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Original Research

# The role of traditional risk factors in explaining the social disparities in cardiovascular death: The national health and Nutrition Examination Survey III (NHANES III)

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ABSTRACT

*Objective:* — To assess the role of traditional risk factors in explaining the association between cumulative social risk exposure and disparities in CVD death among US adults.
*Methods:* — The study included 15,906 participants from the Third National Health and Nutrition Examination Survey III who were CVD-free at enrollment. Baseline social risk factors (minority race, poverty-income ratio<1, education<12 grade, and living single) were used to create a cumulative social risk score (0 to ≥3). CVD death served as the primary outcome. We assessed the contribution of each major CVD risk factor to the link between cumulative social risk exposure and CVD death.
*Results:* — During a median follow-up of 14 years, 1309 CVD deaths occurred. Participants with elevated cumulative social risk score were at increased risk of CVD death, with hazard ratio 1.19(95%CI 1.01–1.41), 1.52(95%CI 1.28–1.79), and 1.46 (95%CI 1.23–1.74) in individuals with score 1, 2 and ≥ 3 respectively, compared with individuals with score of 0. Traditional CVD risk factors explained about one third of the disparities in CVD death in individuals with the elevated social risk exposure. Among the one third effect by combined CVD risk factors, current smoking contributed the largest proportion, accounting for approximately one half of the combined risk factors effect, followed by obesity and diabetes.
*Conclusions:* —Among the traditional risk factors, control of smoking appears to be the greatest opportunity to attenuate the social disparities in CVD death. While these findings call for further studies to identify other pathways that explain the elevated CVD mortality in socially disadvantaged population.

## 1. Introduction

Although mortality from cardiovascular disease (CVD) in the US has been declining in the past decades, CVD remains number one cause of death in the US and globally, accounting for about 17.6 million deaths worldwide [1]. Between 2014 and 2015, direct and indirect costs of CVD were $351.2 billion in the United States alone, which underscore the economic burden of CVD [2].

The influence of social risk factors such as socioeconomic status, race/ethnicity, residential status and social support on incidence, management and outcomes of CVD has been well documented since over a decade ago [3–8]. Associations between cumulative social risk and poorer CVD health and death have been re-demonstrated in recent studies [9,10]. As recommended by the American Heart Association (AHA)'s scientific statement, the next greatest opportunities to improve CVD health and outcomes in the United States are to attenuate or eliminate the adverse influence of social determinants on CVD health [11]. While higher cumulative social risk has been associated with higher risk of CVD death,

*Abbreviations:* AHA, American Heart Association; ACC, American College of Cardiology; BP, blood pressure; CI, confidence interval; CVD, cardiovascular disease; DM, diabetes mellitus; HbA1c, hemoglobin A1c (glycosylated hemoglobin); HLD, hyperlipidemia; HTN, hypertension; NHANES III, National Health and Nutrition Examination Survey III.

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little is known on how much the traditional CVD risk factors (smoking, hypertension, hyperlipidemia, diabetes and obesity) explained the influence of social determinants on CVD outcome. To develop most effective strategies to attenuate or eliminate the social disparities in CVD death, it is important to better understand the contribution of traditional CVD risk factors to the risk of CVD death in socially disadvantaged population. Here we assessed the contribution of traditional CVD risk factors to the CVD death in people with cumulative social risk exposure (Fig. 1 Conceptual illustration).

## 2. Methods

### 2.1. Study populations

The NHANES is a survey program first initiated in the early 1960s with the mission to assess the health and nutritional status of children and adults in the United States. The survey collects data from a nationally representative sample of about 5000 people each year, of which demographic, socioeconomic, dietary and health-related information are also collected by interviews. Essential vitals (e.g. height, weight and blood pressure) are measured by physical exam and physiological markers by laboratory tests. The NHANES III was approved by the National Center for Health Statistics (NCHS) Research Ethics Review Board (ERB), and documented consent was obtained from participants, the survey was conducted between 1988 and 1994. The detailed design and operational process of NHANES III survey was published previously [12]. This analysis included 15,906 participants from the NHANES III who were free of prior CVD (coronary heart disease, heart failure, and stroke) at enrollment.

### 2.2. Measurements of demographics, social risk and traditional CVD risk factors

Age, gender, race/ethnicity, income, educational levels, and smoking status were self-reported and collected by questionnaire [12]. Minority race included blacks and Mexican-American populations. Income was estimated by poverty income ratio which is the ratio of the midpoint of observed family income category to the official poverty threshold (scaled to family size). Low family income was defined as a ratio below 1. Low educational level was defined as education <12 grade. Single living status reflecting social isolation was defined as never married, separated, divorced, widowed or married with spouse not in house hold. A cumulative social risk score (0 to ≥3) was calculated by the numbers of baseline social risk factors (minority race, poverty-income ratio<1, education<12 grade, and living single).

Blood pressure (mmHg) was measured during in-home interview and at medical examination center (MEC) and the average of these blood pressure readings was used for the analysis. Serum total cholesterol, triglycerides and fasting glucose levels were measured by laboratory test as specified by the National Center for Health Statistics [12]. Hypertension was defined as systolic blood pressure ≥130 mm Hg, or diastolic blood pressure ≥85, or the use of antihypertensive medications. Dyslipidemia was defined as serum total cholesterol ≥200 mg/ml or HbA1c ≥ 6.5% or HbA1c ≥ 6.5% or triglycerides ≥150 mg/ml or use of cholesterol medications. Diabetes was defined as fasting blood glucose level ≥126 mg/ml or use of antidiabetic medications. Body mass index (BMI) was calculated from height and weight measured during physical exam. Obesity was defined as BMI ≥30 kg/m$^2$. Current smoking status was classified by self-report using the tobacco-use questionnaire during household interview.

### 2.3. Mortality assessment

The NHANES III participants were followed up for mortality through December 31, 2006. CVD mortality was the primary interest of outcome in the current study for which the probabilistic matching method was used to link NHANES III participants with the National Death Index for vital status and the cause of death in deceased patients. Name, social security number, and date of birth were parts of 12 identifiers used for matching. The follow-up duration was defined as the period between initial examination for NHANES III participation and December 31, 2006, or date of death, whichever occurred first.

### 2.4. Statistical analysis

Baseline characteristics were tabulated across the four social risk score categories (0 to ≥3). Continuous variables were presented as the mean ± standard deviation (SD) and categorical variables were reported as frequency and percentage.

Cox proportional hazard analysis was used to assess the influence of cumulative social risk score on CVD mortality, adjusted for demographics. To further assess the contribution by traditional CVD risk factors, the demographics-adjusted model was additionally adjusted for all CVD risk factors and each individual risk factor (hypertension, diabetes, obesity, current smoking and dyslipidemia). The contribution of each risk factor to the total explanation by all risk factors was then calculated by the magnitude of attenuation in the hazard ratio after addition of individual risk factor divided by the magnitude of attenuation in the hazard ratio after addition of combined risk factors model to the

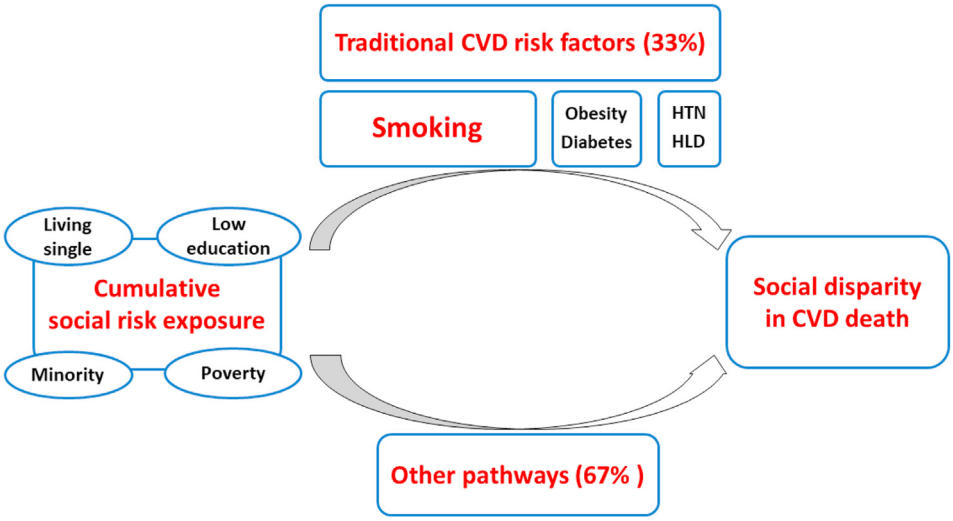


**Fig. 1.** Conceptual Illustration: the contribution of traditional CVD risk factors to CVD death in population with elevated cumulative social risk exposure.

demographics model. Similar analysis method was described in previous publication [13]. Calculation equation used in the current study:

$$\text{contribution } (\%) = \frac{\text{Attenuation of hazard ratio by addition of individual factor to demographic model}}{\text{Attenuation of hazard ratio by addition of all CVD risk factors to demographic model}} \times 100\%$$

All statistical analyses were performed by using SAS version 9.4 (SAS Institute Inc, Cary, NC) and statistical significance was defined by 2-sided p values less than 0.05.

## 3. Results

### 3.1. Baseline characteristics

This analysis included 15,906 participants with average age 45.6 ± 19.5 years, 53.4% women, 57.7% minority race. Among the four groups of cumulative social risk score (0, 1, 2, ≥3), participants with higher social risk score tend to be younger, have higher percentage of women and current smoker, and have higher prevalence of obesity and diabetes (Table 1).

**Table 1**
Baseline characteristics of the study participants.

| Characteristics | All participants (n = 15,906) | Participants stratified by Social Risk Score levels | | | |
|---|---|---|---|---|---|
| | | 0 (n = 3170) | 1 (n = 4685) | 2 (n = 4339) | ≥3 (n = 3712) |
| Age (years) | 45.6 ± 19.5 | 48.7 ± 16.5 | 47.1 ± 19.5 | 43.9 ± 19.9 | 43.3 ± 20.6 |
| Women | 8498 (53.4%) | 1646 (51.9%) | 2449 (52.2%) | 2279 (52.5%) | 2124 (57.2%) |
| Obesity | 3571 (22.4%) | 588 (18.5%) | 1056 (22.5%) | 1010 (23.2%) | 917 (24.7%) |
| Systolic Blood Pressure (mm Hg) | 124.7 ± 19.8 | 123.9 ± 18.1 | 125.4 ± 19.7 | 124.7 ± 19.9 | 124.7 ± 21.0 |
| Diastolic Blood Pressure (mm Hg) | 74.1 ± 10.9 | 75.0 ± 9.7 | 74.5 ± 10.8 | 74.0 ± 11.0 | 73.1 ± 11.7 |
| Antihypertensive medications (%) | 1394 (8.7%) | 314 (9.9%) | 464 (9.9%) | 330 (7.6%) | 286 (7.7%) |
| Diabetes mellitus (%) | 973 (6.1%) | 136 (4.2%) | 262 (5.5%) | 264 (6.0%) | 311 (8.3%) |
| Anti-diabetic medications (%) | 457 (2.8%) | 60 (1.8%) | 116 (2.4%) | 133 (3.0%) | 148 (3.9%) |
| Total Cholesterol (mg/dl) | 203.1 ± 44.4 | 209.2 ± 41.1 | 205.2 ± 45.5 | 201.1 ± 45.2 | 198.1 ± 46.2 |
| Serum Triglycerides (mg/dl) | 140.0 ± 111.8 | 147.2 ± 117.3 | 142.4 ± 120.5 | 136.3 ± 104.3 | 137.3 ± 104.6 |
| Lipid lowering medications (%) | 192 (1.2%) | 64 (2.0%) | 66 (1.4%) | 38 (0.8%) | 24 (0.6%) |
| Current smoking (%) | 4182 (26.2%) | 703 (22.1%) | 1155 (24.6%) | 1160 (26.7%) | 1164 (31.3%) |
| Social Risk score components | | | | | |
| Minority Race | 9190 (57.7%) | 0 (0.0%) | 2207 (47.1%) | 3471 (80.0%) | 3512 (94.6%) |
| Poverty-income ratio <1 | 3689 (23.1%) | 0 (0%) | 117 (2.5%) | 701 (16.1%) | 2871 (77.3%) |
| Education <12 grade | 6125 (38.5%) | 0 (0%) | 946 (20.1%) | 2117 (48.7%) | 3062 (82.4%) |
| Living single | 6482 (40.7%) | 0 (0%) | 1415 (30.2%) | 2389 (55.0%) | 2678 (72.1%) |

### 3.2. Total contribution by CVD risk factors to social disparities of CVD death

During a median follow up of 14 years, 1309 CVD deaths occurred. As shown in Table 2, presence of more social risk factors was associated with greater risk of CVD death. The risk of CVD death in demographic adjusted model was attenuated by 31%, 21% and 37% in people with social risk score 1, 2, and ≥3 versus 0, respectively, after further adjustment for traditional CVD risk factors (Table 2).

### 3.3. Contribution of individual CVD risk factor to social disparities of CVD death

Among all CVD risk factors included in the analysis, current smoking was the most powerful contributing factor, accounting for approximately one half of the combined risk factor effect (53%, 63% and 66% in participants with social risk score ≥3, 2 and 1 respectively), followed by obesity and diabetes which explained 16–18% of risk across social risk categories 1 to ≥3. Hypertension explained 9% and 5% of the elevated risk of CVD death in people with social risk score 2 and ≥ 3, respectively (Table 3).

## 4. Discussion

Addressing the role of social determinants of CVD outcome represents the greatest opportunity to reduce CVD death and to achieve the AHA 2020 Impact Goals [11]. Since many of the fundamental components of an environment with high cumulative social risk exposure are not readily fixable, the recovery process of a disadvantaged social structure may take decades or generations. Meanwhile, we have effective tools and prior experience with success in controlling major traditional CVD risk factors including smoking, HTN, hyperlipidemia, diabetes and obesity. An alternative strategy is to intervene the modifiable pathways which explain the poorer CVD outcome in population with higher social risk exposure. Hence, in order to develop most effective strategies to attenuate or eliminate the adverse social influence, it is important to better understand the contribution of the major modifiable CVD risk factors to the link between social risk exposure and poorer CVD death. First, stratification by cumulative social risk score will provide us information about which particular CVD risk factors are more prevalent in certain socially disadvantaged population. For example, in analysis not stratifying social risk, hypertension had highest overall adjusted population attributable fraction for CVD mortality (40.6%), followed by smoking (13.7%), poor diet (13.2%), physical inactivity (11.9%) and abnormal glucose level (8.8%) [14]. While the strength of contributions could vary in socially disadvantaged population, in the current study, higher prevalence of obesity, diabetes and current smoking, but not hypertension or dyslipidemia were observed in people with higher social risk score. Although participants with higher social risk score include blacks who usually have a disproportionate increase in blood pressure and its risk factors, it is unclear why increased hypertension was not observed in people with higher social risk score. This observation may need further study. Second, it is important to quantify the contributing proportions of each risk factor in the influential pathways connecting social disadvantage toward poorer outcome. A previous study by Redondo-Bravo et al. showed that lower educational attainment was associated with increased risk of subclinical atherosclerosis and approximately 65% of risk was mediated by smoking [15]. More importantly, here we assessed the

**Table 2**
The contribution to social disparities of CVD death by all CVD risk factors.

| Group | Cumulative social risk score | Events/ participants(n) | Contribution by Traditional CVD Risk Factors HR (95% CI) | | |
|---|---|---|---|---|---|
| | | | Demographic model | Demographic model + all CVD risk factors | % decrease in HR comparing all CVD risk factor model to demographic Model[a] |
| **All Participants** | **0** | 218/3170 (6.8%) | *Reference* | *Reference* | *N/A* |
| | **1** | 395/4685 (8.4%) | 1.19 (1.01–1.41) | 1.13 (0.96–1.34) | 31% |
| | **2** | 375/4339 (8.6%) | 1.52 (1.28–1.79) | 1.41 (1.19–1.67) | 21% |
| | **≥3** | 321/3712 (8.6%) | 1.46 (1.23–1.74) | 1.29 (1.08–1.54) | 37% |

Calculation equation.

$$\%\ \text{of contribution} = \frac{\text{Attenuation of hazard ratio by addition all CVD risk factors to demographic model}}{\text{Hazard ratio by demographic model} - 1.00} \times 100\%$$

For example, contribution of combined CVD risk factors in group with social risk score 3 $= \frac{1.46 - 1.29}{1.46 - 1.00} \times 100\% = 37\%$.

[a] The contribution by all CVD risk factor is assessed by estimating the magnitude of attenuation in the HR after addition of all CVD risk factor model to demographic model [13].

proportion of each CVD risk factors in contributing to the social disparities of CVD outcome, and have found that among the traditional CVD risk factors, current smoking plays the major role in explaining the adverse social influence on CVD death. These findings suggest that developing stronger and more effective antismoking measures could be the next greatest opportunity to reduce CVD death in population with high cumulative social risk exposure.

CVD health has been most commonly assessed by the AHA's Life's Simple 7 metrics which is comprised of four health behavior factors (nonsmoking, physical activity, diet and BMI<25 kg/m$^2$) and three medical risk factors (total cholesterol<200 mg/dL, untreated BP < 120/80 mmHg and fasting blood glucose<100 mg/dL). The association between number of ideal CVD health metrics and CVD mortality has been well demonstrated [14,16–18]. About 47% of the decline in the CVD mortality in the recent decades is explained by advancement of medical therapy and secondary prevention, and approximately another 44% is explained by reductions of CVD risk factors [19]. According to the AHA's 2019 update on CVD statistics, over half of US children had ≤4 ideal CVD health metrics (less than 1% met all 7), and 62% of US adults had ≤ 3 ideal CVD health metrics (0% met all 7), from 2013 to 2014 [1]. Meanwhile, increasing evidence suggests that the advances in prevention and therapies have not been equally benefiting populations across different socioeconomic status in the United States. In a study of 11,467 adults aged ≥25 years from the NHANES 1999–2006, individuals with higher cumulative social risk scores (defined by low income, low education, non-white ethnicity, and single-living) were much less likely to achieve 5 or more ideal CVD health components in the Life's Simple 7 [9]. Analysis of 14,162 middle-aged adults in ARIC (Atherosclerosis Risk in Communities Study) showed the African Americans were almost twice more likely to have 2 or more elevated risk factors (hypertension, cholesterol, diabetes and smoking) compared with whites [5]. In the current study, we observed higher prevalence of obesity, diabetes and current smoking among people with higher cumulative social risk score. Analysis of NHANES III data showed associations of higher cumulative social risk score with increased CVD mortality, with hazard ratio of 1.15 (95%CI 0.88–1.49), 1.34(95%CI 0.97–1.85) and 1.64 (95%CI 1.18–2.28) in people with social risk score of 1, 2 or ≥3 respectively [20]. We consistently observed significantly increased risk of CVD death for people with one or more cumulative social risk score in the current study. And better control of smoking, followed by obesity and diabetes represent the greatest opportunities to attenuate this social disparities in CVD death.

As a leading cause of preventable death globally, tobacco use was estimated to account for 7.1 millions deaths worldwide in 2016 [1]. Overall mortality is 3 times higher among US smokers than that for never-smokers [6]. Smoking is not only an independent risk factor for CVD but also appears to have a multiplicative effect with the other traditional CVD risk factors [21]. Increase in CVD risk is observed in all versions of tobacco exposure including cigarette smoke, secondhand smoke, cigar smoking as well as e-cigarette [22,23]. A study of 279,559 participants aged 25 years or older has recently examined the association between smoking disparities and social disadvantages, where cumulative disadvantage index (0–6) was comprised of self-reported past-year unemployment, income below the federal poverty line, education less than high school, disability/limited physical function, serious psychological distress, and heavy drinking. The results showed successively higher odds of current smoking with each additional social disadvantage [24].

**Table 3**
The contribution of each CVD risk factor to the total effect by all CVD risk factors on social disparities of CVD death.

| Variable | Cumulative Social Risk Scores | | | | | |
|---|---|---|---|---|---|---|
| | 1 | | 2 | | ≥3 | |
| | Hazard ratio (95% CI) | Proportion attributable to Factor % | Hazard ratio (95% CI) | Proportion attributable to Factor % | Hazard ratio (95% CI) | Proportion attributable to Factor (%) |
| Demographic Model | 1.19 (1.01–1.41) | | 1.52 (1.28–1.79) | | 1.46 (1.23–1.74) | |
| All CVD risk factor model | 1.13 (0.96–1.34) | | 1.41 (1.19–1.67) | | 1.29 (1.08–1.54) | |
| Addition of each risk factor to the demographic model | | | | | | |
| Hypertension | 1.19 (1.01–1.40) | 0% | 1.51 (1.27–1.78) | 9% | 1.45 (1.22–1.73) | 5% |
| Diabetes | 1.18 (1.00–1.40) | 16% | 1.50 (1.26–1.77) | 18% | 1.43 (1.20–1.70) | 17% |
| Obesity | 1.18 (1.00–1.40) | 16% | 1.50 (1.27–1.78) | 18% | 1.43 (1.20–1.71) | 17% |
| Current smoking | 1.15 (0.98–1.36) | 66% | 1.45 (1.23–1.72) | 63% | 1.37 (1.15–1.63) | 53% |
| Dyslipidemia | 1.19 (1.01–1.41) | 0% | 1.52 (1.28–1.79) | 0% | 1.46 (1.23–1.74) | 0% |

The contribution of each risk factor to the total effect by all CVD risk factors was calculated by the attenuation in the hazard ratio after addition of individual risk factor divided by the attenuation in the hazard ratio after addition of all CVD risk factors model to the demographics model [13].

Calculation equation: $\%\ \text{of contribution} = \frac{\text{Attenuation of hazard ratio by addition of individual factor to demographic model}}{\text{Attenuation of hazard ratio by addition of all CVD risk factors to demographic model}} \times 100\%$

For example, contribution of smoking in group with social risk score 3, the % of contribution $= \frac{1.46 - 1.37}{1.46 - 1.29}$ x $100\% = 53\%$.

With the implementation of multiple tobacco control policies and systems-level regulations, tobacco use in the United States has been declining, with the percentage of smoking declined from 13% in 2002 to 3.4% in 2016 in adolescents, 51% in 1965 to 16.7% in 2015 in males and 34%–13.6% in females [25]. However, such marked reduction in smoking prevalence in the past decade was mostly driven by the improvement among people with 1 or no social disadvantage. The smoking disparities in socially disadvantaged population could be from a combination of less access to tobacco regulatory efforts and antismoking measures being less effective in this particular group [26,27]. The current study has found, among the traditional CVD risk factors, smoking plays the major contributing role on higher CVD death in socially disadvantaged group. Hence, developing stronger and more effective antismoking measures in population with higher cumulative social risk appears to be the next greatest opportunity to reduce CVD death. While traditional CVD risk factors explained about one third of the association between cumulative social risk exposure and elevated hazard of CVD death, these findings underscore the importance of further studies to identify other pathways that explain the link between social risk exposure and CVD outcome.

### 4.1. Strengths and limitation

This study quantitatively assessed the roles of traditional CVD risk factors in explaining the CVD mortality in socially disadvantaged population. In our model, combined CVD risk factors explained about one-third of social influence on CVD death, indicating two-third of the social influence is explained by unknown/unexamined factors. Among CVD risk factors in this analysis, current smoking turned out to be the most powerful explaining factor between higher social risk exposure and higher CVD death, followed by obesity and diabetes. And NHANES III data is from a large, multiethnic, nationally representative sample which strengthens the generalizability of the study results. This study together with prior studies bring the scientific evidence to emphasize the need for more effective smoking control among people with social disadvantages, and the need for more studies to explore other contributing factors other than traditional CVD risk factors to the poorer CVD outcome in population with higher social risk exposure.

Limitations of the study include diet and physical activity as two major CVD health metrics were not included in the current analysis. Due to the quality of information on physical activity such as no duration reported, it was excluded in this study. Though diet was not included in the analysis, the AHA's 2019 update reported about half of US population have poor diet pattern and over 90% of US adults did not meet ideal healthy diet criteria [1]. We would expect further improvement on healthy diet is essentially important for general population and more challenging for people with social disadvantages. Also, baseline CVD metrics and social risk information was used, the changes of these factors during the follow up years were not able to be quantified. As prevalence and control of dyslipidemia, diabetes, hypertension and smoking could have changed in the past decades, our findings from NHANES III will need to be confirmed with more recent cohorts. Information of access to medical care and medical adherence was also not measured in the current study. Current smoking in NHANES III was defined by self-report in a questionnaire, there has been controversial about the discrepancy between self-reported smoking status and biochemical measure, however prior study has shown the smoking information collected by questionnaire in NHANES III can serve as an accurate indicator for smoking status [28]. Our definitions of hypertension, dyslipidemia and diabetes did not take into account whether the participants had these risk factors under control with treatment or not. This leaves room for possible residual confounding. Each of the CVD risk factors we examined may be considered as either one-dimensional or multi-dimensional variable regarding their impact on CVD risk. The approach to quantify the interplay between these risk factors taking into account their possible multi-dimensional impact warrants further investigations. There are also additional factors can be argued as addition to the cumulative social risk exposure such as psychological stress, alcohol drinking, religions or occupation. Finally, equal score was assigned to each social risk factor in the current study, the authors are aware of the possible heterogeneity of the significance of different social risk factors in disease, which will be an important question to be addressed in the near future.

## 5. Conclusions

Understanding the contribution of traditional and modifiable CVD risk factors to the link between cumulative social risk exposure and CVD mortality is a critical step to address the social disparities in CVD death. Based on analysis of NHANES III, among the traditional CVD risk factors, developing more effective strategies to control smoking seems to be the greatest opportunity to attenuate the CVD death in population with social disadvantages. While traditional CVD risk factors explain about one third of the association between cumulative social risk exposure and CVD death, these findings call for further studies to identify other explanations of the poorer CVD outcome in population with higher social risk exposure.

## Author contributions

Dr Muhammad Imtiaz Ahmad had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: Soliman.

Acquisition, analysis, or interpretation of data: Zhang, Soliman, Ahmad.

Drafting of the manuscript: Zhang.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Ahmad.

## Declaration of competing interest

The authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest.

## References

[1] Benjamin EJ, Muntner P, Alonso A, et al. Heart disease and stroke statistics-2019 update: a report from the American heart association. Circulation 2019;139(10): e56–528.
[2] Global Burden of Cardiovascular Diseases C, Roth GA, Johnson CO, et al. The burden of cardiovascular diseases among US States, 1990-2016. JAMA Cardiol 2018;3(5):375–89.
[3] Kaplan GA, Keil JE. Socioeconomic factors and cardiovascular disease: a review of the literature. Circulation 1993;88(4 Pt 1):1973–98.
[4] Pollitt RA, Rose KM, Kaufman JS. Evaluating the evidence for models of life course socioeconomic factors and cardiovascular outcomes: a systematic review. BMC Publ Health 2005;5:7.
[5] Hozawa A, Folsom AR, Sharrett AR, Chambless LE. Absolute and attributable risks of cardiovascular disease incidence in relation to optimal and borderline risk factors: comparison of African American with white subjects-Atherosclerosis Risk in Communities Study. Arch Intern Med 2007;167(6):573–9.
[6] Winkleby MA, Jatulis DE, Frank E, Fortmann SP. Socioeconomic status and health: how education, income, and occupation contribute to risk factors for cardiovascular disease. Am J Publ Health 1992;82(6):816–20.
[7] Mensah GA, Mokdad AH, Ford ES, Greenlund KJ, Croft JB. State of disparities in cardiovascular health in the United States. Circulation 2005;111(10):1233–41.
[8] Mackenbach JP, Cavelaars AE, Kunst AE, Groenhof F. Socioeconomic inequalities in cardiovascular disease mortality; an international study. Eur Heart J 2000;21(14): 1141–51.
[9] Caleyachetty R, Echouffo-Tcheugui JB, Muennig P, Zhu W, Muntner P, Shimbo D. Association between cumulative social risk and ideal cardiovascular health in US adults: NHANES 1999-2006. Int J Cardiol 2015;191:296–300.
[10] Centers for Disease C, Prevention. Vital signs: avoidable deaths from heart disease, stroke, and hypertensive disease - United States, 2001-2010. MMWR Morb Mortal Wkly Rep 2013;62(35):721–7.
[11] Havranek EP, Mujahid MS, Barr DA, et al. Social determinants of risk and outcomes for cardiovascular disease: a scientific statement from the American heart association. Circulation 2015;132(9):873–98.

[12] Plan and operation of the third national health and nutrition examination survey, 1988-94. Series 1: programs and collection procedures. Vital Health Stat 1994; 1(32):1–407.
[13] Howard G, Cushman M, Kissela BM, et al. Traditional risk factors as the underlying cause of racial disparities in stroke: lessons from the half-full (empty?) glass. Stroke 2011;42(12):3369–75.
[14] Yang Q, Cogswell ME, Flanders WD, et al. Trends in cardiovascular health metrics and associations with all-cause and CVD mortality among US adults. J Am Med Assoc 2012;307(12):1273–83.
[15] Redondo-Bravo L, Fernandez-Alvira JM, Gorriz J, et al. Does socioeconomic status influence the risk of subclinical atherosclerosis?: a mediation model. J Am Coll Cardiol 2019;74(4):526–35.
[16] Fang N, Jiang M, Fan Y. Ideal cardiovascular health metrics and risk of cardiovascular disease or mortality: a meta-analysis. Int. J. Cardiol. 2016;214: 279–83.
[17] Murray CJ, Atkinson C, Bhalla K, et al. The state of US health, 1990-2010: burden of diseases, injuries, and risk factors. J Am Med Assoc 2013;310(6):591–608.
[18] Danaei G, Ding EL, Mozaffarian D, et al. The preventable causes of death in the United States: comparative risk assessment of dietary, lifestyle, and metabolic risk factors. PLoS Med 2009;6(4):e1000058.
[19] Ford ES, Ajani UA, Croft JB, et al. Explaining the decrease in U.S. deaths from coronary disease, 1980-2000. N Engl J Med 2007;356(23):2388–98.
[20] Caleyachetty R, Echouffo-Tcheugui JB, Shimbo D, Zhu W, Muennig P. Cumulative social risk and risk of death from cardiovascular diseases and all-causes. Int J Cardiol 2014;177(3):1106–7.
[21] Chang CM, Corey CG, Rostron BL, Apelberg BJ. Systematic review of cigar smoking and all cause and smoking related mortality. BMC Publ Health 2015;15:390.
[22] Bhatnagar A, Whitsel LP, Ribisl KM, et al. Electronic cigarettes: a policy statement from the American Heart Association. Circulation 2014;130(16):1418–36.
[23] Yatsuya H, Folsom AR, Investigators A. Risk of incident cardiovascular disease among users of smokeless tobacco in the Atherosclerosis Risk in Communities (ARIC) study. Am J Epidemiol 2010;172(5):600–5.
[24] Leventhal AM, Bello MS, Galstyan E, Higgins ST, Barrington-Trimis JL. Association of cumulative socioeconomic and health-related disadvantage with disparities in smoking prevalence in the United States, 2008 to 2017. JAMA Intern Med 2019; 179(6):777–85.
[25] US Department of Health and Human Services. The Health Consequences of Smoking—50 Years of Progress: A Report of the Surgeon General. Atlanta, GA: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health; 2014.
[26] National Cancer Institute. A Socioecological Approach to Addressing Tobacco-Related Health Disparities. Bethesda, MD: National Cancer Institute, National Institutes of Health, US Dept of Health and Human Services; 2017.
[27] Higgins ST, Redner R, Priest JS, Bunn JY. Socioeconomic disadvantage and other risk factors for using higher-nicotine/tar-yield (regular full-flavor) cigarettes. Nicotine Tob. Res. 2017;19(12):1425–33.
[28] Caraballo RS, Giovino GA, Pechacek TF, Mowery PD. Factors associated with discrepancies between self-reports on cigarette smoking and measured serum cotinine levels among persons aged 17 years or older: third National Health and Nutrition Examination Survey, 1988-1994. Am J Epidemiol 2001;153(8):807–14.