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A self-assessment tool for screening young adults at risk of type 2 diabetes using Strong Heart Family Study data

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Abstract

Purpose—The purpose of this study is to characterize risk factors associated with type 2 diabetes in young adults ages 18–29 in order to develop a non-invasive risk assessment tool for use with younger American populations.

Methods—The self-assessment tool was developed using the Strong Heart Family Study data. A total of 590 young American Indian adults aged 18–29 (males=242) with normoglycemia and not receiving diabetes treatment were included. Risk factors recommended by the American Diabetes Association were used to assess diabetes risk in these young adults. A logistic regression model was developed to calculate the predicted probability. The area under receiver operating characteristic curve (AUROC) was used to evaluate the model.

Results—The final model showed that parental history of diabetes, obesity level, alcohol consumption, and high fasting glucose even within normal range were significantly associated with onset of prediabetes or diabetes in 5 years. The AUROC value was 0.68 with original and validated data, indicating the risk assessment tool had reasonably good discrimination ability.

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Author Contributions

Yan & Cha contributed equally to this work as the first authors for the study conception and design and the drafting of the manuscript. Yan performed the data analysis. Lee & Wang provided statistical expertise. Mayberry and Umpierrez made critical revisions to the paper.

Conclusions—This new non-invasive screening tool, based on data from American Indian young adults, has potential to screen young adults' early-onset diabetes risk. Future studies are warranted to test this risk assessment tool in other racial/ethnic young adults.

Introduction

Early-onset type 2 diabetes (<40 years old) is consistently and significantly increasing, and is now a serious health care burden.[1,2] Since diabetes complications are closely related to the duration of diabetes and intensity of glycemic control, [3] young adults with early onset diabetes have increased risk of diabetes complications (and co-morbidities) during their productive years. [4–6] Early detection and intervention implementation to prevent diabetes progression are keys to improving health outcomes and quality of life as well as saving health care costs in diabetes care. [1,2]

Despite the importance of implementing diabetes prevention programs in young adults, there has been little success because of the barriers in identifying young adults at risk for type 2 diabetes (T2D).[7] Young adults perceive themselves as healthy, are frequently unaware of their risk of prediabetes or diabetes, and rarely undergo diabetes screenings. Although overweight and obese conditions are recognized diabetes risk factors, 69.2% of Americans are overweight or obese in 2014 [8] and only a subgroup of overweight and obese individuals actually develop diabetes or co-morbidities such as hypertension, hyperlipidemia [9]. Thus, overweight or obese young adults do not consider their overweight/obesity as a serious health condition in need of preventive action.

In an attempt to overcome these challenges, the International Diabetes Federation (IDF) proposes a risk-based approach using three simple steps. Step 1 is identification of community-dwelling individuals at risk for type 2 diabetes using non-invasive risk assessment tools. Step 2 is measurement of risk in a clinic visit using venipuncture blood sample with appropriate diagnostic measures (A1C test, fasting glucose test after at least 8 hours of fasting, or 2-hour oral glucose tolerance test) to diagnose prediabetes/diabetes. Finally, Step 3 is to implement interventions to prevent and stop diabetes progression.[10,11] Based on these recommendations, a self-reported questionnaire has been developed and validated in European populations.[11,12] Likewise, researchers have developed simple tools for detecting undiagnosed diabetes and prediabetes in the general adult population in the United States.[13–17] However, identifying high-risk young Americans using existing non-invasive screening tools (Step 1) has been difficult because the existing instruments disproportionately factor in age and do not consider age-related lifestyle factors when they estimate diabetes risk.

There are several limitations of applying existing diabetes risk-assessment tools in American young adults: First, there is the possibility of a "healthy overweight/obesity" state, a transit occurrence due to the increase in muscle mass, not fat,[18] which makes BMI ineffective predictor of diabetes during young adulthood.[18,19] Second, family history of diabetes can be differently interpreted, and young adults can unintentionally provide inaccurate responses to a survey item (e.g., the patterns of family structure in contemporary society generate different "family" definitions for young adults, or a young individual may be the oldest child

in the family who does not have sibling diabetes history). Third, diabetes comorbidities are highly weighted in the existing risk-assessment tools, although high risk young adults are less likely to suffer from those conditions yet.[5,17,20] Fourth, there are unclear definitions of lifestyle factors such as healthy eating and physical inactivity.[16] These lifestyle factors lack age-specific considerations. For example, binge drinking is common in young adulthood[21] and young adults with prediabetes often have very low basal physical activity per day compared to older cohorts.[20,22] Finally, the cumulative effects of metabolic abnormalities (e.g., hypertension and/or dyslipidemia together) are not considered.[23] Thus, existing tools likely result in high false-positive and false-negative rates in American young adults.

To reduce this scientific gap, this data analysis using Strong Heart Study Family Data (Phase IV and V study data) tried to define diabetes risk factors in young American Indian adults in order to develop an age-specific non-invasive risk assessment tool for use with young adults. This approach is appropriate since the American Indians have the highest prevalence of early onset T2D which allows the researchers to secure adequate numbers to generate a predictive model of early onset T2D.[24] Before the United States' Affordable Care Act in 2010, young adults at risk for early onset T2D were an invisible and non-existent population in medical records or US health care system due to their uninsured or underinsured condition. Additionally, the absolute numbers of young adults with early onset T2D are still relatively small, while are consistently and significantly increasing, to identify risk profiles of early onset T2D.[25]

Materials and Methods

The authors followed and ensured the publication policy of the Indian Heart Service (IHS) using Strong Heart Study data. IHS institutional review board for the protection of human subjects in research (IRB) and tribal approvals were obtained prior to conducting the study and submitting the manuscript to the journal.

Descriptions of the Strong Heart Study and Strong Heart Family Study

Phase I (1989–1991) of the Strong Heart Study started as a survey to determine cardiovascular mortality rate in 4,549 American Indians from 13 American Indian tribes and communities who resided in the following areas: 1) Phoenix, Arizona, 2) southwestern area of Oklahoma, and 3) North and South Dakota. The clinical examination, Phase II study (n=4,500), was conducted between 1993 and1995 and morbidity and mortality (M&M) surveillance was conducted during Phase III (1998–2000).

During the Phase III study, the need for a family study was proposed because of the inherent risk of cardiovascular diseases (CVD). A pilot family study at each geographic area recruited about 10 large families consisting of more than 900 family members. A full family study, the Strong Heart Family Study (SHFS, Phase IV study) was conducted in 2000–2005 (the data are later referred as the SHFS baseline data). A total of 94 families (n=3,776) were recruited. The family cohort was re-examined in 2005–2010 to assess the inheritance of CVD and its risk factors and localized genetic factors that contribute to CVD risk. In addition, surveillance of CVD mortality and morbidity in the original cohort and the family cohort continued to obtain data on risk factor changes.

Participants

Young adults aged 18 –29 years who participated in the SHFS baseline examination were included in the present study. The inclusion criteria included individuals with normal fasting glucose <100mg/dl, no diabetes treatment at baseline and with SHFS follow-up data. Participants without clear glycemic information (n=3) or with conditions affecting erythrocyte turnover (e.g., hemolysis, blood loss) or pregnancy were excluded from the analysis. Those who had prediabetes (n=104, 14%) or diabetes (n=40, 5%) at the baseline or did not participate in follow-up examination (n=7, 1%) were also excluded. Of the 744 young adults, 590 were eligible for participation in this study.

Measurements

The variable selections were performed based on the American Diabetes Association (ADA) position statement for diabetes risk screening [26]. The ADA recommends that all overweight and obese individuals (i.e., body mass index (BMI) ≥ 25) of any age with additional risk factors for type 2 diabetes, and all adults aged 45 years or older, be screened in the clinical setting at 1 to 3 year intervals depending on the initial risk status [26]. Additional risk factors were physical inactivity, first-degree relative with diabetes, members of a high-risk ethnic population including African American, Hispanic, Native American, Asian American, Pacific Islander, women who delivered a baby weighing > 9 lb or were diagnosed with gestational diabetes, hypertension, high density lipoprotein (HDL) <35mg/dl and /or a triglyceride level >250mg/dl, women with polycystic ovary syndrome, HbA1c > 5.7%, impaired glucose tolerance (IGT), or impaired fasting glucose (IFG), and other clinical conditions associated with insulin resistance (e.g., severe obesity, acanthosis nigricans) or history of cardiovascular disease [26]. Because information on gestational diabetes, impaired glucose testing result, and insulin resistance was unavailable in the SHFS data, we excluded these variables in the initial model. Otherwise, variables recommended by the ADA were included in the initial model.

Diabetes Status (Outcome Variable)

The diabetes status was determined according to ADA 2004 criteria. Normoglycemia was defined by fasting glucose <100 mg/dl and prediabetes/diabetes by fasting glucose ≥100mg/dl and a history of taking diabetes medication in second examination of SHFS, respectively. Although HbA1c test has been accepted by the ADA as a diagnostic measure since 2011, HbA1c measurement was only conducted in those patients with fasting plasma glucose ≥100 mg/dl in the SHFS study. Thus, HbA1c was not used as a diagnostic measure of prediabetes and diabetes condition in the current study.

Clinical characteristic and risk factors (Predictors) in young adults

The following socio-demographic, past/current medical history, cardiometabolic risk, and lifestyle factors were considered as potential predictors of early onset diabetes.

1. ***Demographic factors***. Age in year, gender, education level (< high school, high school graduate or above), married (yes, no), and Indian Health Service clinic check-up (yes, no) were included. The parent history of diabetes was obtained from the pedigree data and diabetes status report.

2. ***Past and current health history***. We classified participants as having history of hypertension, or cardiovascular diseases (CVDs) if the participants had reported any history of hypertension or a CVD.

3. ***Cardiometabolic risk***. Body mass index (BMI) calculated by weight and height, waist circumference, the ratio of waist and hip circumference were assessed to define obesity level. For instance, extremely obesity was defined as BMI ≥40 kg/m^2 (men and women), or waist circumference ≥50 inch (men) or ≥49 inch (women) while "obesity" was BMI ≥30 kg/m^2 but <40 kg/m^2 (men and women), or waist circumference ≥40 inch but <50 inch (men) or ≥35 but <49 inch (women). Overweight was BMI ≥25 kg/m^2 but < 30 kg/m^2 (men and women), or waist circumference ≥37inch but < 40 inch (men) or ≥31.5 but < 35 inch (women). These criteria were the same with those of Bang and colleagues' study which has become a basis for the "Type 2 Diabetes Risk Test" currently presented at the ADA website [13,16].

   Blood pressure, total cholesterol, triglyceride, high density lipoprotein cholesterol (HDL-C), low density lipoprotein cholesterol (LDL-C) and fasting plasma glucose level were assessed and included in the initial model. The categorical variables were also defined based on the existing standard guideline and criteria for those variables [27]. For instance, hypertension was defined as taking prescribed medication or systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg. If participants' systolic blood pressure was 120–139 mm Hg or diastolic blood pressure was 80–90 mm Hg, it was considered as pre-hypertension. With regard to the cholesterol level, participants who had high total cholesterol (≥240 mg/dl), low HDL-C (men<40 mg/dl; women<50 mg/dl), high LDL-C (≥130 mg/dl) and high triglyceride (≥150mg/dl) were considered as having metabolic abnormality. Since the mean glucose level at baseline was around 90 mg/dl in those who developed prediabetes/ diabetes in second examination, we set a cut off of 90 m/dl for fasting glucose at baseline as a potential metabolic risk and assigned it as a risk score.

4. ***Lifestyle factors***. Smokers were defined as persons who had smoked at least 100 cigarettes in their lifetime, or smoked cigarettes at the time of Strong Heart Family Study examination. Alcohol users were defined as persons who have ever consumed alcohol beverage and had consumed any alcohol within the last year. Steps per day using a pedometer were used to define physical activity. Based on the current guideline of physical activity recommendation, [22] we dichotomized physical activity condition as physically active (≥10,000 steps per day) and physically inactive (<10,000 steps per day) using the mean steps from first three days' pedometer data. We also used alternative criterion ≥7,500 steps/day to re-check physical active condition by other criterion [22].

Statistical Analysis

All the analyses were conducted using SAS (version 9.3). $P < 0.05$ was considered to indicate statistical significance. Descriptive statistics were used to characterize normal group and prediabetes/diabetes group. Mean and standard deviation (SD) and two-sample t-test for continuous variables and percentage and chi-square tests for categorical variables were used to summarize the data and compare the findings between two groups.

Continuous variables were included in the initial model and later categorized in the final model when we performed multiple logistic regression modeling to derive the probability of developing pre-diabetes and diabetes from baseline to the second examination. The main effects of all the variables were included in the initial model, and stepwise elimination was used to select the significant covariates; if any variable's p-value was greater than or equal to .05 ($P \geq .05$), it was not included in the final model. Potential interaction or non-linear terms also were considered and tested. Odds ratios (ORs) and 95% confidence intervals (CIs) were obtained during the model testing to identify significant predictors of explaining prediabetes/diabetes condition in second examination. Hosmer-Lemeshow statistics was used to assess the model calibration. The predictive ability to discriminate participants was assessed using the Area Under the Receiver Operating Characteristic curve (AUROC) [28]. While ROC curve is a plot referring to sensitivity (Y-axis) versus 1-specificity (X-axis), the AUROC is the area under the curve which measures the predictive power. The higher value of AUROC indicates better predictive power of the model.

A bootstrap resampling method was used to generate a dataset for the data analysis. Bootstrap is a random resampling method to estimate statistic parameters while correcting selection biases. This method considers original data as population and selects random cases to generate resampled data. In the current study, internal 1000 bootstrap resampling was used to further validate the final model's calibration and discrimination abilities. In the SAS software, the SURVEYSELECT procedure was used to create the data with same sample size as original data for both individuals with/without diabetes and fit the model to the bootstrap samples and calculate the bootstrap corrected AUROC and Hosmer-Lemeshow statistics. [29]

Results

Socio-Demographics

Among 590 qualified young adults, 156 (26.45%) developed prediabetes (n=119, 20.17%) or diabetes (n=37, 6.27%) over the 5-year interval between baseline and second examination of SHFS (Table 1). Mean age was 23.24 ± 3.5 years and 41% were male. More than 55% of the participants had greater than high school education. Approximately 35% had a parent history of diabetes, ~75% of them drink alcohol during the past year, and 40% of were current smokers.

Identification of risk factors for model development

To identify risk factors for the final model development, we compared diabetes risk factors between prediabetes/diabetes group and normal glucose group. Table 2 and Table 3

summarized the characteristics of participants according to diabetes status. There were no significant differences in gender, education and marriage status between groups. The mean fasting plasma glucose level at baseline was higher in prediabetes / diabetes group than normal group (P<0.0001). The prediabetes/ diabetes group had 15% more (biological) parent history of diabetes (P=0.0004), and they were 10% less likely to visit a clinic for an annual check-up (P=0.009) than normal glucose group. The prediabetes /diabetes group had higher percentage of alcohol drinking (10% higher) than the normal glucose group (P=0.045).

Almost one-half of the participants in the prediabetes/diabetes group (49%) had fasting glucose higher than 90 mg/dL while only one-third (34%) of normal glucose group at the second examination had a glucose value >90mg/dL) at baseline (P=0.001). The prediabetes/ diabetes group had significant higher mean triglyceride level compared to the normal glucose group (P=0.011). The number of subjects with low HDL (51%) was 11% higher in prediabetes/diabetes group compared to normal glucose group (P=0.006). Participants in the prediabetes/diabetes group were heavier with mean BMI ~ 5 units higher (34.32 ± 8.09) than normal glucose group (29.78± 7.27), p<0.0001. Similarly, prediabetes/diabetes subjects had larger waist (107.68 cm vs. 97.00 cm) and hip (117.25 cm vs. 110.58 cm) circumferences (P<0.0001), with the percentage of larger waist to hip ratio 20% higher in prediabetes/ diabetes group compared to the normal glucose group.

Logistic regression analysis and development of a predictive probability

The initial model included all the demographic factors including age, gender, race/ethnicity, education, marital status, clinic check-up history, parent diabetes history, cardio-metabolic risks including blood pressure, cholesterol, fasting glucose, past health history including history of hypertension and cardiovascular disease and lifestyle factors including smoking, physical activity, alcohol.

After the stepwise elimination, only four variables: obesity, parental history of diabetes, alcohol drinking and fasting blood glucose at baseline remained significant factors to predict the development of prediabetes /diabetes after 5 years in second examination of SHFS (Table 4). The Hosmer and Lemeshow goodness-of-fit test showed our model fitted the data very well (P= 0.99), i.e., there was good agreement between the observed and predicted number of prediabetes/diabetes cases. The internal validation using the bootstrapping method yielded a Hosmer and Lemeshow test p value of 0.1307 indicating good calibration.

The four risk factors jointly yield an AUROC of 0.68 indicating good discrimination ability [28], indicating a good probability of detecting young adults with early onset T2D . The risk of developing prediabetes/diabetes for participants with parental history of diabetes was 1.79 times higher than for participants without parental history of diabetes; the risk for developing prediabetes/diabetes of the participants who used alcohol was 1.74 times higher than those participants who did not use alcohol; the risk for participants with a fasting glucose level greater than 90 mg/dL at baseline was 1.65 times those participants with fasting glucose level less or equal to 90 mg/dL, overweight participants had 2.00 times, obese is 2.84 times, and extremely obese is 4.48 times to develop prediabetes/diabetes compared to normal weight subjects. Thus, the final model equation: logit (P) = −2.79 + 0.58(family history) + 0.55(alcohol drinking) + 0.50 (fasting glucose) + 0.69 (overweight)

+ 1.04 (obese) + 1.50 (extremely obese). For example, for an individual with a parent history of diabetes, drinks alcohol, has fasting glucose > 90mg/dL and is extremely obese, the probability (P) of developing prediabetes/diabetes in 5 years would be 58%: logit (P)= −2.79 + 0.58+ 0.55 + 0.50+1.50 = 0.34, and P = exp(0.34)/[1+exp(0.34)] = 0.58.

Discussion

Higher fasting glucose (within normal glucose range) in addition to parent history, obesity, and alcohol consumption at the baseline were significant factors that predicted 5-year onset of prediabetes/diabetes in the final model, while elevated blood pressure or dyslipidemia were only significant in the initial regression model. These findings are different from a 7-year diabetes risk prediction model based on the Framingham Heart Study (with a majority of Caucasian samples [99%]),[17] which identified elevated blood pressure (≥130/85mm Hg), low HDL-C (<40 mg/dL in men, <50 mg/dL in women) and high triglyceride (≥150mg/dL) as predictors of type 2 diabetes (T2D) in middle-aged Caucasians (45–64 years old) in addition to parent history, obesity, fasting glucose (100–126 mg/dL).[17] On the contrary, our findings are consistent with findings from the Treatment Options for Type 2 diabetes in Adolescents and Youth (TODAY) study. Many youths experienced hyperglycemia but did not have any other metabolic risk factors at the beginning course of T2D.[1,30] Once they developed T2D, youths developed diabetes comorbidities (e.g. hypertension and dyslipidemia) and complications (nephropathy) more rapidly and aggressively than either those with late-onset T2D or youth onset type 1 diabetes.[1,7,30] Thus, the current ADA's position statement for screening prediabetes and asymptomatic diabetes in adults based on the existence of other metabolic aberration enables to yield a false negative rate in young adults at risk for and with type2 diabetes; the researchers and clinicians should contemplate this likelihood.[13]

The impact of alcohol consumption on diabetes incidence may differ by age, gender, and race/ethnicity.[31,32] A U-shaped relationship between alcohol consumption and T2D incidence is reported.[31] As many young adults engage in binge drinking (≥5 alcoholic beverages at one sitting),[21] alcohol consumption may be a factor that increases diabetes risk, rather than a preventive factor in this age population. In our equation, the effect of alcohol consumption to increase diabetes risk was almost same as the impact of family history on prediabetes/diabetes development. Since the current study has limited assessment of the actual amount of alcohol consumed, a future study assessing the amount of alcohol consumption and binge-drinking habits is warranted.

There is no strong evidence that early intervention prior to prediabetes is better than later intervention after prediabetes is present since data from prospective studies are insufficient.[33] Therefore, the ADA suggests that the decision to test for prediabetes/diabetes in asymptomatic adults under 45 years old should be based on clinical judgment and patient preference.[26] Testing to detect prediabetes should be considered in overweight and obese adults with additional risk factors including physical inactivity, first degree relative with diabetes, high risk race/ethnicity, metabolic aberration, gestational diabetes history, polycystic ovary syndrome, prediabetes on previous testing, other clinical conditions with insulin resistance, and/or history of cardiovascular diseases.[26] Recent studies, however,

shows that diabetes progression and complications can develop even before the prediabetes condition.[30,34,35] About 20% of individuals newly diagnosed with type 2 diabetes (based on fasting glucose or OGTT tests) have microvascular complications.[36] These findings of the current study show that young adults with higher fasting glucose, even within the normal glucose range, can develop prediabetes or type2 diabetes in 5 years. Thus, earlier implementation of diabetes prevention programs for overweight/obese young adults who do not have prediabetes yet, but do have high normal fasting glucose (90–99 mg/dL) may necessitate, if the young adult also has other risk factors (e.g, parent history or binge drinking habits).

There may be a concern regarding the accuracy of prediabetes diagnosis due to a small overlap among the diagnostic measures.[37] However, the fasting glucose test (which explains an 8–12 hour fasting condition, 33% –50% of overall glucose level) is a useful and convenient tool for detecting type2 diabetes and is relatively less influenced by age or race unlike HbA1C.[38,39] A combined utilization of diagnostic measures (e.g, HbA1c and fasting glucose) along with considerations of an individual's lifestyle factors would be a stronger approach to develop a more accurate diabetes risk assessment tool for young adults.

Despite the usefulness of our tool to screen undiagnosed diabetes in young adults ages 18–29, there are limitations. First, in contrast to findings in this study, many studies have reported that physical activity is a significant factor for diabetes and its complications.[20,40,41] This may be explained in part because the SHFS study only collected steps per day using a pedometer, which does not consider the intensity of physical activity. Also, the participants in the current study were predominantly sedentary,[22] which potentially generated a floor effect on the data analysis. In addition, baseline physical activity data or past physical activity habits (5 years earlier) were analyzed. The effect of a single bout of aerobic exercise on increasing insulin sensitivity and glucose tolerance only lasts about 24 to 72 hours,[42] and thus the lack of a relationship between the past 5 years physical activity and current glycemic condition is not surprising. A better study meticulously considering those factors should be planned and implemented with young adults, ages 18–29.

Good dietary quality prevents and delays the diabetes progression[41] while poor dietary quality increase the risk of diabetes.[43] In particular, high consumption of added sugar and saturated fat, low consumption of dietary fiber, and binge drinking habits may be closely related to early-onset diabetes and its progression. A comprehensive study considering young adults' dietary habits is warranted in the near future.

This proposing model has its limitations. There are three diagnostic measures of prediabetes/diabetes: fasting glucose, oral glucose tolerance test, and HbA1c.[26] We, however, created the model with the fasting glucose test only yielding an AUROC of 0.68. Different measures or an approach using a combined diagnostic measure may generate different findings. Likewise, the primary outcome is a composite outcome of prediabetes or diabetes. Due to the very small number of participants who developed diabetes, a separate model for prediabetes and diabetes, was not developed respectively, using different equations. Another limitation of the current study is that the diabetes progression from prediabetes to diabetes

was unable to be examined. Future studies are warranted to answer these important research questions.

Implications

A new screening tool based on data from American Indian young adults has potential to assess young adults' early-onset diabetes risk. This new, non-invasive assessment tool enables clinicians and diabetes educators to direct diabetes screening and intervention efforts to at-risk young adults, and thereby prevent early-onset diabetes. For instance, obese young adults who have a parental diabetes history and an unhealthy lifestyle (e.g., binge drinking) need to be informed of their increased risk for developing early-onset T2D and its complications, even if their fasting glucose remains in a normal range (<100mg/dL). These findings warrant a future study to apply and test this risk assessment tool in other races/ethnicities.

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Table 1

Characteristics of Participants Aged 18–29 (N=590) with Normal glucose at SHFS Baseline Examination

Participants' characteristics	Mean (SD) or frequency (%)*
Mean age (SD), years	23.24(3.51)
Men (%)	242(41.02)
High School graduate or above (%)	302(55.11)
Married (%)	88(14.94)
Indian Health Service clinic visit: yes (%)	429(72.71)
Parent history of diabetes (%)	197(33.39)
History of hypertension (%)	49(8.35)
History of cardiovascular diseases (%)	37(6.27)
Current Smoker (%)	237(40.24)
Alcohol drinker (%)	446(75.72)
Physical active (steps/day>=10000) (%)	67(12.98)
Physical active (steps/day>=7500) (%)	142(27.52)

• For continuous variable (i.e., age), mean with standard deviation (SD) was reported. All other variables were reported as frequency with percentage.

Table 2

Comparisons of baseline characteristics between two groups (N=590).

Characteristics	Normal glucose[a] (*n*=434)	Prediabetes or diabetes[a] (*n*=156)	*P*-value
Mean age (SD), years	23.05(3.50)	23.78(3.52)	0.025 *
Men (%)	171(39.40)	71(45.51)	0.183
High School graduate or above (%)	227(56.19)	75(52.08)	0.395
Married (%)	72(16.63)	16(10.26)	0.056
Health care visit (%)	328(75.58)	101(64.74)	0.009 *
Parent history of diabetes (%)	127(29.26)	70(44.87)	0.0004 *
History of hypertension (%)	37(8.56)	12(7.74)	0.751
History of CVD (%)	26(5.99)	11(7.05)	0.639
Current Smoker (%)	179(41.34)	58(37.18)	0.364
Alcohol drinker (%)	317(73.21)	129(82.39)	0.045 *
Physical active (steps/day>=10,000) (%)	54(14.06)	13(9.85)	0.214
Physical active (steps/day>=7,500) (%)	216(56.25)	67(50.76)	0.274

[a] Diabetes status is defined at second examination (posterior to 5 years of the baseline).

* $P<0.05$

Table 3

Comparisons of metabolic risk factors at baseline between two groups (N=590).

Characteristics	Normal glucose (*n*=434)[a]	Prediabetes or diabetes (*n*=156)[a]	*P*-value
	n (%) or Mean (SD)	n (%) or Mean (SD)	
[†] Obesity status			
Under- /normal- weight	89(20.60)	12(7.74)	
Overweight	95(21.99)	25(16.13)	<0.0001*
Obese	197(45.60)	82(52.90)	
Extremely Obese	51(11.81)	36(23.23)	
Waist to Hip ratio: > 0.90 in men; > 0.85 in women	220(51.16)	111(72.55)	<0.0001*
Hypertension status			
Normal	269(62.27)	86(55.48)	0.215
Prehypertension : 120–139 or DBP:80–89	126(29.17)	57(36.77)	
Hypertension : SBP≥140 or DBP≥90	37(8.56)	12(7.74)	
Total cholesterol level≥240 mg/dl	159(36.64)	60(38.46)	0.686
HDL (< 40 mg/dL in men or < 50 mg/dL in women	167(38.57)	80(51.28)	0.006*
LDL≥130mg/dL	34(7.83)	11(7.05)	0.752
Triglycerides≥150 mg/dl	139(32.03)	64(41.03)	0.043*
Glucose at baseline > 90mg/dl	147(33.87)	76(48.72)	0.001*
Body mass index (kg/m^2)	29.78(7.27)	34.32(8.09)	<0.0001*
Waist circumference, cm	97.00(16.94)	107.68(17.86)	<0.0001*
Hip circumference, cm	110.58(14.48)	117.25(15.03)	<0.0001*
Systolic BP , mmHg	115.49(11.59)	117.74(12.18)	0.041*
Diastolic BP, mmHg	72.90(10.29)	75.29(10.25)	0.013*
Total cholesterol level, mg/dl	169.20(31.26)	170.64(29.00)	0.615
Triglyceride level, mg/dl	128.10(76.08)	146.10(74.17)	0.011*
HDL level, mg/dl	50.73(12.98)	47.46(12.9)	0.007*
LDL level, mg/dl	92.95(25.91)	94.15(24.25)	0.612
Baseline Fasting plasma glucose , mg/dl	87.49(6.36)	90.04(6.60)	<0.0001*
Baseline HbA1c (%)	5.07(0.28)	5.29(0.43)	0.002*

[a] Diabetes status is defined at second examination(posterior to 5 years of the baseline).

[†] We defined obesity condition with a combination of BMI and waist circumference criteria. Extremely obesity was defined as BMI≥40 kg/m^2 (men and women), or waist circumference ≥50 inch (men) or ≥49 inch (women) while “obesity” was BMI ≥30 kg/m2 but <40 kg/m2 (men and women), or waist circumference ≥40 inch but <50 inch (men) or ≥35 but <49 inch (women). Overweight was BMI ≥25 kg/m^2 but < 30 kg/m^2 (men and women), or waist circumference ≥37inch but < 40 inch (men) or ≥31.5 but < 35 inch (women).

* $P<0.05$

Table 4

Logistic regression model for the Prediction of prediabetes/diabetes in 5 years

Risk factor	Odds Ratio (95% CI)	p-value	Estimated Coefficient
Intercept			−2.79
Parental history of diabetes			
No	Ref		
Yes	1.79 (1.21–2.65)	0.004	0.58
Obesity status			
Normal	Ref		
Overweight	2.00 (0.94 – 4.25)	0.073	0.69
Obese	2.84 (1.46 – 5.51)	0.002	1.04
Extremely obese	4.48 (2.11–9.52)	<0.0001	1.50
Alcohol use			
No	Ref		
Yes	1.74 (1.07–2.81)	0.025	0.55
Fasting glucose level at baseline			
Less or equal to (<=90mg/dL)	Ref		
Greater than (>90mg/dL)	1.65 (1.12 –2.43)	0.011	0.50