Full title: Association Between Cumulative Social Risk and Ideal Cardiovascular Health in US Adults: NHANES 1999-2006

Short title: Cumulative Social Risk and Ideal Cardiovascular Health

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Abstract

Background: The American Heart Association developed the Life's Simple 7 metric for defining cardiovascular health. Little is known about the association of co-occurring social risk factors on ideal cardiovascular health.

Methods: Using data on 11,467 adults aged ≥ 25 years from the National Health and Nutrition Examination Survey 1999–2006, we examined the association between cumulative social risk and ideal cardiovascular health in US adults. A cumulative risk score (range 0 to 3 or 4) was created by summing four social risk factors (low family income, low education level, minority race, and single-living status). Ideal levels for each component in Life's Simple 7 (blood pressure, cholesterol, glucose, BMI, smoking, physical activity, and diet) were used to create an ideal Life's Simple 7 score [0–1 (low), 2, 3, 4, and 5–7 (high)].

Results: Adults with low income (odds ratio [OR]=0.30, [95% CI 0.23-0.39]), low education [0.22 (0.16-0.28)], who are non-white [0.44 [0.36-0.54]) and single-living [0.79 (0.67-0.95)] were less likely to have 5-7 versus 0 ideal Life's Simple 7 scores after adjustment for age and sex. Adults were less likely to attain 5-7 versus 0 ideal Life's Simple 7 scores as exposure to the number of social risk factors increased [OR (95% CI) of 0.58(0.49-0.68); 0.27 (0.21-0.35); and 0.19 (0.14-0.27) for cumulative social risk scores of 1, 2, and 3 or 4, respectively, each versus 0].

Conclusions: US adults with an increasing number of socially risk factors, were progressively less likely to attain ideal levels of cardiovascular health factors.

Introduction

The American Heart Association (AHA) 2020 goals for cardiovascular health promotion and disease reduction [1] align closely with the concept of primordial prevention. Consistent with this mission, the AHA published a metric for assessing overall cardiovascular health in adults. This metric is comprised of 7 modifiable cardiovascular risk factors (cigarette smoking, dietary imbalance, physical inactivity, obesity, adverse blood lipids, high blood pressure, and diabetes[2]) that have been labeled Life's Simple 7 for public health messaging. According to the metric, individuals with all of these factors in the ideal range are classified as having "ideal" cardiovascular health, and others are classified as having "intermediate" or "poor" cardiovascular health depending on the levels of these factors.

While it is recognized that primordial prevention of these risk factors may be the best approach to reduce the future burden of CVD,[3, 4] public health and preventive medicine programs are typically focused on secondary and tertiary prevention strategies. To achieve primordial prevention of CVD, i.e. the prevention of the occurrence of cardiovascular risk factors, more attention is needed on the social risk factors that influence the distribution of cardiovascular risk factors[5]. Social risk factors such as low income, poor education, racial discrimination and social isolation may play an important role in shaping the context in which modifiable cardiovascular risk factors arise. However, to date, the extant literature examining CVD risk factors has mainly treated social determinants as single exposures without consideration of their cumulative effect (i.e. exposure to multiple social risk factors at the same time)[6].

We have previously shown that exposure to an increasing number of social risk factors was associated with a significantly increased risk of CVD mortality.[7] Determining the influence of cumulative social risk on ideal cardiovascular health may help identify approaches to improve cardiovascular health. The aim of the present study was to examine the association between cumulative social risk and ideal cardiovascular health utilizing data from a non-institutionalized representative sample of the U.S. population who participated in the 1999–2006 National Health and Nutrition Examination Survey (NHANES).

Methods

Study population

NHANES consists of cross-sectional, multistage, stratified, clustered probability samples of the US civilian non-institutionalized population conducted by the National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention. The NHANES analyzed in the current report were conducted in 4 waves from 1999-2006 (1999–2000, 2001–2002, 2003–2004 and 2005–2006) and the data from these waves were combined following NCHS recommendations.[8] Participants completed a household interview and underwent a clinical examination, which included blood collection. We limited the analysis to adults aged ≥ 25 years who were both interviewed and examined, and did not have prevalent CVD as defined below. All participants gave written informed consent and the NHANES study protocol was approved by the NCHS Institutional Review Board.

Social risk factors

Individual social risk factors: The four social risk factors of interest were self-reported through the household questionnaire and included low family income, low education level, minority race/ethnic group, and single-living status (as a measure of social isolation/low level of social support). Income was assessed using the poverty income ratio, which is the ratio of the midpoint of observed family income category to the official poverty threshold (scaled to family size), published annually by the US Census Bureau (Series P-60). To define low versus high family income, the poverty income ratio was dichotomized into below 1.00 (below the official definition of poverty) and 1.00 or greater (income above the poverty level) respectively. Education level was assessed as the number of years of education attended and completed, which was then dichotomized into low education (< 12 years) and high education (≥12 years). Race was defined as non-white status (i.e. Black, Mexican-American, other Hispanic, Other Race) or white status (non-Hispanic White). Single-living was defined as widowed or divorced, separated or never married, or non-single living as married or living as married. In addition to examining each individual social risk factor, we created a sum of the social risk factors present in each individual. Due to the small number of participants with 4 social risk factors, we grouped these individuals with their counterparts who had 3 social risk factors.

Life's Simple 7

The Life's Simple 7 cardiovascular health metric was adapted from the AHA metric.[1] Definitions of poor, intermediate and ideal levels for each metric of cardiovascular health including cigarette smoking, body mass index [BMI], physical activity, diet, total cholesterol, blood pressure, blood glucose are provided in Supplementary table 1. Cigarette smoking status was determined by self-report. Body weight and height were measured using standardized procedures during the study visit and BMI was calculated as weight in kilograms divided by the square of height in meters. Physical activity was assessed using the Computer-Assisted Personal Interviewing-CAPI (interviewer administered) questionnaire that assesses the frequency and duration of participation in moderate and vigorous physical activity during the past 30 days[, 8]. The weekly frequency of bouts of physical activity was calculated and the weekly number of minutes of moderate activity and the weekly number of minutes of vigorous activity were summed[9]. We used the Healthy Eating Index (HEI) score as our healthy dietary score instead of the AHA dietary criteria, which includes 3 of the 5 criteria included in the AHA healthy dietary score: fruits and vegetables, whole grains, and sodium. We had insufficient information to include sugar-sweetened beverages and fish consumption. Dietary intake was assessed using a dietary quality score, the HEI score derived on the basis of information from a single 24-hour recall questionnaire. The HEI includes 3 of the 5 primary criteria included in the AHA healthy dietary score: fruits and vegetables, whole grains, and sodium. Serum total cholesterol was measured enzymatically on a Hitachi 717 Analyzer or a Hitachi 912 Analyzer

(Roche Diagnostics, Indianapolis, IN). Up to 4 blood pressure measurements were obtained after a quiet rest in a sitting position for 5 minutes, using a mercury sphygmomanometer. The average of the last 2 measurements or the only measurement for participants who had 1 measurement were used[9]. Current use of antihypertensive medications was based on self-report. The AHA metric uses fasting plasma glucose to determine hyperglycemia, however we used hemoglobin A_{1C} (HbA_{1C}) concentrations to maximize our sample size because, by design, many NHANES participants did not have fasting blood samples. For each participant, we summed the number of ideal Life's Simple 7 components. The total Life's Simple 7 score range could range from 0 to 7 and was categorized as 0–1, 2, 3, 4, and 5–7. Higher scores indicate a better cardiovascular health profile. Participants with 0 or 1 ideal Life's Simple 7 components were grouped as were participants with 5, 6, or 7 ideal Life's Simple 7 components, due to small sample sizes in these categories.

Statistical methods

Of the 16,310 participants aged 25 years or older without prevalent CVD (defined as a self-reported history of stroke, myocardial infarction or heart failure), we excluded those with missing information on one or more Life's Simple 7 components (n=4,274). We further excluded participants with missing data on the poverty index ratio (n=981), educational level (n=10) and single-living status (n=308). After these exclusions, a final sample of 11,467 (70.3% of the eligible sample) participants were included in our analysis. Those excluded due to missing information were less likely to be male (41.0% vs. 49.4%; $p<0.001$), and more likely to have low family income (20.0% vs. 15.4%; $p<0.001$), belong to a minority race/ethnic group (55.5% vs. 47.9%; $p<0.001$), have low education (35.1% vs. 28.6%; $p<0.001$), live as a single person (39.8% vs. 33.2%; $p<0.001$) and have a lower median Life's Simple 7 total score (14 vs. 15; $p=0.0001$).

Baseline characteristics of included participants were calculated. Age-sex adjusted odds ratios (OR) and 95% Confidence Intervals (CI) of each of Life's Simple 7 component (poor, intermediate, and ideal) were calculated for each social risk factor (low family income, low education, non-white status, single living status) using multinomial logistic regression. Multinomial logistic regression was used to estimate age-sex adjusted OR and 95% CI for the associations between individual social risk factors and ideal Life's Simple 7 scores (2, 3, 4, and 5-7 versus 0-1). Age-sex adjusted odds ratios and 95% CI for higher ideal Life's Simple 7 scores (2, 3, 4, and 5-7 versus 0-1) by cumulative social risk score (1, 2, and 3 or 4 each versus 0) were also estimated using multinomial logistic regression. We tested if the cumulative social risk score was associated with ideal Life's Simple 7 scores independent of each individual social risk factor. To do so, we created models that included a continuous variable for cumulative social risk score and each individual social risk factor, and assessed whether the variable for cumulative social risk remained statistically significant. All analyses were conducted using Stata version 11.0 (College Station, TX: StataCorp LP) accounting for complex sampling design of NHANES. Weights were applied to all analyses to generate US population estimates.

Results

The characteristics of participants are presented in Table 1. The median age of participants was 48 years (25^{th} – 75^{th} percentiles: 37-64 years), and approximately 48.8% were males. The percentage of the population with social risk factors ranged from 10.2% (low family income) to 30.0% (single-living). A total of 31.5% of participants reported one social risk factor; 14.6% reported 2 and 7.0% reported three or four social risk factors. Also, 17.3% of the population had 0-1 ideal health metrics and 13.0% of participants had 5-7 ideal health metrics.

After age-sex adjustment, participants with low family income compared to those with high family income, were less likely to have ideal levels of smoking, physical activity, and HbA_{1c} (Table 2). Participants with low compared with high education were less likely to have ideal levels for smoking, physical activity, blood pressure and HbA_{1c} (each $p<0.001$). Non-white compared to white participants were less likely to have ideal levels for BMI, physical activity, diet, blood pressure and HBA_{1c} but more likely to have ideal levels of smoking and cholesterol. Participants living as a single person compared to those not single-living were less likely to have ideal levels for smoking, and blood pressure.

Table 3 shows the odds ratios (95% CI) of ideal Life's Simple 7 scores for each individual social risk factor after adjustment for age and sex Participants with low versus high income, low versus high education, non-white versus white race, and single-living versus not single-living, had an increasingly lower odds of obtaining higher ideal Life's Simple 7 scores (all p-values < 0.01).

Table 4 shows odds ratios (95% CI) for ideal Life's Simple 7 scores associated with exposure to cumulative social risk after adjustment for age and sex. Participants with a greater number of social risk factors were significantly less likely to have higher ideal Life's Simple 7 scores. When we controlled for each one of the individual social risk factors, the cumulative effects of social risk factors on the ideal Life's Simple 7 scores remained significant (data not shown).

Discussion

This study demonstrated that US adults who were socially disadvantaged were less likely to attain ideal levels of several components of the American Heart Association's Life's Simple 7. As exposure to the number of social risk factors increased, individuals were less likely to attain ideal levels of cardiovascular health behaviors and factors assessed using the Life's Simple 7 metric. These findings highlight the importance of accounting for multiple social risk factors in examining associations between social risk factors and ideal cardiovascular health in the general population.

Social disadvantage, primarily using single indicators of socioeconomic status, have been previously shown to be associated with differences in the presence of CVD risk factors[10-12] and recently including cardiovascular health[13-15]. Using population-based cross-sectional data from the US, Fang et al demonstrated that those with a lower educational level had lower ideal cardiovascular health scores[13]. Using data from six cross-sectional studies between 1978–2006 in Denmark, Olsen et al showed that while the proportion of women with ideal cardiovascular health increased from 2% in 1978 to 13% in 2006 there was a 5-fold difference in 2006 between the highest and lowest educated women. Similarly, in a population-based cross-sectional study in Bosnia and Herzegovina, Jankovic et al demonstrated that adults with low or medium education level had significantly lower number of ideal cardiovascular health metrics[14]. However, social risk factors originating from an individual's environment are seldom singular experiences[16, 17] and we have shown that cumulative social risk measures may better represent social disadvantage than do single indicators. Comparative cross-national research is needed to ascertain whether the association between cumulative social risk exposure and ideal cardiovascular health is generalizable outside of the US.

The major strength of our study is the use of data from a large nationally representative sample of US adults to examine cumulative social risk and ideal cardiovascular health. However, there are several limitations to the current analysis. First, the current analysis utilized a cross-sectional design, which prevents the confirmation of a temporal association between cumulative social risk and ideal cardiovascular health. Second, the distribution of social risk factors and ideal Life's score may be different now. However, given the persistence of social disparities in health including cardiovascular disease[6, 18-20], we would therefore expect that the findings in a more contemporary sample would still show that adults with exposure to multiple social risk factors are less likely to attain higher ideal Life's Simple 7 scores. Third, we opted to include the social risk factors in the cumulative social risk score unweighted and thus make no assumptions about the relative strength of association between different social risk factors and Life's Simple 7 scores. Different weights could end up being proposed for different health behaviors/factors for the same components. Also, specific weights could be given based on specific datasets. Thus, it is not certain that weights derived from this dataset would be generalizable to another dataset**.** In this study, what was shown to be important was the quantity not the quality of social risk factor exposures. Another assumption was that components of the cumulative social risk metric have no temporal order. Social risks may form chains of sequential social risks and thus tend to occur together or social risks may more follow one another sequentially but risk of health behaviors or biological factors are not increased until the effect of the final exposure in the chain ("trigger effect")[21]. Chronicity of exposure to social risk factors in adulthood are also ignored in the cumulative social risk metric, and may also be important for influencing later cardiovascular health. Future research might overcome some of the aforementioned concerns, by collecting data on the age of when the adult was exposed to a specific social risk factor and whether exposure to the social risk factor continues. Fourth, those with missing information were more likely to have low family income, belong to a minority race/ethnic group, have low education, be single living and have a lower median Life's Simple 7 total score. Thus the current findings are probably underestimates of the true magnitude of the association between cumulative social risk and ideal cardiovascular health. Finally, we also acknowledge the possibility that residual confounding may attenuate the strong ORs estimates in this study.

Our results have possible policy implications. Link et al. posited that CVD risk factors and their accumulation are the expression of fundamental causes linked to one's position in the social structure [22]. Low socioeconomic position, having a low level of education, being of a minority racial/ethnic group, and being socially isolated are social risk factors that are associated with CVD risk factors, and may best be addressed through primordial prevention. However, current CVD prevention policies/strategies lack emphasis on primordial prevention[4, 23]. One reason for this might be that addressing social risk factors lacks quick and easy solutions[24]. Programs that improve access to education and employment (thus raising income and lifting families out of poverty), prevent (or mitigate) personal experiences of discrimination, institutional racism, and internalized racism, or mobilize local resources to offer social support can be instrumental to primordial prevention of CVD. While this is outside the realm of typical clinical practice, at a minimum, appreciation that multiple social factors can influence ideal cardiovascular health may help clinicians develop and implement more effective lifestyle management plans[25]. Clinical and public health practitioners can also respond to socially disadvantaged people's social needs through improved referral capacity to social services or other appropriate community-based resources [26].

A recent study indicated that the AHA 2020 target of improving cardiovascular health by 20% by 2020 will not be reached, partly because current policies prioritize secondary CVD preventative measures [27]. Evaluating the cost-effectiveness of primordial prevention programs targeting social risk factors are challenging, as some programs may need to start early in the life course. The time horizon to clinical cardiovascular disease events would therefore be long and while costs may accrue in the present the benefit may become apparent only in the distant future.

While no single prevention approach can fulfill the AHA goal to improve cardiovascular health by 2020, if the role of cumulative social risk exposure is not sufficiently addressed in the pursuit of ideal cardiovascular health, social disparities in cardiovascular health may persist.

In summary, achieving ideal levels of several cardiovascular health behaviors and factors was less likely in socially disadvantaged US adults. In addition, as the exposure to the number of social risk factors increased, US adults were increasingly less likely to achieve ideal levels of cardiovascular health. These findings underscore the need for sufficient resources and appropriate approaches to address multiple social risk exposure among socially disadvantaged adults. These results should inform the AHA's efforts to promote primordial prevention in order to achieve its 2020 goals to reduce the burden of CVD. Given the number and magnitude of social risk factors faced by US adults, simply addressing one particular social risk factor may not fully support adults achieving ideal cardiovascular health.

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Table 1. Characteristics of Adults 20 years and older in NHANES 1999-2006 without prevalent cardiovascular disease

Characteristic	
Age, median (25^{th} – 75^{th} percentiles) years	48 (37-64)
Sex	
Male, n (%)	5668 (48.8)
Female, n (%)	5799 (51.2)
Individual social risk factors	
Low family income, n (%)	1769 (10.2)
Low education level, n (%)	3279 (17.1)
Minority Race, n (%)	5488 (25.8)
Single-living, n (%)	3803 (30.0)
Number of Social Risk factors	
0, n (%)	3507 (46.9)
1, n (%)	3606 (31.5)
2, n (%)	2673 (14.6)
3 or 4, n (%)	1681 (7.0)
Mean physically active, min/wk (95% CI)[†]	424.6 (398.4-450.8)
Mean Healthy Eating Index Score, % (95% CI)[†]	49.1 (48.7-49.5)
Mean total cholesterol, mg/dL (95% CI)[†]	205.0 (203.7-206.3)
Mean systolic blood pressure, mm Hg (95% CI)[†]	122.9 (122.3-123.5)
Mean diastolic blood pressure, mm Hg (95% CI)[†]	72.4 (72.0-72.8)
Ideal Life's Simple 7 score categories[‡]	
0-1	2429 (17.3)
2	2884 (24.1)
3	2970 (26.3)
4	2019 (19.3)
5-7	1165 (13.0)
Life's Simple 7 Score (7-21), median (interquartile range)[§]	15 (13-16)

Abbreviations: 95% CI, 95% Confidence Intervals

Prevalence estimates are weighted

[‡]A value of 1 was assigned for each Life's 7 component if the criterion for ideal cardiovascular health was met (supplement table 1). A value of 0 was assigned if the criterion was not met. The total score range was thus 0-7, categorized as 0–1, 2, 3, 4, and 5–7.

[§]Each Life's Simple 7 component was also assigned a score of 1, 2, or 3 points to represent poor, intermediate, or ideal health, respectively (supplement table 1). The points were summed such that the total Life's Simple 7 score could range from 7 (all components poor) to 21 (all components ideal).

Table 2. Odds ratios for Life's Simple 7 components associated with individual social risk factors among 1999-2006 NHANES participants†

Components	**Low Family Income**	**Low Educational Level**	**Non-white**	**Single-living**
	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)	Odds ratio (95% CI)
Smoking				
Poor	Ref	Ref	Ref	Ref
Intermediate	0.36 (0.30-0.44)	0.45 (0.37-0.54)	0.80 (0.67-0.96)	0.46 (0.39-0.54)
Ideal	0.45 (0.38-0.53)	0.47 (0.41-0.54)	1.21 (1.03-1.42)	0.56 (0.49-0.64)
Body mass Index				
Poor	Ref	Ref	Ref	Ref
Intermediate	0.85 (0.71-1.02)	0.96 (0.86-1.07)	0.99 (0.89-1.11)	0.93 (0.82-1.06)
Ideal	0.87 (0.73-1.04)	0.86 (0.74-1.01)	0.72 (0.63-0.83)	1.11 (0.99-1.25)
Physical Activity				
Poor	Ref	Ref	Ref	Ref
Intermediate	0.45 (0.37-0.53)	0.96 (0.86-1.07)	0.99 (0.89-1.11)	0.93 (0.82-1.06)
Ideal	0.32 (0.27-0.38)	0.86 (0.73-1.01)	0.72 (0.63-0.83)	1.11 (0.99-1.25)
Diet				
Poor	Ref	Ref	Ref	Ref
Intermediate	0.83 (0.74-0.94)	0.82 (0.74-0.91)	1.16 (1.05-1.27)	0.84 (0.75-0.94)
Ideal	0.81 (0.10-6.48)	0.40 (0.10-1.61)	0.14 (0.03-0.63)	0.39 (0.10-1.56)
Cholesterol				
Poor	Ref	Ref	Ref	Ref
Intermediate	0.83 (0.71-0.97)	0.87 (0.76-1.00)	1.05 (0.93-1.20)	0.87 (0.76-1.00)
Ideal	0.90 (0.77-1.06)	1.00 (0.86-1.16)	1.22 (1.06-1.39)	0.96 (0.83-1.12)
Blood Pressure				
Poor	Ref	Ref	Ref	Ref
Intermediate	0.77 (0.62- 0.97)	0.77 (0.67-0.88)	0.69 (0.62-0.77)	0.78 (0.69-0.89)
Ideal	0.83 (0.67-1.02)	0.70 (0.61-0.81)	0.63 (0.54-0.73)	0.72 (0.62-0.83)
Hemoglobin A_{1c}				
Poor	Ref	Ref	Ref	Ref
Intermediate	0.61 (0.45-0.82)	0.70 (0.55-0.88)	0.76 (0.60-0.95)	0.89 (0.73-1.09)
Ideal	0.42 (0.33-0.53)	0.44 (0.36-0.53)	0.28 (0.23-0.35)	0.83 (0.67-1.03)

†CI – confidence interval. Odds ratios are adjusted for age and sex

Table 3. Odds ratios for ideal Life's Simple 7 scores associated with individual social risk factors among 1999-2006 NHANES participants†

Ideal Life's Simple 7 scores	Low Family Income	Low Educational Level	Non-white	Single-living
0-1	Ref	Ref	Ref	Ref
2	0.75 (0.60-0.94)	0.68 (0.59-0.77)	0.76 (0.67-0.86)	1.04 (0.89-1.20)
3	0.69 (0.57-0.84)	0.59 (0.52-0.67)	0.74 (0.62-0.88)	0.99 (0.84-1.16)
4	0.56 (0.45-0.69)	0.44 (0.36-0.53)	0.63 (0.52-0.75)	0.90 (0.74-1.09)
5-7	0.30 (0.23-0.39)	0.22 (0.16-0.28)	0.44 (0.36-0.54)	0.79 (0.68-0.95)
p value	<0.001	<0.001	<0.001	0.012

†Data in table are odds ratio (95% confidence interval). Odds ratios are adjusted for age and sex

Table 4. Odds ratios for ideal Life's Simple 7 scores associated with cumulative social risk score among 1999-2006 NHANES participants

	Number of social risk factors†		
Ideal Life Simple 7 scores	1	2	3 or 4
0-1 (ref)	1 (reference)	1 (reference)	1 (reference)
2	0.80 (0.69-0.93)	0.68 (0.57-0.82)	0.71 (0.57-0.89)
3	0.79 (0.67-0.93)	0.63 (0.52-0.77)	0.61 (0.48-0.78)
4	0.68 (0.56-0.83)	0.47 (0.36-0.60)	0.44 (0.33-0.57)
5-7	0.58 (0.49-0.68)	0.27 (0.21-0.35)	0.19 (0.14-0.27)

† Data in table are odds ratio (95% confidence interval). Odds ratios are adjusted for age and sex.

The reference group consists of adults with no social risk factors.