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Modifiable Lifestyle Risk Factors and Incident Diabetes in African Americans

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Abstract

Introduction—The associations of modifiable lifestyle risk factors with incident diabetes are not well investigated in African Americans (AAs). This study investigated the association of modifiable lifestyle risk factors (exercise, diet, smoking, TV watching, and sleep disordered breathing burden) with incident diabetes among AAs.

Methods—Modifiable lifestyle risk factors were characterized among 3,252 AAs in the Jackson Heart Study free of diabetes at baseline (2000–2004) using baseline questionnaires and combined into risk factor categories: poor (0–3 points), average (4–7 points), and optimal (8–11 points). Incidence rate ratios (IRR) for diabetes (fasting glucose ≥126 mg/dL, physician diagnosis, use of diabetes drugs, or glycosylated hemoglobin A1c (HbA1c) ≥6.5%) were estimated using Poisson regression modeling adjusting for age, sex, education, occupation, systolic blood pressure, and BMI. Outcomes were collected 2005–2012 and data analyzed in 2016.

Results—Over 7.6 years there were 560 incident diabetes cases (mean age=53.3 years, 64% female). An average or optimal compared to a poor risk factor categorization was associated with a

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21% (IRR=0.79, 95% CI=0.62, 0.99) and 31% (IRR=0.69, 95% CI=0.48, 1.01) lower risk of diabetes. Among BMI <30 kg/m^2 participants, IRRs for average or optimal compared to poor categorization were 0.60 (95% CI=0.40, 0.91) and 0.53 (95% CI=0.29, 0.97), versus 0.90 (95% CI=0.67, 1.21) and 0.83 (95% CI=0.51, 1.34) among participants with BMI ≥30 kg/m^2.

Conclusions—A combination of modifiable lifestyle factors are associated with a lower risk of diabetes among AAs, particularly among those without obesity.

INTRODUCTION

Type 2 diabetes mellitus (diabetes) is more prevalent among African Americans (AAs) compared to non-Hispanic whites (NHWs).[1,2] Recent trends indicate that diabetes incidence has plateaued among NHWs, but continues to rise among AAs.[1] Modifiable diabetes risk factors such as physical activity, sedentary behaviors, and smoking are well described in NHWs[3–5]; however, the association of other modifiable lifestyle risk factors with diabetes, including sleep parameters, are less well known. In the U.S.-based Cardiovascular Health Study,[6] among older adults (aged >65 years), the low-risk lifestyle group defined by more favorable physical activity, diet, smoking, alcohol consumption, BMI, and waist circumference, had an 89% lower diabetes risk compared to the high-risk group. In the American Association of Retired Persons Diet and Health Study,[7] self-reported favorable levels of lifestyle factors including BMI, diet, smoking, alcohol consumption, and physical activity were associated with a 72% and 84% lower risk of diabetes among men and women, respectively. Although these prior studies are consistent in their findings, they were primarily conducted among NHWs. Evidence on the role of modifiable risk factors among AAs is lacking. Data from the Multi-Ethnic Study of Atherosclerosis suggests that increasing attainment of ideal cardiovascular health components (including total cholesterol, blood pressure, dietary intake, tobacco use, physical activity, and BMI) is associated with lower risk of incident diabetes among AAs.[8] A key limitation of prior investigations was the inclusion of BMI in combined modifiable lifestyle risk factor metrics, which is counterintuitive as: (1) obesity may be a transient state in the pathway to diabetes and (2) the relationship between adiposity and diabetes may vary by race/ethnicity as evidenced by stronger relationships between BMI and diabetes among NHWs versus AAs.[9–11] Thus, this study investigates the association of lifestyle factors including dietary intake, physical activity, sedentary behavior, sleep disordered breathing burden (SDBB), and smoking with incident diabetes in AAs, as well as the modifying effect of baseline adiposity and glycemia. The hypothesis is that a combination of higher amounts of healthy dietary intake and physical activity and lower amounts of sedentary behavior, SDBB, and smoking will be associated with lower risk of incident diabetes.

METHODS

Study Sample

The Jackson Heart Study (JHS) is a prospective study of the development and progression of cardiovascular disease in a cohort of 5,301 AA adults, aged 21–94 years from the tri-county area of metropolitan Jackson, Mississippi. Enrollment and baseline examinations were performed from 2000–2004 with two subsequent in-person follow-up examinations from

2005–2008 and 2009–2013. Details about the study design, recruitment, and methods used have been described elsewhere.[12] The JHS was approved by the University of Mississippi Medical Center IRB, and the participants gave written informed consent.

Measures

Baseline information was obtained using standardized questionnaires including: demographics, occupation (management/professional versus not), level of education (≥Bachelor's degree versus <Bachelor's degree), alcohol use, and current prescription medication usage. Calibrated devices were used by certified technicians and nurses to measure participants' weight, waist circumference (average of two measurements around the umbilicus), and height. BMI was calculated as weight (kilograms)/ height^2 (meters). Resting seated blood pressure (BP) was measured twice at 5-minute intervals using an appropriately sized cuff with standard Hawksley random-zero instruments and measurements were averaged. Fasting blood samples were processed and stored using a standardized protocol.[12,13] Fasting glucose and insulin concentrations were measured on a Vitros 950 or 250, Ortho-Clinical Diagnostics analyzer using standard procedures that met the College of American Pathologists accreditation requirement.[13] Insulin resistance was estimated using homeostatic model assessment (HOMA) for insulin resistance (HOMA-IR) = (fasting plasma glucose [mg/dL] × fasting plasma insulin [mU/mL]) ÷ 405.[14] A high-performance liquid chromatography system was used to measure glycosylated hemoglobin A1c (HbA1c) concentrations. Serum concentrations of total adiponectin were measured by an enzyme-linked immunosorbent assay (ELISA) system with interassay coefficient of variation of 8.8%.[15]

Modifiable lifestyle risk factors were measured at the baseline exam (2000–2004), as described below.

Physical activity was assessed using the validated JHS Physical Activity Cohort survey,[16,17] and defined according to the American Heart Association categorization.[18] Physical Activity was considered optimal if participant achieved ≥150 minutes/week moderate intensity or ≥75 minutes/week vigorous intensity physical activity or ≥ 150 minutes/week moderate/ vigorous physical activity, average if participant performed 1–149 minutes/week moderate intensity or 1–74 minutes/week vigorous intensity physical activity or 1–149 minutes/week of moderate/vigorous intensity physical activity, and poor if less than these levels. Time spent watching TV in the last year was measured in hours/day assessed using the JHS Physical Activity Cohort survey.[16,17] Potential responses were ≥4 hours/day, 2–4 hours/day, 1–2 hours/day, 1–7 hours/week, and <1 hour/week. TV watching was categorized as optimal (<1 hour/day), average (1–3.99 hours/day), or poor (≥4 hours/day).[19]

Dietary intake was assessed using a culturally appropriate, validated 158-item food frequency questionnaire administered in-person by trained AA interviewers.[20,21] Diet quality was operationalized using the American Heart Association categorization with slight modifications.[18] Components (based on 2,000-kcal/day intake) included: fruits and vegetables ≥4.5 cups/day; fish >3.5 ounces, twice per week (non-fried); sodium <1,500 mg/ day; sugar-sweetened beverages <450 kcal/week; and whole grains ≥3 servings/day. Participants were assigned 1 point per ideal dietary component for a total score ranging from

0 to 5. Dietary intake was classified as optimal (4–5 dietary components), average (2–3 dietary components), or poor (0–1 dietary components).

Smoking status was classified as optimal (never smoking or quit ≥12 months ago), average (Quit <12 months ago), or poor (current smoking).[8]

SDBB was assessed using an analytic method created by Fülop et al [22] Prevalent sleep symptoms were defined as a positive response to a limited set of five questions adapted from the Berlin Sleep Questionnaire.[23] The SDBB was quantified by first coding the responses to the sleep symptom questions (*Never, Seldom, Sometimes, Often, or Almost always*) from 0 for "Never" to 4 for "Almost always" and then summing the individual scores, resulting in a sleep burden score that ranged from 0 to 20. Sleep burden was classified as "None" (score: 0), "Mild" (score: 1–5), "Moderate" (score: 6–10), or "Severe" (score: ≥11).[22]

A modifiable lifestyle risk factor score was created, as done in prior analyses,[6–8,24] using the five baseline modifiable lifestyle factors selected a priori: physical activity, TV watching (a proxy of sedentary behaviors), diet, smoking, and sleep disordered breathing. Each baseline metric was given 0 points for poor status, 1 point for average status, and 2 points for optimal status, except for sleep which was assigned points for severity of SDBB: 0 points for severe, 1 point for moderate, 2 points for mild, and 3 points for none. The modifiable lifestyle risk factor score was classified into three levels: Poor (0–3 points), Average (4–7 points), or Optimal (8–11 points) modifiable lifestyle risk factor status (Table 1).

Diabetes was defined as HbA1c ≥6.5%, fasting blood glucose ≥126 mg/dL, taking diabetes medications or with a self-reported physician diagnosis.[25] Persons without diabetes at baseline, meeting criteria for diabetes at one of the two subsequent exams were considered to have incident diabetes.

Statistical Analysis

Participants with diabetes at baseline (n=1,152), missing diabetes status at baseline (n=61), missing diabetes data at follow-up (n=689) or missing data on baseline covariates (n=147) were excluded. The 897 excluded participants without known diabetes at baseline were predominantly male, with lower educational status, occupational status, BMI, physical activity and higher systolic BP, and current smoking, (p<0.01 for all comparisons, Appendix Table 1). Baseline characteristics of all participants were compared using appropriate parametric or non-parametric tests for continuous variables and the chi-square test for categorical variables. Spearman's correlations were compared between individual modifiable lifestyle risk factors (Appendix Table 2). The association of modifiable lifestyle risk factors or risk factor score with incident diabetes was examined by comparing participants with average or optimal versus poor status (reference group). Unadjusted diabetes incidence rates for modifiable risk factor scores were calculated using person-time analysis assuming a Poisson distribution. Poisson regression modeling was utilized to estimate incident rate ratios (IRR) for diabetes. Sequential modeling was performed as follows: Model 1: age, sex; Model 2: Model 1 and education, current occupation status, alcohol use, systolic blood pressure; Model 3: Model 2 and BMI; Model 4: Model 2 and waist circumference. Statistical significance was defined as two-sided α<0 05. Associations of modifiable lifestyle risk factors with incident diabetes may differ by age, sex, BMI, waist circumference, and glycemic status, multiplicative interaction testing with application of the likelihood ratio test was performed with a *p*-value of <0.10 considered statistically significant (Appendix Table 3). Results for BMI, waist circumference, and glycemic status were significant and sensitivity analyses were performed with stratification by: (1) baseline normoglycemia (fasting plasma glucose <100 mg/dL and HbA1c <5.7%) vs prediabetes (fasting blood glucose 100–125 mg/dL or HbA1c 5.7–6.4%)[26]; (2) central obesity (waist circumference ≥35 inches in women and ≥40 inches in men) vs normal waist circumference[27]; and (3) BMI <30 vs BMI ≥30 kg/m^2. Analyses were performed in 2016 using Stata, version 13.1.

RESULTS

The baseline characteristics of the 3,252 participants stratified by modifiable risk factor categories (poor, average, and optimal) are presented in Table 2. Participants with a more favorable risk factor profile had higher education, adiponectin and lower waist circumference, BMI, systolic BP, diastolic BP, HOMA-IR, but no difference in HbA1c. Participants in the optimal category of modifiable risk factor status had higher baseline levels of factors potentially associated with lower risk of diabetes including physical activity and optimal dietary intake, and lower baseline levels of factors perceived to increase diabetes risk including sleep disordered breathing, TV watching, and smoking (Table 2).

During a median follow-up of 7.5 years, 560 participants developed diabetes (incidence rate 22.9 per 1,000 person–years) (Table 2). The unadjusted incident rates decreased in a monotonic fashion with a rate ratio of 0.93 (95% CI=0.88, 0.98) per 1 unit in increase in score (Appendix Figure 1). Diabetes incidence rates per 1,000 person–years among participants in categories of poor, average or optimal modifiable risk were 28.7 (95% CI=23.0, 35.8), 22.9 (95% CI=20.8, 25.1) and 16.9 (95% CI=12.6, 22.8), respectively, with a rate ratio of incident diabetes per category of 0.79 (95% CI=0.66, 0.94) (Table 2). Participants who developed diabetes had higher baseline BMI (33.6 vs 30.7 kg/m^2), waist circumference (105.0 vs 97.2 cm), systolic BP (128 vs 124 mmHg), fasting plasma glucose (97 mg/dL vs 89 mg/dL) and HbA1c (5.9% vs 5.4%) (*p* for comparisons <0.001, Appendix Table 4).

The adjusted IRRs for incident diabetes associated with baseline modifiable lifestyle risk factors are presented in Table 3. After adjustment for covariates including BMI, the direction of the association of individual risk factors with incident diabetes was as expected, but non-significant. For the combined modifiable risk factors scores, in adjusted analysis without a measure of adiposity (Model 2), the IRRs for average or optimal compared to poor categories were 0.79 (95% CI=0.62, 1.00) and 0.66 (95% CI=0.45, 0.96), respectively. After adjustment for covariates including BMI, the IRRs for average or optimal compared to poor categories were 0.79 (95% CI=0.62, 0.99) and 0.69 (95% CI=0.48, 1.01), respectively. A modifiable risk factor category increase (poor to average or average to optimal) was associated with an 18% lower risk of incident diabetes (*p*=0.03). Similar results were seen with adjustment for waist circumference instead of BMI.

For participants with BMI <30 kg/m^2, after adjustment for covariates including BMI, the IRRs for average or optimal compared to poor categories were 0.60 (95% CI=0.40, 0.91) and 0.53 (95% CI=0.29, 0.97), respectively, compared to 0.90 (95% CI=0.67, 1.21) and 0.83 (95% CI=0.51, 1.34) among participants with BMI ≥30 kg/m^2. For participants with normal waist circumference, after adjustment for covariates including BMI, the IRRs for average or optimal compared to poor categories were 0.55 (95% CI=0.33, 0.91) and 0.56 (95% CI=0.26, 1.21), respectively, compared to 0.89 (95% CI=0.68, 1.17) and 0.80 (95% CI=0.52, 1.22), among participants with central obesity. For participants with baseline normoglycemia, in multivariable adjusted models prior to adjustment for measures of adiposity, the IRRs for average or optimal compared to poor categories were 0.64 (95% CI=0.43, 0.96) and 0.57 (95% CI=0.31, 1.04) among participants, respectively, compared to 0.90 (95% CI=0.69, 1.19) and 0.80 (95% CI=0.52, 1.23) among participants with prediabetes. The findings among normoglycemic participants were attenuated and became non-significant after adjustment for BMI or waist circumference.

DISCUSSION

In this large, contemporary, prospective cohort study, AAs with average and optimal modifiable risk factor scores had a 21% and 31% lower risk of incident diabetes, respectively, compared to participants with a poor modifiable risk factor score. Compared with previous studies examining the combined effects of multiple risk factors on the incidence of diabetes that included AAs,[8] this study used a different approach. First, factors above and beyond physical activity and dietary intake were accounted for, namely sedentary behaviors, smoking, and sleep disorders, that may influence insulin sensitivity. Second, BMI was not included as a modifiable risk factor as done previously,[6–8,24] but instead findings were adjusted or stratified by BMI. The rationale is that obesity is a known precursor of diabetes[9] and weight reduction is proven to reduce diabetes risk[28]; however, it remains difficult to achieve in large populations of AAs using current approaches including community-based translations of the Diabetes Prevention Program.[29,30] Thus, the results indicate that a cumulative modification of several risk factors above and beyond physical activity and diet may lower risk of diabetes independent of adiposity.

Analyses of modifiable lifestyle risk factors with incident diabetes are limited among AAs. In the Multi-Ethnic Study of Atherosclerosis, improved levels (ideal versus poor cardiovascular health) of a combination of total cholesterol, blood pressure, dietary intake, tobacco use, physical activity, and BMI were associated with 66% lower risk of diabetes among AAs (n=1,293).[8] Individually, improved levels of smoking, physical activity or dietary intake were not associated with lower risk of diabetes among AAs, whereas more TV watching was associated with increased risk of diabetes, consistent with data from the Black Women's Health Study.[8,19,31] Consistent with the SDBB findings, obstructive sleep apnea has been linked with incident diabetes in a study including AAs.[32] In this study, the individual effect of each modifiable lifestyle risk factor on diabetes incidence was non-significant but in the expected direction, though this was attenuated after accounting for BMI. These results differ from larger analyses of NHWs in which ideal dietary intake,[33] higher physical activity,[19] sleep disordered breathing,[34,35] and smoking[36] were individually associated with a lower risk of developing diabetes. Results from this study suggest that the combination of adjusting modifiable risk factors to optimal levels is likely to result in the greatest benefit for lowering diabetes risk among AAs. A key finding is that the associations varied by BMI, waist circumference, and baseline glycemic status with the greater magnitude of associations observed among participants with BMI <30 kg/m^2, normal waist circumference, and normoglycemia at baseline. Therefore, AAs at the lower end of the diabetes risk spectrum may derive greater long-term benefit from prevention strategies focused on the outlined modifiable lifestyle risk factors. A combination of clinical practice guidelines that emphasize a healthy lifestyle in metabolically normal AAs and public health policies that focus on primordial prevention by directing resources to increase physical activity and healthy diet and reduce sedentary activities and smoking are likely necessary to reduce the burden of diabetes in AA communities.[2,37–40]

Limitations

Strengths of the study include the large, socioeconomically diverse, AA cohort with over a decade of follow-up, the validated questionnaires, and the comprehensive ascertainment of diabetes. Additionally, adiposity was accounted for using BMI and waist circumference, to show the robustness of the findings. Despite these strengths, there are several limitations. First, the JHS participants are from one geographic area in the southeastern U.S. and may not be representative of all AAs. Second, the JHS does not include other racial/ethnic groups to allow for racial/ethnic comparisons. Third, although validated,[17,21] self-reported measures of physical activity, dietary intake, and SDBB were used, thus there was a potential for misclassification and residual confounding by these variables due to lack of precision compared to objective measures. The 4-point scoring system for SDBB versus 3 points for the other components gives a slightly greater "weight" for this component Longitudinal tracking of risk factors that would account for changes over time was not included, which may have minimized misclassification. Smoking was considered a modifiable lifestyle risk factor, consistent with prior studies,[6–9] but may also be considered an addiction.[41] Lastly, the relationship of modifiable lifestyle risk factors with incident diabetes may have been underestimated, as individuals with impaired glucose tolerance, may have remained undetected.

CONCLUSIONS

The findings underscore the importance of combining both primordial prevention and primary prevention approaches to curb the toll of diabetes among AAs. Lifestyle interventions to reduce obesity have focused on individuals with high BMI or prediabetes (high-risk approach) or both. This study suggests that a complementary approach that includes AAs at the earlier stages in the continuum of risk may improve results for diabetes prevention. This indicates a need for a societal approach for primordial and primary preventive interventions targeting a combination of modifiable risk factors in those traditionally considered to be at low risk, especially among AAs.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Definitions of Modifiable Lifestyle Risk Factors and Total Score

Modifiable Lifestyle Risk Factors	Points			
	0	1	2	3
Current smoking, months	Yes	Former ≤12	Never or quit ≥12	--
TV watching, hours/day	>4	1–4	<1	--
AHA physical activity, minutes/week MVPA[a]	<1	1–149	>150	--
AHA healthy diet score, components[b]	0–1	2–3	4–5	--
Sleep disordered breathing burden[c]	Severe	Moderate	Mild	None
Modifiable Lifestyle Risk Factors Points	0–3	4–7	8–11	
Modifiable Lifestyle Risk Factor Total Score	Poor	Average	Optimal	

[a]AHA physical activity: Poor health: (1) 0 minutes of moderate physical activity and (2) 0 minutes of vigorous physical activity; Average health: (1) 0 < minutes of moderate physical activity <150 or (2) 0 < minutes of vigorous physical activity <75 or (3) 0 < minutes of combined MVPA <150; and Optimal health: (1) minutes of moderate physical activity ≥150 or (2) minutes of vigorous physical activity ≥75 or (3) minutes of combined MVPA ≥150.

[b]Adapted for JHS: ruits and vegetables: ≥4.5 cups/day (1.08 liters); Fish: >3.5 ounces (98 g), twice per week, Sodium: <1,500 mg/day, Sugar sweetened beverages: <450 kcal/week and Whole grains: ≥3 servings/day.

[c]Sleep Disordered Breathing Burden: Fülöp et al[22]

AHA, American Heart Association; MVPA, moderate to vigorous physical activity; JHS, Jackson Heart Study

Table 2

Baseline Characteristics of Participants by Modifiable Diabetes Lifestyle Risk Factor Score[a]

Baseline characteristics	All n=3 252	Poor n=365	Average n=2544	Optimal n=343	*p*-value[b]
Age, years	53.3 (12.5)	52.3 (10.7)	53.5 (12.8)	53.2 (11.5)	*p*=0. 27
Female, sex, N (%)	**2,066 (64)**	**199 (55)**	**1,643 (65)**	**224 (65)**	***p*=0. 001**
Education >Bachelor's degree, N (%)	**1,217 (37)**	**77 (21)**	**943 (37)**	**197 (57)**	***p*<0. 001**
Occupation, management/professional, N (%)	**1,287 (40)**	**92 (25)**	**1,000 (39)**	**195 (57)**	***p*<0. 001**
Alcohol use, N (%)	**1,616 (50)**	**222 (61)**	**1,216 (48)**	**178 (52)**	***p*<0. 001**
Systolic blood pressure (mmHg)	**125 (17)**	**127 (18)**	**125 (17)**	**122 (17)**	***p*<0. 001**
Diastolic blood pressure (mmHg)	**79 (10)**	**81 (11)**	**79 (10)**	**78 (10)**	***p*=0. 004**
Waist circumference (cm)	**98.6 (15.7)**	**101.1(1 7.5)**	**98.8 (15.6)**	**94.3(12 .9)**	***p*<0. 001**
BMI (kg/m^2)	**31.2 (7.0)**	**31.4 (7.8)**	**31.4 (7.1)**	**29.6 (5.4)**	***p*<0. 001**
Fasting plasma glucose (mmol/l, mg/dl)[c]	**5.0 (0.5), 90 (9)**	**5.1 (0.5), 91 (9)**	**5.0 (0.5), 90 (9)**	**4.9 (0.4), 89 (8)**	***p*<0. 001**
Hemoglobin A1c (%) (n=3,176)[c]	5.5 (0.5)	5.5 (0.5)	5.5 (0.5)	5.5 (0.4)	*p*=0. 53
Homeostatic model assessment of insulin resistance (HOMA-IR) (n=3,125)	**3.6 (2.3)**	**3.8 (2.5)**	**3.6 (2.2)**	**3.1 (10.7)**	***p*<0. 001**
Adiponectin (ng/mL) (n=3,193)	**5,304 (3,866)**	**4,546 (3,220)**	**5,327 (3,753)**	**5,948 (5,027)**	***p*<0. 001**
Current smoking, N (%)	**383 (12)**	**227 (62)**	**154 (6)**	**2 (1)**	***p*<0. 001**
TV watching <1 hour/day, N (%)	**468 (14)**	**8 (2)**	**298 (12)**	**162 (47)**	***p*<0. 001**
Sleep disordered breathing burden (None), N (%)	**351 (11)**	**8 (2)**	**233 (9)**	**110 (32)**	***p*<0. 001**
Ideal AHA physical activity, N (%)	**697 (21)**	**3 (1)**	**452 (18)**	**242 (71)**	***p*<0. 001**
Ideal AHA dietary intake, N (%)	**24 (1)**	**0.0 (0)**	**8 (0.3)**	**16 (5)**	***p*<0. 001**
Incident diabetes, (rate per 1,000 person-years, (95% CI))	**22.9 (21. 1–24.9)**	**28.7 (23.0–35.8)**	**22.9 (20.8, 25.1)**	**16.9 (12.6, 22.8)**	***p*=0. 001**

Notes: Boldface indicates statistical significance ($p<0.05$).

[a]Modifiable diabetes lifestyle risk factor score: Poor (Score 0–3), Average (Score 4–7), Optimal (Score 8–11)

Smoking: Current smoker (0 points), ormer ≤12 months (1 point), Never or quit ≥12 months (2 points)

TV watching: >4 hours/day (0 points), 1–4 hours/day (1 point), <1 hour/day (2 points)

AHA physical activity: poor (0 points), intermediate (1 point), ideal (2 points)

AHA healthy diet: poor (0 points), intermediate (1 point), ideal (2 points)

Sleep Disordered Breathing Burden: Severe (0 points), Moderate (1 point), Mild (2 points), None (3 points)[22]

[b]Mean (SD) or percentages are listed, *p*-values calculated using chi-square (categorical variables), ANOVA (parametric continuous variables), Kruskal-Wallis test (non-parametric continuous variables) and Mantel-Cox for incident rate comparisons.

[c]SI conversion factors: Fasting plasma glucose conversion to mmol/L (0.0555). Hemoglobin A1c conversion from % to mmol/mol = 10.93 × % – 23.5.

AHA, American Heart Association; SI, International System of Units

Table 3

Association of Modifiable Diabetes Risk Factors With Incident Diabetes Over 8 Years

Exposures	Poisson regression model – Incident rate ratio (95% CI) for incident diabetes n=3,252 with 560 cases				
	N/Diabetes cases	Model 1[a]	Model 2[a]	Model 3[a]	Model 4[a]
Smoking					
Current	383/68	ref	ref	ref	ref
Former <12 months	30/5	0.65 (0.26, 1.63)	0.66 (0.27, 1.65)	0.72 (0.29, 1.79)	0.72 (0.29, 1.77)
Never or quit ≥12 months	2,839/487	0.90 (0.70, 1.15)	0.90 (0.70, 1.16)	0.83 (0.64, 1.06)	0.83 (0.65, 1.07)
Continuous[b]		0.95 (0.84, 1.08)	0.96 (0.84, 1.08)	0.91 (0.80, 1.03)	0.91 (0.81, 1.04)
TV watching					
≥4 hours/day	1,117/211	ref	ref	ref	ref
1–3.9 hours/day	1,667/281	0.95 (0.79, 1.13)	0.96 (0.80, 1.15)	0.97 (0.81, 1.17)	0.99 (0.82, 1.18)
<1 hour/day	468/68	0.88 (0.67, 1.15)	0.91 (0.69, 1.19)	0.95 (0.72, 1.25)	0.95 (0.72, 1.25)
Continuous[b]		0.94 (0.83, 1.07)	0.95 (0.84, 1.08)	0.97 (0.86, 1.11)	0.98 (0.86, 1.11)
Physical activity					
Poor	1,468/279	ref	ref	ref	ref
Intermediate	1,087/181	0.97 (0.80, 1.16)	0.99 (0.82, 1.20)	1.00 (0.83, 1.21)	1.01 (0.84, 1.22)
Ideal	697/100	0.84 (0.67, 1.06)	0.88 (0.70, 1.11)	0.91 (0.72, 1.15)	0.92 (0.72, 1.16)
Continuous[b]		0.93 (0.83, 1.03)	0.95 (0.85, 1.06)	0.96 (0.86, 1.07)	0.97 (0.86, 1.08)
Healthy diet score					
Poor	2,063/354	ref	ref	ref	ref
Intermediate	1,165/203	0.92 (0.78, 1.10)	0.95 (0.79, 1.13)	0.93 (0.78, 1.11)	0.94 (0.78, 1.11)
Ideal	24/3	0.64 (0.20, 1.99)	0.66 (0.21, 2.06)	0.74 (0.24, 2.33)	0.77 (0.24, 2.40)
Continuous[b]		0.91 (0.77, 1.08)	0.94 (0.79, 1.11)	0.92 (0.78, 1.10)	0.93 (0.78, 1.10)
Sleep disordered breathing burden					
Severe	113/23	ref	ref	ref	ref
Moderate	880/182	0.95 (0.64, 1.42)	0.97 (0.65, 1.45)	0.95 (0.64, 1.40)	0.96 (0.65, 1.41)
Mild	1,908/299	0.73 (0.49, 1.08)	0.74 (0.50, 1.10)	0.77 (0.53, 1.13)	0.78 (0.54, 1.14)
None	351/56	0.73 (0.46, 1.15)	0.75 (0.47, 1.18)	0.83 (0.53, 1.31)	0.84 (0.53, 1.31)

Exposures	Poisson regression model – Incident rate ratio (95% CI) for incident diabetes n=3,252 with 560 cases				
	N/Diabetes cases	Model 1[a]	Model 2[a]	Model 3[a]	Model 4[a]
Continuous[b]		**0.85 (0.75, 0.95)**	**0.85 (0.76, 0.96)**	0.89 (0.79, 1.01)	0.90 (0.80, 1.01)
Combined modifiable lifestyle risk factors score[c]					
Poor	365/79	ref	ref	ref	ref
Average	2,544/437	**0.78 (0.61, 0.98)**	**0.79 (0.62, 1.00)**	**0.79 (0.62, 0.99)**	0.80 (0.63, 1.01)
Optimal	343/44	**0.63 (0.43, 0.90)**	**0.66 (0.45, 0.96)**	0.69 (0.48, 1.01)	0.71 (0.49, 1.03)
Continuous[b]		**0.79 (0.66, 0.94)**	**0.81 (0.67, 0.97)**	**0.82 (0.68, 0.98)**	**0.83 (0.69, 1.00)**

Notes: Boldface indicates statistical significance ($p<0.05$).

[a]Model 1: age, sex; Model 2: Model 1 + education, current occupation status, alcohol use, systolic blood pressure; Model 3: Model 2 + BMI; Model 4: Model 2 + waist circumference

[b]Continuous per categorical increase in modifiable lifestyle risk factor category.

[c]Modifiable lifestyle risk factor score: Poor Score (0–3), Average (4–7), Optimal (8–11) (Smoking: Current smoker (0 points), ormer ≤12 months (1 point), Never or quit ≥12 months (2 points); TV watching: >4 hours/day (0 points), 1–4 hours/day (1 point), <1 hour/day (2 points); AHA physical activity: poor (0 points), intermediate (1 point), ideal (2 points); AHA healthy diet: Poor (0 points), Intermediate (1 point), Ideal (2 points); Sleep disordered breathing burden: Severe (0 points), Moderate (1 point), Mild (2 points), None (3 points)

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Table 4

The Stratified Associations of Modifiable Diabetes Risk Factors With Incident Diabetes Over 8 Years

Exposures	N/Diabetes cases	Model 1[a]	Model 2[a]	Model 3[a]	Model 4[a]
		Poisson regression model – Incident rate ratio (95% CI)			
Incident diabetes stratified by WHO BMI categories					
Modifiable lifestyle risk factor score -BMI <30 kg/m^2 (n=1,634)					
Poor	177/27	ref	ref	ref	ref
Average	1,246/138	**0.63 (0.42, 0.93)**	**0.64 (0.43, 0.96)**	**0.60 (0.40, 0.91)**	**0.62 (0.42, 0.92)**
Optimal	211/18	**0.53 (0.30, 0.96)**	0.57 (0.31, 1.04)	**0.53 (0.29, 0.97)**	0.55 (0.30, 1.00)
Continuous[b]		**0.71 (0.52, 0.96)**	**0.73 (0.54, 1.00)**	**0.70 (0.51, 0.96)**	**0.71 (0.52, 0.97)**
Modifiable Lifestyle Score- BMI >30 kg/m^2 (n=1,618)					
Poor	188/52	ref	ref	ref	ref
Average	1,298/299	0.90 (0.67, 1.20)	0.90 (0.67, 1.21)	0.90 (0.67, 1.21)	0.90 (0.67, 1.21)
Optimal	132/26	0.81 (0.51, 1.30)	0.83 (0.51, 1.34)	0.83 (0.52, 1.34)	0.84 (0.52, 1.36)
Continuous[b]		0.90 (0.72, 1.13)	0.91 (0.72, 1.14)	0.91 (0.72, 1.14)	0.91 (0.73, 1.15)
Normal waist circumference versus central obesity					
Modifiable lifestyle risk factor score -normal waist circumferenc e (n=1,126)					
Poor	125/19	ref	ref	ref	ref
Average	856/70	**0.57 (0.35, 0.92)**	**0.56 (0.34, 0.92)**	**0.55 (0.33, 0.91)**	**0.55 (0.34, 0.91)**
Optimal	145/11	0.54 (0.26, 1.13)	0.58 (0.27, 1.24)	0.56 (0.26, 1.21)	0.57 (0.27, 1.23)
Continuous[b]		0.69 (0.47, 1.01)	0.70 (0.47, 1.05)	0.69 (0.46, 1.04)	0.69 (0.46, 1.04)
Modifiable lifestyle risk factor score -central obesity (n=2,126)					
Poor	240/60	ref	ref	ref	ref
Average	1,688/367	0.88 (0.67, 1.16)	0.89 (0.68, 1.17)	0.89 (0.68, 1.17)	0.89 (0.68, 1.17)
Optimal	198/33	0.77 (0.50, 1.17)	0.77 (0.51, 1.20)	0.80 (0.52, 1.22)	0.80 (0.52, 1.22)
Continuous[b]		0.88 (0.72, 1.08)	0.88 (0.72, 1.09)	0.89 (0.73, 1.10)	0.89 (0.73, 1.10)
Normal versus prediabetes					
Modifiable lifestyle risk factor score[c] -normoglyce mia at baseline (n=1,836)					
Poor	195/20	ref	ref	ref	ref

Exposures	N/Diabetes cases	Model 1[a]	Model 2[a]	Model 3[a]	Model 4[a]
		Poisson regression model – Incident rate ratio (95% CI)			
Average	1,426/78	**0.56 (0.34, 0.91)**	**0.58 (0.36, 0.96)**	0.63 (0.38, 1.02)	0.65 (0.40, 1.07)
Optimal	215/10	0.48 (0.23, 1.03)	0.53 (0.24, 1.15)	0.63 (0.29, 1.37)	0.65 (0.30, 1.44)
Continuous[b]		**0.65 (0.44, 0.97)**	0.68 (0.46, 1.02)	0.74 (0.49, 1.10)	0.76 (0.51, 1.14)
Modifiable lifestyle risk factor Score[c] - prediabetes at baseline (n=1,416)					
Poor	170/59	ref	ref	ref	ref
Average	1,118/359	0.91 (0.69, 1.19)	0.90 (0.69, 1.19)	0.89 (0.68, 1.18)	0.90 (0.68, 1.18)
Optimal	128/34	0.80 (0.52, 1.21)	0.80 (0.52, 1.23)	0.81 (0.53, 1.23)	0.81 (0.53, 1.24)
Continuous[b]		0.90 (0.73, 1.10)	0.90 (0.73, 1.10)	0.90 (0.73, 1.10)	0.90 (0.73, 1.10)

Notes: Boldface indicates statistical significance ($p<0.05$).

[a]Model 1: age, sex; Model 2: Model 1 + education, current occupation status, alcohol use, systolic blood pressure; Model 3: Model 2 + BMI; Model 4: Model 2 + waist circumference

[b]Continuous per categorical increase in modifiable lifestyle risk factor category.

[c]Modifiable lifestyle risk factor score: Poor score (0–3), Average (4–7), Optimal (8–11); (Smoking: Current smoker (0 points), ormer ≤12 months (1 point), Never or quit ≥12 months (2 points); TV watching: >4 hours/day (0 points), 1–4 hours/day (1 point), <1 hour/day (2 points); AHA Physical activity: poor (0 points), intermediate (1 point), ideal (2 points); AHA healthy diet: poor (0 points), intermediate (1 point), ideal (2 points); Sleep disordered breathing burden: Severe (0 points), Moderate (1 point), Mild (2 points), None (3 points)

AHA, American Heart Association