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Revisiting the Association between Cardiovascular Risk Factors and Diabetes: Data from a Large Population-Based Study

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Abstract

Purpose—The purpose of the study was to examine the association between cardiovascular risk factors and the presence of diabetes in a large population-level dataset.

Methods—A secondary analysis was conducted using data from the 2007 Behavioral Risk Factor Surveillance System (BRFSS), a population based survey (N=403,137) conducted in the U.S.

Results—The majority of the respondents was middle-aged and overweight. About half of the sample reported little or no physical activity. Estimates from a logistic regression model for a weighted sample of white, black, and Hispanic adults revealed that having hypertension or elevated cholesterol were strong predictors of diabetes even when controlling for age, gender, race, education, income, body mass index, smoking status, and physical activity.

Conclusions—The results confirmed the importance of diabetes educators counseling patients with hypertension or hypercholesterolemia about their increased risk for developing diabetes.

Keywords

diabetes; hypertension; hypercholesterolemia; BRFSS

Almost 23.6 million Americans are diagnosed with diabetes, a number that is likely to increase in the future because of the ongoing epidemic of overweight (body mass index [BMI] 25-29.9 kg/m^2) and obesity (BMI≥30 kg/m^2) in the United States (U.S.).[1, 2] Determining risk factors for type 2 diabetes is important to prevent or delay its development and to assist in early detection of the disease. Previous epidemiological studies have shown that older age, male gender, non-white race, obesity, lower level of socioeconomic status, smoking history, sedentary lifestyle, and having cardiovascular-related conditions such as hypertension and hypercholesterolemia contribute to the development of diabetes.[3-10] While the original Framingham study cohort had an equal comparison of cardiovascular disease (CVD) between

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non-diabetics and diabetics, after 20 years of the prospective study, the incidence of cardiovascular disease among men with diabetes was twice that among men without diabetes. Among women with diabetes, the incidence of cardiovascular disease was three times that among women without diabetes. [11] Fifty years later, the Framingham Offspring Study showed that hypertension and dyslipidemia among cardiovascular disease risk factors are significant risk factors for diabetes.[8] Although the previous data found that diabetes status was a risk factor for cardiovascular disease, the American Diabetes Association (ADA) recently estimated that 5.7 million people (or nearly one quarter) of persons with diabetes are unaware that they have the disease.[2] Therefore, it is important to revisit the relative strength of CVD risk factors alone or in combination for predicting diabetes risk among population data. The purpose of this study was to examine the association between CVD risk factors and the presence of diabetes in a large (N=403,137) representative sample in the U. S. to determine if previously reported associations remain and to discuss implications for the diabetes educator in addressing this public health problem.

Methods

Study Design and Sample

This study was a secondary analysis of the 2007 Behavioral Risk Factor Surveillance System (BRFSS) data. [12] The BRFSS, administered by state health departments, the District of Columbia, Puerto Rico, the U.S. Virgin Islands, and Guam in collaboration with the CDC, is the world's largest on-going survey of health risk behaviors associated with the leading causes of death. [13] Trained health interviewers in each state survey a probability sample of community-dwelling adults age 18 years and older living in residential settings, using computer-assisted telephone interviewing in both English and Spanish, as described elsewhere. [14] State-level data were pooled to produce national estimates.

Measures

Diabetes status (dependent variable) was assessed by the question [15] “Have you ever been told by a doctor that you have diabetes?” Female respondents who answered affirmatively were further asked “Was this only when you were pregnant?” For this report, respondents with gestational diabetes were excluded.

Risk factors for CVD (hypertension and hypercholesterolemia) were ascertained from responses to the questions [15] “Have you ever been told by a doctor, nurse or other health professional that you have high blood pressure?” and “Have you ever been told by a doctor, nurse or other health professional that your blood cholesterol is high?” Potential responses to hypertension status included “yes”, “no”, “yes, but only during pregnancy”, “told borderline high or pre-hypertensive”, “don't know/not sure”, and “refused”. Respondents who either didn't know or refused were excluded from the analysis. Females with hypertension only during pregnancy and respondents with “borderline high” or “pre-hypertensive” were included as normal blood pressure in the analysis. Those who affirmed having had their cholesterol checked were further questioned for high cholesterol status (yes/no).

Behavioral risk factors for CVD included smoking status and level of physical activity. Smoking status was classified as a current smoker, former smoker, and never-smoker. Two types of physical activity lasting at least 10 consecutive minutes were assessed: moderate activity (causing a small increase in pulse or respiratory rate) and vigorous activity (causing a large increase in pulse or respiratory rate). In addition, examples of activity were provided to respondents to help them better estimate physical activity level: brisk walking, bicycling, vacuuming, and gardening were examples of moderate activity and running, aerobics, and heavy yard work were examples of vigorous activity. Respondents were asked how many days

per week they were active and how long they were active on those days. The BRFSS further categorized these physical activity data as meeting recommendations (at least moderate and/or vigorous physical activity for 30 min/day, 5 days/week), insufficient physical activity, and no physical activity.

Demographic characteristics included age, sex, race (Whites, Blacks, and Hispanics), education (≤12 years and >12 years), and income (≤ $50,000/year and > $50,000/year); BMI ($kg/m^2$) was calculated from the respondents' self-reported height and weight without shoes.

Analytic Strategy

Data analyses were conducted using SAS (version 9.1.3; SAS Institute, Cary, NC) complex survey procedures which correctly estimate the variance of an estimate from complex sample surveys such as the BRFSS. The 2007 BRFSS data were weighted according to the formula in the BFRSS Codebook that considers the number of adults in the respondent's household, the number of residential telephone numbers in the respondent's household, and size of the sample strata (the number of telephones in the area code where the data were collected) to obtain the estimated means and frequencies of the population. Along with these means and frequencies, 95% confidence intervals (CI) were reported to show how precisely these estimated values represent the population. A post-stratification adjustment was also performed on the data according to the BRFSS Codebook to statistically account for persons who did not respond to the survey or did not have a telephone to be contacted. Weighting the data served to ensure a sample was reflective of the entire population and adjusted for the possibility that a non-representative sample was obtained. We set ‘don't know’ and ‘refuse’ responses to missing values and excluded them from the analysis. For these analyses, we only included people who identified themselves as being White, Black, or Hispanic.

Means with standard errors, frequency distributions and cross tabulations with chi-square tests of independence were presented to describe the total sample and by self-reported diabetes status. Binary logistic regression was conducted to examine possible predictors of diabetes. Age, sex, race, education, income, smoking status, BMI, physical activity, hypertension, and hypercholesterolemia were selected a priori for consideration in the binary logistic regression models to predict the probability of having diabetes. Each odds ratio with corresponding 95% CI in the logistic regression model shows the independent effect of each variable for predicting diabetes status after controlling for the effect of the other variables. Multicollinearity among independent variables was not a problem when they were examined using tolerance values and variance inflation factors. The level of statistical significance was set at .05 for two-sided hypothesis testing.

Results

Description of Respondents

The majority of respondents were middle-aged and overweight (See Table 1). About 50% of the sample reported they had either little or no physical activity, and almost 20% were current smokers. Hypertension and hypercholesterolemia were common, with about 30% of the sample reported they were diagnosed with hypertension by their health care provider and about 40% indicated awareness of elevated cholesterol levels.

Respondents with diabetes were significantly ($p<.001$) older and more likely to be non-white, less educated, and of lower economic status, and currently or formerly smoking. Those with diabetes tended to be obese (mean BMI 31.4 ± .07) while those without diabetes, on average, were overweight (mean BMI 27.1 ± .02). Almost 25% of respondents with diabetes reported no physical activity, compared with 12% of the respondents without diabetes. Both

hypertension and hypercholesterolemia were more prevalent among persons with diabetes than those without diabetes ($p < .001$).

Black respondents were significantly more likely to have diabetes (12.3%) than the total sample (8.8%), white respondents (8.0%), or Hispanic respondents (9.1%). Approximately 68% of blacks were overweight or obese (mean BMI 29.02 ± .07), approximately 60% did not meet physical activity recommendations, 33.4% reported hypercholesterolemia, and 36.5% reported hypertension. Hispanic respondents also had multiple risk factors for diabetes: 62% were overweight or obese (mean BMI 27.82 ± .08), 56.2% did not meet physical activity recommendations, 33.8% reported hypercholesterolemia, and 21% reported hypertension.

Risk Factors for Diabetes

Logistic regression was performed to determine the odds of developing diabetes based on age, gender, race, education, income, BMI, smoking status, physical activity, hypertension, and hypercholesteremia (Table 2). Based on a multivariate binary logistic regression, hypertension and elevated cholesterol were found to be the strongest predictors of diabetes. After controlling for the other factors, diabetes was 2.36 times more likely to be present in respondents with hypertension (95% CI: 2.23, 2.51) and 1.94 times more likely among those with high cholesterol (95% CI: 1.84, 2.05). In addition, weight gain was an important risk factor for diabetes; the risk of diabetes increased 9% with each additional unit of BMI after controlling for all other variables. For example, when a woman who is 64 inches tall and weighs 145 pounds (BMI 25) gains 12 pounds (BMI 27) there is an 18% increase in the risk for developing diabetes. Moreover, compared to Whites, black adults were 1.7 times more likely to have diabetes (95% CI: 1.57, 1.87) and Hispanics were 1.64 times more likely to have diabetes (95% CI: 1.47, 1.83).

Discussion

The associations between cardiovascular risk factors and diabetes were examined using the most currently available BRFSS data that used an extraordinary large sampling of over a third of a million Americans. The results of the present study confirm that hypertension and/or elevated cholesterol significantly increase the odds of having co-existing diabetes. They further support the positions of the American Heart Association (AHA) and the ADA that hypertension, hypercholesterolemia, and diabetes frequently co-exist and need to be treated in unison. [16] The ADA and the AHA both recognize that CVD is the leading cause of death in persons with diabetes. Among the ADA's clinical guidelines for standards of medical care are recommendations for control of elevated blood pressure and lipid levels and promotion of heart-healthy lifestyles. [16] Likewise, the AHA encourages weight loss, increased physical activity, controlling high blood pressure, and reduction in cholesterol as important interventions to reduce the risk of cardiovascular morbidity in persons with diabetes. However, current standards of medical care by the ADA [16] recommend testing for diabetes in adults age 45 years and older only if the BMI is more than 25 kg/m^2. For a younger age, testing for diabetes is recommended if there are additional risk factors such as sedentary lifestyle, family history, member of a high-risk ethnic group, hypertension, and abnormal HDL cholesterol or triglyceride. Indeed, these results suggest that greater vigilance is warranted in screening adults with hypertension or elevated cholesterol levels, who are at risk for diabetes.

Non-Hispanic Blacks and Hispanics have a significantly higher prevalence of overweight and obesity than non-Hispanic Whites. [17] Approximately 68% of Blacks and 62% of Hispanics in the BRFSS survey were overweight or obese. This is particularly ominous because of the strong link between excessive weight and increased risk of type 2 diabetes [7, 18, 19], given that approximately 85% of adults with type 2 diabetes are either overweight or obese. [20] Results of the Diabetes Prevention Program trial provided irrefutable evidence to support the

importance of weight loss in diabetes prevention when it demonstrated that for every 1 kg of body weight that was lost, the risk of developing diabetes was reduced 16 % after controlling for changes in diet and physical activity. [21]

Caution needs to be exercised about inferring causal relationships from the survey's cross-sectional design that relied on self-report data. The use of a telephone survey increases the ability to obtain the large, population-level sample; however, it systematically excludes individuals without telephones. The weaknesses are compensated by using weighted data for analysis and balanced by the fact that the BRFSS is a large, randomly selected, population-based sample.

Self-report data have a potential response bias that may result from an over- and under-estimation of height and weight. However, Kawada and colleagues found a high correlation between self-reported height and weight and actual measurements. [22] Moreover, self-reported weights have been used in the National Weight Control Registry since 1994 [23] and have been shown to be valid in various studies. [24-26] Moderate to high concordance was observed between self-reported chronic health conditions (including diabetes, hypertension, and hypercholesterolemia) gathered in response to BRFSS questions, and health maintenance organization (HMO) medical records. [27] In addition, we acknowledge that the amount of physical activity measured by the self-reported questionnaires may have over- or under-reported the actual physical activity performed due to social desirability bias and recall bias even though self-report physical activity measures are beneficial to collect data from a large number of people at low cost.[28] A limitation of the original BRFSS survey is that respondents with diabetes are not asked to classify their disease as type 1, type 2, secondary to pancreatic dysfunctions from cystic fibrosis, or drug induced, unless their diabetes was diagnosed only during pregnancy. Type 2 diabetes accounts for approximately 90% of all cases of diabetes, [2] and the assumption can be made that the majority of persons who confirmed they had “diabetes” were in fact diagnosed with type 2 diabetes. Approximately 30% of all cases of diabetes are estimated as undiagnosed, this suggests that there may be respondents with diabetes that were misclassified as not having diabetes. [29] Likewise, because hypertension and hypercholesterolemia are “silent” diseases without overt symptoms that are problematic to patients, many cases may have been undiagnosed, with respondents thus incorrectly classified as not having the disease.

Implications for Diabetes Educators

There are two main public health approaches for the prevention and early identification of type 2 diabetes: a population-based approach and a targeted approach. A population-based approach focuses on changing the lifestyle and environmental determinants in the general population to promote healthy diet and physical activity. Examples of a population-based approach include policy initiatives to promote physical activity, labeling requirements for foods, and pedestrian friendly built environments to increase physical activity. The targeted approach directs preventive measures only for those persons at high risk for the future development of type 2 diabetes.

Instead of population-based universal screening, targeted or opportunistic screenings in high-risk populations are recommended for type 2 diabetes.[30] For public health benefits, targeting people with hypertension for diabetic screening has been shown to be more cost-effective than universal screening.[31-33] The results of a study conducted in France suggested that diabetes screening in people with risk factors such as hypertension and dyslipidemia in a primary care setting resulted in lower frequency of undiagnosed diabetes in the high risk population.[34] The implication of these findings for public health nursing is that these health care professionals in community-based care settings need to counsel their clients with hypertension or

hypercholesterolemia about their increased risk for developing diabetes. Indeed, instituting protocols that systematically prompt providers to screen for diabetes in these patients is both timely and warranted.

Our findings specifically warrant more involvement of diabetes educator in diabetes prevention and management as part of the strategy of targeting persons at high risk. The high prevalence of diabetes among persons with hypertension or hypercholesterolemia suggests that screening and providing prevention counseling for diabetes among individuals with these CVD risk factors is an important intervention for diabetes educators to consider. In addition, the findings reinforce the importance of screening for diabetes among men, Black and Hispanic populations, smokers, persons with a sedentary lifestyle, and those with a lower socioeconomic status. Because certain risk factors such as age, gender, race and family history cannot be modified, it is important to address among persons at high-risk for diabetes, those risk-factors that are modifiable. Most important, a reasonable (e.g., 7%) reduction in body weight among persons who are overweight or obese, increased physical activity, and stopping smoking will not only help lower CVD risk but also significantly reduce the likelihood of developing type 2 diabetes.

Conclusions

Although there have been numerous study reports that have explored the association between cardiovascular risk factors and the risk of diabetes,[8-10] this analysis is important because it uses population-level data to draw its conclusions. Because of this, the authors believe that the analysis adds strong evidence that patients with cardiovascular risk factors are at high risk for diabetes and that proactive diabetes education might not only improve their cardiac status but also prevent or delay the occurrence of diabetes mellitus.

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Table 1

Description of the Total BRFSS 2007 Weighted Sample and Comparison of Respondents With and Without Diabetes

Variables	Total Sample (N=403,137)		Respondents Without Diabetes (n=349158)		Respondents With Diabetes (n=44528)		p-value
	Mean (SE)	%	Mean (SE)	%	Mean (SE)	%	
Age (years)	46.44 (.06)		45.1 (.06)		59.8 (.16)		<.001
Gender							
Male		48.2		48.7		49.4	.142
Female		51.8		51.3		50.6	
Race							
Whites		73.8		74.5		67.9	<.001
Blacks		10.3		9.8		15.7	
Hispanics		15.9		15.7		16.4	
Education							
High school		40.9		39.7		52.0	<.001
More than high school		59.1		60.3		48.0	
Income							
Less than $50,000		51.8		50.0		68.3	<.001
$50,000 or more		48.2		50.0		31.7	
Smoking Status							
Current smoker		19.4		19.8		15.4	<.001
Former smoker		24.5		23.5		35.9	
Never smoker		56.1		56.8		48.6	
BMI (kg/m^2)	27.5 (.02)		27.1 (.02)		31.4 (.07)		<.001
Physical Activity							
Meet Recommendations		48.8		50.3		34.5	<.001
Insufficient Physical Activity		37.8		37.5		40.1	
No Physical Activity		13.4		12.2		25.4	
Blood Pressure							
Normal		72.0		75.9		32.9	<.001
Hypertension		28.0		24.1		67.1	
Cholesterol							

Variables	Total Sample (N=403,137)		Respondents Without Diabetes (n=349158)		Respondents With Diabetes (n=44528)		p-value
	Mean (SE)	%	Mean (SE)	%	Mean (SE)	%	
Normal		62.4		65.6		37.0	<.001
High Cholesterol		37.6		34.4		63.0	

Table2

Results of Logistic Regressions Predicting Having Diabetes

Variables	Odd Ratio	95% CI Lower	95% CI Upper
Age	1.04	1.04	1.04
Gender			
Male	1.26	1.20	1.33
Female	1		
Race			
Whites	1		
Blacks	1.71	1.57	1.87
Hispanics	1.64	1.47	1.83
Blood Pressure			
Normal	1		
Hypertension	2.36	2.23	2.51
Cholesterol			
Normal	1		
High Cholesterol	1.94	1.84	2.05
BMI (kg/m^2)	1.10	1.09	1.10
Smoking Status			
Current smoker	1.11*	1.03	1.20
Former smoker	1.12*	1.05	1.18
Never smoker	1		
Physical Activity			
Meet Recommendations	1		
Insufficient Physical Activity	1.14	1.08	1.21
No Physical Activity	1.37	1.27	1.48
Education			
high school	1.16	1.10	1.23
More than high school	1		
Income			
Less than $ 50,000	1.40	1.32	1.48
$50,000 or more	1		

* p<.01 and all other p-values < .0001

Note: All other variables were controlled to predict the independent effect of each variable for predicting diabetes status.