HHS Public Access

Author manuscript

Diabetes Obes Metab. Author manuscript; available in PMC 2018 September 01.

Published in final edited form as:

Diabetes Obes Metab. 2017 September ; 19(9): 1260–1266. doi:10.1111/dom.12949.

Evaluation of the Modified FINDRISC Diabetes Score to Identify Individuals at High Risk for Diabetes among Middle-aged White and Black ARIC Study Participants

Manjusha Kulkarni, PhD[1,2], **Randi E. Foraker, PhD**[2], **Ann Marie McNeill, PhD**[3], **Cynthia Girman, PhD**[4], **Sherita Hill Golden, MD**[5], **Wayne D. Rosamond, PhD**[6], **Bruce Duncan, MD**[7], **Maria Ines Schmidt, MD**[7], and **Jaakko Tuomilehto, PhD**[8,9,10,11]

[1]School of Health and Rehabilitation Sciences, Division of Medical Laboratory Science, Ohio State University, Columbus, OH 43210, USA [2]Division of Epidemiology, College of Public Health, The Ohio State University, Columbus, OH, USA [3]Merck Sharp & Dohme Corp., Whitehouse Station, NJ, USA [4]CERobs Consulting, LLC, Chapel Hill, NC, and also Department of Epidemiology, Gillings School of Global Public Health, UNC, Chapel Hill, NC USA [5]Department of Medicine, Division of Endocrinology, Diabetes, and Metabolism, Johns Hopkins University School of Medicine, Baltimore, MD, USA [6]Department of Epidemiology, Gillings Global School of Public Health, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA [7]Postgraduate Program in Epidemiology, School of Medicine, Federal University of Rio Grande do Sul, Rio Grande do Sul, Brazil [8]Chronic Disease Prevention Unit, National Institute for Health and Welfare, Helsinki, Finland [9]Centre for Vascular Prevention, Danube-University Krems, Krems, Austria [10]Dasman Diabetes Institute, Safat, Kuwait [11]Diabetes Research Group, King Abdulaziz University, Jeddah, Saudi Arabia

Abstract

Objective—To evaluate a modified Finnish Diabetes Risk Score (FINDRISC) score for predicting the risk of incident diabetes among white and black middle-aged Atherosclerosis Risk in Communities (ARIC) study participants.

Research Design and Methods—We assessed 9,754 ARIC cohort participants who were free of diabetes at baseline. Logistic regression and receiver operator characteristic (ROC) curves were used to evaluate a modified FINDRISC score for predicting incident diabetes after 9 years of

Corresponding Author: Randi E. Foraker, 334 Cunz Hall, 1841 Neil Avenue, Division of Epidemiology, College of Public Health, The Ohio State University, Columbus, OH, USA; Phone 614-292-9916; Fax 614-688-3533.

DUALITY OF INTEREST

A.M.M. is an employee of, and owns stock in, Merck & Co. Inc.

AUTHORS CONTRIBUTIONS

M.M.K. assisted with data analysis, and wrote and edited the manuscript. C.G., S.H.G., W.D.R., B.D., and M.I.S. provided subject matter expertise and edited the manuscript. J.T. developed the FINDRISC and edited the manuscript. A.M.M. designed the study, oversaw the data collection, and wrote and edited the manuscript. R.E.F. conducted data analysis and wrote and edited the manuscript, and is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

PRIOR PRESENTATION

None

follow-up, overall and by race/gender group. The modified FINDRISC score we used comprised age, body mass index, waist circumference, blood pressure medication, and family history.

Results—The mean FINDRISC score [range: 2 (lowest risk) −17 (highest risk)] for black women was higher (9.9±3.6) than for black men (7.6±3.9), white women (8.0±3.6), and white men (7.6±3.5). The incidence of diabetes generally increased across deciles of FINDRISC score for all four race/gender groups. ROC curve statistics for the FINDRISC score showed the highest area under the curve for white women (0.77) and lowest for black men (0.70).

Conclusions—We used a modified FINDRISC score to predict the 9-year risk of incident diabetes in a biracial United States population. The modified risk score can be useful for the early screening of incident diabetes in biracial populations, which may be helpful for early interventions to delay or prevent diabetes.

INTRODUCTION

The worldwide prevalence of diabetes was 8% in 2012 and approximately 5.1 million people aged between 20 and 79 years died from diabetes in 2013.[1] The prevalence of diabetes in the adult population of the United States (US) had exceeded 11% by the year 2010.[2] What many believe to be an epidemic of type 2 diabetes around the world has fueled interest in the development of simple and affordable screening strategies to identify participants who would benefit from aggressive lifestyle or pharmacologic prevention strategies.[3,4]

To improve upon the predictive properties of fasting or 2-hour glucose tolerance, several multivariable models have been published[5–13] that utilize a combination of risk factor profiles and measures of glucose disturbances with clinical variables. Although such “complex” algorithms may be appropriate for etiologic investigations of the underlying causes of the development of type 2 diabetes, they may be impractical from the standpoint of public health screening efforts to identify individuals at high-risk of glucose disturbances who would benefit principally from primary prevention strategies.[5,6,9,10]

There are multiple reviews of diabetes risk scores in the literature.[14–16] A recent database search yielded a total of 8,864 records for diabetes risk scores, but only 145 of them were actually tested in populations, and details of only 96 models were available.[14] These studies took place in 17 countries on six different continents: 30 in Europe, 25 in North America, 21 in Asia, 8 in Australasia, 8 in the Middle East, 1 in South America, and 1 in Africa.[15] Some of the simpler diabetes risk scores include Finnish Diabetes Risk Score (FINDRISC),[17] ADA,[18] Cambridge,[19] German Risk Score,[20] Rotterdam,[21] and Inter99[22] which were developed to screen for prevalent or incident diabetes, based on a combination of age, family history of diabetes, history of gestational diabetes, anthropometric measures (weight, height, body mass index [BMI], waist circumference), levels of physical activity, dietary habits, use of anti-hypertensives or corticosteroids, and other constructs that do not require laboratory measurements. In Europe, the FINDRISC has been recommended by the European Society of Cardiology (ESC) and European Association of the Study of Diabetes (EASD) for the general population.[23]

Specifically, the FINDRISC[17] has been externally validated to identify participants at high risk for incident diabetes and to predict prevalent undiagnosed diabetes, impaired fasting glucose, or the metabolic syndrome in Finnish, Italian, and Greek populations.[17, 24] Recently, a cross-sectional analysis of the FINDRISC risk score was carried out with NHANES data to identify participants with undiagnosed diabetes and pre-diabetes in US populations.[25] The purpose of the current study was to prospectively evaluate the ability of the FINDRISC to predict diabetes (treated or untreated) during 9 years of follow up among white and black middle-aged men and women in the US.

METHODS

Data from baseline (Visit 1) of the Atherosclerosis Risk in Communities (ARIC) study was used to identify participants with prevalent diabetes and to ascertain participants' values on FINDRISC algorithm components. Follow-up visits 2, 3, and 4 (occurring at approximately 3-year intervals) were used to ascertain incident diabetes status. Since not all self-reported FINDRISC data were available for analysis, we evaluated the diagnostic properties of a modified FINDRISC using receiver operator characteristic (ROC) curves. We assessed the ability of the modified FINDRISC to predict incident diabetes during 9 years of follow-up, for the overall population and within race/gender groups, in participants with no evidence of diabetes at baseline.

Study population

The ARIC study is a prospective study of 15,792 people aged 45–64 years from four US communities:[26–27] Forsyth County, North Carolina, Jackson, Mississippi, suburbs of Minneapolis, Minnesota, and Washington County, Maryland. We excluded 48 participants who were not white or black, and blacks living in the Minnesota and Maryland study communities (n=55), due to a lack of power to make inferences to these populations. We also excluded 516 participants at baseline who were not fasting 8 hours or more, as well as 71 participants with unknown fasting status at the time of the baseline exam. An additional 1,611 participants were excluded for having diabetes at baseline and 95 were not included due to missing prevalent diabetes status at baseline. The number of participants missing data on FINDRISC score components such as BMI (kg/m^2), waist circumference (cm), hypertensive medication use within the last two weeks, and family history of diabetes (paternal and maternal, living, or deceased) was 1,279. Finally, 2,363 participants were excluded for not having complete information on incident diabetes status throughout 9 year follow-up, resulting in 9,754 participants available for this analysis.

Study definition of diabetes

The definition of diabetes was the same for all four visits: a fasting blood glucose concentration of ≥126 mg/dl, self-reported, diagnosis by a physician, or the use of any medication for diabetes or high blood glucose.

FINDRISC

The FINDRISC algorithm was developed in the Finnish population to screen for individuals at high risk of developing diabetes[17] and includes the following measures: age; BMI; waist circumference; physical activity; daily consumption of fruits, vegetables, and berries; history of medication use for hypertension; self-reported history of elevated glucose (or gestational diabetes); and family history of diabetes (Table S1). We used a modified FINDRISC due to characteristics of our study population and available data, as described below. The comparison of the original FINDRISC with our modified FINDRISC with respect to variables and their associated score points is given in Table S1. The original[17] FINDRISC ranged from 0–26 while our modified FINDRISC ranged from 2–17.

The age strata of eligible ARIC participants at baseline corresponded to the FINDRISC algorithm of 45–54 years and 55–64 years with two and three points, respectively. Meanwhile, the anthropometric measures of BMI and waist circumference were assessed at baseline for each cohort member, and defined exactly as shown in Table 1, consistent with the original FINDRISC.

Data on physical activity and fruit, vegetable, and berry consumption were not collected in ARIC at baseline in a manner consistent with the original[17] FINDRISC (Table S1). Specifically, while participants were asked about physical activity at work and during leisure time, duration of activity was not captured. Similarly, data were ascertained at baseline regarding participants' consumption of particular fruits and vegetables, but not fruits, vegetables, and berries as food categories. Thus, we were not able to consider questions on physical activity and diet in the present analysis. It should be noted, however, that a simplified FINDRISC model without indicators of fruit and vegetable consumption and physical activity was successfully validated to predict type 2 diabetes risk prevalence in an Omani population[28] and with disease incidence without the dietary question in a German population.[29]

Participants were asked to bring containers of all medications used in the past two weeks to the baseline visit. ARIC study staff additionally asked participants about specific types of medications, including, "*Were any of the medications you took during the past two weeks for high blood pressure?*" These data were used to ascertain whether a participant was taking high blood pressure medication on a regular basis (Table S1). Meanwhile, data limitations precluded inclusion of history of self-reported elevated blood glucose (Table S1). At baseline, ARIC study staff asked participants specifically about the use of glucose-lowering drugs and assessed fasting blood glucose of all participants, but did not inquire about gestational diabetes or history of other elevated blood glucose readings.

Although participants were asked to report parental history of diabetes at baseline, participants were not asked whether grandparents, siblings, or children had been diagnosed with diabetes. Thus, participants were assigned 5 points on the modified FINDRISC score if their biological mother or father ever had, or now has, diabetes (Table S1).

Data analysis

We used logistic regression to estimate odds ratios and 95% confidence intervals (OR, 95% CI) for the association between the modified FINDRISC and incident diabetes. To investigate the utility of the score to predict the outcome of interest, the modified FINDRISC was modeled as a continuous variable, and ROC curves were generated by plotting the sensitivity of the score versus the false-positive rate (1-specificity) for the overall study sample. Stratified analyses were then conducted according to race/gender groups to evaluate the consistency of the predictive properties of the modified FINDRISC for white and black men and women. We reported area under the curve (AUC) statistics for the study population, overall and by race/gender group.

To investigate the magnitude of association between each individual FINDRISC component and the outcome of incident diabetes (overall and by race/gender group), we also modeled the modified FINDRISC components separately as categorical variables. This analysis allowed us to understand the individual contribution of each of the components in the presence of the other factors. In an ad hoc analysis, we calculated AUCs and confidence intervals (CIs) for waist circumference and BMI alone, as categorical variables, due to the magnitude of the ORs for these FINDRISC components. Analyses were done using SAS version 9.2 (SAS institute, Inc. Cary NC.).

RESULTS

Baseline characteristics of ARIC study participants stratified by incident diabetes status at the end of 9 years follow-up are given in Table 1. The overall 9-year cumulative incidence of diabetes was 12.1% (1180/9754). By race/gender group, the cumulative incidence of diabetes was 20.3% for black women, 18.8% for black men, 12.4% for white men, and 8.6% for white women (data not shown; can be calculated from events and non-events in Table 3). Among individuals who developed diabetes, 49% were obese, over 70% had a high waist circumference, 40% reported use of anti-hypertensive medication at baseline, and 38% had a parental history of diabetes (Table 1). The mean modified FINDRISC was 10.5 (SD 3.3) among those who developed diabetes and 7.8 (SD 3.6) among those who did not.

The baseline characteristics of the study population by race/gender groups are given in Table 2. Forty-two percent of black women were obese and 70% had a high waist circumference, while only 27% of black men were obese and 28% had a high waist circumference (Table 2). Twenty-one percent of whites were obese, but gender differences in high waist circumference were observed: 63% of women versus 30% of men had a high waist circumference. The mean modified FINDRISC for black women was also higher than that of black men, white women, and white men at baseline. Antihypertensive medication use at baseline was common among all gender/by race subgroups (22%–44%), and was highest among black women.

Figure 1 represents the risk of incident diabetes for each race/gender subgroup by decile of the modified FINDRISC. The risk of diabetes generally increased in a dose-response manner across FINDRISC deciles for all race/gender groups. With the exception of white women, the distributions displayed an inflection point (increase) at the sixth decile, corresponding to

a modified FINDRISC of 9 (Figure 1). We also observed that within the same decile of the FINDRISC the magnitude of risk varied considerably across race/gender groups. Of note, the number of eligible ARIC participants was lower for blacks than for whites. Therefore, there were relatively small numbers of incident diabetes cases among blacks in each decile of risk which may have resulted in unstable estimates.

The ROC curve statistics for the continuous FINDRISC, overall and by race/gender groups, are given in Table 3. The area under the curve (AUC) for the risk of incident diabetes was highest for white women (0.77) and lowest for black men (0.70). We also modeled the individual FINDRISC components as categorical variables and observed multivariable ORs and 95% CIs for incident diabetes as shown in Table 4. Overall, the odds of diabetes were highest for obese study participants (4.00, 3.15–5.07), controlling for age, waist circumference, antihypertensive medication, and family history of diabetes.

Among black women (2.39, 1.00–5.75), black men (4.65, 1.96–11.0) and white men (3.13, 1.98–4.96), high waist circumference was the most dominant predictor of incident diabetes (Table 4). Meanwhile, obese BMI (3.42, 2.33–5.02) had the largest effect on risk for white women (Table 4). Family history of diabetes had a smaller magnitude of effect among black men compared to other race/gender groups (Table 4).

The ad hoc analyses of waist circumference and BMI yielded AUCs of 0.72 (0.71, 0.74) for waist circumference alone, and 0.73 (0.71, 0.74) for BMI alone in the overall sample (data not shown). Meanwhile, high waist circumference alone (5.08, 4.09–6.31) was associated with incident diabetes in the overall sample, and the magnitude of effect was highest among white women (7.67, 4.62–12.7) and lowest for black women (3.75, 1.88–7.50). Obese BMI alone (7.05, 5.85–8.48) was associated with incident diabetes in the overall sample, and its effect was highest for white women and lowest for black women (Table S2).

DISCUSSION

We used a modified FINDRISC algorithm to predict incident diabetes in the ARIC cohort among the subset of the original cohort without missing diabetes status at all follow-up visits. In this population, the risk of diabetes generally increased with an increase in the FINDRISC for all race/gender groups. At some deciles of the modified FINDRISC algorithm, the scores appear to represent different levels of absolute risk within each race/gender group. This difference was most prominent for black women in the highest decile of risk, corresponding to a modified FINDRISC of 14 to17. Thus, we found that while the FINDRISC is predictive within race/gender groups, it does not appear from these data that there is a single threshold for absolute risk that can be applied to a diverse population. This is in keeping with previous findings in other populations.[30]

Scores such as the FINDRISC may be especially useful for identifying people at-risk for diabetes outside of traditional medical care settings, since existing diabetes risk prediction algorithms that require fasting or 2-hour glucose measures also limit the contexts in which they can be applied. Prediction of diabetes with these non-clinical algorithms has been shown in most cases to improve only marginally beyond algorithms composed of fasting or

post-prandial glucose measures plus more well-established and clinically-available risk factors for diabetes. For the first time, we used a modified FINDRISC score for diabetes prediction among a diverse US-based population.

We analyzed the impact of each FINDRISC component in multivariable analyses, and found different magnitudes of effect for the components by race/gender group. For example, waist circumference was more predictive of incident diabetes than BMI among black men, but not among white women. In the context of using the FINDRISC algorithm as part of public health screening efforts to identify populations at greater risk for diabetes, our results from this subset of the original ARIC cohort indicate that either different threshold cut-points for different race and gender groups may be needed, or that for optimal utility, the algorithm may need to be calibrated to derive different metrics for the individual components for different race-, gender- or race-by-gender groups in order to derive a common score that represents a similar magnitude of risk for all groups.

Our results indicated that the modifiable measures of adiposity (BMI and waist circumference) were associated with higher odds of diabetes than other risk score components. Consistent with previous analyses in ARIC[30] and other population-based studies, we demonstrated that obesity and high waist circumference were critical for the prediction of diabetes but that age, use of anti-hypertensive medication, and family history of diabetes were not as strong of predictors for incident diabetes in this population. The AUCs for waist circumference (0.72) and BMI alone (0.73), were almost comparable to the modified FINDRISC (0.74) for the overall sample. Although this was true for our study sample, we do not have the data to determine whether this finding would be externally valid for other populations. It is possible that these observed relationships are due to the specific measures of adiposity and their correlations with other co-occurring factors not controlled for in our study sample. For example, the prevalence of obesity in our study population was higher compared to previous populations in which the FINDRISC was evaluated, including German[29] and US-representative[25] populations.

An unmodified FINDRISC was recently evaluated in a US population using NHANES [25] data. Notably, the overall AUC (0.74 for ARIC versus 0.75 for NHANES) was similar, yet race- (0.74 for ARIC whites, 0.71 for ARIC blacks versus 0.76 for NHANES whites and blacks) and gender- (0.70 for men and 0.77 for women in ARIC versus 0.74 for men and 0.78 for women in NHANES) specific estimates differed slightly, using undiagnosed diabetes as the endpoint of comparison in NHANES. There were some key differences between these investigations: our analysis was longitudinal and assessed incident diabetes, while the NHANES analysis was cross-sectional and identified participants with undiagnosed diabetes and pre-diabetes.[25] Also, the NHANES analysis used the original FINDRISC to evaluate diabetes while we used a modified FINDRISC in the current study.

Our study included a large, multicenter, biracial population for analysis. To our knowledge, the current investigation using data from the ARIC study represents the first time the FINDRISC has been used for cross-temporal prediction of incident diabetes among black and white individuals living in the US. A possible limitation of the FINDRISC in our study population is that the metric does not differentiate between obesity and morbid obesity (BMI

>40 kg/m^2), even though there may be a difference in the incidence of diabetes for obese versus morbidly obese participants.

Although the original FINDRISC score includes simple measures of physical activity (30 minutes a day on most days) and dietary patterns (fruit and vegetable consumption), developers of the algorithm have clarified that neither item added much to the predictive power of the statistical model, but were included in the risk score for public health purposes to emphasize the importance of physical activity and diet in the prevention of diabetes.[31] Thus, not utilizing these two measures in the ARIC data likely did not affect the diagnostic properties of the modified FINDRISC in this population. However, it should be acknowledged that we also were not able to account for prior history of elevated glucose/gestational diabetes, nor extended family history of diabetes. Limitations of our data source may have precluded the characterization of conditions such as pre-diabetes, which may contribute to the predictive power of the FINDRISC in certain race/gender groups.

A limitation of using these ARIC data to re-calibrate the FINDRISC score, as previously described, is the differential loss to follow-up of persons of minority race/gender groups. Of note, these same groups have a smaller representation to begin with, have competing risks which may have precluded their eligibility for these analyses, and may be more likely to be missing diabetes status during follow-up.

Regardless of these limitations, the modified FINDRISC may be useful for the early screening of incident diabetes in biracial populations. Importantly, the score could be used as a tool for informing the public about risk factors associated with diabetes in order to help them to make healthy lifestyle choices to address obesity. Such an assessment of diabetes risk may allow for early intervention to delay or prevent diabetes. Finally, caution should be employed when interpreting this type of diabetes prediction model in biracial populations as we found differential prediction by race.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

The authors thank the staff and participants of the ARIC study for their important contributions.

FUNDING

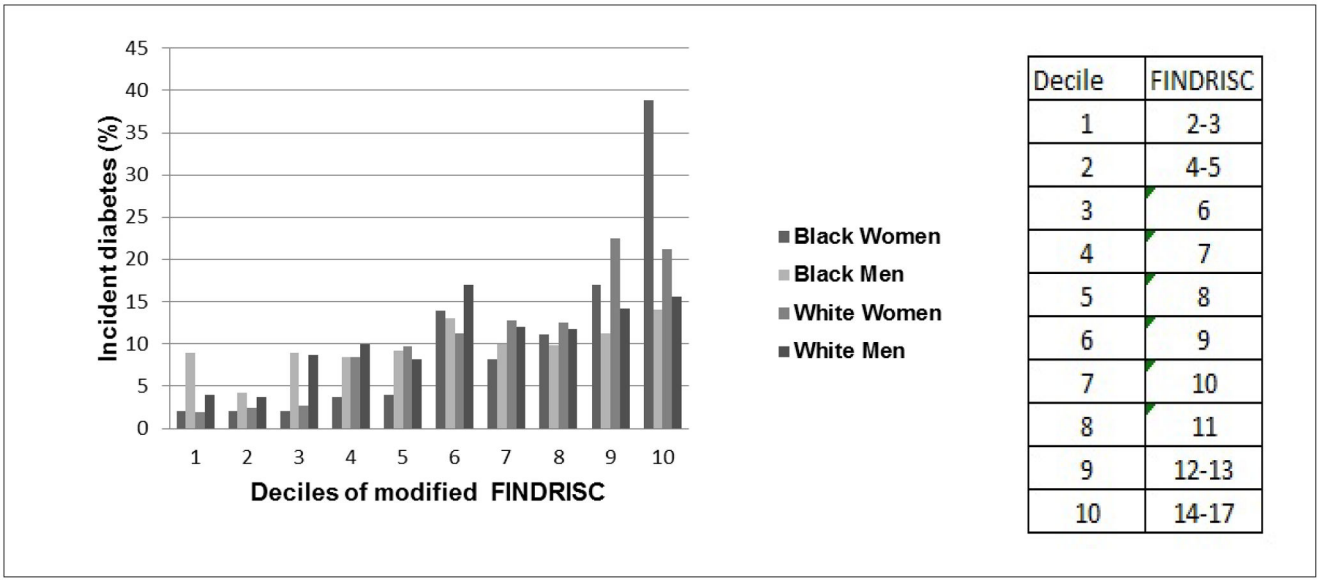
This research was funded in part by National Institutes of Health; National Heart, Lung and Blood Institute; and National Research Service Award training grant 5-T32-HL007055. The Atherosclerosis Risk in Communities Study is carried out as a collaborative study supported by National Heart, Lung, and Blood Institute contracts (HHSN268201100005C, HHSN268201100006C, HHSN268201100007C, HHSN268201100008C, HHSN268201100009C, HHSN268201100010C, HHSN268201100011C, and HHSN268201100012C), R01HL087641, R01HL59367 and R01HL086694.

References

1. The Diabetes Atlas. [Accessed May 27 2013] 6Available at: www.idf.org/e-atlas

2. National Diabetes Clearinghouse. National Diabetes Statistics. NIH; USA: 2011. http://diabetes.niddk.nih.gov/dm/pubs/statistics/#Diagnosed20http://diabetes.niddk.nih.gov/dm/pubs/statistics/#Diagnosed20http://diabetes.niddk.nih.gov/dm/pubs/statistics/#Diagnosed20
3. Simmons RK, Unwin N, Griffin SJ. International diabetes federation: an update of the evidence concerning the prevention of type 2 diabetes. Diabetes Res Clin Pract. 2010; 87:143–149. [PubMed: 19913319]
4. Yates T, Davies M, Khunti K. Preventing type 2 diabetes: can we make the evidence work? Postgrad Med J. 2009; 85:475–480. [PubMed: 19734515]
5. Wilson PW, Meigs JB, Sullivan L, Fox CS, Nathan DM, D'Agostino RB Sr. Prediction of incident diabetes mellitus in middle-aged adults: the Framingham Offspring Study. Arch Intern Med. May 28; 2007 167(10):1068–1074. [PubMed: 17533210]
6. Stern MP, Williams K, Haffner SM. Identification of persons at high risk for type 2 diabetes mellitus: do we need the oral glucose tolerance test? Ann Intern Med. Apr 16; 2002 136(8):575–581. [PubMed: 11955025]
7. Schmidt MI, Duncan BB, Bang H, et al. Identifying individuals at high risk for diabetes: The Atherosclerosis Risk in Communities study. Diabetes Care. Aug; 2005 28(8):2013–2018. [PubMed: 16043747]
8. Schmidt MI, Duncan BB, Vigo A, et al. Detection of undiagnosed diabetes and other hyperglycemia states: the Atherosclerosis Risk in Communities Study. Diabetes Care. May; 2003 26(5):1338–1343. [PubMed: 12716785]
9. Kanaya AM, Wassel Fyr CL, de Rekeneire N, et al. Predicting the development of diabetes in older adults: the derivation and validation of a prediction rule. Diabetes Care. Feb; 2005 28(2):404–408. [PubMed: 15677800]
10. Hanley AJ, Karter AJ, Williams K, et al. Prediction of type 2 diabetes mellitus with alternative definitions of the metabolic syndrome: the Insulin Resistance Atherosclerosis Study. Circulation. Dec 13; 2005 112(24):3713–3721. [PubMed: 16344402]
11. Abdul-Ghani MA, Williams K, DeFronzo RA, Stern M. What is the best predictor of future type 2 diabetes? Diabetes Care. Jun; 2007 30(6):1544–1548. [PubMed: 17384342]
12. Stern MP, Williams K, Haffner SM. Identification of persons at high risk for type 2 diabetes mellitus: do we need the oral glucose tolerance test? Ann Intern Med. 2002; 136(8):575–581. [PubMed: 11955025]
13. Aekplakorn, Bunnag P, Woodward M, et al. A risk score for predicting incident diabetes in the Thai population. Diabetes Care. 2006; 29(8):1872–1877. [PubMed: 16873795]
14. Noble D, Mathur R, Dent T, Meads C, Greenhalgh T. Risk models and scores for type 2 diabetes: systematic review. BMJ. 2011; 343:d7163. [PubMed: 22123912]
15. Brown N, Critchley J, Bogowicz P, et al. Risk scores based on self reported or available clinical data to detect undiagnosed Type 2 Diabetes: a systematic review. Diabetes Res Clin Pract. 2012; 98:369–385. [PubMed: 23010559]
16. Abbasi A, Peelen LM, Corpeleijn E, van der Schouw YT, Stolk RP, Spijkerman AM, van der ADL, Moons KG, Navis G, Bakker SJ, Beulens JW. Prediction models for risk of developing type 2 diabetes: systematic literature search and independent external validation study. BMJ. 2012 Sep 18.345:e5900. [PubMed: 22990994]
17. Lindström J, Tuomilehto J. The diabetes risk score: a practical tool to predict type 2 diabetes risk. Diabetes Care. 2003; 26(3):725–731. [PubMed: 12610029]
18. Selvin E, Crainiceanu CM, Brancati FL, Coresh J. Short-term variability in measures of glycemia and implications for the classification of diabetes. Arch Intern Med. Jul 23; 2007 167(14):1545–1551. [PubMed: 17646610]
19. Rahmana M, Simmons RK, Harding AH, Wareham NJ, Griffin SJ. A simple risk score identifies individuals at high risk of developing Type 2 diabetes: a prospective cohort study. Family Practice. 2008; 25(3):191–196. [PubMed: 18515811]
20. Herman WH, Smith PJ, Thompson TJ, Engelgau MM, Aubert RE. A new and simple questionnaire to identify people at increased risk for undiagnosed diabetes. Diabetes Care. Mar; 1995 18(3):382–387. [PubMed: 7555482]

21. Griffin SJ, Little PS, Hales CN, Kinmonth AL, Wareham NJ. Diabetes risk score: towards earlier detection of type 2 diabetes in general practice. Diabetes Metab Res Rev. May-Jun;2000 16(3): 164–171. [PubMed: 10867715]
22. Schulze MB, Hoffmann K, Boeing H, et al. An accurate risk score based on anthropometric, dietary, and lifestyle factors to predict the development of type 2 diabetes. Diabetes Care. Mar; 2007 30(3):510–515. [PubMed: 17327313]
23. Rydén L, Rydén L, Grant PJ, Anker SD, Berne C, Cosentino F, Danchin N, Deaton C, Escaned J, Hammes HP, Huikuri H, Marre M, Marx N, Mellbin L, Ostergren J, Patrono C, Seferovic P, Uva MS, Taskinen MR, Tendera M, Tuomilehto J, Valensi P, Zamorano JL, Seferovic P, Uva MS, Taskinen MR, Tendera M, Tuomilehto J, Valensi P, Zamorano JL. Task Force on diabetes, pre-diabetes, and cardiovascular diseases of the European Society of Cardiology (ESC); European Association for the Study of Diabetes (EASD). Task Force on diabetes, pre-diabetes, and cardiovascular diseases of the European Society of Cardiology (ESC). ESC guidelines on diabetes, pre-diabetes, and cardiovascular diseases developed in collaboration with the EASD – summary. Diab Vasc Dis Res. 11(3):133–73.
24. Makrilakis K, Liatis S, Grammatikou S, Perrea OC, Stathi C, Tsiligros P, Katsilambros N. Validation of the Finnish diabetes risk score (FINDRISC) Questionnaire for screening for undiagnosed type 2 diabetes, and the metabolic syndrome dysglycaemia in Greece. Diabetes Metab. 2011; 37(2):144–151. [PubMed: 21144787]
25. Lu Zhang L, Zhenzhen Zhang Y, Gang Hu GL. Evaluation of Finnish diabetes risk score in screening undiagnosed diabetes and prediabetes among U.S. adults by gender and race: NHANES 1999–2010. PLoS One. 2014; 9(5):e97865. [PubMed: 24852786]
26. The ARIC Investigators. The Atherosclerosis Risk in Communities (ARIC) Study: design and objectives. Am J Epidemiology. 1989; 129:687–702.
27. Jackson R, Chambless LE, Yang K, Byrne T, Watson R, Folsom A, Shahar E, Kalsbeek W. Differences between respondents and nonrespondents in a multicenter community-based study vary by gender ethnicity: the Atherosclerosis Risk in Communities (ARIC) Study Investigators. J Clin Epidemiol. 1996; 49:1441–1446. [PubMed: 8970495]
28. Al-Lawati JA, Tuomilehto J. Diabetes risk score in Oman: A tool to identify prevalent type 2 diabetes among Arabs of the Middle East. Diabetes Res Clin Pract. 2007; 77:438–44. [PubMed: 17306410]
29. Bergmann A, Li J, Wang L, Schulze J, Bornstein SR, Schwarz PE. A simplified Finnish diabetes risk score to predict type 2 diabetes risk and disease evolution in a German population. Horm Metab Res. 2007; 39:677–682. [PubMed: 17846976]
30. Schmidt MI, Duncan BB, Watson RL, Sharrett Arm, Brancati FL, Heiss G. A metabolic syndrome in whites and African-Americans. The Atherosclerosis Risk in Communities baseline study. Diabetes Care. 1996; 19(5):414–418. [PubMed: 8732701]
31. Heianza Y, Arase Y, Hsieh SD, Saito K, Tsuji H, Kodama S, Tanaka S, Ohashi Y, Shimano H, Yamada N, Hara S, Sone H. Development of a new scoring system for predicting the 5 year incidence of type 2 diabetes in Japan: the Toranomon Hospital Health Management Center Study 6 (TOPICS 6). Diabetologia. 2012; 55(12):3213–3223. [PubMed: 22955996]



Decile	FINDRISC
1	2-3
2	4-5
3	6
4	7
5	8
6	9
7	10
8	11
9	12-13
10	14-17

Figure 1.
Nine-year risk of incident diabetes by deile of the modified FINDRISC: ARIC study

Table 1

Baseline characteristics (n, %) of participants with and without incident diabetes over 9 years' follow-up: ARIC study.

	Diabetes N=1,180	**No Diabetes N=8,574**
Age		
45–54 years	646 (54.8)	4,705 (54.9)
55–64 years	534 (45.2)	3,869 (45.1)
Gender		
Female	676 (51.1)	4,829 (56.3)
Male	647 (48.9)	3,745 (43.7)
Race		
Black	351 (29.7)	1,425 (16.6)
White	829 (70.3)	7,149 (83.4)
Study community		
Forsyth	279 (23.6)	2,247 (26.2)
Jackson	301 (25.5)	1,269 (14.8)
Minnesota	257 (21.8)	2,659 (31.0)
Washington	343 (29.1)	2,399 (28.0)
Body mass index (BMI)		
Normal <25 kg/m^2	154 (13.1)	3,359 (39.1)
Overweight 25–≤30 kg/m^2	451 (38.2)	3,504 (40.9)
Obese >30 kg/m^2	575 (48.7)	1,711 (20.0)
Waist circumference		
Low (Women <80cm; Men <94cm)	96 (8.1)	2,177 (25.4)
Medium (Women 80–88cm; Men 94–102cm)	231 (19.6)	2,696 (31.4)
High (Women >88cm; Men >102cm)	853 (72.3)	3,701 (43.2)
Hypertensive medication		
Yes	477 (40.4)	2,037 (23.8)
No	703 (59.6)	6,537 (76.2)
Parental history of diabetes		
Yes	446 (37.8)	1,989 (23.2)
No	734 (62.2)	6,585 (76.8)
Modified FINDRISC score (mean, SD)	10.5 (3.3)	7.8 (3.5)

Table 2

Distributions (n, %) of the modified FINDRISC score and its individual components: ARIC study

	Black Women (n=1,149)	Black Men (n=627)	White Women (n=4,282)	White Men (n=3,696)
Age (years)				
45–54	745 (64.8)	393 (62.7)	2,375 (55.5)	1,838 (49.7)
55–64	404 (35.2)	234 (37.3)	1,907 (44.5)	1,858 (50.3)
Body mass index, kg/m^2				
<25	237 (20.6)	185 (29.5)	2,070 (48.3)	1,021 (27.6)
25–≤30	431 (37.5)	272 (43.4)	1,336 (31.2)	1,916 (51.8)
>30	481 (41.9)	170 (27.1)	876 (20.5)	759 (20.6)
Waist circumference, cm				
Low (Women/<80; Men/<94)	116 (10.1)	274 (43.7)	819 (19.1)	1,064 (28.8)
Medium (Women/80–88; Men/94–102)	225 (19.6)	177 (28.2)	1,101 (25.7)	1,424 (38.5)
High (Women/>88; Men/>102)	808 (70.3)	176 (28.1)	2,362 (55.2)	1,208 (32.7)
Antihypertensive medications				
Yes	506 (44.0)	191 (30.5)	1,010 (23.6)	807 (21.8)
No	643 (56.0)	436 (69.5)	3,272 (76.4)	2,889 (78.2)
Family history of diabetes				
Yes	379 (33.0)	178 (28.4)	1,044 (24.4)	834 (22.6)
No	770 (67.0)	449 (71.6)	3,238 (75.6)	2,862 (77.4)
Modified FINDRISC score				
Mean (SD)	*9.9 (3.6)*	*7.6 (3.9)*	*8.0 (3.6)*	*7.7 (3.5)*

Table 3

Area under the curve (AUC) statistics for the modified FINDRISC to predict incident diabetes among ARIC participants during 9-year follow-up

	AUC (95% CI)	Event	Non-event
Overall	0.74 (0.72, 0.75)	1,180	8,574
Black Women	0.71 (0.68, 0.75)	233	916
Black Men	0.70 (0.65, 0.75)	118	509
White Women	0.77 (0.74, 0.79)	369	3,913
White Men	0.71 (0.68, 0.73)	460	3,236

Table 4

The association (OR*, 95% CI) between the individual components of the modified FINDRISC and incident diabetes, overall and by race/gender group: ARIC study.

	Overall	African American Women	African American Men	Caucasian Women	Caucasian Men
Age (years)					
45–54	1 (referent)	1 (referent)	1 (referent)	1 (referent)	1 (referent)
55–64	0.99 (0.87, 1.12)	0.92 (0.67, 1.25)	0.92 (0.60, 1.41)	1.10 (0.88, 1.38)	0.94 (0.77, 1.16)
Body mass index (kg/m^2)					
Normal <25	1 (referent)	1 (referent)	1(referent)	1 (referent)	1 (referent)
Overweight 25–≤30	2.04 (1.65, 2.53)	0.92 (0.48, 1.78)	0.95 (0.45, 2.02)	1.97 (1.37, 2.85)	1.21 (0.82, 1.78)
Obese >30	4.00 (3.15, 5.07)	1.62 (0.83, 3.14)	1.13 (0.44, 2.96)	3.42 (2.33, 5.02)	2.50 (1.56, 4.00)
Waist circumference (cm)					
Low (Men <94; Women <80)	1 (referent)	1(referent)	1 (referent)	1 (referent)	1 (referent)
Medium (Men 94–≤102; Women 80–≤88)	1.34 (1.03, 1.74)	0.69 (0.27, 1.74)	2.27 (1.11, 4.64)	1.40 (0.77, 2.57)	2.09 (1.40, 3.14)
High (Men >102; Women >88)	1.92 (1.47, 2.50)	2.39 (1.00, 5.75)	4.65 (1.96, 11.0)	2.82 (1.56, 5.10)	3.13 (1.98, 4.96)
Antihypertensive medication					
No	1 (referent)	1 (referent)	1(referent)	1 (referent)	1 (referent)
Yes	1.61 (1.41, 1.84)	1.42 (1.06, 1.92)	1.24 (0.81, 1.90)	2.29 (1.82, 2.87)	1.32 (1.05, 1.66)
Family history of Diabetes					
No	1 (referent)	1 (referent)	1 (referent)	1 (referent)	1 (referent)
Yes	1.85 (1.62, 2.11)	2.10 (1.56, 2.82)	1.27 (0.82, 1.97)	1.89 (1.50, 2.38)	1.89 (1.52, 2.34)

*Odds ratios are adjusted for all other variables in the table.