Sleep and Breathing (2019) 23:777–784
https://doi.org/10.1007/s11325-018-01776-1

SLEEP BREATHING PHYSIOLOGY AND DISORDERS • ORIGINAL ARTICLE

Self-reported snoring and incident cardiovascular disease events: results from the Jackson Heart Study

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Received: 8 November 2018 / Revised: 11 December 2018 / Accepted: 24 December 2018 / Published online: 13 February 2019

Abstract

Purpose Evidence suggests that snoring is associated with increased risk for cardiovascular disease (CVD) events such as myocardial infarction and stroke. Limited data exists pertaining to this association among African Americans. We therefore examined the association between self-reported habitual snoring and incident CVD in the Jackson Heart Study (JHS), a population-based cohort study of African Americans.

Methods Self-reported data on snoring and risk factors for CVD were collected at baseline (2000–2004). Participants were followed prospectively for the development of incident CVD. Habitual snoring was defined as *present* if the participants reported it as "often" or "almost always" or *absent* if reported as "sometimes," "never," or "seldom." A CVD event included stroke, myocardial infarction, coronary revascularization procedure, or fatal CHD event. Cox proportional hazards models assessed the independent association between self-reported habitual snoring and incident CVD event adjusting for multiple covariates, including age, sex, hypertension, body mass index, diabetes, hypercholesterolemia, and smoking status.

Results The snorer group consisted of 787 participants (mean age 52.1 years) and the nonsnorer group consisted of 3708 participants (mean age 54.9 years). Frequency of incident CVD events in the snorer group was not significantly different from the nonsnorer group. The fully adjusted hazard ratio for a CVD event in the snorer group was 1.01 (95% confidence interval [0.69, 1.47], p value of 0.96).

David M. Rosen and Vaishnavi Kundel are co-first authors, and contributed equally to this work.

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Conclusion In conclusion, self-reported habitual snoring was not associated with incident CVD among this large African American cohort. Future studies providing objective data on snoring and sleep apnea may provide more information on the snoring-CVD association among African Americans.
Trial registration Identification Number: NCT00005485

Keywords Snoring · Cardiovascular disease · Stroke · Coronary artery disease · Sleep apnea

Introduction

Snoring is extremely common in the USA. According to the National Sleep Foundation, snoring affects 90 millions adult Americans, of which 37 million adults report snoring routinely [1]. Snoring is a sound made during sleep due to vibration of soft tissue structures located in the posterior pharynx. Snorers are typically not aware of their noisy breathing; instead, they are informed about it, most often by their bed partners. Snoring is the most common presenting symptom among patients who have obstructive sleep apnea (OSA). OSA is associated with numerous cardiovascular diseases (CVD) including hypertension [2, 3], stroke [4–7], coronary heart disease (CHD) [6, 8, 9] and all-cause mortality [10]. Whether snoring, independent of comorbid OSA, is associated with CVD events is unknown. Some studies have reported that habitual snoring is not associated with increased risk for CVD [11, 12], whereas others report an increased risk for CVD events [13–15]. In particular, one study [16] has shown that snoring may increase the risk of carotid atherosclerosis independent of OSA, and another study from the Women's Health Initiative (predominantly white [84.5%], postmenopausal women) has shown a weak but statistically significant association between snoring and CVD. Although evidence suggests that African Americans are at increased risk for CVD [17, 18], few of the abovementioned studies have examined the association between snoring and CVD among African Americans. We therefore examine the association between self-reported habitual snoring and incident CVD in the Jackson Heart Study (JHS) [4], which represents an African American population at high risk for CVD.

Methods

We used data from the JHS. All JHS participants provided informed consent and the study protocol was approved by the University of Mississippi Medical Center Institutional Review Board. Details of the study design and participant recruitment for the JHS have been published elsewhere [19, 20]. In addition, methods for testing and disease classification are described in detail elsewhere [21, 22].

The JHS is a single-site, population-based cohort study of African Americans living in the USA. It was designed to investigate risk factors and burden of CVD in this population. The JHS cohort [19] has 5301 participants from the Jackson site of the Atherosclerosis Risk in Communities (ARIC) study (31%), and other randomly chosen participants (17%), or volunteers (30%) and their family members (22%) from Jackson, Mississippi. Participants were enrolled from September 2000 until March 2004. Five thousand two hundred fifty-two of the 5301 participants answered questionnaires at the time of the first exam (labeled as exam 1, occurring from 2000 to 2004). Participants were extensively interviewed by trained study staff members for information which included but was not limited to demographics, medical history, and sleep apnea symptoms. The participants were followed at regular intervals via annual detailed telephone interviews. CVD-related outcomes including death were abstracted from medical records and adjudicated, or obtained via death certificates stating CHD as a cause of death. From the JHS cohort of 5301 participants, 49 participants had missing snoring data and two answered "do not know" to the snoring questions, thus leaving an analytic sample of 5250 participants. Since our primary outcome is incident CVD events, we excluded 591 participants due to any prior CHD/stroke and an additional 164 for missing CVD outcomes, resulting in an analytic cohort of 4495 participants.

Our primary exposure was self-reported snoring. During the in-person baseline examination, participants were interviewed by research staff and asked to respond to the statement "you are told that you snore loudly and bother others" with an answer of "almost always," "often," "sometimes," "seldom" or "never." In order to capture routine snoring, an answer of "often" or "almost always" categorized a participant as a snorer and an answer of "sometimes," "seldom," or "never" categorized a participant as a nonsnorer. Snoring was evaluated as a categorical variable with nonsnorers serving as the reference group.

The primary outcome was an incident CVD event defined as hospitalization for a stroke, myocardial infarction, coronary revascularization procedure, or death from CHD. The coronary revascularization procedure included coronary artery bypass graft surgery or coronary angiography with stent placement or thrombectomy. Trained personnel conducted annual telephone follow-up interviews to determine vital status and whether the participant had any relevant diagnostic tests, hospitalizations, or other significant health events since the last contact. Upon the death of a cohort member, physicians, medical examiners, coroners, and next of kin were contacted in

order to obtain more details about the events surrounding the death. Records of hospitalizations and deaths were reviewed in a centralized location to identify CVD events. Trained medical staff conducted additional review and adjudication of events, if necessary. More details of this adjudication process have been outlined elsewhere [23].

Baseline demographic data that were utilized as covariates were age, sex, marital status, highest level of education achieved, and income status. Marital status was categorized as married, divorced/widowed/separated, or never been married. Highest level of education was classified as some high school, high school graduate or equivalency, some college, or at least a bachelor's degree. Income status was categorized as low, lower-middle, upper-middle, and affluent based on annual household income. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (units as kg/m^2).

Presence or absence of hypertension, diabetes, and hyperlipidemia was ascertained using standard and previously described methods [24]. Presence or absence of prior history of atrial fibrillation, heart failure, or family history of CHD or stroke was also ascertained in a similar manner [24]. Smoking status was derived from participant's report of being a "never," "former," or "current" smoker.

The distribution of the covariates among the snoring categories was evaluated using statistical tests (Student's *t* test, Wilcoxon test or chi-square) appropriate for their distributions. Using a Cox proportional hazards model, we calculated a hazard ratio (HR) for the rate of CVD events in the snorer group compared to the nonsnorer group. We report partially and fully adjusted HRs. The partially adjusted model included age and sex as covariates. The fully adjusted model included age, sex, education, income, marital status, smoking status, BMI, hypertension, diabetes, hypercholesterolemia, prior history of atrial fibrillation, prior history of heart failure, family history of heart diseases, and family history of stroke. We also report HR for an intermediate model that adjusted for all the covariates in the fully adjusted model excluding hypertension and diabetes (as these may be in the causal pathway of the association we are testing). Person-years of follow-up started at the baseline examination and ended with the earliest CVD event date among censoring date (12/31/2012), date of death, or lost-to-follow-up.

The overall missing rate of covariates was 10% while excluding income, and 23% while including it. We addressed this amount of missing data by using multiple imputation (MI). We used multivariate imputation by chained equations (MICE) in R to impute missing covariates for ten times and generate pooled estimates and standard errors in SAS while using PROC MIANALYZE. We also ran complete case analyses (CC) and compared the final results between the CC and MI approaches. All of our statistical analyses were performed using SAS 9.2 software (SAS Institute, Cary, NC) and R (Vienna, Austria).

Results

As seen in Table 1, there were 787 individuals in the snorer group (18% of the analytic cohort) and 3708 in the nonsnorer group (82% of the analytic cohort). Those in the snorer group had a higher prevalence of hypertension, diabetes, and majority were of female sex. Snorers were also younger, had a higher BMI, and were more likely to be married and have a higher education (see Table 1).

Average time to incident CVD event was 4.9 years (± 3.0) in the snorer group and 5.4 years (± 3.3) in the nonsnorer group. Table 2 contains the partially adjusted HR (age and sex) for incident CVD for snorers (787) compared to nonsnorers (3708), which was 1.08 (model 1) with a 95% confidence interval (CI) of [0.79, 1.47]. After additional adjustment for education, income, marital status, smoking status, BMI, hypertension, diabetes, hypercholesterolemia, prior history of atrial fibrillation, prior history of heart failure, family history of heart diseases, and family history of stroke in the fully adjusted model, the HR for incident CVD for snorers (624) compared to nonsnorers (2955) was 1.01 (model 3) with a 95% CI of [0.69, 1.47] (see Table 2). An intermediate model that adjusted for all the covariates in the fully adjusted model excluding hypertension and diabetes resulted in a HR of 1.12 (model 2) (95% CI: 0.78–1.62). Our results did not change significantly after accounting for missing data using MICE (data not shown). Kaplan-Meier plots were generated to assess the association between snoring and CVD outcomes. Three separate plots were created—one for overall CVD events, one for CHD events only, and one for stroke events only. These plots are shown in Fig. 1, and did not show a significant association between snoring status and overall CVD events, or snoring and CHD or stroke events alone.

Finally—since snoring has been suggested to preferentially increase carotid atherosclerosis due to local vibratory pro-inflammatory mechanism [15]—in our secondary data analysis, we investigated if habitual snoring preferentially increases stroke risk vs. coronary heart disease event risk. Our results from these secondary analyses did not confirm this theory with similar nonsignificant HRs for the risk of stroke (HR 1.10, 95% CI: 0.65–1.85, $p = 0.73$) and CHD events (1.07, 95% CI: 0.69–1.65, $p = 0.76$).

Discussion

Our study examined the association between snoring and CVD events in a large community-based cohort of adult

Table 1 Baseline characteristics of the study cohort

	Overall (n = 4495)	Nonsnorer (n = 3708,82%)	Snorer (n = 787,18%)	p value[a]
Age (years), mean ± SD	54.4 ± 12.7	54.9 ± 13.0	52.1 ± 11.0	< .0001
Diagnosis of HTN, N (%)	2664 (59.7%)	2167 (58.9%)	497 (63.6%)	0.0156
BMI (kg/m^2), mean ± SD	31.8 ± 7.2	31.1 ± 6.9	34.7 ± 7.9	< .0001
Diagnosis of diabetes, %	738 (16.8%)	573 (15.8%)	165 (21.5%)	0.0001
Hypercholesterolemia, %	1267 (30.7%)	1028 (30.1%)	239 (33.2%)	0.1011
Sex, N (%)				0.0070
Male	1611 (35.8%)	1296 (34.9%)	315 (40.0%)	
Female	2884 (64.2%)	2412 (65.0%)	472 (60.0%)	
Education, N (%)				0.0695
Less than high school	728 (16.3%)	623 (16.8%)	105 (13.4%)	
High school/GED	899 (20.1%)	738 (20.0%)	161 (20.6%)	
> HS but < bachelor	1325 (29.6%)	1073 (29.0%)	252 (32.3%)	
Bachelor degree or higher	1526 (34.1%)	1263 (34.2%)	263 (33.7%)	
Income, N (%)				0.0655
Low	551 (14.4%)	561 (14.5%)	95 (14.1%)	
Lower-middle	898 (23.5%)	765 (24.3%)	133 (19.8%)	
Upper-middle	1150 (30.1%)	931 (29.6%)	219 (32.5%)	
Affluent	1221 (32.0%)	995 (31.6%)	226 (33.6%)	
Marital status, N (%)				0.0166
Married	2488 (55.5%)	2017 (54.6%)	471 (60.0%)	
Divorced/widowed/separated	1405 (31.4%)	1178 (31.9%)	227 (28.9%)	
Never been married	587 (13.1%)	500 (13.5%)	87 (11.1%)	
Prior h/o atrial fibrillation, N (%)	11 (0.2%)	9 (0.2%)	2 (0.2%)	1.0000
Prior h/o heart failure, N (%)	52 (1.2%)	48 (1.3%)	4 (0.5%)	0.0610
Family h/o heart disease, N (%)	1449 (32.2%)	1167 (31.5%)	282 (35.8%)	0.0175
Family h/o stroke, N (%)	794 (17.7%)	651 (17.6%)	143 (18.2%)	0.6818
Smoking status, N (%)				0.0266
Never smoked	3116 (69.8%)	2601 (70.7%)	515 (65.9%)	
Former smoker	792 (17.7%)	638 (17.3%)	154 (19.7%)	
Current smoker	555 (12.4%)	442 (12.0%)	113 (14.4%)	

[a] p values were obtained using appropriate statistical tests for the association of snoring and variables of interest

BMI body mass index, *GED* general equivalency diploma, *H/o* history of, *HS* high school, *HTN* hypertension, *SD* standard deviation

African Americans. We did not find a significant association between self-reported habitual snoring and incident CVD events defined as stroke, myocardial infarction, coronary revascularization procedure, or death from CHD after accounting for a large number of potential confounding variables. We also created intermediate models leaving out hypertension and diabetes which may be on the causal pathway of the association we are testing; this did not change our results.

Our findings are in agreement with other studies that have failed to show an association between snoring and CVD. Specifically, and most relevant to our study population, the Multiethnic Study of Atherosclerosis (MESA) consisting of 1452 habitual snorers, 208 with physician diagnosed sleep apnea (PDSA), and 3678 normal participants also showed no significant association between snoring and CVD events. The MESA cohort included over 1000 African American participants of which 337 were habitual snorers [12]. Interestingly in this study, PDSA, as opposed to snoring, was associated with CVD events and all-cause mortality. This suggests that self-reported snoring may not be as important as sleep apnea (possibly due to its more specific association with overnight hypoxemia) for CVD risk.

Our study has several strengths. It is the largest study of African Americans that has examined the association between

Table 2 Estimated hazard ratios of CVD events for snorers vs. nonsnorers

	Snorer			Hazard ratios comparing snorer to nonsnorer (95% CI)			Cox proportional hazard model	
	N	CVD events	Incidence rate (events/1000 person-years)	*N*	CVD events	Incidence rate (events/1000 person-years)	Hazard ratios comparing snorer to nonsnorer (95% CI)	*p value*
Unadjusted	787	48	6.4	3708	260	7.5	0.85 (0.62, 1.16)	0.30
Model 1[a]	787	48	6.4	3708	260	7.5	1.08 (0.79, 1.47)	0.63
Model 2[b] (excluding hypertension and diabetes)	627	37	6.3	2969	191	7.1	1.12 (0.78, 1.62)	0.55
Model 3[c] (including hypertension and diabetes)	624	36	6.2	2955	190	7.0	1.01 (0.69, 1.47)	

[a] Model 1 adjusted for age and sex

[b] Model 2 adjusted for adjusted for age, sex, education, income, marital status, smoking status, BMI, hypercholesterolemia, prior history of atrial fibrillation, prior history of heart failure, family history of heart diseases, and family history of stroke

[c] Model 3 adjusted for age, sex, education, income, marital status, smoking status, BMI, hypertension, diabetes, hypercholesterolemia, prior history of atrial fibrillation, prior history of heart failure, family history of heart diseases, and family history of stroke

CVD cardiovascular disease

self-reported snoring and CVD, two prevalent conditions. Furthermore, the infrastructure of this large cohort study served well to ascertain both the exposure and outcome variables in a standardized manner. Finally, the population-based cohort increases the generalizability of our study findings as opposed to referral-based cohorts.

Limitations

The principle limitation of this study is the lack of objective assessment of snoring and OSA. Self-reported snoring assessed in this cohort of patients is more likely to represent comorbid OSA in addition to snoring. Given that snoring is the most common presenting symptom of the syndrome, it is often difficult to dissect the effects of snoring on CVD events *independent* of comorbid OSA.

The null findings in our study may be attributed to several potential explanations and limitations of this work:

(1) It may be that there is indeed no true association between snoring and CVD events, possibly due to the wider spectrum of sleep-disordered breathing captured by self-reported snoring, rather than polysomnographically measured sleep apnea. Therefore, the inevitable inclusion of milder disease (OSA) in this population of self-reported snorers may less strongly predict CVD events as compared to more severe OSA.

(2) Another possible reason for the null findings in our study may be due to misclassification of snoring. The prevalence of snoring in the JHS population was less than 20%, which is significantly lower in comparison to that of previous population-based studies [25, 26]. African Americans (especially males) have been shown to have the greatest level of difficulty in recalling snoring and other sleep related symptoms [27]. Furthermore, nonwhite individuals are more likely to be unsure of their snoring status, or report snoring inaccurately. Contrary to this, our study had a very low prevalence of unsure snoring responses (n = 2 reported "do not know" for their snoring status). It is possible that the way the question was phrased ("You are told that you snore loudly and bother others") resulted in misclassification due to an obligatory response, despite being unsure of their snoring status. Therefore, it is possible that the JHS interviewer technique may have led to a lack of unsure responses. Additionally, approximately 20% of the population within the nonsnorer group had a less than high school education, and almost 45% were either divorced, separated, or unmarried. Prior studies have shown that individuals who are unmarried, without bedpartners, unemployed, or have a lower education status may not accurately report snoring [27]. All of these factors may have influenced misclassification of self-reported snoring in our study and biased the results towards the null.

(3) A third potential explanation for the null findings for the association between snoring and CVD events may be due to lack of adequate power to determine a significant association. Cardiovascular outcome studies typically have tens of thousands of patients, and we therefore may have been underpowered.

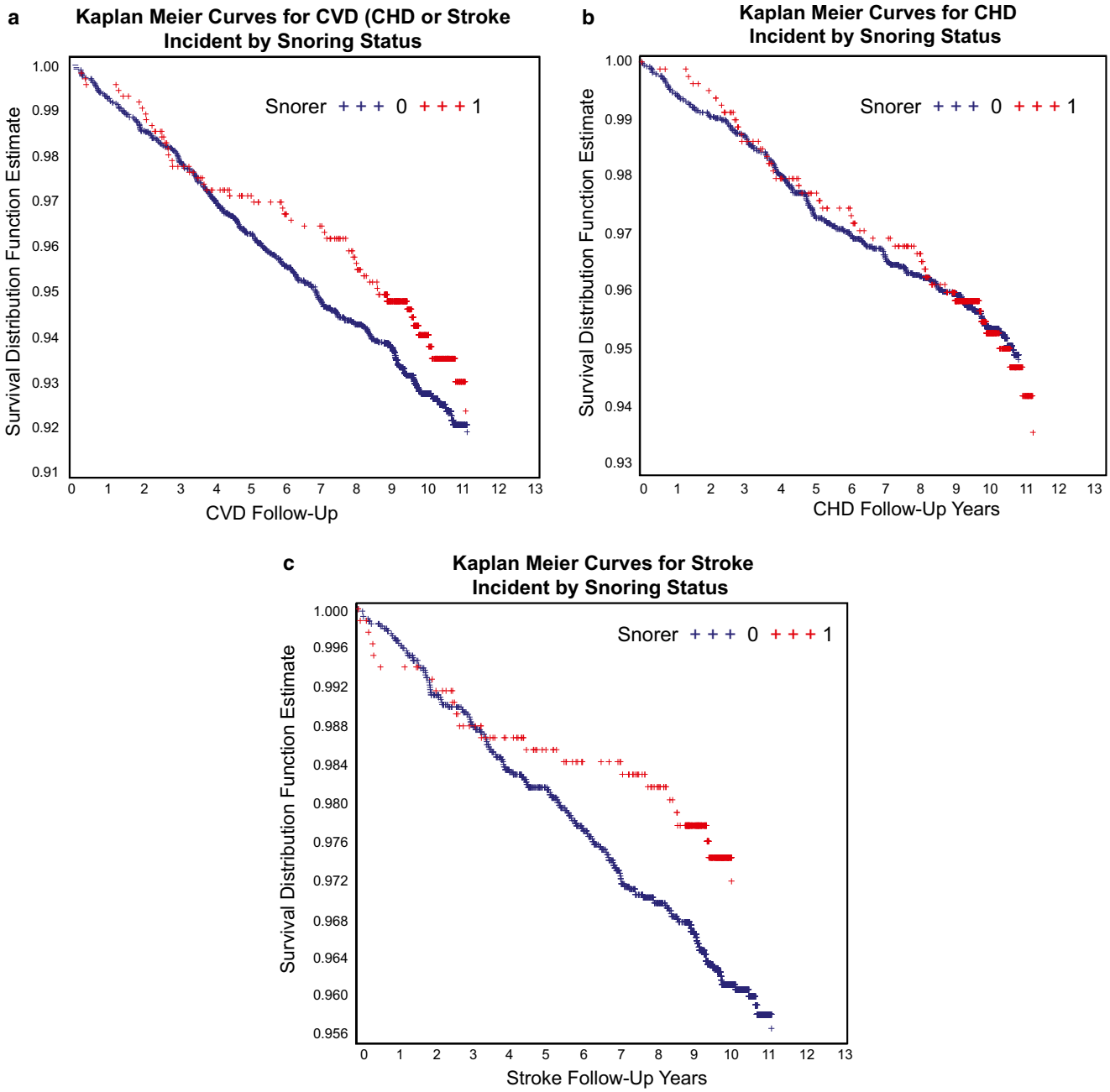

Fig. 1 Kaplan-Meier plots for the association between snoring and cardiovascular events. Figures **a**, **b**, and **c** show the KM plots demonstrating the association between snoring and overall CVD events, CHD events alone, and stroke events alone. CVD, cardiovascular disease; CHD, coronary heart disease; KM, Kaplan-Meier

Our study touches upon a recurring problem within much of the literature dedicated to the assessment of habitual snoring—that it lacks an agreed-upon, gold standard definition. The determination of the presence of habitual snoring should be standardized and quantified to allow for uniformity in comparing study findings. Minute details such as microphone placement during a polysomnogram and whether to rely on a snoring sound's intensity or frequency should be further investigated in order to obtain objective snoring data and definitively answer the question of whether habitual snoring is independently associated with atherosclerosis and CVD, independent of sleep apnea status objectively evaluated by sleep testing.

Conclusion

We do not have evidence to support an independent association between self-reported snoring and risk of CVD events among African Americans from the JHS. Future studies of the snoring-CVD association among African Americans will be better served with the inclusion of more objective data on both snoring and sleep apnea.

Acknowledgments Drs. Rosen, Shah, and Kaplan contributed to the study design. Na Guo and Michael Rueschman did the statistical analysis. Drs. Rosen, Shah, Redline, Min, and Michael Rueschman interpreted the data. Drs. Redline, Shah, Kundel, Min, and Rosen contributed to the review of the data analysis. Dr. Rosen was the primary author who was responsible for the writing of this manuscript. Many sections of the manuscript were further edited by Dr. Shah and Dr. Kundel after Dr. Rosen was unable to work on revisions of this manuscript due to graduation from fellowship. The authors thank the participants and data collection staff of the Jackson Heart Study.

Funding The Jackson Heart Study (JHS) is supported and conducted in collaboration with Jackson State University (HHSN268201800013I), Tougaloo College (HHSN268201800014I), the Mississippi State Department of Health (HHSN268201800015I/HHSN26800001), and the University of Mississippi Medical Center (HHSN268201800010I, HHSN268201800011I and HHSN268201800012I) contracts from the National Heart, Lung, and Blood Institute (NHLBI) and the National Institute for Minority Health and Health Disparities (NIMHD). The study analysis was also supported by funding from Dr. Shah's National Institute of Health/National Heart, Lung, and Blood Institute Research Career Development Award (5K23HL125923-03).

Compliance with ethical standards

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

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent Informed consent was obtained from all individual participants included in the study.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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