of v_1, v_2 or v_3. Sample selection from initial recruitment through the final analytic sample is detailed in Fig. 1. Based on this participant flowchart, of the original $N = 3720$ participant recruited in HANDLS, 1609 had complete data on LS7 at v_3, of whom 1465 had data on CES-D scores at visits 1, 2 or 3, which was the final analytic sample. Using a probit model with a binary outcome (1 = selected, 0 = unselected) in which main predictors were socio-demographic variables, the selected group was younger than the remaining HANDLS participants ($p < 0.001$), even upon adjustment for race, sex and poverty status.

2.3. Depressive symptoms

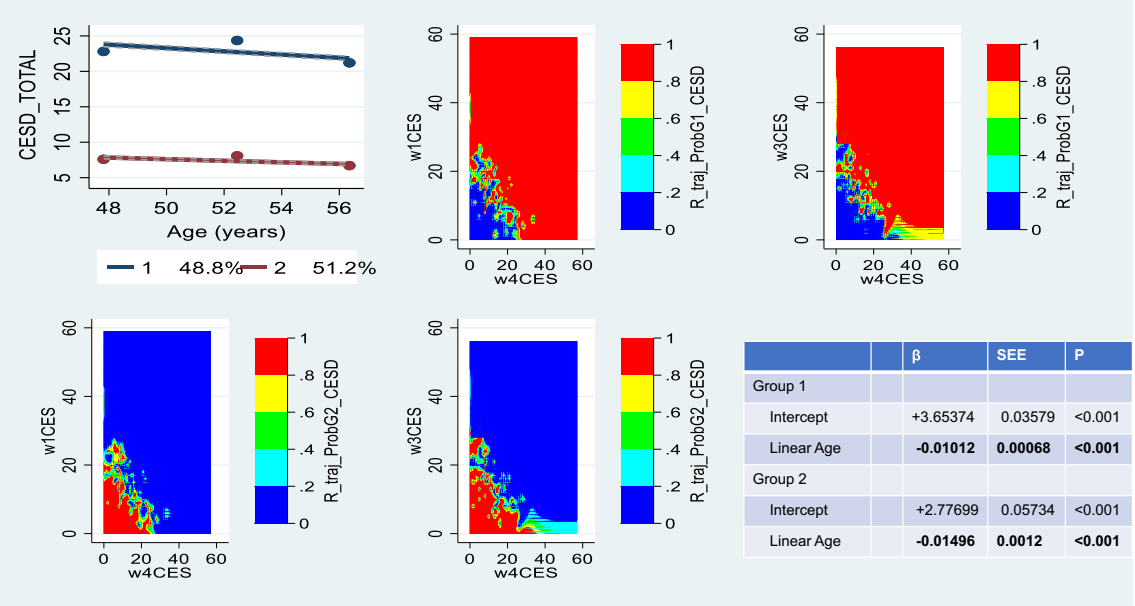
At each HANDLS MRV visit, depressive symptoms were measured by the 20-item Center of Epidemiological Studies-Depression (CES-D), a symptom rating scale assessing self-reported depressed mood (Radloff, 1977) with adequate psychometric properties in numerous samples of older adults (Beekman et al., 1997). A total score ($CES\text{-}D_{total}$) ≥16 reflects elevated depressive symptoms (EDS) (Beydoun et al., 2016). Prior analyses revealed the $CES\text{-}D_{total}$ exhibited invariant factorial structure between the first National Health and Nutrition Examination Survey and pilot HANDLS data (Nguyen et al., 2004). We studied trajectories in the total score and domain-specific CES-D scores in relation to LS7. These domains included: (1) Somatic complaints (e.g. poor sleep, poor appetite); (2) Depressive affect (e.g. feeling sad); (3) Positive affect (e.g. having positive thoughts) and (4) Interpersonal problems (e.g. having trouble in social settings) (Nguyen et al., 2004). The raw sub-scores were used by summing up the scores on symptoms that were shown to fall under each domain. Details regarding which items (scored between 0 and 3) are used to construct each domain are previously described (Nguyen et al., 2004). In this study, CES-D scores (total and sub-domain scores) were measured at visit 1, 2 and/or 3. Trajectory models used assumed missingness at random, which allowed us to use the largest possible study sample.

2.4. Life's simple 7

Using AHA guidelines, the LS7 metrics were defined in detail in Supplemental method 1 and Table S1. Using the average of two 24 h recalls from HANDLS v_3, we estimated intakes of foods and nutrients, as described elsewhere (Fanelli Kuczmarski et al., 2019). Physical activity was measured during the MRV v_3 (2013–2017) using the validated Baecke questionnaire (BQ) (Baecke et al., 1982), which asked participants to report time spent on moderate and vigorous activity (See details in supplement). BMI was calculated with body height and weight measured by trained health technicians. Cholesterol and glucose were analyzed using standard laboratory automation methods at Quest. Blood pressure was measured using a mercury sphygmomanometer and the arithmetic mean of left and right seated systolic and diastolic pressures were used in this analysis. Self-reports on smoking excluding second-hand smoke was obtained from participants. To calculate a total score for LS7, a component that achieved ideal, intermediate, and poor were given 2 points, 1 point, and 0 point, respectively. Therefore, the total score ranged from 0 to 14 points, with higher scores indicating better cardiovascular health. Detailed description of the component calculations of the LS7 is available in supplemental materials.

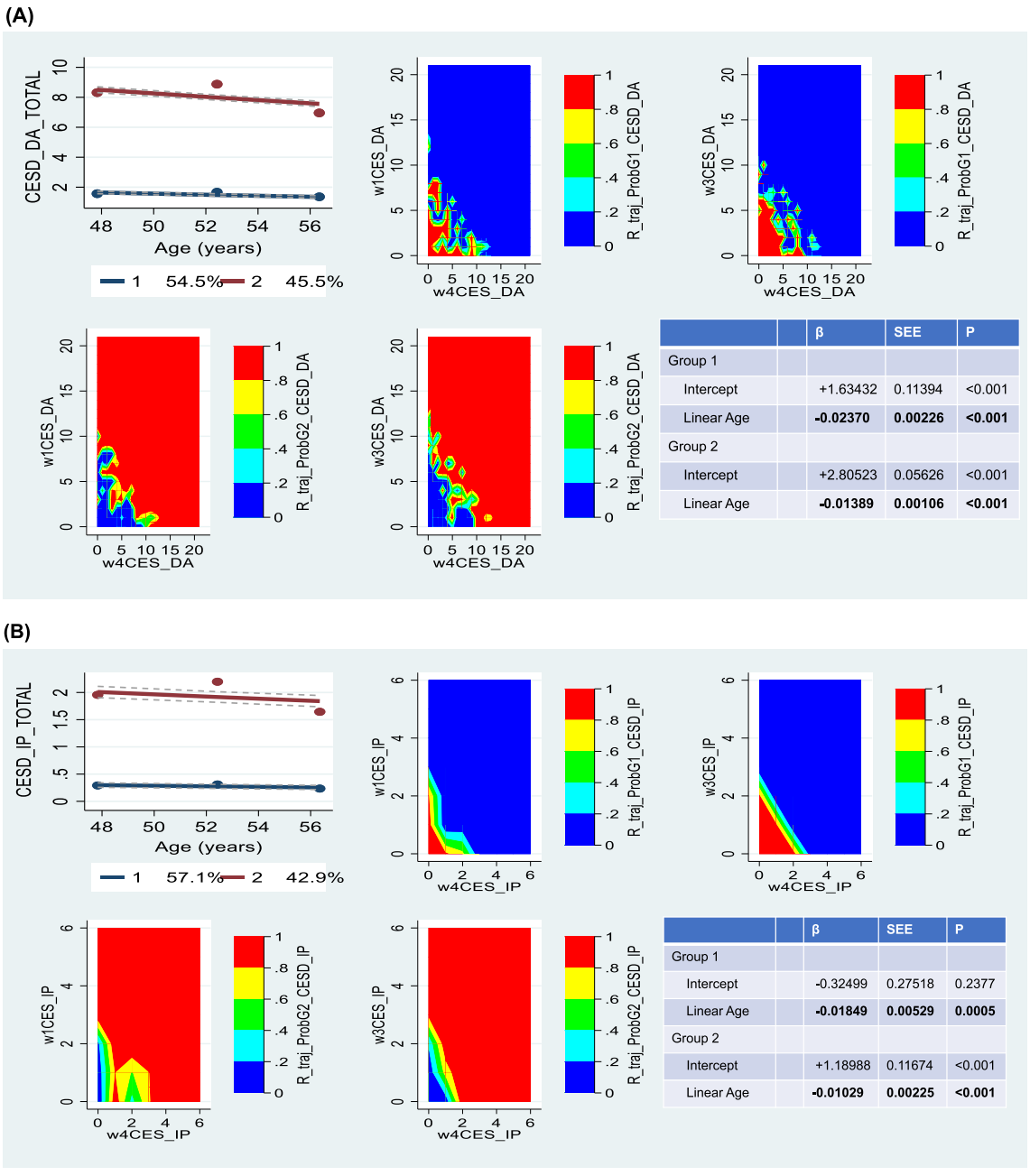
2.5. Covariates

Multiple covariates were assessed as potential confounders shown to predict LS7 components and antecedent risk factors to depressive symptoms. All these covariates were either fixed or measured at the baseline visit v_1. These included sex (male, female), self-identified race (White, African American), poverty status (below vs. above 125 % the federal poverty line), v_1 age (continuous, years), v_1 educational attainment (less than high school, high school, more than high school), v_1 employment status (employed vs. not employed), v_1 marital status (married vs. unmarried), v_1 current illicit drug use (opiates, cocaine or marijuana, yes vs. no), self-rated health (Poor/fair, good, very good/excellent), v_1 co-morbidity index. The latter index was composed to 4 binary elements and ranged between 0 and 4. Those were hypertension, diabetes, dyslipidemia, cardiovascular disease and inflammatory conditions. Cardiovascular diseases consisted of any of following conditions: atrial fibrillation, angina, coronary artery disease, congestive heart failure, myocardial infarction. Inflammatory conditions were any of the following: multiple sclerosis, lupus, gout, rheumatoid arthritis,



		β	SEE	P
Group 1				
Intercept		+3.65374	0.03579	<0.001
Linear Age		**-0.01012**	**0.00068**	**<0.001**
Group 2				
Intercept		+2.77699	0.05734	<0.001
Linear Age		**-0.01496**	**0.0012**	**<0.001**

Fig. 2. Trajectories of CES-D total score between v1 and v3: HANDLS 2004–2017.
Abbreviations: CES-D = Center for Epidemiologic Studies-Depression; LS7 = Life's Simple 7; HANDLS = Healthy Aging in Neighborhoods of Diversity Across the Life Span; v_1 = visit 1; v_2 = visit 2; v_3 = visit 3.



		β	SEE	P
Group 1				
Intercept		+1.63432	0.11394	<0.001
Linear Age		**-0.02370**	**0.00226**	**<0.001**
Group 2				
Intercept		+2.80523	0.05626	<0.001
Linear Age		**-0.01389**	**0.00106**	**<0.001**

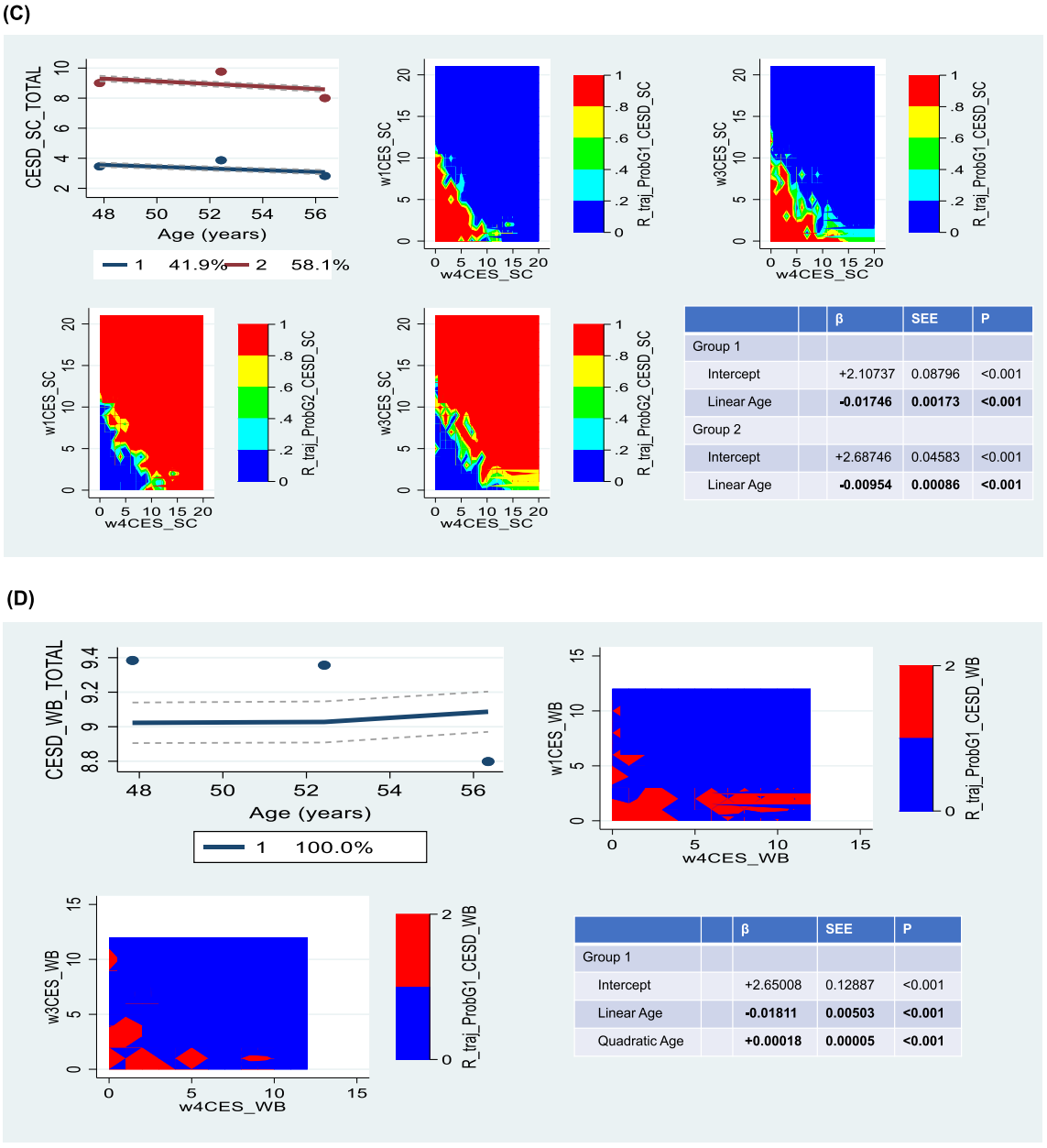
		β	SEE	P
Group 1				
Intercept		-0.32499	0.27518	0.2377
Linear Age		**-0.01849**	**0.00529**	**0.0005**
Group 2				
Intercept		+1.18988	0.11674	<0.001
Linear Age		**-0.01029**	**0.00225**	**<0.001**

Fig. 3. A–D Trajectories CES-D domain scores between v1 and v3: HANDLS 2004–2017.
Abbreviations: CES-D = Center for Epidemiologic Studies-Depression; LS7 = Life's Simple 7; HANDLS = Healthy Aging in Neighborhoods of Diversity Across the Life Span; v_1 = visit 1; v_2 = visit 2; v_3 = visit 3.

psoriasis, thyroid disorders. We operationalized poverty status using the 2004 US Census Bureau poverty thresholds (Bureau, 2004) based on household income and total family size (including children <18 years). Basic socio-demographic covariates were complete by design, while other measures assessed during the MRV phase of v_1 had some missing data. However, after accounting for missingness in all key variables (CES-D scores and LS7), covariates had <5 % missingness individually out of the final eligible sample (n = 1465). Thus, multiple imputation was conducted using chained equations as described in previous studies (Beydoun et al., 2021; Beydoun et al., 2023).

2.6. Statistical analysis

All analyses were conducted using Stata release 16 (STATA, 2019). First, study sample characteristics were described by fixed, baseline and trajectories in key variables across race and sex, using means and proportions, as well as bivariate linear, logistic, and multinomial logit models to examine racial and sex differences in continuous, binary and categorical multi-level covariates, respectively. We then further adjusted those models for the remaining socio-demographic factors among age, sex, race and poverty status to determine whether racial and sex differences remained statistically significant. This was applied to both continuous and categorical characteristics, using multiple regression modeling. Trajectories in CES-D total and domain scores between v_1



		β	SEE	P
Group 1				
Intercept		+2.10737	0.08796	<0.001
Linear Age		**-0.01746**	**0.00173**	**<0.001**
Group 2				
Intercept		+2.68746	0.04583	<0.001
Linear Age		**-0.00954**	**0.00086**	**<0.001**

		β	SEE	P
Group 1				
Intercept		+2.65008	0.12887	<0.001
Linear Age		**-0.01811**	**0.00503**	**<0.001**
Quadratic Age		**+0.00018**	**0.00005**	**<0.001**

Fig. 3. (*continued*).

and v_3 were obtained using group-based trajectory models (GBTM) (supplemental method 2) using a zero-inflated Poisson model (Jones, 2007). Empirical Bayes estimators of intercept and slope from mixed-effects linear regression models with up to 3 CES-D score repeats were estimated to validate the trajectory groups obtained from GBTM (see supplemental method 3).

Trajectories in CES-D scores were then used to predict LS7 total and individual scores at follow-up v_3 using a series of ordinary least square linear (for total LS7 score) and ordinal logistic regression (for LS7 component scores) models. Models adjusted sequentially for v_1 age, sex and race (Model 1), Model 1 + poverty status, educational attainment, marital status, employment status (Model 2), Model 2 + current drug use, co-morbidity index and self-rated health (Model 3). All models were adjusted for the inverse mills ratio to account for sample selectivity by age, sex, race and poverty status, using a 2-stage Heckman selection approach as was done in earlier studies (Beydoun et al., 2021).

3. Results

3.1. Study sample characteristics by sex and race

GBTM analyses was conducted in alternative number of groups, and alternative specification of the age predictor. The modeling process resulted in two two-trajectory patterns or groups for the total score of CES-D when modeling against linear age. Higher order age was attempted (quadratic, cubic), though a simpler linear age model had a comparable fit based on BIC. Fig. 2 shows the GBTM results from the linear age model with 2 groups, which were labelled as follows: Group 1: "High declining" and Group 2: "Low declining", based on the trajectory Figure and the model results for intercept and linear age slope (intercept for group 1 > intercept for group 2; slopes for both groups were negative with $P < 0.001$). A similar pattern was observed for 3 of the 4 domains (Fig. 3A–C), whereas only one category was found for the positive affect domain (Fig. 3D). Table 1 describes the study sample's key characteristics, while testing differences across sex and race groups. Of the 1465

Table 1
Study sample characteristics by sex and by race: HANDLS, 2004–2017[1].

	Overall (n = 1465)	Women (n = 854)	Men (n = 611)	P_{sex}[3]	White adults (n = 577)	African American adults (n = 888)	P_{race}[3]
Socio-demographic, lifestyle and health-related factors at v_1							
% Men	41.7	–	–	–	41.1	42.1	0.69
% African American	60.6	60.2	61.2	0.69	–	–	–
Age, years	47.8 ± 0.23	47.9 ± 0.3	47.6 ± 0.3	0.52	48.3 ± 0.4	47.4 ± 0.3	0.057
% Below poverty	39.7	43.0	35.2	**0.003**[2]	33.1	44.0	**<0.001**[2]
Education, %							
<High school	6.7	6.5	7.1	0.60	9.0	5.0	**<0.001**[2]
High school	60.0	60.4	59.5	Ref	55.1	63.2	Ref
>High school	33.2	33.2	33.4	0.86	35.4	31.8	**0.039**
Employed, %	62.1	59.2	66.2	**0.007**	63.6	61.0	0.35
Married, %	32.4	29.1	36.9	**0.002**[2]	40.5	27.0	**<0.001**[2]
Current drug use, %	18.5	14.5	24.0	**<0.001**[2]	11.9	22.7	**<0.001**[2]
Self-rated health, %							
Poor/fair	24.2	25.6	22.1	0.68	26.7	22.5	**0.042**[2]
Good	41.0	42.5	38.8	Ref	38.3	42.6	Ref
Very good/excellent	34.9	31.9	39.1	**0.015**[2]	35.0	34.8	0.36
Co-morbidity index	1.13 ± 0.04	1.21 ± 0.05	1.02 ± 0.05	**0.007**[2]	1.13 ± 0.05	1.13 ± 0.05	1.00
Hypertension, % yes	43.1	45.1	40.3	0.080	38.4	46.3	**0.004**[2]
Diabetes, % yes	13.5	14.1	12.6	0.73	14.3	12.9	0.21
High cholesterol, % yes	25.8	24.5	27.7	0.19	31.1	22.1	**<0.001**[2]
Cardiovascular disease, % yes	15.0	16.1	13.3	0.16	12.6	16.6	**0.047**[2]
Inflammatory conditions, % yes	14.3	18.3	8.6	**<0.001**[2]	15.8	13.2	0.19
Depressive symptoms and domains, v1, v2 and v3							
V1 scores	(n = 1345)	(n = 786)	(n = 559)		(n = 553)	(n = 792)	
Total	14.89 ± 0.31	15.60 ± 0.43	13.90 ± 0.44	**0.007**[2]	15.7 ± 0.51	14.32 ± 0.39	**0.028**[2]
Depressed affect	4.61 ± 0.14	5.01 ± 0.19	4.04 ± 0.19	**<0.001**[2]	4.98 ± 0.23	4.35 ± 0.17	**0.022**[2]
Interpersonal problems	1.00 ± 0.04	0.94 ± 0.05	1.08 ± 0.06	0.073[2]	0.94 ± 0.06	1.04 ± 0.05	0.23
Somatic complaints	6.64 ± 0.12	6.91 ± 0.17	6.26 ± 0.17	**0.007**[2]	6.80 ± 0.20	6.52 ± 0.15	0.25[2]
Positive affect	9.38 ± 0.08	9.30 ± 0.10	9.50 ± 0.11	0.19	9.05 ± 0.12	9.62 ± 0.10	**<0.001**[2]
V2 scores	(n = 1415)	(n = 835)	(n = 580)		(n = 557)	(n = 858)	
Total	16.03 ± 0.31	16.7 ± 0.43	15.04 ± 0.46	**0.008**[2]	16.77 ± 0.53	15.55 ± 0.39	0.057[2]
Depressed affect	4.94 ± 0.13	5.33 ± 0.19	4.40 ± 0.19	**0.001**[2]	5.31 ± 0.23	4.71 ± 0.17	**0.031**[2]
Interpersonal problems	1.12 ± 0.04	1.11 ± 0.05	1.14 ± 0.06	0.72	1.12 ± 0.06	1.12 ± 0.05	0.96
Somatic complaints	7.30 ± 0.12	7.55 ± 0.16	6.94 ± 0.06	**0.012**[2]	7.37 ± 0.20	7.25 ± 0.15	0.61
Positive affect	9.36 ± 0.07	9.31 ± 0.10	9.42 ± 0.11	0.48	9.04 ± 0.13	9.56 ± 0.09	**0.001**[2]
V3 scores	(n = 1423)	(n = 828)	(n = 595)		(n = 563)	(n = 860)	
Total	13.77 ± 0.29	14.33 ± 0.40	13.00 ± 0.42	**0.022**	14.57 ± 0.50	13.25 ± 0.35	**0.025**[2]
Depressed affect	3.90 ± 0.12	4.16 ± 0.16	3.54 ± 0.17	**0.009**[2]	4.39 ± 0.20	3.58 ± 0.15	**0.001**[2]
Interpersonal problems	0.83 ± 0.03	0.83 ± 0.04	0.84 ± 0.05	0.87	0.80 ± 0.05	0.85 ± 0.04	0.47
Somatic complaints	5.83 ± 0.11	6.04 ± 0.15	5.55 ± 0.17	**0.031**	6.16 ± 0.19	5.62 ± 0.14	**0.019**[2]
Positive affect	8.80 ± 0.08	8.70 ± 0.11	8.93 ± 0.13	0.17	8.79 ± 0.13	8.81 ± 0.11	0.99
Trajectories in depressive symptoms and domains, v1–v3							
Total CES-D score							
High declining	48.9	48.8	45.8	**0.044**	51.6	52.8	0.095[2]
Low declining	51.1	51.2	54.2	Ref	48.4	47.2	Ref
Depressed affect							
High declining	45.2	48.8	40.0	**0.001**[2]	48.7	42.9	**0.030**[2]
Low declining	54.8	51.2	60.0	Ref	51.3	57.1	Ref
Interpersonal problems							
High declining	42.9	41.8	44.4	0.33	41.9	43.5	0.56
Low declining	57.1	58.2	55.6	Ref	58.1	56.5	Ref
Somatic complaints							
High declining	58.2	59.3	56.8	Ref	58.9	57.8	Ref
Low declining	41.8	40.7	43.2	0.35	41.1	42.2	**0.025**
Positive affect							
Curvilinear, quadratic	100.0	100.0	100.0	–	100.0	100	–
LS7 and components at v3							
LS7 total score	7.55 ± 0.05	7.38 ± 0.07	7.78 ± 0.07	**<0.001**[2]	7.56 ± 0.09	7.54 ± 0.06	0.82
LS7 BMI	0.74 ± 0.02	0.62 ± 0.03	0.90 ± 0.03	**<0.001**[2]	0.72 ± 0.03	0.74 ± 0.03	0.63
LS7 BP	1.46 ± 0.02	1.43 ± 0.02	1.50 ± 0.03	0.068	1.60 ± 0.03	1.37 ± 0.03	**<0.001**[2]
LS7 cholesterol	1.52 ± 0.02	1.43 ± 0.02	1.64 ± 0.03	**<0.001**[2]	1.46 ± 0.03	1.56 ± 0.02	**0.008**[2]
LS7 cigarette smoking	0.88 ± 0.02	0.93 ± 0.03	0.81 ± 0.03	**0.005**[2]	0.93 ± 0.04	0.85 ± 0.03	0.077
LS7 diet	0.40 ± 0.01	0.42 ± 0.02	0.38 ± 0.02	0.18	0.37 ± 0.02	0.42 ± 0.02	0.054[2]
LS7 physical activity	1.04 ± 0.01	1.00 ± 0.02	1.08 ± 0.02	**0.005**[2]	1.01 ± 0.02	1.05 ± 0.02	0.21
LS7 fasting blood glucose	1.52 ± 0.02	1.55 ± 0.02	1.47 ± 0.03	**0.034**[2]	1.47 ± 0.03	1.54 ± 0.02	**0.036**

Abbreviations: BMI = Body mass index; BP = blood pressure; CES-D = Center for Epidemiologic Studies-Depression; δ = annualized rate of change; HANDLS = Healthy Aging in Neighborhoods of Diversity Across the Life Span; v_1 = visit 1; v_2 = visit 2; v_3 = visit 3.

[1] Values are means ± SE for continuous variables or % for categorical variables.

[2] $P < 0.05$ for null hypothesis that the sex or race parameter $\beta = 0$, multiple line and multinomial logit models, that included age, sex, race and poverty status as covariates.

[3] P_{sex} and P_{race} are *P*-values associated with sex and race parameters (null hypothesis $\beta = 0$), entered each as the only predictor in a linear or multinomial logit model, when study characteristics are continuous or categorical, respectively. Ref is the referent category of the categorical characteristic.

Table 2
Depressive symptoms trajectories (v1–v3) or DEP_{traj} and their association with v3 LS7, overall and by sex and race: OLS linear regression models; HANDLS, 2004–2017[1].

	Overall ($n = 1465$)		Women ($n = 854$)		Men ($n = 611$)		White adults ($n = 577$)		African American adults ($n = 888$)	
	β ± SEE	*P*	β ± SEE	*P*	β ± SEE	*P*	β ± SEE	*P*	β ± SEE	*P*
Model 1										
High declining vs. low declining	−0.669 ± 0.101	**<0.001**[3]	−0.828 ± 0.136	**<0.001**	−0.469 ± 0.151	**0.002**	−0.941 ± 0.173	**<0.001**	−0.507 ± 0.123	**<0.001**
Model 2										
High declining vs. low declining	−0.447 ± 0.107	**0.001**	−0.623 ± 0.145	**<0.001**	−0.250 ± 0.158	0.11	−0.543 ± 0.185	**0.003**	−0.394 ± 0.130	**0.002**
Model 3										
High declining vs. low declining	−0.273 ± 0.107	**0.011**[2]	−0.450 ± 0.145	**0.002**	−0.058 ± 0.159	0.71	−0.283 ± 0.182	0.12	−0.281 ± 0.131	**0.031**

Abbreviations: CES-D = Center for Epidemiologic Studies-Depression; DEP_{traj} = Depressive symptom trajectories; HANDLS = Healthy Aging in Neighborhoods of Diversity Across the Life Span; LS7 = Life's simple 7; OLS = ordinary least square; v_1 = visit 1; v_2 = visit 2; v_3 = visit 3.

[1] Values are OLS regression coefficients β with their standard errors of the estimate (SEE) and associated *P*-values for null hypothesis that $\beta = 0$. All models adjusted for the inverse mills ratio. Model 1 adjusted for age, sex and race. Model 2 is Model 1 further adjusted for poverty status, education, married vs. non-married, employed vs. not employed, Model 3 is Model 2 further adjusted for co-morbidity index, self-rated health and current drug use.

[2] $P < 0.05$ for Sex × DEP_{traj} based on separate models testing the statistical significance for Sex × DEP_{traj} in unstratified models, where Sex and DEP_{traj} are added as main effects.

[3] $P < 0.05$ for Race × DEP_{traj} based on separate models testing the statistical significance for Race × DEP_{traj} in unstratified models, where Race and DEP_{traj} are added as main effects.

selected participants, there were 854 women and 577 White adults; African American adults comprised 60 % of the sample. The most notable differences across sex were those of poverty status (% below poverty: 43 % in women vs. 35.2 % in men, $p = 0.003$), as well as other socio-economic, lifestyle and health-related factors, namely employment, marital status, current drug use, self-rated health, co-morbidity index, and inflammatory condition (% yes), indicating a less favorable status among women, even upon further adjustment for poverty status, race and baseline age. In multiple regression models adjusted for race, age and poverty status, sex differences in depressive symptoms trajectories ("high declining" vs. "low declining": total score and depressed affect) and LS7 total score at follow-up remained detectable. Specifically, women were more likely than men to be in the "high declining" depressive symptoms category than men, while having a lower LS7 total score compared to men, indicating poorer CVH. With the exception of 2 LS7 components, namely BP and diet, significant sex differences were observed. Men scored higher than women for LS7 BMI, cholesterol and physical activity, while a reverse pattern was observed for LS7 cigarette smoking and fasting blood glucose.

African American participants were more likely than White participants to have household incomes below poverty at baseline, a pattern that was not altered upon further adjustment by sex and baseline age. They also were less likely to be married, and more likely to report current drug use, hypertension and cardiovascular, with a reverse pattern observed for high cholesterol, and self-reported poor/fair health status.

Importantly, depressive symptoms' total score was on average lower among African American participants compared with White participants, particularly with respect to lower depressed affect score and higher well-being score at the first two visits and increased depressed affect and somatic complaints at v_3. This trajectory resulted in 42.9 % group membership of African American participants in the "high declining" depressed affect as opposed to 48.7 % among White participants ($p = 0.030$), a difference that was not altered with adjustment for sex, age and poverty status. LS7 total score did not differ across the two racial groups, owing to opposing direction of association between race and two components of LS7, namely LS7 BP and cholesterol.

3.2. Trajectories in depressive symptoms total score and their association with LS7 total score across sex and race

Trajectories in depressive symptoms are modeled against LS7 total score in Table 2, while adjusting for key potential confounders in a serial fashion and stratifying by sex and by race. Overall, "high declining depressive symptoms across visits" vs. the "low declining" group was associated with -0.67 ± 0.10 lower scores on LS7 total score ($p < 0.001$) in the model adjusted for age, sex, race and the inverse mills ratio (model 1). This effect that was markedly attenuated upon further adjustment for socio-economic factors, namely marital status, education, employment and poverty status, to a reduction by -0.45 ± 0.10 score-points ($p < 0.001$), and remained statistically significant for the fully adjusted model with a reduction by -0.27 ± 0.10 ($p < 0.010$). In fully adjusted models, an association between depressive symptoms trajectories ("high declining" vs "low declining") and LS7 total score was not detected among men and White adults but was statistically significant among African American adults (β ± SE: -0.281 ± 0.131, $p = 0.031$). Most notably, the relationship also remained detectable among women (Model 1: β ± SE: -0.83 ± 0.14, $P < 0.001$; Model 3: β ± SE: -0.45 ± 0.14, $P = 0.002$).

3.3. Trajectories in domains of depressive symptoms and their association with LS7 total score

Based on Table 3 findings, "high declining" vs. "low declining" somatic complaints in the total sample, were associated with a reduction in LS7 total score by 0.673 points ($p < 0.001$), an effect that was attenuated to a reduction of 0.472 points when adjusting for socio-economic factors ($p < 0.001$), and 0.308 points when further adjusting for lifestyle and health-related factors ($p = 0.004$). Similar effects were observed for the

Table 3
Depressive symptom domain trajectories (v1–v3) and their association with v3 LS7, overall and by sex and race: OLS linear regression models; HANDLS, 2004–2017[1].

	Overall (n = 1465)	P
	β ± SEE	
Depressed affect		
Model 1		
High declining vs. low declining	−0.600 ± 0.102	<0.001
Model 2		
High declining vs. low declining	−0.398 ± 0.106	<0.001
Model 3		
High declining vs. low declining	−0.250 ± 0.106	0.019
Interpersonal problems		
Model 1		
High declining vs. low declining	−0.477 ± 0.103	0.001
Model 2		
High declining vs. low declining	−0.322 ± 0.103	0.002
Model 3		
High declining vs. low declining	−0.213 ± 0.102	0.037
Somatic complaints		
Model 1		
High declining vs. low declining	−0.673 ± 0.102	<0.001
Model 2		
High declining vs. low declining	−0.472 ± 0.105	<0.001
Model 3		
High declining vs. low declining	−0.308 ± 0.105	0.004

Abbreviations: CES-D = Center for Epidemiologic Studies-Depression; DEP_{traj} = Depressive symptom trajectories; HANDLS = Healthy Aging in Neighborhoods of Diversity Across the Life Span; LS7 = Life's simple 7; OLS = ordinary least square; v_1 = visit 1; v_2 = visit 2; v_3 = visit 3.

[1] Values are OLS regression coefficients β with their standard errors of the estimate (SEE) and associated P-values for null hypothesis that β = 0. All models adjusted for the inverse mills ratio. Model 1 adjusted for age, sex and race. Model 2 is Model 1 further adjusted for poverty status, education, married vs. non-married, employed vs. not employed, Model 3 is Model 2 further adjusted for co-morbidity index, self-rated health and current drug use.

other two domain trajectories, namely those for depressed affect and interpersonal problems.

3.4. Trajectories in depressive symptoms total score and their association with LS7 domains across sex and race

Using a series of ordinal logistic regression models with LS7 components as alternative outcomes and CES-D total score trajectory as the main exposure (Table 4), LS7 PHYSICAL ACTIVITY was the main component to be linked with elevated depressive symptoms over time, even upon adjustment for baseline socio-economic, lifestyle and health-related factors (β ± SE: −0.494 ± 0.130, $P < 0.001$). This relationship held among women, White and African American adults, but not among men. The strength of this association was significantly greater among White adults when compared with African American adults in the sample ($p < 0.05$ for Race × DEP_{traj}). A similar pattern was found for cigarette smoking LS7 among women.

4. Discussion

To our knowledge, this is the first study to examine trajectories in depressive symptoms and their domains in relation to cardiovascular health as measured the LS7 in urban middle-aged adults. Several key findings were observed, including some heterogeneity by sex and by race. Overall and among women, "high declining depressive symptoms across visits" vs. the "low declining" group was significantly associated with lower scores on LS7 total score in all models from the minimally adjusted to the full model adjusted for socio-economic factors, lifestyle and health-related factors. Moreover, in fully adjusted models, the "high declining" vs. "low declining" depressive symptoms group was associated with a lower score on LS7 physical activity.

4.1. Previous studies

4.1.1. LS7 disparities by sex and race

Using data from national surveys, Egan et al. examined socio-demographic differences in LS7 among US adults aged ≥20 y (N = 32,803) from the National Health and Nutrition Examination Surveys 1999–2016 (Egan et al., 2020). Similar to our present study, they scored LS7 components as 0, 1 or 2, reflecting poor, intermediate and ideal levels, but further categorized the total score into 3 categories: poor (0–4 points), intermediate (5–9), and ideal (10–14) (Egan et al., 2020). Their findings showed that non-Hispanic black adults compared to Non-Hispanic white (NHW) and Hispanic adults were the least likely to have optimal LS7 scores, despite having higher income and education compared to Hispanics (Egan et al., 2020). This finding is consistent with structural racism as well as the Hispanic paradox. Egan et al. also found that middle-aged and older adults had lower LS7 scores compared with the younger group aged <45 y (Egan et al., 2020). Using repeated cross-sectional analyses of the NHANES between 1988 and 2014, Brown et al. found that racial/ethnic disparities in LS7 among adults aged 25y or more, persisted over time and the narrowing was due to worsening of CVH among NHW adults over time, rather than improvements among NHB or Mexican American adults (Brown et al., 2018). A longitudinal study using data from the Atherosclerosis Risk in Communities bi-racial cohort, assessed socio-demographic and socio-economic determinants for changes in LS7 over time (n = 11,049, baseline age: 44–66 y, follow-up time: 6 years). This study found that African American participants had 59 % greater odds of transitioning to a poor LS7 as opposed to retaining the ideal status through follow-up compared to their White counterparts (OR = 1.59; 1.33, 1.89) (Lassale et al., 2022), with similar effects found for several socio-economic factors. In contrast, our study did not detect any racial disparities in the LS7 total score. Nevertheless, when examining components, racial disparities in the LS7 BP were observed with poorer scores among African American adults, an association that was not altered upon adjustment for sex, age and poverty status.

4.1.2. LS7 and psychosocial factors

Several previous studies have examined mental health and other psychosocial factors and their association with CVH as measured by the LS7. Most notably, a cross-sectional analysis of the Jackson Heart Study (N = 4734) concluded that optimism was positively associated with ideal composite LS7 score, particularly the components of physical activity, diet and smoking among African American adults (Sims et al., 2019). Using the same cohort, another study concluded that the combination of high stress and high depressive symptoms was associated with poorer LS7 metrics among hypertensive African American adults (Langford et al., 2021). In a cross-sectional study of an ethnically diverse population of healthcare employees, individuals with negative self-perceived psychological factors had a lower prevalence of ideal CVH as measured by the LS7 criteria. Despite homogeneity of effects by sex, women tended to show a stronger association as compared with men (Mathews et al., 2018). All these findings are in line with ours, though only one of those previous studies was conducted in an ethnically diverse population without specifically examining depressive symptoms in relation to LS7 (Mathews et al., 2018).

4.2. Strengths and limitations

Our study has several notable strengths. First, this study included adequate numbers of African American participants, powering subset analyses that allow tests whether the association between depressive symptoms and cardiovascular health differed by race. Given that the

Table 4
Depressive symptom trajectories (v1–v3) and their association with v3 LS7 components, overall and by sex and race: ordinal logistic regression models; HANDLS, 2004–2017[1].

	Overall (n = 1465)		Women (n = 854)		Men (n = 611)		White adults (n = 577)		African American adults (n = 888)	
	β ± SEE	*P*	β ± SEE	*P*	β ± SEE	*P*	β ± SEE	*P*	β ± SEE	*P*
LS7 BMI										
Model 1										
High declining vs. low declining	+0.032 ± 0.100	0.75	−0.019 ± 0.135	0.89	0.114 ± 0.151	0.45	−0.214 ± 0.161	0.18	+0.176 ± 0.129	0.17
Model 2										
High declining vs. low declining	−0.034 ± 0.108	0.75	−0.048 ± 0.147	0.74	−0.011 ± 0.162	0.95	−0.120 ± 0.178	0.50	+0.011 ± 0.137	0.94
Model 3										
High declining vs. low declining	+0.010 ± 0.113	0.93	+0.007 ± 0.155	0.96	+0.035 ± 0.169	0.84	+0.011 ± 0.188	0.95	−0.006 ± 0.143	0.97
LS7 BP										
Model 1										
High declining vs. low declining	**−0.235 ± 0.106**	**0.027**	−0.341 ± 0.139	**0.014**	−0.115 ± 0.166	0.49	***−0.340 ± 0.181***	***0.061***	−0.191 ± 0.131	0.15
Model 2										
High declining vs. low declining	−0.159 ± 0.114	0.16	+0.307 ± 0.151	**0.042**	−0.011 ± 0.177	0.95	−0.329 ± 0.200	0.10	−0.082 ± 0.139	0.56
Model 3										
High declining vs. low declining	−0.112 ± 0.118	0.34	+0.237 ± 0.156	0.13	+0.020 ± 0.185	0.92	−0.149 ± 0.210	0.48	−0.091 ± 0.145	0.53
LS7 cholesterol										
Model 1										
High declining vs. low declining	+0.017 ± 0.108	0.87	−0.062 ± 0.135	0.65	0.099 ± 0.182	0.59	+0.078 ± 0.169	0.65	−0.026 ± 0.141	0.85
Model 2										
High declining vs. low declining	−0.017 ± 0.116	0.88	−0.135 ± 0.148	0.36	+0.114 ± 0.194	0.56	+0.012 ± 0.187	0.95	−0.050 ± 0.150	0.74
Model 3										
High declining vs. low declining	−0.091 ± 0.120	0.45	−0.204 ± 0.153	0.18	+0.032 ± 0.201	0.88	−0.052 ± 0.194	0.79	−0.121 ± 0.155	0.44
LS7 cigarette smoking										
High declining vs. low declining	**−0.680 ± 0.099**	**<0.001**	**−0.766 ± 0.130**	**<0.001**	**−0.529 ± 0.154**	**0.001**	**−0.691 ± 0.157**	**<0.001**	**−0.659 ± 0.128**	**<0.001**
Model 2										
High declining vs. low declining	**−0.349 ± 0.106**	**0.001**	**−0.462 ± 0.140**	**0.001**	−0.156 ± 0.166	0.35	−0.224 ± 0.174	0.20	**−0.414 ± 0.135**	**0.002**
Model 3										
High declining vs. low declining	−0.053 ± 0.177	0.764	**−0.319 ± 0.146**	**0.029**	−0.013 ± 0.175	0.94	−0.129 ± 0.183	0.48	−0.258 ± 0.141	0.067
LS7 diet										
Model 1										
High declining vs. low declining	**−0.255 ± 0.108**	**0.019**	**−0.358 ± 0.141**	**0.011**	−0.145 ± 0.171	0.40	**−0.499 ± 0.176**	**0.005**	−0.104 ± 0.138	0.45
Model 2										
High declining vs. low declining	−0.129 ± 0.116	0.26	−0.187 ± 0.153	0.22	−0.098 ± 0.182	0.59	−0.217 ± 0.197	0.27	−0.077 ± 0.146	0.60
Model 3										
High declining vs. low declining	−0.060 ± 0.120	0.62	−0.124 ± 0.158	0.43	−0.012 ± 0.190	0.95	−0.172 ± 0.206	0.41	−0.013 ± 0.151	0.93
LS7 physical activity										
Model 1										
High declining vs. low declining	**−0.867 ± 0.119**	**<0.001**[2]	**−1.008 ± 0.164**	**<0.001**	**−0.683 ± 0.175**	**<0.001**	**−1.168 ± 0.189**	**<0.001**	**−0.663 ± 0.154**	**<0.001**
Model 2										
High declining vs. low declining	**−0.690 ± 0.126**	**<0.001**[2]	**−0.826 ± 0.175**	**<0.001**	**−0.511 ± 0.185**	**0.006**	**−0.921 ± 0.206**	**<0.001**	**−0.551 ± 0.162**	**0.001**
Model 3										
High declining vs. low declining	**−0.494 ± 0.130**	**<0.001**[2]	**−0.620 ± 0.181**	**0.001**	−0.321 ± 0.192	0.094	**−0.652 ± 0.212**	**0.002**	**−0.409 ± 0.167**	**0.015**
LS7 fasting blood glucose										
Model 1										

(*continued on next page*)

Table 4 (*continued*)

	Overall ($n = 1465$)		Women ($n = 854$)		Men ($n = 611$)		White adults ($n = 577$)		African American adults ($n = 888$)	
	β ± SEE	*P*	β ± SEE	*P*	β ± SEE	*P*	β ± SEE	*P*	β ± SEE	*P*
High declining vs. low declining	−0.111 ± 0.107	0.30	−0.084 ± 0.144	0.56	−0.177 ± 0.163	0.28	−0.162 ± 0.169	0.34	−0.073 ± 0.140	0.60
Model 2										
High declining vs. low declining	−0.112 ± 0.115	0.33	−0.105 ± 0.155	0.50	−0.175 ± 0.173	0.31	−0.111 ± 0.187	0.55	−0.096 ± 0.147	0.51
Model 3										
High declining vs. low declining	+0.004 ± 0.121	0.97	−0.020 ± 0.163	0.90	+0.000 ± 0.184	1.00	−0.016 ± 0.198	0.94	+0.012 ± 0.154	0.94

Abbreviations: CES-D = Center for Epidemiologic Studies-Depression; DEP_{traj} = Depressive symptom trajectories; HANDLS = Healthy Aging in Neighborhoods of Diversity Across the Life Span; LS7 = Life's simple 7; OLS = ordinary least square; v_1 = visit 1; v_2 = visit 2; v_3 = visit 3.

[1] Values are ordinal logistic regression coefficients β with their standard errors of the estimate (SEE) and associated P-values for null hypothesis that β = 0. All models adjusted for the inverse mills ratio. Model 1 adjusted for age, sex and race. Model 2 is Model 1 further adjusted for poverty status, education, married vs. non-married, employed vs. not employed, Model 3 is Model 2 further adjusted for co-morbidity index, self-rated health and current drug use.

[2] P_{race} are based on separate models testing the statistical significance for Race × DEP_{traj} in unstratified models.

parent study was also balanced by sex, differentials by this socio-demographic factor were also tested in an optimally powered manner. Second, we could clearly differentiate a "high declining" vs. a "low declining" depressive symptoms group as a trajectory over 3 visits and an average of 8 years of follow-up. This was the case for total and domain-specific depressive symptoms. Such distinction allowed us to examine how "high declining" depressive symptoms pattern may determine cardiovascular health at follow-up, as compared to a "low declining" pattern, using a data driven method known as GBTM and combining it with regression analysis. Third, this is the first study to test this research question among middle-aged urban adults. Although the study was limited to Baltimore city, findings can be generalized to at least 14 urban communities of similar racial and socio-economic composition across the US.

Our study has some limitations. First, missingness in the dietary data was higher than for other components of LS7 affecting the final sample size of the analytic sample to a greater extent than other data used to compute this index. Moreover, although HANDLS is a fixed cohort, some participants who were not examined at v_1, were examined later and vice versa. The degree to which newly examined participants at later waves differ from those who joined from baseline MRV visit may have affected our findings. More specifically, we were unable to account for survival bias because those who died before the second and third visit were excluded and thus were not assessed for LS7. Since those with less optimal LS7 score have higher risk of death, this may bias the depression-LS7 association toward the null. Finally, the relationship between depressive symptoms and LS7 is often thought of being bi-directional, whereby it is equally possible that cardiovascular health causes higher depressive symptoms or that higher depressive symptoms causes poorer cardiovascular health. Nevertheless, in our present study the lack of adequate data at visits 1 and 2 on physical activity, precluded our ability to study LS7 and depressive symptoms in a bi-directional manner. Therefore, we focused on the direction of elevated depressive symptoms over time potentially leading to poorer CVH. Given the observational nature of this study, it is still possible that CVH at follow-up is a reflection of CVH at baseline and therefore the relationship found is in fact bi-directional.

4.3. Conclusions

In summary, poorer cardiovascular health, particularly less-than optimal physical activity, was linked to chronically elevated depressive symptoms, overall and among women. More observational research is needed in an attempt to replicate our main finding in comparable samples of middle-aged urban adults. Specifically, future studies should examine how trajectories in depressive symptoms can alter trajectories in LS7 over time in a time-lagged manner. Pending these observational results, randomized trials should also examine whether treating depressive symptoms can affect cardiovascular health as measured by LS7 over time, differentially by sex and by race.

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CRediT authorship contribution statement

MAB: Study concept, plan of analysis, data management, statistical analysis, literature search and review, write-up of the manuscript, revision of the manuscript.

MFG: Plan of analysis, assistance with statistical analysis, literature search and review, write-up of parts of the manuscript, revision of the manuscript.

SH: Plan of analysis, assistance with statistical analysis, literature search and review, write-up of parts of the manuscript, revision of the manuscript.

HAB: Plan of analysis, literature search and review, write-up of parts of the manuscript, revision of the manuscript.

MTFK: Assistance with statistical analysis, literature search and review, write-up of parts of the manuscript, revision of the manuscript.

MKE: Data acquisition, write-up of parts of the manuscript, revision of the manuscript.

ABZ: Data acquisition, plan of analysis, write-up of parts of the manuscript, revision of the manuscript.

Conflict of interest

All authors declare no conflict of interest.

Data availability

Upon request, data can be made available to researchers with

approved proposals, after they have agreed to confidentiality as required by our IRB. Policies are publicized on: https://handls.nih.gov. Data access request can be sent to principal investigators (PI) or the study manager, Jennifer Norbeck at norbeckje@mail.nih.gov. These data are owned by the National Institute on Aging at the NIH. The PIs have made those data restricted to the public for two main reasons: "(1) The study collects medical, psychological, cognitive, and psychosocial information on racial and poverty differences that could be misconstrued or willfully manipulated to promote racial discrimination; and (2) Although the sample is fairly large, there are sufficient identifiers that the PIs cannot guarantee absolute confidentiality for every participant as we have stated in acquiring our confidentiality certificate." Code book and statistical analysis script can be readily obtained from the corresponding author, upon request, by e-mail contact at baydounm@mail.nih.gov.

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Appendix A. Supplementary data

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Life's simple 7 and its association with trajectories in depressive symptoms among urban middle-aged adults

By Beydoun, M. A. et al.

Supplementary Method 1: Life's simple 7 description

Life's simple 7 body mass index, total cholesterol, fasting glucose, smoking and blood pressure

Using BMI <25 kg/m^2 as "ideal"(Kulshreshtha et al., 2013; Lloyd-Jones et al., 2010), we categorized "poor" BMI as BMI≥ 30 kg/m^2 and "intermediate" as BMI≥ 25 kg/m^2 and BMI <30 kg/m^2 , from measured weight and height. Measured total cholesterol were used to categorize "poor" or <200mg/dL, "intermediate" or≥200 and <240 mg/dL and "ideal" or≥240 mg/dL cholesterol(Kulshreshtha et al., 2013; Lloyd-Jones et al., 2010). Measured fasting glucose were used to categorize "poor" or <100mg/dL, "intermediate" or≥100 and <126 mg/dL and "ideal" or≥126 mg/dL glucose while fasting(Kulshreshtha et al., 2013; Lloyd-Jones et al., 2010). We defined "ideal" smoking status as never tried or tried but never used regularly, "intermediate" as former user and "poor" as current user(Kulshreshtha et al., 2013; Lloyd-Jones et al., 2010). Lastly, we defined "ideal" blood pressure as <120 mm Hg systolic and <80 mm Hg diastolic, "intermediate" as systolic≥120 & <140 mm Hg and diastolic≥80 & <90 mm Hg, and "poor" as systolic≥140 mm Hg with >=90 mm Hg diastolic blood pressure from measured blood pressure data(Kulshreshtha et al., 2013; Lloyd-Jones et al., 2010).

Dietary assessment in HANDLS, v_3 (2013-2017)

The Automated Multiple Pass Method (AMPM) of dietary data collection developed by the United States Department of Agriculture (USDA) was administered by trained interviewers to collect food intake on 2 days from each v_3 (aka wave 4) HANDLS study participant(Moshfegh et al., 2008; Raper, 2004). The time between the 24-hour recalls was 4 to 10 days. The first recall was done in-person and the second recall was done by telephone. Participants had access to an illustrated food model booklet and other aides to help them with portion estimation. Data on the types and quantities of foods and beverages consumed collected in the AMPM were imported into USDA's Survey Net, a computer-assisted food coding processing system. Each food and beverage reported was assigned an 8-digit code from the USDA Food and Nutrient Database for Dietary Studies (FNDDS), 2013-2014(Group). These codes were assigned by either the Survey Net or nutritionists who were trained dietary coders.

FNDDS was used to convert foods and beverages consumed by HANDLS study participants into gram amounts and to determine intake values for sodium, fiber and carbohydrate. These nutrient values were calculated for each recall day and then averaged to determine two of the dietary components for Life Simple 7. The USDA Food Patterns Equivalents Database 2013–14 was used to convert the foods and beverages in FNDDS to food groups(Ridker, 2003). Cup equivalents for fruits and vegetables and ounce equivalents for grains and fish were calculated for use in creating the diet metric. The calculation of energy from sugar sweetened beverages involved a two-step process since sugar is added to non-sweetened beverages prior to consumption. In AMPM, added sugar to coffee, tea and other beverages is given a combination code. Trained coders combined the additions to the main beverage and created a sugar sweetened beverage food group. The sugar sweetened beverage group included presweetened coffee, coffee substitutes, and tea, coffee, coffee substitutes, and tea with added sugar, regular soft drinks, fruitades and drinks, fruit-flavored beverages, nonalcoholic beer, wine, and cocktails, energy drinks, and sweetened fluid replacement drinks.

Life's simple 7 dietary component

The dietary component of the cardiovascular health metrics was defined according to the American Heart Association's Life Simple 7 factors(Lloyd-Jones et al., 2010). For diet, the ideal metric was determined based on intake of the following 5 healthful components: fruits and vegetables (≥ 4.5 Cup equivalents/day), fish (≥ two 3.5 oz servings/week), fiber-rich whole grains (≥ 3-oz equivalent servings/day or ≥ 1.1 gm fiber per 10 gm carbohydrate/day, the equivalent of a fiber to carbohydrate ratio ≥ 0.11 gm/day), sodium (<1500 mg/day), sugar sweetened beverages (≤ 450 kcal/week)(Lloyd-Jones et al., 2010). The ideal metric is based on an intake of 2,000 kcal(Lloyd-Jones et al., 2010). The ideal intake goals were scaled accordingly to the actual intake levels of participants(Lloyd-Jones et al., 2010). If a participant achieved the goal, one point was assigned. The points were summed and those with 4-5 points were coded as ideal, 2-3 points, as intermediate, and 0-1 point, as poor(Lloyd-Jones et al., 2010).

Life's simple 7 dietary component

Baecke questionnaire for physical activity (BQ)(Baecke et al., 1982), HANDLS wave 4:

The Baecke questionnaire comprises of 3 domains, and a total of 16 questions. Each domain (work, sports, and non-sports leisure activity) uses a five-point Likert scale from never to very often per question. However, the work domain in HANDLS was deemed unreliable. With scores from one to five points for each of the two remaining domains, the total score can range from three (minimum) to ten (maximum). We followed the original scoring system for each domain: mean score of four sports-related questions defined "sports", and mean score of four habitual physical activities during leisure time defined "non-sports leisure activity". Specific questions on hours per week and months per year of participation were asked for the two most frequently reported sports activities. The initial questionnaire was administered in a face-to-face setting to assess test-retest reliability. At the end of the process, the two chosen domains "sports" and "non-sports leisure" were scored and totaled for each participant.

The detailed procedure is as follows: We had two domains for physical activity in the construction of the HANDLS Life's Simple 7 score- sports and leisure. The sports component of the physical activity criteria included the following self-reported questions (from BPAQ):

- Do you play sports or are you physically active in your leisure time or time awake? (yes/no)
- What sport of physical activity do you do most frequently? (low intensity e.g. walking, moderate intensity, e.g. biking, high intensity, e.g. basketball)
- How many hours a week do you play or do your most frequent activity? (<1 hour, 1-2 hours, 2-3 hours, 3-4 hours, >4 hours)
- What sport or physical activity do you do next most frequently? (low intensity e.g. walking, moderate intensity, e.g. biking, high intensity, e.g. basketball)

The leisure component followed a similar list of questions and the detailed code can be provided upon request. Combining leisure and sports, the LS7 PA component was scored based on the total minutes per week spent doing either activity, accounting for intensity. The main

criterion used for optimal physical activity was ≥150 min/wk moderate intensity or ≥75 min/wk vigorous intensity or combination. Meeting this criterion yielded a score of 2. No activity yielded a score of 0, while any activity not meeting criterion yielded a score of 1 (**Supplementary Table 1**). Supplemental Table 2 lists the variables used to create the LS7 PA. The detailed code can be provided upon request.

Life's Simple 7 Total Score

HANDLS Life's Simple 7 (LS7) total score was calculated by assigning 2 points for ideal, 1 point for intermediate, and zero points for poor for each criteria. A total of 14 possible scores defined the range from worst LS7 (0) to best LS7 (14). This score has also been classified in other studies as inadequate (0–4), average (5–9) or optimum (10–14) cardiovascular health.(Kulshreshtha et al., 2013) In contrast to ideal health, poor health is characterized by current smoking, meeting no more than 1 of 5 dietary recommendations, engaging in no physical activity, and having elevated levels of BMI (≥30 kg/m^2), BP (SBP ≥140 mm Hg or DBP ≥90 mm Hg), total cholesterol (≥6.22 mmol/L), and fasting glucose (≥6.99 mmol/L). Further details for poor and intermediate levels of each component are given in **supplementary Table 1**.(Thacker et al., 2014)

CES-D

Group	Parameter	Standard Estimate	T for Error	H0: Parameter=	Prob > T
1	Intercept	3.65374	0.03579	102.086	0
	Linear	-0.01012	0.00068	-14.97	0
2	Intercept	2.77699	0.05734	48.433	0
	Linear	-0.01496	0.00112	-13.375	0

Group membership					
1	(%)	48.83335	1.42242	34.331	0.0000
2	(%)	51.16665	1.42242	35.972	0.0000

BIC=-19044.11 (N=4183) BIC=-19041.49 (N=1465) AIC=-19028.26 ll=

Parameter estimates for adding risk factors

3.65374, -0.01012, 2.77699, -0.01496, 0.04667

Parameter estimates

3.65374, -0.01012, 2.77699, -0.01496, 48.83335, 51.16665

Text

Entropy = 0.937

CES DA

Group	Parameter	Standard Estimate	T for Error		H0: Parameter=	Prob > T
1	Intercept	1.63432	0.11394		14.344	0
	Linear	-0.0237	0.00226		-10.503	0
2	Intercept	2.80523	0.05626		49.858	0
	Linear	-0.01389	0.00106		-13.046	0

Group membership						
1	(%)	54.46364	1.46523	37.171	0.0000	
2	(%)	45.53636	1.46523	31.078	0.0000	

BIC=-12188.93 (N=4211) BIC=-12186.29 (N=1465) AIC=-12173.07 ll= -12168.07

Parameter estimates for adding risk factors

1.63432, -0.02370, 2.80523, -0.01389, -0.17902

Parameter estimates

1.63432, -0.02370, 2.80523, -0.01389, 54.46364, 45.53636

Entropy = 0.909

CES IP

Group	Parameter	Standard Estimate	T for Error		H0: Parameter=	Prob > T
1	Intercept	-0.32499	0.27518		-1.181	0.2377
	Linear	-0.01849	0.00529		-3.495	0.0005
2	Intercept	1.18988	0.11674		10.192	0
	Linear	-0.01029	0.00225		-4.568	0
Group membership						
1 (%)		57.12541	1.98571	28.768	0.0000	
2 (%)		42.87459	1.98571	21.592	0.0000	

BIC= -5597.59 (N=4211) BIC= -5594.95 (N=1465) AIC= -5581.72 ll= -5576.72

Parameter estimates for adding risk factors

-0.32499, -0.01849, 1.18988, -0.01029, -0.28697

Parameter estimates

-0.32499, -0.01849, 1.18988, -0.01029, 57.12541, 42.87459

Entropy = 0.717

CES SC

Group	Parameter	Standard Estimate	T for Error	H0: Parameter=	Prob > T
1	Intercept	2.10737	0.08796	23.958	0
	Linear	-0.01746	0.00173	-10.078	0
2	Intercept	2.68746	0.04583	58.644	0
	Linear	-0.00954	0.00086	-11.111	0

Group membership					
1	(%)	41.85479	1.64974	25.370	0.0000
2	(%)	58.14521	1.64974	35.245	0.0000

BIC=-12098.56 (N=4211) BIC=-12095.92 (N=1465) AIC=-12082.69 ll=

Parameter estimates for adding risk factors

2.10737, -0.01746, 2.68746, -0.00954, 0.32874

Parameter estimates

2.10737, -0.01746, 2.68746, -0.00954, 41.85479, 58.14521

Entropy = 0.827

CES WB

		Standard	T	for	H0:	
Group	Parameter	Estimate	Error		Parameter=	Prob > T
1	Intercept	2.65008	0.12887		20.564	0
	Linear	-0.01811	0.00503		-3.604	0.0003
	Quadratic	0.00018	0.00005		3.789	0.0002
Group membership						
1 (%)		100.00000	0.00000			
BIC=-10816.62 (N=4211) BIC=-10815.03 (N=1465) AIC=-10807.10 ll= -10804.10						
Parameter estimates						
2.65008, -0.01811, 0.00018						
Entropy = .						