Preventive Medicine 126 (2019) 105772

Contents lists available at ScienceDirect

Preventive Medicine

journal homepage: www.elsevier.com/locate/ypmed

Association of cardiovascular health through early adulthood and health-related quality of life in middle age: The Coronary Artery Risk Development in Young Adults (CARDIA) Study

Lindsay R. Pool[a,*], Hongyan Ning[a], Mark D. Huffman[a], Jared P. Reis[b], Donald M. Lloyd-Jones[a], Norrina B. Allen[a]

[a] Department of Preventive Medicine, Feinberg School of Medicine, Northwestern University, Chicago, IL, USA
[b] Division of Cardiovascular Sciences, National Heart, Lung, and Blood Institute, Bethesda, MD, USA

ARTICLE INFO

Keywords:
Ideal cardiovascular health
Quality of life
Self-rated health

ABSTRACT

Previous studies have linked cardiovascular health (CVH) and health-related quality of life (HRQoL), but only in cross-sectional analyses where temporality cannot be established. The aim of this study was to determine trajectories of CVH from early adulthood to middle age, and examine their association with HRQoL in middle age. This analysis, conducted in 2018, included 3275 participants of the Coronary Artery Risk Development in Young Adults (CARDIA) study who completed a year 30 follow-up exam in 2015/2016. Group-based trajectory modeling was used to create CVH trajectories, according to American Heart Association definitions, from baseline through follow-up year 20. HRQoL was assessed by the Medical Outcomes Study 12-Item Short Form Health Survey at year 30, which included the physical component summary score (PCS), the mental component summary score (MCS), and overall self-rated health (SRH). The mean (SD) age of the sample was 55.1 (3.6) years, 1868 (57%) were women, and 1541 (47%) were black. Five CVH trajectories were identified, 31% of CARDIA participants maintained ideal CVH during follow-up. Maintaining ideal CVH was associated with higher PCS and MCS, and lower odds of fair/poor SRH as compared to the other trajectory groups. Compared to the consistently low CVH group, those who maintained ideal CVH had on average a 5.9 point higher PCS (95% CI, 4.2–7.7), a 2.5-point higher MCS (95% CI, 0.5–4.4), and 84% lower odds of fair/poor SRH (95% CI, 0.09, 0.31). Our findings suggest that maintaining ideal CVH from early adulthood results in higher health-related quality of life in middle age.

1. Introduction

The American Heart Association's 2020 Strategic Impact Goals introduced the concept of ideal cardiovascular health (CVH), defined as meeting optimal levels of seven modifiable behaviors and factors (known as Life's Simple 7) (Lloyd-Jones et al., 2010). Ideal CVH has been associated with clinical health outcomes, including incident cardiovascular disease (CVD) (Folsom et al., 2011; Dong et al., 2012) and all-cause and cardiovascular-specific mortality (Ford et al., 2012; Yang et al., 2012). In longitudinal studies of CVH, levels typically decline across the life course, but those who maintain CVH over time have better health outcomes, including lower CVD risk (Liu et al., 2012).

Health-related quality of life (HRQoL) is a measure of perceived physical and mental functioning that may be an early marker of preclinical disease (Jylha, 2009; Barger et al., 2016). HRQoL is considered both a risk factor for and consequence of low levels of CVH (Rumsfeld et al., 2013), and cross-sectional studies have demonstrated associations between CVH metrics and different components of HRQoL, including overall self-rated health, physical and mental functioning, and number of “unhealthy” days over the past month (Osibogun et al., 2018; Daviglus et al., 2003; Allen et al., 2015; Odom et al., 2016; Manczuk et al., 2017; Ogunmoroti et al., 2017; Veromaa et al., 2017). However, these associations have been shown solely in cross-sectional studies, which cannot establish whether low HRQoL is a cause or consequence of low CVH.

In this study, we use repeated measures of the Life's Simple 7 behaviors and factors over a 20-year period to determine trajectories of CVH from early adulthood to middle age among participants of the

* Corresponding author at: Department of Preventive Medicine, Northwestern University Feinberg School of Medicine, 680 N. Lake Shore Drive, 14th Floor, Chicago, IL 60611, USA.
E-mail address: lindsay.pool@northwestern.edu (L.R. Pool).

https://doi.org/10.1016/j.ypmed.2019.105772
Received 2 April 2019; Received in revised form 24 June 2019; Accepted 14 July 2019
Available online 16 July 2019

Coronary Artery Risk Development in Young Adults (CARDIA) study. We then examine the association between CVH trajectories and HRQoL as measured in middle age.

2. Methods

2.1. Study population

The Coronary Artery Risk Development in Young Adults (CARDIA) study is a longitudinal, community-based study of adults recruited from four metropolitan regions – Birmingham, AL, Chicago, IL, Minneapolis, MN, and Oakland, CA – during early adulthood (ages 18–30 years) in 1985/1986 ($N = 5115$) (Friedman et al., 1988). CARDIA recruitment was intended to be balanced on age, sex, race, geography, and socioeconomic status. CARDIA participants provided written informed consent at each exam with approval from institutional review boards at each study site. We included 3275 participants who completed a year 30 (2015/2016) follow-up exam. These analyses were conducted in 2018 using data provided by the CARDIA coordinating center.

2.2. Measures

Ideal CVH is comprised of seven factors and behaviors – blood pressure, cholesterol, glucose, body mass index, physical activity, smoking, and diet quality (Lloyd-Jones et al., 2010). We included data from baseline and follow-up years 7 (1992/1993) and 20 (2005/2006), because all seven CVH components were collected using standard protocols at these particular exams. Blood pressure was measured in triplicate after 5 min of quiet rest, and the average of the last two measurements were used. Total cholesterol and glucose were measured from venipuncture blood draws taken after at least 8 h of fasting. Body mass index was calculated as weight in kilograms divided by the square of height in meters using anthropometric measures collected by trained study personnel. Medication status for hypertension, high cholesterol, and diabetes was self-reported, as was smoking status. A validated physical activity questionnaire was used to ascertain amount of time per week spent engaging in 13 categories of activity over the past 12 months, which was then summarized to standardized units of total activity that account for intensity and duration (Jacobs et al., 1989). Average daily dietary intake of food groups and specific nutrients was computed from an interviewer-administered diet history covering the past 28 days using a validated instrument (McDonald et al., 1991).

Each of the seven factors and behaviors was categorized as ideal (2 points), intermediate (1 point), or poor (0 points). The values that constitute ideal, intermediate, and poor for each measure are shown in Appendix Table 1. The total points received across each of the measures was summed to create a composite score of CVH (range 0–14) at baseline and follow-up years 7 (1992/1993) and 20 (2005/2006). The total CVH score was used in the group-based trajectory models.

HRQoL was measured via the Medical Outcomes Study 12-Item Short Form Health Survey (SF-12), which contains the Physical Component Summary (PCS) score and Mental Component Summary (MCS) score (Ware Jr. et al., 1996). The PCS covers quality of life related to physical functioning, pain, and ability to perform daily activities. The MCS covers quality of life related to social functioning, emotional status, and vitality. Both the PCS and MCS have standardized summary scores with a mean of 50 points and a standard deviation of 10. Two week test-retest reliability estimates are 0.89 and 0.76 of the PCS and MCS, respectively, and the PCS and MCS are highly correlated with the Medical Outcomes Study 36-Item Short-Form Health Survey (R^2 of 0.91 and 0.92, respectively) (Ware Jr. et al., 1996). A higher score corresponds with higher levels of HRQoL.

Additionally, participants were asked to report their overall self-rated health (SRH) based on a 5-unit question about health in the past 30 days, ranging from poor to excellent. Consistent with other research (Allen et al., 2015; Odom et al., 2016), we dichotomized self-rated health into those rating their health as excellent/very good/good versus fair/poor.

Models assessing the association between CVH and HRQoL were adjusted for potential confounding variables including age, sex (male/female), race (black/white), study center, educational attainment (high school diploma or less, some college, or college degree), income category (< $35,000, $35,000–$75,000, or > $75,000), and self-reported history of the following chronic conditions: arthritis, cancer, mental disorders (includes nervous, emotional, and mental disorders and diagnosed depression), lung disease (includes asthma, emphysema, chronic bronchitis, and chronic obstructive pulmonary disease), and high-risk alcohol use (more than 14 drinks per week). For time-varying socioeconomic status and health status, we used those assessed at follow-up exam 30, to ensure that covariates were most representative of the participant's status through the years of exposure development.

2.3. Statistical analyses

Group-based trajectory modeling was used to identify unique clusters of individuals based on their CVH scores from baseline through follow-up year 20, using SAS PROC TRAJ (Nagin and Odgers, 2010). Trajectory classes and appropriate functional forms were determined using the Bayesian Information Criterion. Participants were assigned the trajectory for which they had the highest probability of belonging to each group (posterior predictive probability). To account for uncertainty in the trajectory group assignment, we generated 10 multiple imputations of group membership using the posterior predictive probabilities (Siddique et al., 2012). We then fit all statistical models separately on each of multiply imputed data sets and combined results across the multiple imputations. We visually assessed the trajectories to determine the baseline start points and patterns across time, and describe the patterns using the terms high (CVH greater than or equal to 10), moderate (CVH between 7 and 10), and low (CVH less than or equal to 7).

Multivariable linear regression was used to estimate the association between the CVH trajectory groups and the PCS and MCS scores, separately. Multivariable logistic regression was used to estimate the association between CVH trajectory groups and the dichotomized SRH variable. Each multivariable model used a sequential modeling strategy, first adjusting for demographics (age, sex, race, and study center), then adding socioeconomic status (education and income), and finally comorbid conditions (arthritis, cancer, mental disorders, lung disease, and high-risk alcohol use). We assessed the associations between trajectory groups and HRQoL for potential interaction by race and sex. We also conducted two sensitivity analyses in which we adjusted for body mass index at Y30 (2015/2016) to determine whether the association was attributable to adiposity, and excluded participants who developed CVD during follow-up to determine the influence of incident CVD on our results. All analyses were conducted using SAS statistical software version 9.4 (SAS Institute Inc., Cary, NC).

3. Results

There were 3275 participants who completed a year 30 (2015/2016) follow-up exam. The mean (SD) age was 55.1 (3.6) years, 1868 (57%) were women, and 1541 (47%) were black.

We identified 5 distinct CVH trajectories for the CARDIA participants: 30.8% of the sample maintained favorable CVH during the 20-year follow-up (high-steady); 29.1% started with favorable levels of CVH but declined over time (high-declining); 10.8% maintained an intermediate level of CVH over the 20 years (moderate-steady); 24.8% started an intermediate level of CVH but declined over time (moderate-declining); and 4.4% of participants had low levels of CVH across follow-up (low-declining) (Fig. 1).

There were differences in demographic and health conditions as reported at follow-up year 30 across the 5 CVH trajectory groups

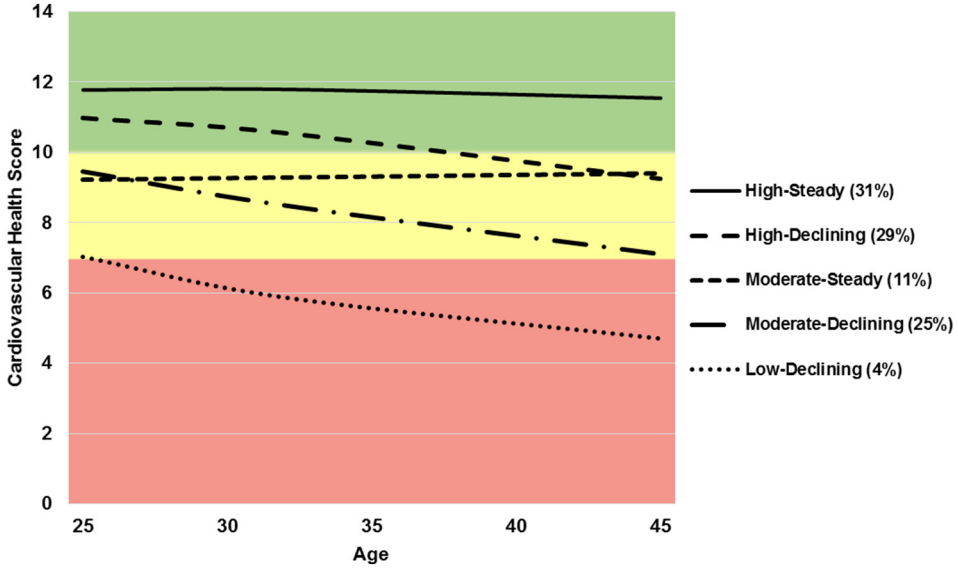

Fig. 1. Cardiovascular health score trajectories among CARDIA participants from baseline through follow-up year 20.

(Table 1). Those in the high-steady CVH group were more likely to be white race, college educated, higher income, have better CVH factors and behaviors, and have fewer comorbid chronic conditions. Baseline values of the demographics and health conditions are reported in Appendix Table 2; while socioeconomic differences by future trajectory groups were present at baseline, comorbid health conditions were rare across all groups.

In the model adjusted for demographics only, physical HRQoL, as measured by the PCS, was higher for those who maintained ideal levels of CVH (high-steady) as compared with all other CVH trajectory groups. These significant differences in the PCS remained after further adjustment for chronic health conditions: those who maintained ideal CVH (high-steady) group had a 1.8-point higher PCS (95% CI, 1.0–2.7) compared with higher-declining CVH; a 1.8-point higher PCS (95% CI, 0.4–3.2) compared with moderate-steady CVH; a 3.7-point higher PCS (95% CI, 2.7–4.7) compared with moderate-declining CVH; and a 5.9-point higher PCS (95% CI, 4.2–7.7) compared with low-declining CVH.

Differences in mental HRQoL, as measured by the MCS, between for those who maintained ideal levels of CVH (high-steady) as compared with all other CVH trajectory groups were smaller than differences in the PCS, and attenuated after further adjustment for chronic health conditions. Those who maintained ideal CVH (high-steady) group had a 0.5-point higher MCS (95% CI, −0.3–1.4) compared with higher-declining CVH; a 1.0-point higher MCS (95% CI, −0.3–2.3) compared with moderate-steady CVH; a 1.0-point higher MCS (95% CI, 0.1–1.9) compared with moderate-declining CVH; and a 2.5-point higher MCS (95% CI, 0.5–4.4) compared with low-declining CVH (Table 2).

The odds of being in fair/poor SRH at follow-up year 30 were significantly higher in a dose-response pattern for all other CVH trajectory groups as compared with those who maintained ideal levels of CVH (high-steady), after adjustment for demographics, socioeconomics, and chronic health conditions (Fig. 2). As compared with maintaining ideal CVH (high-steady group), the high-declining CVH group had 2.18 times the odds of fair/poor SRH (95% CI, 1.37, 3.48), the moderate-steady CVH group had 2.16 times the odds of fair/poor SRH (95% CI, 1.13, 4.12), the moderate-declining CVH group had 3.12 times the odds of fair/poor SRH (95% CI, 1.92, 5.07), and the low-declining CVH group had 6.17 times the odds of fair/poor SRH (95% CI, 3.32, 11.76).

We investigated potential interaction for both sex and race with the CVH trajectories for physical HRQoL, but did not find evidence of either (Appendix Tables 3/4) as patterning was consistent for both men and women ($P = 0.68$) and blacks and whites ($P = 0.52$). Women who maintained ideal CVH (high-steady) had a 6.1-point higher PCS (95% CI, 3.8–8.5) as compared with those who had low-declining CVH, while men who maintained ideal CVH (high-steady) had a 5.5-point higher PCS (95% CI, 3.0–8.1) as compared with those who had low-declining CVH. Likewise, blacks who maintained ideal CVH (high-steady) had a 5.2-point higher PCS (95% CI, 3.0–7.4) as compared with those who had low-declining CVH, while whites who maintained ideal CVH (high-steady) had a 6.6-point higher PCS (95% CI, 3.6–9.7) as compared with those who had low-declining CVH. In sensitivity analyses in which we adjusted for body mass index at year 30 (2015/2016) and excluded participants with incident CVD during follow-up, results remained unchanged.

4. Discussion

In this study, we found that CVH trajectories were associated with physical and mental HRQoL as well as self-rated health. Those who started off with ideal CVH and maintained ideal CVH from early adulthood to middle age had higher HRQoL than those with lower levels of CVH at baseline and across 20 years of follow-up. These associations were robust to adjustment for socioeconomic status, as well as comorbid conditions that have been linked to lower HRQoL and may also limit the likelihood of having ideal behavioral components of CVH, such as arthritis and lung disease.

Our findings were consistent with previous research that has shown cross-sectional associations between CVH levels, and overall self-rated health and number of days reported as “unhealthy” physically and mentally over the past month (Allen et al., 2015; Odom et al., 2016; Manczuk et al., 2017; Ogunmoroti et al., 2017; Veromaa et al., 2017). However, previous studies have conceptualized lower self-rated health as a risk factor for low CVH (Allen et al., 2015; Odom et al., 2016; Veromaa et al., 2017), and also low CVH as a risk factor for lower self-rated health (Manczuk et al., 2017; Ogunmoroti et al., 2017), demonstrating a need for longitudinal analysis establishing temporality of risk factors. Longitudinal change in some of the health behaviors comprising ideal CVH – including smoking and body mass index – had been shown to be associated with HRQoL (Kozak et al., 2011; Strandberg et al., 2008), but no study had yet examined change in the full CVH score metric with HRQoL. Our study extended previous findings by demonstrating that longitudinal change in CVH was associated with HRQoL in middle age.

We found that participants who maintained ideal CVH during the 20 year follow-up period had significantly higher levels of HRQoL as compared to those who had ideal CVH levels at the start of follow-up

Table 1
Demographic and health characteristics of CARDIA participants by cardiovascular health trajectory groups at follow-up year 30 (2015/2016).

	High-steady (30.8%)	High-declining (29.1%)	Moderate-steady (10.8%)	Moderate-declining (24.8%)	Low-declining (4.4%)
Demographics					
Age, M (SD)	55.5 (3.5)	55.1 (3.6)	55.0 (3.8)	54.8 (3.7)	54.4 (3.6)
Black race, %	25.1	48.2	51.0	66.6	73.8
Male, %	37.9	47.5	45.5	42.5	44.7
Study center, %					
Birmingham, AL	15.2	23.6	21.3	28.1	30.6
Chicago, IL	24.7	21.7	21.6	21.0	21.2
Minneapolis, MN	26.0	25.2	29.1	22.3	25.3
Oakland, CA	34.1	29.5	28.0	28.6	22.8
Education, %					
High school	10.8	21.4	29.6	32.2	46.9
Some college	16.4	26.7	26.1	34.9	35.0
College degree	72.7	51.5	43.8	32.4	16.1
Income, %					
< $35,000	11.2	19.7	22.4	35.1	49.3
$35,000–$75,000	21.5	26.6	28.1	24.1	22.1
> $75,000	66.2	52.5	48.1	38.8	23.6
Comorbid conditions					
Arthritis, %	11.2	10.0	10.2	9.2	10.9
Cancer, %	13.7	10.7	9.6	9.7	9.5
Mental disorders, %	25.3	24.3	23.4	26.2	31.3
Lung disease, %	13.4	18.8	19.1	22.7	34.6
High risk alcohol use, %[a]	7.9	9.1	11.4	9.0	9.8
CVD, %	1.6	3.7	4.5	7.4	17.4
Cardiovascular health components					
SBP, M (SD)	115.4 (14.6)	122.1 (16.2)	120.3 (15.9)	125.3 (17.3)	124.5 (20.2)
DBP, M (SD)	70.4 (10.3)	75.2 (10.6)	74 (10.9)	76.7 (10.9)	76.2 (13.4)
Hypertension meds, %	13.1	33.2	29.0	53.1	66.7
Total cholesterol, M (SD)	194.3 (33.8)	192.3 (37.3)	193.2 (39.7)	189 (41.1)	184.6 (41.9)
Cholesterol meds, %	9.1	20.0	19.0	29.8	44.8
Glucose, M (SD)	94.1 (16.2)	102.4 (30.9)	99.3 (25.5)	110.8 (40.1)	124.1 (53.0)
Diabetes meds, %	2.2	8.7	6.0	21.5	36.3
Smoking status, %					
Never	75.8	67.7	52.1	50.4	24.3
Former	20.0	20.3	30.8	25.1	32.9
Current	3.2	11.3	15.7	23.5	38.7
Physical activity, M (SD)	421.6 (279)	317.2 (268)	316.4 (262)	234.5 (230)	150.2 (187)
Body mass index, M (SD)	26.6 (0.2)	30.7 (6.1)	30.6 (6.7)	34.1 (7.9)	36.7 (8.2)
Dietary quality, M (SD)[b]					
Whole grains, servings/day	2.03 (1.57)	1.47 (1.32)	1.67 (1.57)	1.24 (1.21)	1.03 (1.39)
Fruits/vegetables, servings/day	7.21 (3.54)	5.58 (3.2)	5.98 (3.36)	5.07 (3.15)	3.95 (2.67)
Fish, servings/week	6.82 (7.27)	6.31 (8.39)	7.11 (8.52)	6.5 (8.93)	5.65 (9.3)
Sugar-sweetened beverages, servings/week	3.03 (5.15)	6.2 (8.61)	5.54 (7.83)	8.14 (11.2)	9.68 (13.5)
Sodium, mg/day	2914 (623)	2979 (640)	3007 (684)	2947 (652)	2999 (700)

CVD, cardiovascular disease; DBP, diastolic blood pressure; SBP, systolic blood pressure.
[a] High-risk alcohol use defined as 14 or more drinks per week.
[b] Dietary intake information was not collected at follow-up year 30, dietary data reported are from follow-up year 20.

but declined over time. This adds HRQoL as an additional outcome for which maintaining ideal levels of CVH is positively associated, alongside CVD and mortality (Folsom et al., 2011; Dong et al., 2012; Ford et al., 2012; Yang et al., 2012; Liu et al., 2012). Notably, a trajectory group that would have started with intermediate or low levels of CVH but improved their CVH over time was not identified in group-based trajectory analysis. The lack of a unified group of individuals improving CVH over time underscores the importance of maintaining existing CVH levels over time. Indeed, those who maintained intermediate levels of CVH had similar HRQoL scores as compared to those who had high levels of CVH at baseline but declined over time.

HRQoL has been associated with incident CVD and all-cause mortality (Barger et al., 2016; Pinheiro et al., 2019; Kroenke et al., 2008; Haring et al., 2011). Given the age range of the participants, few in our sample developed clinical CVD (4.7%), though there were differences by CVH trajectory group with those who maintained ideal CVH over time having the lowest levels of incident CVD. When those who had developed CVD during follow-up were excluded in a sensitivity analysis, results were nearly identical. But, there is evidence that suggests measures of HRQoL may be a marker of preclinical disease risk, above and beyond more conventional cardiovascular biomarkers like C-reactive protein, triglycerides, or urinary albumin (Barger et al., 2016; Haring et al., 2011). HRQoL could serve as an early indicator of declining CVH and possible development of CVD. In a study examining levels of PCS and MCS and incident CVD, those who had PCS scores less than 50 and MCS scores above 50 – as was the case for all observed trajectory groups in our analysis besides high-steady – there was a 24% higher risk of developing CVD (Pinheiro et al., 2019). In another study, a PCS difference of 5 points conferred a 35% higher risk of all-cause mortality (Kroenke et al., 2008). Subjective questions about overall health status, ability to physically function, and ability to engage in daily activities may be clinically useful as a predictor of future CVD risk and overall mortality.

Despite our findings demonstrating associations between CVH trajectories and both physical and mental HRQoL, the associations between CVH and mental HRQoL were smaller and less robust. It is possible that the physical HRQoL scale better captures the specific declines in quality of life that would be associated with lower CVH, while the

Table 2
Multivariable-adjusted mean (95% CI) HRQoL physical and mental component scores at year 30 by cardiovascular health trajectories of CARDIA participants.

	Model 1[a]	Model 2[b]	Model 3[c]
Physical component summary score			
High-steady	52.1 (51.5, 52.7)	50.6 (49.9, 51.2)	50.5 (49.9, 51.1)
High-declining	49.5 (48.8, 50.2)	48.5 (47.8, 49.2)	48.7 (48.0, 49.3)
Moderate-steady	49.3 (47.8, 50.8)	48.5 (47.2, 49.8)	48.7 (47.5, 49.9)
Moderate-declining	46.8 (46.0, 47.5)	46.6 (45.8, 47.3)	46.8 (46.1, 47.5)
Low-declining	42.9 (41.3, 44.5)	43.6 (42.1, 45.2)	44.6 (42.9, 46.2)
Mental component summary score			
High-steady	52.8 (52.1, 53.5)	52.0 (51.3, 52.8)	52.1 (51.4, 52.8)
High-declining	51.9 (51.2, 52.6)	51.4 (50.7, 52.1)	51.6 (51.0, 52.2)
Moderate-steady	51.4 (50.2, 52.6)	50.9 (49.7, 52.2)	51.1 (50.1, 52.2)
Moderate-declining	51.0 (50.3, 51.7)	50.8 (50.1, 51.5)	51.1 (50.5, 51.8)
Low-declining	48.2 (46.5, 49.9)	48.6 (46.9, 50.4)	49.6 (47.9, 51.4)

[a] Model 1: adjusted for race, sex, study center, and age.
[b] Model 2: adjusted for model 1 + educational attainment and household income.
[c] Model 3: adjusted for model 2 + comorbid conditions: arthritis, cancer, mental disorders, lung disease, high-risk alcohol use.

mental HRQoL scale is not as sensitive to CVH-associated quality of life. However, previous research has shown that mental health does not have the same age-related decline that is observed with physical functioning (Jorm, 2000). Nevertheless, more research is warranted as CVH has been previously linked to onset of depression in an older cohort (Adams et al., 2018), and there may be sensitive periods in which decline in CVH may be linked to mental health and functioning. We did adjust for mental disorders as a possible confounder, and estimates were attenuated with the addition of this variable, likely due to the close relationship between mental health conditions and mental HRQoL. Likewise, adjustment for alcohol use attenuated estimates, and high-risk coping mechanisms can negatively impact both CVH and mental HRQoL (Ogunmoroti et al., 2019; Salonsalmi et al., 2017).

Optimal body mass index is a strong predictor of the preservation of overall CVH in early adulthood (Gooding et al., 2015), and is also associated with higher HRQoL (Bottone Jr et al., 2013; Jia et al., 2016). We performed a sensitivity analysis in which we adjusted for BMI at year 30 to determine whether BMI alone could account for the associations we observed in our analysis. Our findings did not change qualitatively change with the addition of BMI to the models. We therefore conclude that while BMI is an important component of the CVH score, the CVH score as a composite has associations with HRQoL that are unique from the association between BMI and HRQoL.

4.1. Limitations

By using the CARDIA study cohort, we were able to access standardized measurement of CVH factors and behaviors that allowed for creation of trajectories from early adulthood to middle age. This study was nevertheless subject to several limitations. First, group-based trajectory modeling identifies general patterns of latent classes and assigns each participant to one of these classes. There is possibility for misclassification, however we attempted for some level of uncertainty by imputing of group membership using the posterior predictive probabilities and analyzing the imputed data. Second, the SF-12 was not administered at the baseline CARDIA exam, and thus we were unable to adjust for baseline HRQoL and possible influence of reverse causality. Third, these results may not be generalizable to individuals outside of CARDIA sampling frame, such as other racial/ethnic groups or rural populations.

5. Conclusion

In conclusion, this study demonstrated an association between trajectories of CVH across two decades and subsequent HRQoL in middle age, robust to comorbid conditions associated with both HRQoL and CVH. Our findings suggest that maintaining ideal CVH in early adulthood results in higher levels of physical and mental functioning and overall self-rated health as compared to those who do not maintain ideal CVH. These results add to the disease risk, health outcomes, well-being indicators, and mortality endpoints that are associated with ideal CVH.

Financial disclosure

Mark Huffman receives grant support from the World Heart Federation to serve as its senior program advisor for the Emerging Leaders program, which is supported by unrestricted educational grants from Boehringer Ingelheim and Novartis with previous support from AstraZeneca and Bupa. He also receives support from the American Heart Association, Verily, and AstraZeneca for work unrelated to this project.

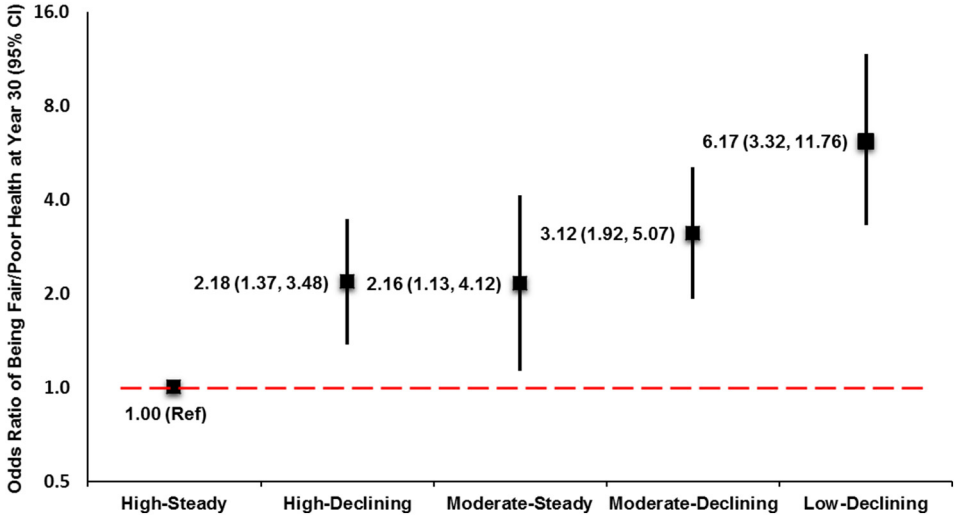

Fig. 2. Odds ratios of the association between cardiovascular health trajectories of cardia participants and fair/poor self-rated health.
Adjusted for race, study center, age, educational attainment, household income, and comorbid conditions: arthritis, cancer, mental disorders, lung disease, and high-risk alcohol use.

Declaration of Competing Interest

The Coronary Artery Risk Development in Young Adults Study (CARDIA) is supported by contracts HHSN268201800003I, HHSN268201800004I, HHSN268201800005I, HHSN268201800006I, and HHSN268201800007I from the National Heart, Lung, and Blood Institute (NHLBI).

Disclaimer: The views expressed in this manuscript are those of the authors and do not necessarily represent the views of the National Heart, Lung, and Blood Institute; the National Institutes of Health; or the U.S. Department of Health and Human Services.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2019.105772.

References

Adams, S., Conner, S., Himali, J.J., et al., 2018. Vascular risk factor burden and new-onset depression in the community. Prev. Med. 111, 348–350.
Allen, N.B., Badon, S., Greenlund, K.J., Huffman, M., Hong, Y., Lloyd-Jones, D.M., 2015. The association between cardiovascular health and health-related quality of life and health status measures among U.S. adults: a cross-sectional study of the National Health and Nutrition Examination Surveys, 2001–2010. Health Qual. Life Outcomes 13, 152.
Barger, S.D., Cribbet, M.R., Muldoon, M.F., 2016. Participant-reported health status predicts cardiovascular and all-cause mortality independent of established and non-traditional biomarkers: evidence from a representative US sample. J. Am. Heart Assoc. 5 (9).
Bottone Jr., F.G., Hawkins, K., Musich, S., et al., 2013. The relationship between body mass index and quality of life in community-living older adults living in the United States. J. Nutr. Health Aging 17 (6), 495–501.
Daviglus, M.L., Liu, K., Pirzada, A., et al., 2003. Favorable cardiovascular risk profile in middle age and health-related quality of life in older age. Arch. Intern. Med. 163 (20), 2460–2468.
Dong, C., Rundek, T., Wright, C.B., Anwar, Z., Elkind, M.S., Sacco, R.L., 2012. Ideal cardiovascular health predicts lower risks of myocardial infarction, stroke, and vascular death across whites, blacks, and Hispanics: the northern Manhattan study. Circulation 125 (24), 2975–2984.
Folsom, A.R., Yatsuya, H., Nettleton, J.A., Lutsey, P.L., Cushman, M., Rosamond, W.D., 2011. Community prevalence of ideal cardiovascular health, by the American Heart Association definition, and relationship with cardiovascular disease incidence. J. Am. Coll. Cardiol. 57 (16), 1690–1696.
Ford, E.S., Greenlund, K.J., Hong, Y., 2012. Ideal cardiovascular health and mortality from all causes and diseases of the circulatory system among adults in the United States. Circulation 125 (8), 987–995.
Friedman, G.D., Cutter, G.R., Donahue, R.P., et al., 1988. CARDIA: study design, recruitment, and some characteristics of the examined subjects. J. Clin. Epidemiol. 41 (11), 1105–1116.
Gooding, H.C., Shay, C.M., Ning, H., et al., 2015. Optimal lifestyle components in young adulthood are associated with maintaining the ideal cardiovascular health profile into middle age. J. Am. Heart Assoc. 4 (11).
Haring, R., Feng, Y.S., Moock, J., et al., 2011. Self-perceived quality of life predicts mortality risk better than a multi-biomarker panel, but the combination of both does best. BMC Med. Res. Methodol. 11, 103.
Jacobs Jr., D.R., Hahn, L.P., Haskell, W.L., Pirie, P., Sidney, S., 1989. Validity and reliability of short physical activity history: cardia and the Minnesota heart health program. J. Cardpulm. Rehabil. 9 (11), 448–459.
Jia, H., Zack, M.M., Thompson, W.W., 2016. Population-based estimates of decreases in quality-adjusted life expectancy associated with unhealthy body mass index. Public Health Rep. 131 (1), 177–184.
Jorm, A.F., 2000. Does old age reduce the risk of anxiety and depression? A review of epidemiological studies across the adult life span. Psychol. Med. 30 (1), 11–22.
Jylha, M., 2009. What is self-rated health and why does it predict mortality? Towards a unified conceptual model. Soc. Sci. Med. 69 (3), 307–316.
Kozak, A.T., Daviglus, M.L., Chan, C., Kiefe, C.I., Jacobs Jr., D.R., Liu, K., 2011. Relationship of body mass index in young adulthood and health-related quality of life two decades later: the Coronary Artery Risk Development in Young Adults study. Int. J. Obes. 35 (1), 134–141.
Kroenke, C.H., Kubzansky, L.D., Adler, N., Kawachi, I., 2008. Prospective change in health-related quality of life and subsequent mortality among middle-aged and older women. Am. J. Public Health 98 (11), 2085–2091.
Liu, K., Daviglus, M.L., Loria, C.M., et al., 2012. Healthy lifestyle through young adulthood and the presence of low cardiovascular disease risk profile in middle age: the Coronary Artery Risk Development in (Young) Adults (CARDIA) study. Circulation 125 (8), 996–1004.
Lloyd-Jones, D.M., Hong, Y., Labarthe, D., et al., 2010. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American Heart Association's strategic Impact Goal through 2020 and beyond. Circulation 121 (4), 586–613.
Manczuk, M., Vaidean, G., Dehghan, M., Vedanthan, R., Boffetta, P., Zatonski, W.A., 2017. Ideal cardiovascular health is associated with self-rated health status. The Polish Norwegian Study (PONS). Int. J. Cardiol. 230, 549–555.
McDonald, A., Van Horn, L., Slattery, M., et al., 1991. The CARDIA dietary history: development, implementation, and evaluation. J. Am. Diet. Assoc. 91 (9), 1104–1112.
Nagin, D.S., Odgers, C.L., 2010. Group-based trajectory modeling in clinical research. Annu. Rev. Clin. Psychol. 6, 109–138.
Odom, E.C., Fang, J., Zack, M., Moore, L., Loustalot, F., 2016. Associations between cardiovascular health and health-related quality of life, behavioral risk factor surveillance system, 2013. Prev. Chronic Dis. 13, E99.
Ogunmoroti, O., Utuama, O.A., Salami, J.A., et al., 2017. Association between self-rated health and ideal cardiovascular health: the Baptist Health South Florida Employee study. J. Public Health 1–8.
Ogunmoroti, O., Osibogun, O., McClelland, R.L., Burke, G.L., Nasir, K., Michos, E.D., 2019. Alcohol and ideal cardiovascular health: the Multi-Ethnic Study of Atherosclerosis. Clin. Cardiol. 42 (1), 151–158.
Osibogun, O., Ogunmoroti, O., Spatz, E.S., Burke, G.L., Michos, E.D., 2018. Is self-rated health associated with ideal cardiovascular health? The Multi-Ethnic Study of Atherosclerosis. Clin. Cardiol. 41 (9), 1154–1163.
Pinheiro, L.C., Reshetnyak, E., Sterling, M.R., Richman, J.S., Kern, L.M., Safford, M.M., 2019. Using health-related quality of life to predict cardiovascular disease events. Qual. Life Res. 28 (6), 1465–1475.
Rumsfeld, J.S., Alexander, K.P., Goff Jr., D.C., et al., 2013. Cardiovascular health: the importance of measuring patient-reported health status: a scientific statement from the American Heart Association. Circulation 127 (22), 2233–2249.
Salonsalmi, A., Rahkonen, O., Lahelma, E., Laaksonen, M., 2017. The association between alcohol drinking and self-reported mental and physical functioning: a prospective cohort study among City of Helsinki employees. BMJ Open 7 (4), e014368.
Siddique, J., Chung, J.Y., Brown, C.H., Miranda, J., 2012. Comparative effectiveness of medication versus cognitive-behavioral therapy in a randomized controlled trial of low-income young minority women with depression. J. Consult. Clin. Psychol. 80 (6), 995–1006.
Strandberg, A.Y., Strandberg, T.E., Pitkala, K., Salomaa, V.V., Tilvis, R.S., Miettinen, T.A., 2008. The effect of smoking in midlife on health-related quality of life in old age: a 26-year prospective study. Arch. Intern. Med. 168 (18), 1968–1974.
Veromaa, V., Kautiainen, H., Juonala, M., Rantanen, A., Korhonen, P.E., 2017. Self-rated health as an indicator of ideal cardiovascular health among working-aged women. Scand. J. Prim. Health Care 35 (4), 322–328.
Ware Jr., J., Kosinski, M., Keller, S.D., 1996. A 12-Item Short-Form Health Survey: construction of scales and preliminary tests of reliability and validity. Med. Care 34 (3), 220–233.
Yang, Q., Cogswell, M.E., Flanders, W.D., et al., 2012. Trends in cardiovascular health metrics and associations with all-cause and CVD mortality among US adults. JAMA 307 (12), 1273–1283.