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Associations between cumulative social risk, psychosocial risk, and ideal cardiovascular health: Insights from the HeartSCORE study

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ABSTRACT

Background: Limited studies have assessed the effects of psychosocial risk factors on achievement of ideal cardiovascular health *(CVH)*.
Methods: Using the Heart Strategies Concentrating on Risk Evaluation (HeartSCORE) cohort, we examined the cross-sectional associations of cumulative social risk (CSR) and three psychosocial factors (depression, stress, perceived discrimination) with *ideal CVH*. CSR was calculated by assigning one point for each of: low family income, low education level, minority race (Black), and single-living status. *Ideal CVH* was calculated by assigning one point for ideal levels of each factor in American Heart Association's Life's Simple 7. *Ideal CVH* was dichotomized into fewer versus higher by combining participants achieving <3 versus ≥3 factors. Logistic regression models were used to calculate odds ratios (ORs) and 95% confidence intervals (CIs) of having fewer *ideal CVH* factors. Psychosocial factors were assessed as mediators of the association between CSR and *ideal CVH*.
Results: We included 2000 participants (mean age 59.1 [7.5] years, 34.6% male, 42.7% Black, and 29.1% with low income), among whom 60.6% had <3 ideal CVH factors. The odds of having fewer *ideal CVH* factors increased significantly with increasing CSR scores from 1 to 2, to ≥3 compared to individuals with CSR score of zero, after adjusting for age and sex (OR [95% CIs]: 1.77 [1.41 - 2.22]; 2.09 [1.62 - 2.69] 2.67 [1.97 - 3.62], respectively). Taking the components of ideal CVH separately, higher CSR was directly associated with odds of being in 'non-ideal' category for six of the seven factors, but was inversely associated with probability of being in 'non-ideal' category for cholesterol. The association was modestly attenuated after adjusting for depression, stress, and perceived discrimination (corresponding OR [95% CI]: 1.69 [1.34 - 2.12], 1.96 [1.51 - 2.55], 2.34 [1.71 - 3.20]). The psychosocial factors appeared to mediate between 10% and 20% of relationship between CSR and *ideal CVH*.
Conclusions: Increased CSR was associated with lower probability of achieving *ideal CVH* factors. A modest amount of the effect of CSR on *ideal CVH* appeared to be mediated by depression, stress and perceived discrimination. Public health strategies aimed at improving ideal cardiovascular health may benefit from including interventions targeting social and psychosocial risk factors.

1. Background

In 2010, the American Heart Association (AHA) formally introduced the concept of *ideal cardiovascular health* (CVH), which comprises 7 cardiovascular health related factors: smoking history, body mass index (BMI), physical activity, diet, total cholesterol, blood pressure, and fasting plasma glucose [1]. Ideal CVH was developed for characterizing cardiovascular health in the United States at a population level. It was

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designed to assist in monitoring progress toward AHA's Impact Goal of improving CVH for all Americans by 20%, and reducing deaths from cardiovascular disease and stroke by 20%. Accordingly, ideal CVH has undergirded the AHA's public health campaign aligned with the organization's impact goal, *My Life's Simple 7* [1,2].

The 7 factors of ideal CVH have well-established associations with major adverse cardiovascular events, including stroke, myocardial infarction, and heart failure[3–10] Lower attainment of ideal CVH has also been associated with markers of subclinical cardiac disease, such as increased arterial stiffness, increased carotid artery intima thickness, and lower coronary artery calcium scores [11–15]. Both sets of associations affirm the utility of ideal CVH in identifying primordial and primary prevention strategies in public health to improve cardiac outcomes [16,17]. cc

A growing body of evidence has identified complex relationships between ideal CVH, social risk, psychosocial risk factors, and adverse cardiovascular outcomes (Fig. 1) [2,15,18–23]. Studies have reported disparities by sex, race, educational attainment, and income in achievement of ideal CVH [18,24,25]. In addition, markers of psychosocial risk such as depression, perceived discrimination, and stress have been inversely associated with ideal CVH [2,26,27]. For example, depression has been associated with lower ideal CVH score [28]. Similar inverse associations have been observed for social risk factors such as low income, low education, and race [29]. Social risk refers to sociodemographic and environmental factors portending to social disadvantage and disparities in health outcomes. In prior works, we have combined four markers of social risk – racial minority status, low income, low educational attainment, and single living status as *cumulative social risk* (CSR), and demonstrated an additive effect on the risk of clinical and subclinical CVD outcomes [15,19].

To date, few studies have ascertained the associations of social risk factors and achievement of individual components of ideal CVH metrics. Prior studies have not explored the additive effects of CSR on achievement of ideal CVH [19]. In addition, to our knowledge, no prior studies have evaluated possible mediating effects of depression, perceived discrimination, and stress on the relationship between social risk factors and ideal CVH. Elucidating the general interplay between these commonly measured social, socioeconomic, and psychosocial factors, and ideal CVH may have implications for resource allocation, public health campaign targeting, and decision-making in health policy related to cardiovascular prevention [1].

In this study, we examined the associations of CSR with ideal CVH using data from the Heart Strategies Concentrating on Risk Evaluation (HeartSCORE) study. In addition, given extant literature on relationship of depression and stress with ideal CVH and poor health outcomes as discussed above, we conducted a mediation analysis to evaluate the influence of these psychosocial risk factors on the relationship between CSR and ideal CVH.

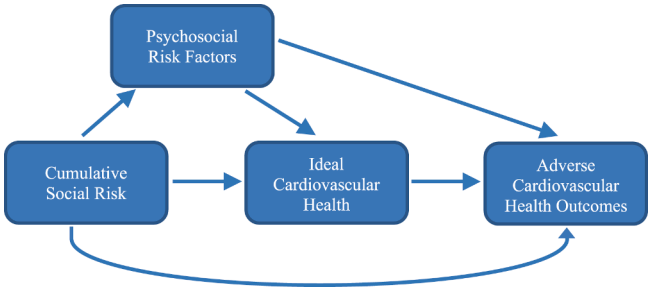

Fig. 1. Conceptual model of interrelationships between cumulative social risk, psychosocial risk factors, ideal cardiovascular health and adverse cardiovascular outcomes.

2. Methods

2.1. Study design

We used data from the Heart SCORE study. Heart SCORE began in 2003 as a community-based cohort study of 2000 participants conducted in Allegheny County, PA. Its methods have been described previously [30]. Participants were 45 to 75 years old at entry. Individuals with a comorbid condition that was expected to limit life expectancy to <5 years and individuals unable to undergo annual follow-up visits were excluded. The study was approved by the Institutional Review Board at the University of Pittsburgh. All subjects provided written informed consent.

2.2. Data collection

Demographic and medical histories were collected at the baseline visit. Participants completed detailed demographic and lifestyle questionnaires including information on self-reported race, marital/cohabiting status, education, income, smoking, physical activity and dietary habits. BMI was evaluated by a standard study measurement of weight and height. Blood pressure was measured twice using a manual sphygmomanometer and an appropriately sized cuff after 5 minutes of rest in a seated position. The average of the two readings was taken. Hypertension was defined as a systolic blood pressure ≥140 mmHg or a diastolic pressure ≥90 mmHg, history of physician-diagnosed hypertension, or current use of anti-hypertensive medication. Lipid panel and glucose were measured in fasting venous blood drawn using standard laboratory techniques at the University of Pittsburgh Medical Center clinical laboratory. Diabetes mellitus was defined as fasting glucose ≥126 mg/dL or a history of previously diagnosed diabetes treated with diet, oral agents, and/or insulin.

2.3. Cumulative social risk (CSR)

Cumulative social risk was quantified by assigning a score of one for the presence of each of four social factors, as described previously [15,19,31] i) racial minority (Black) ii) single living status, iii) low income, and iv) low educational level. Single living status included those who were not married or cohabiting. Low educational level was defined as those who did not complete a high school diploma. Individual annual income was reported as "<$10K", "$10K to <$20K", "$20K to <$40L", "$40K to <$80K", and "≥$80K." Low income was defined as those making <$20,000 a year or those having trouble paying for their basic needs.

2.4. AHA ideal cardiovascular health variables

In accordance with AHA definitions, ideal cardiovascular health was defined as the simultaneous presence of four ideal health behaviors (nonsmoking, BMI <25 kg/m2, physical activity at goal, and diet consistent with current recommendations) and three ideal health factors (untreated total cholesterol <200 mg/dL, untreated BP <120/80mm Hg, and untreated fasting glucose <100 mg/dL) in the absence of clinical CVD. For each participant, attainment of ideal CVH status for each variable was determined as described previously [5]. A value of 1 was assigned when ideal health status was achieved and 0 when ideal health status was not achieved. For smoking, ideal behavior was defined as never smoker, or quit smoking for 12 months. Physical activity was evaluated using the Lipid Research Clinic questionnaire [32] which includes questions about type and frequency of physical activity at work and during leisure time and permits classification of individuals as very active, moderately active, and inactive. The questionnaire provided approximations of ideal vs non-ideal physical activity. The PrimeScreen questionnaire [33] was used to evaluate average daily consumption of fruits and vegetables. A cutoff value of 3 servings/day of fruits and

vegetables has been shown to correlate closely with 5 servings/day when derived from more extensive food frequency questionnaires [33]. The questionnaire was used to classify individuals as having an ideal (≥3 servings/day) or non-ideal (<3 servings/day) consumption of fruits and vegetables. We were not able to quantify fish, fiber-rich whole grains, sodium, and sugar-sweetened beverages consumption as recommended by AHA.

2.5. Psychosocial factors

The assessment of depressive symptoms was based on the 20-item Center for Epidemiologic Studies Depression Scale (CES-D) [34]. Individuals with score >=16 were categorized as depressed.

The assessment of perceived stress was based on the Cohen Stress Scale [35,36]. Perceived discrimination was assessed using the Williams, Yu, Jackson, & Anderson Perceived Discrimination Scale [37]. Participants were given a total score based on the sum of the scores on the individual questions. We coded all items in the Perceived Discrimination questionnaire so that higher scores represent more perceived discrimination.

2.6. Statistical methods

Participant characteristics were summarized by number of ideal CVH variables. To ensure presence of sufficient numbers within each group, we categorized participants into those with three or more ideal CVH variables vs. those with less than three ideal CVH variables. A cut off value of >=3 was used (instead of >=4 or >=5) because there were too few individuals with 4, 5, 6, or 7 ideal CVH factors, compared to the overall cohort (4 factors = 237 individuals, 5 factors = 79 individuals, 6 factors = 23 individuals, 7 factors = 1 individual, in total comprising 17% of the overall cohort). We also categorized ideal CVH into 4 categories as 0, 1, 2, or >=3 ideal CVH variables. For CSR, we grouped participants into the following four categories: CSR=0, CSR=1, CSR=2 and CSR≥3. Standardized categorization of CSR by score does not exist, partially due to variable definitions of CSR [15,22]. The number of individuals with complete data on each of the variables studied is shown in Table 1.

We assessed the association of CSR and psychosocial risk factors with attainment of ideal CVH. We used logistic regression models to estimate the association of additive categories of CSR, or individual components of CSR with probability of a) being in 'non-ideal' category for the individual components of ideal CVH, b) being in lower category of dichotomized ideal CVH metrics. In supplementary analyses, we used ordinal logistic regression where the response variable has multiple categories (4 categories of ideal CVH as described above). Ordinal logistic regression estimates the odds of an individual being in a certain category of the outcome variable compared to reference category for a given level of an exposure variable. We calculated the odds ratios (ORs) and 95% confidence intervals (95% CIs). We adjusted for age and sex as these were demographic factors not already included in our CSR score. As this is a primordial prevention study looking at cardiovascular risk factors (not outcomes), it was not appropriate to mutually adjust for other cardiovascular risk factors.

We performed a mediation analysis to assess the potential role of psychosocial factors (i.e., depression, stress, and perceived discrimination) in explaining the association between CSR and achievement of higher ideal CVH scores by adding the psychosocial factors to logistic regression models relating CSR and ideal CVH, in a model adjusted for age and sex. The mediation analyses were conducted using the methods described by Ananth and VanderWeele, based on the estimated total, direct, and indirect effects of CSR on ideal CVH, as computed on the relative risk scale [38]. The ORs estimate the probability of belonging to the category of individual with < 3 ideal CVH factors compared to the group with ≥3 ideal CVH factors. The total effect is the OR that is unadjusted for the proposed mediator (psychosocial factors in this study).

Table 1
Study characteristics by presence of ideal cardiovascular health (ideal CVH) factors.

Risk Factors	*N*	Overall (SD)	< 3 ideal CVH Factors (SD)	≥3 ideal CVH Factors (SD)	*z*-value	*p*-value
Age	2000	59.1 (7.5)	59.4 (7.4)	58.5 (7.6)	7.9	<0.01
Male sex	2000	693 (34.6)	432 (35.7%)	261 (33.1%)	1.4	0.24
SBP (mmHg)	1998	136.7 (19.7)	140.6 (18.9)	130.7 (19.5)	127.3	<0.0
Diabetes	1989	203 (10.2)	180 (15.0%)	23 (2.9%)	127.3	<0.01
BMI (kg/m^2)	1979	30.1 (6.3)	31.7 (6.3)	27.7 (5.6)	207.9	<0.01
TC (mg/dL)	1988	213.1 (42.7)	215.7 (43.4)	209.1 (41.4)	11.1	<0.01
HDL-c (mg/dL)	1988	57.5 (15.0)	56.2 (14.3)	59.5 (15.7)	22.3	<0.01
TG (mg/dL)	1986	123.4 (75.4)	132.6 (77.6)	109.4 (69.7)	46.2	<0.01
Cumulative Social Risk Factors						
Race - Black (%)	2000	854 (42.7)	578 (47.7)	276 (35.0)	31.7	<0.01
Low income (%)	2000	582 (29.1)	396 (32.7)	186 (23.6)	19.3	<0.01
Low educational attainment (%)	2000	47 (2.4)	38 (3.1)	9 (1.1)	8.3	<0.01
Single marital status (%)	2000	849 (42.5)	557 (46.0)	292 (37.0)	15.1	<0.01
Depression, Stress, and Perceived Discrimination						
Depression[a]	1977	244 (12.3)	166 (13.9%)	78 (10.0%)	6.8	<0.01
CESD score	1977	6.9 (8.0)	7.4 (8.3)	6.2 (7.4)	10.6	<0.01
Cohen score	1978	4.3 (3.0)	4.4 (3.1)	4.1 (2.9)	4.2	0.02
DIS score	2000	11.2 (6.2)	11.6 (6.2)	10.7 (6.3)	9.4	<0.01

ideal CVH – ideal cardiovascular health, *SBP* – systolic blood pressure, *BMI* – body mass index, *TC* – total cholesterol, *HDL-c* – high-density lipoprotein cholesterol, *TG* – triglycerides, *CESD* – Center for Epidemiologic Studies Depression Scale, Cohen stress scale, *DIS* – discrimination score,

[a] Depression was defined as a CESD score greater than or equal to 16

N – represents the number of individuals with available complete data for each variable.

The direct effect is the OR that is adjusted for the proposed mediator. The indirect effect is calculated by dividing the total effect by direct effect. All analyses were performed using Stata software (Stata Corp., version 14, Texas, USA). P-values <0.05 were considered statistically significant.

3. Results

3.1. Participant characteristics

The study included 2000 participants, 65.4% were female, and the mean (SD) age was 59.1 (7.5) years (see Table 1 for baseline characteristics stratified by category of ideal CVH factors achieved). Of the participants, 42.7% were Black, 29.1% earned low income, 2.4% had low educational attainment, and 42.5% had single marital status. Additionally, 12.3% of participants had depression as defined by the CES-D scale. The average Perceived Stress Scale score of the cohort was 4.3, and the average Perceived Discrimination Scale score was 11.2. Among the participants, 39.5% achieved 3 or more ideal CVH factors,

1.2% achieved 6 or 7 ideal cardiovascular health factors, and 11% of participants did not achieve any ideal CVH factors. Compared to participants with 3 or more ideal CVH factors, participants with less than 3 ideal cardiovascular health factors were significantly older, more likely to be male, and more likely to have each component of CSR. They were also more likely to report depression, higher stress score, and higher perceived discrimination score.

3.2. Cumulative social risk

The associations between accumulation of CSR and the odds of achievement of ideal CVH are shown in Table 2. Individuals with 1, 2, and >=3 CSR scores had progressively increasing odds of being in lower ideal CVH category compared to individuals with 0 CSR in age and sex adjusted model (OR 1.77, 2.09, 2.67, respectively, all p-values <0.001). This association was modestly attenuated but remained significant with adjustment for depression, stress, and perceived discrimination. The Central Illustration shows a stacked column plot of the proportion of individuals achieving a given number of ideal CVH factors (zero, one, two, three, four or more factors) by each individual social risk factor. The individual components of CSR were associated with higher odds of being in a category with fewer number ideal CVH factors in age and sex adjusted models. The association remained significant mainly for race when the CSR factors were mutually adjusted for each other (Supplemental Table 1).

Table 3 demonstrates the odds of achieving each of the 7 ideal CVH factors by CSR score. For 6 of the 7 ideal cardiovascular health factors – fasting blood glucose, blood pressure, BMI, smoking status, diet and physical activity – the odds of being in 'non-ideal' category increased significantly with increasing CSR score, generally in a dose-response relationship. By contrast, for total cholesterol, individuals with higher CSR were more likely to achieve ideal total cholesterol levels.

3.3. Depression, stress, and perceived discrimination

Associations between depression, stress, and perceived discrimination and achievement of ideal CVH are shown in Table 4. After adjusting for age and sex, individuals with higher depression, stress, and perceived discrimination scores were significantly more likely to have fewer (<3 versus ≥3) ideal CVH factors. The association between CSR and ideal CVH was modestly attenuated after adjusting for these psychosocial factors (Table 2). Depression, stress, and perceived discrimination combined appeared to mediate between 10 and 20% of the relationship between CSR and probability of achieving ideal CVH factors (Table 5).

Table 2
Odds ratio of belonging to a lower category of ideal cardiovascular health achievement by levels of cumulative social risk.

Cumulative Social Risk (CSR) Score	*≥ 3 ideal CVH Factors OR*	*< 3 ideal CVH Factors OR (95% CI)*	*p-value*
		Adjusted for age and sex	
CSR = 1	Ref	1.77 (1.41 - 2.22)	<0.01
CSR = 2	Ref	2.09 (1.62 - 2.69)	<0.01
CSR ≥3	Ref	2.67 (1.97 - 3.62)	<0.01
		Adjusted for age, sex, depression, stress, and perceived discrimination	
CSR = 1	Ref	1.69 (1.34 - 2.12)	<0.01
CSR = 2	Ref	1.96 (1.51 - 2.55)	<0.01
CSR ≥3	Ref	2.34 (1.71 - 3.20)	<0.01

CSR – cumulative social risk, *ideal CVH* – ideal cardiovascular health, *BMI* – body mass index, Ref -reference
Odds ratio represents probability of belonging to category of individuals with <3 ideal CVH factors, compared to the group with ≥3 ideal CVH factors.

4. Discussion

Using data from the HeartSCORE study including 2000 participants, we demonstrated the significant impact of social risk and psychosocial risk factors on ideal cardiovascular health. Individuals with increasing CSR score were significantly more likely to have fewer ideal CVH factors. Further, we demonstrated that the accumulation of social risk factors has an exposure-response relationship with odds of having fewer ideal CVH factors. This study further demonstrated that individuals with depression, stress, and perceived discrimination were more likely to have fewer ideal CVH factors. Psychosocial factors appeared to mediate a modest amount of the association between CSR and probability of achieving ideal CVH metrics.

Our findings complement previous literature that demonstrates the associations between socioeconomic disadvantage, social risk, and adverse cardiovascular outcomes [14,15,18,19,21,23]. In examining CSR, our findings are consistent with the presence of known disparities in cardiovascular outcomes, particularly by sex [24], race [5,39,40], educational attainment, and socioeconomic status [18]. Similar to prior studies [18,21] we found that accumulation of adverse social conditions (as captured by an increasing CSR score) was associated with increasing odds of having fewer ideal CVH factors in a dose-response fashion. Importantly, our study also investigated the mediating effect of depression, stress, and perceived descrimination on the link between CSR and ideal CVH.

When assessing each ideal CVH factor individually, the odds of achieving ideal value for most factors significantly decreased with increased CSR score. However, the magnitude of the association was different between the factors. The associations were more pronounced for smoking, diet, and BMI, which is in line with what has been reported previously. In particular, the study by Pulkki-Råback et al examined the association between psychosocial factors in youth and the attainment of ideal CVH in adulthood, showing that greater exposure to positive psychosocial factors was associated with a greater likelihood of having normal weight and being a nonsmoker in adulthood, thus suggesting that weight development and the prevention of smoking may be particularly responsive to psychosocial prevention [41]. Taken together, this reinforces the relevance of a life course approach in the design of strategies to improve psychosocial conditions for all, which holds promise to improve cardiovascular health and a healthier transition to adulthood and aging.

On the other hand, we found that individuals with higher CSR were more likely to achieve ideal total cholesterol. Of note, a prior study conducted by Caleyachetty et al. in 2015 on CSR and ideal CVH using the National Health and Nutritional Examination Survey (NHANES) data demonstrated similar findings, with Black participants having significantly higher odds of achieving ideal cholesterol than their counterparts [19]. We suspect that this finding may have resulted from our dichotomization of the ideal CVH variable as ideal and non-ideal, where the non-ideal category included individuals with either intermediate and poor ideal CVH factors. Thus, it is possible that individuals with lower cumulative social risk have overall better medical follow up and be more likely to have statin prescription for primary prevention (compared to individuals with higher CSR), hence falling in the intermediate ideal CVH category (non-ideal in our classification).

Elucidating possible role of psychosocial risk factors in mediating the association between CSR and ideal CVH is paramount, as both have been associated with adverse cardiovascular outcomes [2,11,15,23,25,42–46]. Our findings suggest that, depression, stress, and perceived discrimination together play a mediating role in the association between higher CSR and poorer ideal CVH. This finding complements existing literature that outlines associations between these psychosocial risk factors and ideal CVH [2,28,44,45,47]. Psychosocial factors, such as depression have been linked to a psychosocial model of 'the perfect storm' in cardiovascular disease, with destructive amplification of each other when both are present [26]. Our findings, within the context of

Table 3
Odds ratio of being in non-ideal category for each of the individual ideal cardiovascular health factors by levels of cumulative social risk.

Ideal CVH Factor	*CSR = 0*	*CSR = 1* *OR* (95% CI)*	*p-value*	*CSR = 2* *OR* (95% CI)*	*p-value*	*CSR ≥ 3* *OR* (95% CI)*	*p-value*
Fasting blood glucose	Ref	1.21 (0.94,1.57)	0.14	1.65 (1.24,1.94)	<0.01	1.83 (1.33,2.53)	<0.01
Blood pressure	Ref	1.20 (0.87,1.65)	0.27	2.32 (1.56,2.72)	<0.01	3.17 (1.87,5.37)	<0.01
Total cholesterol	Ref	0.79 (0.59,1.05)	0.1	0.61 (0.45,0.93)	<0.01	0.47 (0.33,0.67)	<0.01
Diet	Ref	1.62 (1.27,2.07)	<0.01	2.10 (1.58,2.38)	<0.01	2.44 (1.75,3.42)	<0.01
Physical activity	Ref	1.36 (1.03,1.79)	0.03	1.72 (1.24,2.05)	<0.01	1.77 (1.20,2.60)	<0.01
BMI	Ref	1.59 (1.19,2.12)	<0.01	2.31 (1.63,2.66)	<0.01	3.10 (1.97,4.87)	<0.01
Smoking	Ref	1.47 (1.15,1.87)	<0.01	1.77 (1.35,2.04)	<0.01	2.79 (2.01,3.87)	<0.01

*Odds Ratios are for probability of being in non-ideal category for each of the ideal CVH factors. Ideal CVH for each factor was defined as follows: fasting blood glucose: <100 mg/dL, not on glucose lowering medication; blood pressure: <120/<80 mmHg, not on blood pressure lowering medication; total cholesterol: <200 mg/dL, not on cholesterol lowering medication; diet: as defined by American Heart Association Strategic Planning Task Force and Statistics Committee[1]; physical activity: moderate intensity activity ≥150 minutes/week or vigorous intensity ≥75 minutes/week; BMI: <25 kg/m^2, smoking: never smoker or quit > 12 months ago.
CSR – cumulative social risk, *ideal CVH* – ideal cardiovascular health, *BMI* – body mass index, OR – odds ratio, CI – confidence interval, Ref – reference.

Table 4
Odds ratio of belonging to a lower category of ideal cardiovascular health achievement by level of psychosocial risk factors.

Psychosocial Risk Factors (top vs. bottom third)	*≥3 ideal CVH Factors*	*< 3 ideal CVH Factors* *OR* (95% CI)*	*p-value*
		Adjusted for age and sex	
Depression	Ref	1.51 (1.21-1.89)	<0.01
Stress	Ref	1.24 (1.00-1.54)	0.05
Perceived Discrimination	Ref	1.45 (1.16-1.80)	<0.01

Ideal CVH – ideal cardiovascular health, OR – odds ratio; CI – confidence interval, Ref – reference.
Odds ratio represents probability of belonging to category of individuals with <3 ideal CVH factors, compared to the group with ≥3 ideal CVH factors, adjusted for age and sex.

Table 5
Mediation analysis of impact of psychosocial risk on relationship between cumulative social risk and ideal cardiovascular health.

Cumulative Social Risk (CSR)	Total effect *OR* (95% CI)*	Direct effect *OR* (95% CI)*	Indirect effect *OR* (95% CI)*	Percent modified (%) *% (95% CI)*
CSR = 1	1.77 (1.41-2.22)	1.69 (1.34-2.12)	1.05 (1.05-1.05)	10.4 (8.2-17.1)
CSR = 2	2.09 (1.62-2.69)	1.96 (1.51-2.55)	1.07 (1.05-1.07)	11.9 (8.3-17.7)
CSR ≥ 3	2.67 (1.97-3.62)	2.34 (1.71-3.20)	1.14 (1.13-1.15)	19.8 (16.0-26.8)

CSR – cumulative social risk, OR – odds ratio, CI – confidence interval.
*Odds ratio represents probability of belonging to category of individuals with <3 ideal CVH factors, compared to the group with ≥3 ideal CVH factors, adjusted for age and sex.

prior literature, ultimately articulates a potential expansion of the current CSR paradigm to include these additional psychosocial risk factors. Further investigation is warranted in assessing how each of these individual factors mediate associations between CSR and ideal CVH.

Our findings have significant public health implications. Prior studies focused on cardiovascular disease have outlined the significant cost-effectiveness of primordial health strategies, such as community-based programs to improve nutrition and comprehensive smoke-free laws in public spaces, relative to public spending on cardiovascular disease risk at later stages [48]. Given the mediating effect of depression noted in this study, as well as findings from previous studies, additional primordial strategies for cardiovascular health may also include access to mental health care for vulnerable populations [26,27,47]. The CSR paradigm and its additive impact on probability of achieving ideal CVH factors, shown in this study and by others, suggest possible benefit in targeting primordial health strategies to vulnerable populations, such as communities with high rates of minority population or low income. Interventions, such as those informed by ideal CVH, may interface with built environments, and may include creation of more communal spaces and enrichment of civic life to address social isolation, eliminating food deserts and ensuring nearby access to health care for minority communities, etc. [49–51]. Our findings regarding the particularly significant effect of CSR on smoking, diet, and BMI within the ideal CVH framework supports further attention to primary and primordial public health strategies addressing these issues. In efforts to target interventions, geographic mapping of CSR could further inform resource allocation for primordial prevention strategies for cardiovascular public health.

Our study has some limitations. First, our sample from HeartSCORE is a prospective cohort of residents in a Pittsburgh metropolitan area, and therefore may not be generalizable to a broader national population. Second, we merged categories 3 and 4 of CSR to avoid low prevalence groups and provide more precise estimates of effect. Furthermore, from our findings, it is not clear whether the various components of CSR carry equal weight or if the potential effects are additive, sub-additive, or multiplicative. Future studies with a larger sample size can help assess the relative weight and interaction of each component of the CSR construct. Third, the definition of social risk can vary between studies and the current CSR construct may not be applicable in other settings. For example, our definition of race within CSR was self-reported, and was limited to Blacks as only minority group. Fourth, this study was not comprehensive in assessing all potential psychosocial risk factors that may mediate the relationship between ideal CVH and CSR such as anxiety, hostility, and goal orientation. Also, we did not account for use of pharmacologic and non-pharmacologic treatment of depression in this study. These will be important future directions for this endeavor. Fifth, we did not access other potential mediators of the association between CSR and ideal CVH, such as access to health care and adherence to medications, which could be assessed in future investigations to further elucidate the relationship between CSR and ideal CVH. Finally, we acknowledge that our model and statistical analysis may not fully account for the complexity of the true relationships between CSR, ideal CVH, and psychosocial factors.

5. Conclusion

In cross-sectional analyses of the HeartSCORE cohort, we found that increased CSR was associated with higher odds of having fewer *ideal CVH* factors. Taking the components of ideal CVH separately, higher CSR was associated with higher odds of being in 'non-ideal' category for six of the seven factors (i.e., ideal fasting blood sugar, cholesterol, BMI,

smoking status, diet, and physical activity). By contrast, for cholesterol, higher CSR was associated with higher likelihood of being in 'ideal' category. A modest amount of the effect of CSR on *ideal CVH* appeared to be mediated by psychosocial risk factors – depression, stress, and perceived discrimination. Future studies may consider assessing the utility of inclusion of mental health strategies targeting psychosocial factors such as depression in public health measures focused on optimization of cardiovascular risk factors and primordial prevention of cardiovascular disease.

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Disclosures

None declared.

CRediT authorship contribution statement

Julia Berkowitz: Conceptualization, Writing – original draft, Writing – review & editing, Visualization. **Vishal Khetpal:** Conceptualization, Writing – original draft, Writing – review & editing, Visualization. **Justin B Echouffo-Tcheugui:** Conceptualization, Methodology, Writing – review & editing. **Claudia E Bambs:** Conceptualization, Methodology, Writing – review & editing. **Aryan Aiyer:** Conceptualization, Methodology, Writing – review & editing. **Kevin E. Kip:** Conceptualization, Methodology, Writing – review & editing. **Steven E. Reis:** Conceptualization, Methodology, Writing – review & editing. **Sebhat Erqou:** Conceptualization, Methodology, Data curation, Formal analysis, Investigation, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

All authors declared no conflict of interest.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ajpc.2022.100367.

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