Observational Study

Fatty liver index as a simple predictor of incident diabetes from the KoGES-ARIRANG study

Dhananjay Yadav, PhD,a,c Eunhee Choi, PhDb,∗, Song Vogue Ahn, MD, PhDa,c, Sang Baek Koh, MD, PhDa,c, Ki-Chul Sung, MD, PhDd, Jang-Young Kim, MD, PhDd,g, Ji Hye Huh, MDc,f

Abstract

The fatty liver index (FLI), calculated from serum triglyceride, body mass index, waist circumference, and gamma-glutamyltransferase, is considered a surrogate marker of nonalcoholic fatty liver disease (NAFLD). We investigated whether FLI predicts the development of diabetes mellitus (DM) and assessed the predictive ability of FLI for new onset of DM in a prospective population-based cohort study.

We analyzed a total of 2784 adults (944 men and 1840 women) aged 40 to 70 years without DM at baseline. Participants were classified according to FLI values into 3 groups: FLI < 30, no NAFLD; 30 ≤ FLI < 59, intermediate NAFLD; and FLI ≥ 60, participants with NAFLD. The area under the receiver-operating characteristic curve (AUC), net reclassification improvement (NRI), and integrated discrimination improvement (IDI) were calculated to determine whether FLI improved DM risk prediction.

During a mean of 2.6 years follow-up, 88 (3.16%) participants developed DM. The odds ratio analyzed from multivariable-adjusted models (95% confidence interval [CI]) for new onset of DM increased in a continuous manner with increased FLI (<30 vs 30–59 vs ≥60 = 1 vs 1.87 [95% CI 1.05–3.33] vs 2.84 [95% CI 1.4–5.75], respectively). The AUC significantly increased when FLI was added to the conventional DM prediction model (0.835, 95% CI: 0.789–0.881, P = 0.0289 vs traditional DM prediction model). The category-free NRI was 0.417 (95% CI: 0.199–0.635) and the IDI was 0.015 (95% CI: 0.003–0.026) for overall study participants.

We found that FLI, a surrogate marker of hepatic steatosis, resulted in significant improvement in DM risk prediction. Our finding suggests that FLI may have clinical and prognostic information for incident DM among the Korean adult population.

Abbreviations: ALT = alanine aminotransferase, AST = aspartate aminotransferase, AUC curve = area under the receiver-operating characteristic curve, BMI = body mass index, DBP = diastolic blood pressure, DM = diabetes mellitus, FBG = fasting blood glucose, FLI = fatty liver index, GGT = gamma-glutamyltransferase, HDL-C = high-density lipoprotein cholesterol, HOMA-IR = homeostasis model assessment of insulin resistance, hs-CRP = high-sensitivity C-reactive protein, IDI = integrated discrimination improvement, NBC = net reclassification improvement, SBP = systolic blood pressure, TG = triglyceride, WC = waist circumference.

Keywords: diabetes mellitus, fatty liver index, integrated discrimination index, net reclassification improvement, prospective study

1. Introduction

Nonalcoholic fatty liver disease (NAFLD), characterized by increased fat storage in the liver in the absence of excessive alcohol consumption, is the most prevalent form of liver disease in developed countries, including Korea.[1,1] High prevalence of NAFLD is due to the adherence of rapidly growing Westernized lifestyle and has been estimated to range from 10% to 25% in Korea.[2] NAFLD is known to be closely associated with obesity, insulin resistance, dyslipidemia, and diabetes mellitus (DM) and is now regarded as the hepatic manifestation of metabolic syndrome.[3,4]

Because NAFLD and type 2 DM share similar pathogenesis such as insulin resistance, oxidative stress, and inflammation, it has been hypothesized that NAFLD may associate with increased risk of DM. Moreover, altered secretion of hepatokines such as fetuin-A, fibroblast growth factor 21, and selenoprotein P in the inflamed liver is directly associated with impairment of glucose metabolism.[5] Accordingly, many studies have evaluated the association between NAFLD and DM.[6,7] In fact, Cusi et al.[8] demonstrated that 80% of patients with DM had liver fat that might be accompanied by a more violent course of inflammation and fibrosis (i.e., nonalcoholic steatohepatitis) in the later stage of disease. Further, some prospective studies have also reported that NAFLD was associated with the development of DM in community-based cohort studies.[9,10] Given that DM is a
2. Methods

2.1. Study population

The study participants were taken from the Korean Genome and Epidemiology Study on Atherosclerosis Risk in Rural Areas in the Korean General Population (KoGES-ARIRANG). This longitudinal cohort study was designed with a focus to determine the prevalence, incidence, and risk factors for metabolic disorders such as hypertension, diabetes, obesity, and cardiovascular disease. All participants were aged between 40 and 70 years belonging to the rural area of Wonju and Pyeongchang in South Korea. The baseline study was executed from November 2005 to January 2008, encompassed 5178 adults (2127 men and 3051 women). Study participants were invited to join the first follow-up visit (2008–2011) and 3862 (74.6%) attended. Participants with unavailable data for FLI (N = 12) and DM (N = 575) at baseline were excluded. We excluded participants with a history of cardiovascular disease (N = 48) at baseline and excessive alcohol consumption (alcohol consumption > 140 g/wk for men and 70 g/wk for women) (N = 442) and 1 subject with missing information on DM at follow-up. Finally, 2784 participants (944 men and 1840 women) were included in the present analysis (Fig. 1). All participants were given a written informed consent to participate in this survey, and the protocol was approved by the institutional review board of Wonju Severance Christian Hospital, and this study was carried out in accordance with the ethical standards of the Helsinki Declaration.

2.2. Data collection and measurements

At study entry and follow-up survey, each participant completed both medical history and lifestyle questionnaire according to the standardized procedure. For anthropometrical measurements, body weight, height, and waist circumference (WC) were measured whilst participants were fully clothed. BMI was calculated by the formula: weight (in kg)/height2 in meter. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured with a standard mercury sphygmomanometer twice on the right arm of participants (Baumanometer, Copiague, NY). The mean of the 2 readings was utilized in the data analysis. A self-reported questionnaire (yes/no) was used for the information on smoking and current alcohol intake. Subjects answering to the question “do you perform physical exercise regularly enough to make you sweat?” were assigned to the regular exercise group.

Venous blood samples were collected from all participants after an overnight fast. Fasting glucose, fasting insulin, HbA1c, high-sensitivity C-reactive protein (hs-CRP), and homeostasis model assessment of insulin resistance (HOMA-IR) were measured by the standardized protocol described elsewhere. Lipid profiles and liver enzymes were determined by enzymatic methods (Advia 1650; Siemens, Tarrytown, NY). Serum concentrations of adiponectin and leptin were measured by radioimmunoassay (RIA) (LINCO Research, Inc., Saint Charles, MO).

2.3. Definition of incident diabetes

The study endpoint was development of DM at the follow-up visit, defined by criteria of the American Diabetes Association as follows: 8-hour fasting blood glucose (FBG) ≥ 126 mg/dL, or HbA1c level ≥ 6.5%, or 2-hour plasma glucose level ≥ 200 mg/dL during a 75-g oral glucose tolerance test. In addition, participants who reported currently taking antidiabetic medicine during the follow-up were considered to have DM.

2.4. Definition of fatty liver (NAFLD) according to fatty liver index

The FLI, a surrogate marker of NAFLD, was analyzed on the basis of the report by Bedogni et al as follows: FLI = (0.953 × logc, where:

- FLI: Fatty Liver Index
- c: Concentration of gamma-glutamyltransferase (GGT) in mg/dL
- β: Constant
- logc: Logarithmic transformation of GGT concentration

The FLI is composed of body mass index (BMI), triglyceride (TG), gamma-glutamyltransferase (GGT), and waist circumference (WC). Earlier, 1 study in the general population in Italy. The FLI is composed of body mass index called the fatty liver index (FLI) for predicting NAFLD in the Korean general population has reported that NAFLD determined by FLI was well correlated with hepatic steatosis diagnosed by abdominal ultrasonography. To date, although 3 previous studies have analyzed the association between FLI and new onset of DM in French, Korean, and German populations, there is no information on its role and clinical utility as a predictor of incident DM.

Therefore, the aim of the study was to evaluate the predictive role of FLI for incident DM in a Korean rural cohort. In addition, more simple tests based on biochemical analysis and anthropometrical parameters that could overcome these issues are advocated. A decade ago, Bedogni et al reported a simple index called the fatty liver index (FLI) for predicting NAFLD in the general population in Italy. The FLI is composed of anthropometrical parameters that could overcome these issues are advocated. A decade ago, Bedogni et al reported a simple index called the fatty liver index (FLI) for predicting NAFLD in the general population in Italy. The FLI is composed of anthropometrical parameters that could overcome these issues are advocated. A decade ago, Bedogni et al reported a simple index called the fatty liver index (FLI) for predicting NAFLD in the general population in Italy. The FLI is composed of body mass index (BMI), triglyceride (TG), gamma-glutamyltransferase (GGT), and waist circumference (WC). Earlier, 1 study in the general population in Italy. The FLI is composed of anthropometrical parameters that could overcome these issues are advocated. A decade ago, Bedogni et al reported a simple index called the fatty liver index (FLI) for predicting NAFLD in the general population in Italy. The FLI is composed of body mass index (BMI), triglyceride (TG), gamma-glutamyltransferase (GGT), and waist circumference (WC). Earlier, 1 study in the general population in Italy. The FLI is composed of anthropometrical parameters that could overcome these issues are advocated. A decade ago, Bedogni et al reported a simple index called the fatty liver index (FLI) for predicting NAFLD in the general population in Italy. The FLI is composed of body mass index (BMI), triglyceride (TG), gamma-glutamyltransferase (GGT), and waist circumference (WC). Earlier, 1 study in the general population in Italy. The FLI is composed of anthropometrical parameters that could overcome these issues are advocated. A decade ago, Bedogni et al reported a simple index called the fatty liver index (FLI) for predicting NAFLD in the general population in Italy. The FLI is composed of body mass index (BMI), triglyceride (TG), gamma-glutamyltransferase (GGT), and waist circumference (WC). Earlier, 1 study in the general population in Italy. The FLI is composed of anthropometrical parameters that could overcome these issues are advocated. A decade ago, Bedogni et al reported a simple index called the fatty liver index (FLI) for predicting NAFLD in the general population in Italy. The FLI is composed of body mass index (BMI), triglyceride (TG), gamma-glutamyltransferase (GGT), and waist circumference (WC). Earlier, 1 study in the general population in Italy. The FLI is composed of anthropometrical parameters that could overcome these issues are advocated. A decade ago, Bedogni et al reported a simple index called the fatty liver index (FLI) for predicting NAFLD in the general population in Italy. The FLI is composed of anthropometrical parameters that could overcome these issues are advocated. A decade ago, Bedogni et al reported a simple index called the fatty liver index (FLI) for predicting NAFLD in the general population in Italy. The FLI is composed of anthropometrical parameters that could overcome these issues are advocated. A decade ago, Bedogni et al reported a simple index called the fatty liver index (FLI) for predicting NAFLD in the general population in Italy. The FLI is composed of anthropometrical parameters that could overcome these issues are advocated.
2.5. Statistical analysis

Data are expressed as frequencies with percentage or means with standard deviation. The association between new onset of diabetes and FLI categories was analyzed by the two-sample t test, one-way analysis of variance (ANOVA), and chi-square test, as applicable. Pearson correlation analysis was used to evaluate the association between FLI and baseline metabolic parameters. Multivariate analysis was performed to assess the independent association of baseline FLI with new onset of diabetes. Three models were used for the adjustment. First, the age- and sex-adjustment analyses were used in the first model. Second, we further adjusted for family history of diabetes, smoking, alcohol intake, and regular exercise. Finally, in the third model, we adjusted for baseline levels of SBP, fasting glucose, HOMA-IR (log-transformed), high-density lipoprotein cholesterol (HDL-C), and total cholesterol. The odds ratios and 95% confidence intervals (CIs) were analyzed with reference to the increase in FLI indices. We also calculated the additional effect of FLI using area under the receiver-operating characteristic (AUC) curve to demonstrate the improvement in the diagnostic accuracy. Furthermore, we used NRI and IDI calculations to quantify the improvement in actual reclassification and sensitivity based on the addition of FLI in the traditional existing model.\( ^{21} \)P values <0.05 were considered statistically significant, and all statistical analyses were performed using SAS 9.2 Ver. (SAS Institute Inc., Cary, NC).

3. Results

3.1. Baseline characteristics of the population according to the development of DM and FLI

During an average follow-up of 2.6 years, 88 (3.16%) participants developed DM. Baseline characteristics of the incident DM group and nonincident DM group are shown in Table 1. Baseline blood pressure, BMI, WC, total cholesterol, TG, aspartate aminotransferase (AST), and alanine aminotransferase (ALT), GGT, total bilirubin, FBB, postprandial blood glucose (PPG), HbA1c, fasting insulin, HOMA-IR, creatinine, and FLI were significantly higher in individuals who developed DM than in those who did not. HDL-C and adiponectin levels were significantly lower in participants who developed DM compared with those who did not. There were no significant differences in hs-CRP, leptin, exercise, current smoker, and alcohol intake between the 2 groups.

The characteristics of study participants categorized into 3 groups according to the baseline FLI are shown in Table 2. A total of 335 (12.03%) participants had NAFLD as assessed by FLI. Considering age, participants in group 2 (intermediate) were significantly older than those in group 1 (no NAFLD) or group 3 (NAFLD). As the FLI elevated, participants were more likely to be drinkers, current smokers, and insulin-resistant. Moreover, we found a positive association between FLI groups and SBP, DBP, BMI, WC, total cholesterol, TG, AST, ALT, GGT, FBG, PPG, HbA1c, fasting insulin, HOMA-IR, creatinine, leptin, and hs-CRP levels, whereas a negative association was found with HDL-C, total bilirubin, and adiponectin levels.

3.2. Correlation of FLI and metabolic parameters

Table 3 shows a correlation between FLI and baseline metabolic parameters. FLI score was positively correlated with SBP, BMI, total cholesterol, TG, AST, ALT, GGT, FBG, PPG, HbA1c, fasting insulin levels, HOMA-IR, leptin, creatinine, and hsCRP. There was a significant negative association between FLI and HDL-C, total bilirubin, and adiponectin levels.

3.3. Assessment of FLI for the prediction of new onset of DM over 2.6 years

Table 4 shows the multiple logistic regression models for risk of incident DM according to the categories of FLI. The odds ratio for incident DM increased across FLI groups following adjustment for age and gender. This trend remained significant even after further adjustment of smoking, regular exercise, family history of DM, and alcohol intake. In fully adjusted model including baseline FBG, baseline SBP, HDL-C, and HOMA-IR, the odds ratios (95% CI) for new-onset DM in group 2 (FLI: 30–59) and group 3 (FLI: ≥60) were 1.87 (95% CI: 1.05–3.33) and 2.84 (95% CI: 1.40–5.75), respectively, compared to those in group 1 (FLI: <30; P for trend <0.012). We also analyzed the odds ratios of each 4 component of FLI (TG, BMI, WC, and GGT) for new-onset DM. As a result, we found that TG, BMI, and WC were independently associated with incident DM even after adjustment for confounding factors. However, GGT did not significantly increase the odds ratios for incident DM in a fully adjusted model (Supplemental Table 1, http://links.lww.com/MD/B172).

3.4. Additional clinical information for prediction of incident DM

The addition of FLI to traditional risk models including conventional risk factors for the prediction of incident DM is shown in Fig. 2. The AUC for predicting future incidence of DM using age, gender, family history, smoking, regular exercise, alcohol intake, FBG, baseline SBP, HDL-C, total cholesterol, and log-transformed HOMA-IR was 0.818 (95% CI: 0.769–0.867). The AUC significantly increased when FLI was added to the conventional DM prediction model (0.835, 95% CI: 0.789–0.881, P = 0.0289 versus traditional DM prediction model). However, the addition of BMI and/or WC to conventional DM prediction model did not significantly improve the AUC values (Supplemental Table 2, http://links.lww.com/MD/B172). We also assessed whether the addition of FLI to the conventional DM prediction model can improve the predictive ability for new-onset DM using NRI and IDI. We found that the category-free NRI was 0.417 (95% CI: 0.199–0.635, P = 0.0002) and the IDI was 0.015 (95% CI: 0.003–0.026, P = 0.0121) for the overall study participants. Thus, the addition of FLI to the basic DM risk model correctly reclassified 40% more cases in the overall study population.
Development of a simple index that identifies those at high risk of DM is important because DM can be mostly preventable through lifestyle modifications. However, no widely accepted risk prediction score that has been validated. Therefore, we hypothesized that FLI, a surrogate marker of NAFLD, might be applied as an additional risk marker for DM development in a population-based cohort.

We noted a significant improvement in the AUC with the addition of FLI (FLI ≥ 60) and the development of DM. These findings are steady with results of other cohort studies on NASH and incident DM. However, previous studies did not discuss the possibility of FLI as a prognostic tool of incident DM in a clinical setting. Our study demonstrated that the incorporation of FLI into traditional DM risk prediction models significantly improved the prediction of DM after 2.6 years of follow-up. Specifically, as shown in Fig. 2, there was a statistically significant improvement in the AUC with the addition of FLI (P=0.0289). To further explore the added value of FLI as a predictor, we applied specific statistical techniques including 2 metrics, IDI, and NRI. The NRI can provide clinical information by presenting the quantified improvement resulting from the addition of a new biomarker to the logistic previous model and the IDI can provide clinical information on increased sensitivity through the addition of new markers without sacrificing specificity.
The present study showed that FLI considerably improved the NRI and IDI, which is known to be more sensitive than the AUC for determination of improvement in the predictive value.[30]

These results indicate that FLI might act as an additional contributor to predicting the risk of incident DM when applied with conventional risk factors. Thus, FLI could increase the predictive ability for identification of participants at future risk for developing DM and therefore has a clinical role in screening for type 2 diabetes. Our results also indicate that the FLI, a simple parameter of FLI—WC, BMI, TG, and GGT—is a useful and easily surrogated measure of hepatic steatosis, is a useful and easily

### Table 2
Baseline characteristics of study participants according to the FLI group.

|                | Group 1 (FLI < 30) | Group 2 (FLI 30–59) | Group 3 (FLI ≥ 60) | P      |
|----------------|-------------------|---------------------|--------------------|--------|
| Number, %      | 1759 (83.18)      | 690 (24.78)         | 335 (12.03)        | <0.0001|
| Age, y         | 54.00±8.2         | 56.21±8.06          | 55.54±7.88         | <0.0001|
| Gender, male, %| 428 (24.33)       | 310 (44.93)         | 206 (61.49)        | <0.0001|
| SBP, mm Hg     | 126.4±16.73       | 133.22±17.34        | 136.49±19.17       | <0.0001|
| DBP, mm Hg     | 80.16±11.44       | 84.51±11.01         | 86.64±11.94        | <0.0001|
| BMI, kg/m²     | 23.04±2.34        | 26.22±2.31          | 28.14±3.07         | <0.0001|
| Waist circumference, cm | 78.11±6.72  | 88.24±5.52          | 93.84±6.4          | <0.0001|
| Total cholesterol, mg/dL | 194.21±33.52 | 210.25±30.19        | 213.3±42.02        | <0.0001|
| TG, mg/dL      | 103.61±46.04      | 171.78±74.4         | 245.04±183.68      | <0.0001|
| HDL-C, mg/dL   | 47.66±10.51       | 43.02±9.44          | 42.15±9.59         | <0.0001|
| AST, IU/L      | 24.4±8            | 26.76±8.79          | 34.81±19.85        | <0.0001|
| ALT, IU/L      | 19.53±8.79        | 26.04±13.03         | 38.03±24.16        | <0.0001|
| GGT, IU/L      | 16.33±11.21       | 30.01±23.44         | 75.78±102.8        | <0.0001|
| Total bilirubin, mg/dL | 0.87±0.3    | 0.83±0.28           | 0.84±0.3           | <0.0001|
| FBG, mg/dL     | 80.46±8.04        | 92.23±8.74          | 94.84±8.98         | <0.0001|
| PPG, mg/dL     | 76.73±60.6        | 90.93±62.86         | 99.33±64           | <0.0001|
| HbA1c, %       | 5.34±0.35         | 5.49±0.38           | 5.56±0.38          | <0.0001|
| Fasting insulin, µU/mL | 7.75±3.58  | 9.49±4.11           | 11.22±4.79         | <0.0001|
| HOMA-IR        | 1.69±0.82         | 2.14±1              | 2.59±1.17          | <0.0001|
| Apolipoprotein, µg/mL | 11.78±6.070 | 9.30±4.489          | 7.44±4.150         | <0.0001|
| Leptin, ng/l   | 5.87±4.87         | 7.92±6.24           | 9.29±7.56          | <0.0001|
| Creatinine, µg/dL | 0.58±0.27   | 0.96±0.16           | 1.1±0.18           | <0.0001|
| hs-CRP, mg/L   | 1.63±5.1          | 2.06±3.64           | 2.72±6.46          | 0.0006|
| Family history of diabetes, % | 179 (11.12) | 64 (10.58)  | 28 (10.08)  | 0.8347|
| Regular exercise, % | 565 (32.23) | 219 (32.02) | 83 (25) | 0.003|
| Current smoker, % | 281 (16.03) | 194 (28.28) | 143 (42.81) | <0.0001|
| Alcohol intake, % | 529 (30.18) | 285 (41.36) | 203 (60.96) | <0.0001|

ALT = alanine aminotransferase, AST = aspartate aminotransferase, BMI = body mass index, DBP = diastolic blood pressure, FBG = fasting blood glucose, FLI = fatty liver index, GGT = gamma-glutamyltransferase, HbA1c = glycated hemoglobin, HDL-C = high density lipoprotein cholesterol, hs-CRP = high-sensitivity C-reactive protein, HOMA-IR = homeostasis model assessment of insulin resistance, PPG = postprandial glucose, SBP = systolic blood pressure, TG = triglyceride.

### Table 3
Simple correlation between FLI and metabolic parameters.

|                | Correlation coefficient | P      |
|----------------|------------------------|--------|
| SBP, mm Hg     | 0.254                  | <0.0001|
| DBP, mm Hg     | 0.25                   | <0.0001|
| Total cholesterol, mg/dL | 0.254        | <0.0001|
| TG, mg/dL      | 0.576                  | <0.0001|
| HDL-C, mg/dL   | −0.261                 | <0.0001|
| AST, IU/L      | 0.307                  | <0.0001|
| ALT, IU/L      | 0.458                  | <0.0001|
| GGT, IU/L      | 0.455                  | <0.0001|
| Total bilirubin, mg/dL | −0.063      | 0.0009|
| FBG, mg/dL     | 0.255                  | <0.0001|
| PPG, mg/dL     | 0.151                  | <0.0001|
| HbA1c, %       | 0.253                  | <0.0001|
| Fasting insulin, µU/mL | 0.331       | <0.0001|
| HOMA-IR        | 0.36                   | <0.0001|
| Apolipoprotein, µg/mL | −0.356     | <0.0001|
| Leptin, ng/L   | 0.254                  | <0.0001|
| Creatinine, µg/dL | 0.174            | <0.0001|
| hs-CRP, mg/L   | 0.079                  | <0.0001|

ALT = alanine aminotransferase, AST = aspartate aminotransferase, DBP = diastolic blood pressure, FBG = fasting blood glucose, GGT = gamma-glutamyltransferase, HbA1c = glycated hemoglobin, HDL-C = high density lipoprotein cholesterol, hs-CRP = high-sensitivity C-reactive protein, HOMA-IR = homeostasis model assessment of insulin resistance, PPG = postprandial glucose, SBP = systolic blood pressure, TG = triglyceride.
Table 4
Odds ratios and 95% confidence intervals for diabetes according to FLI categories.

| All participants | FLI |
|------------------|-----|
|                  | <30 | 30–59 | ≥60 |
| Incident diabetes| 31  | 48    | 24  |
| Crude OR         | 1   | 1.21  | 1.76 |
| Model 1          | 1   | 1.21  | 1.76 |
| Model 2          | 1   | 1.21  | 1.76 |
| Model 3          | 1   | 1.21  | 1.76 |

Model 1: adjusted for age, gender. Model 2: model 1 + adjusted for family history, smoking, regular exercise, alcohol intake. Model 3: model 2 + adjusted for FBG, baseline SBP, HDL-C, total cholesterol, log_HOMA-IR. FBG = fasting blood glucose, FLI = fatty liver index, HDL-C = high density lipoprotein cholesterol, log_HOMA-IR = homeostasis model assessment of insulin resistance, SBP = systolic blood pressure, OR = odds ratio.

Figure 2. The comparison of area under the receiver-operating characteristic curve for incident diabetes mellitus (DM) according to adding or not fatty liver index to the conventional DM prediction risk model. Age, gender, family history of DM, smoking, regular exercise, alcohol intake, fasting blood glucose, baseline systolic blood pressure, high density lipoprotein-cholesterol, total cholesterol, and log-transformed homeostatic model assessment.

accessible tool for identifying individuals at high risk for DM. In addition, we demonstrated that FLI could provide additional information for the prediction of future DM beyond the conventional risk factors. A further long-term follow-up study with larger sample size is prerequisite to generalize the value of this risk-scoring tool for predicting incident DM.

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