Validation of the Finnish diabetes risk score (FINDRISC) questionnaire for screening for undiagnosed type 2 diabetes, dysglycaemia and the metabolic syndrome in Greece

K. Makrilakis a,*, S. Liatis a, S. Grammatikou a, D. Perrea b, C. Stathi a, P. Tsiligros a, N. Katsilambros a, b

a First Department of Propaedeutic Medicine, Athens University Medical School, Laiko General Hospital, 17, Ag. Thoma street, 11527 Athens, Greece
b Laboratory for Experimental Surgery and Surgical Research, “Christeas Hall”, University of Athens Medical School, Athens, Greece

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Abstract

Aim. – The present study aimed to validate the Finnish Type 2 Diabetes Risk Score (FINDRISC) questionnaire for its ability to predict the presence of any glucose homoeostasis abnormalities and the metabolic syndrome (MetS) in the Greek population.

Methods. – Validation was performed on a sample of individuals who had agreed to participate in a screening program for type 2 diabetes (T2D) prevention (the Greek part of the DE–PLAN study), using both FINDRISC and oral glucose tolerance tests (OGTT). Impaired fasting glucose (IFG) was defined as a fasting plasma glucose level of 6.1–6.9 mmol/L, and impaired glucose tolerance (IGT) as a 2-h plasma glucose of 7.8–11.0 mmol/L. The predictive value of the FINDRISC was cross-sectionally evaluated using the area under the receiver operating characteristic (AUROC) curve method.

Results. – A total of 869 individuals (379 men, aged 56.2 ± 10.8 years) were screened from the general population living in the city and suburbs of Athens. OGTT revealed the presence of unknown diabetes in 94 cases (10.8%), IFG in 85 (9.8%) and IGT in 109 (12.6%). The sensitivity of a FINDRISC score greater or equal to 15 (45% of the population) to predict unknown diabetes was 81.9% and its specificity was 59.7%. The AUROC curve for detecting unknown diabetes was 0.724 (95% CI: 0.677–0.770). For any dysglycaemia, the AUROC curve was 0.716 (0.680–0.752) while, for detection of the MetS, it was 0.733 (0.699–0.767).

Conclusion. – The FINDRISC questionnaire performed well as a screening tool for the cross-sectional detection of unknown diabetes, IFG, IGT and the MetS in the Greek population.

Keywords: Diabetes screening; FINDRISC questionnaire; Diabetes prevention; Diagnosis; Type 2 diabetes; Impaired fasting glucose; Impaired glucose tolerance; Greece

Résumé

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But. – La présente étude avait pour but de valider le questionnaire finlandais FINDRISC en termes de prévision des anomalies de la glycorégulation et du syndrome métabolique dans la population grecque.

Méthodes. – La validation a été réalisée à partir d’un échantillon d’individus qui avaient accepté de participer à un programme de dépistage dans le cadre de la prévention du diabète type 2 (DT2) (participation grecque à l’étude DE–PLAN), en utilisant le score FINDRISC ainsi qu’une hyperglycémie provoquée par voie orale (HGPO). L’hyperglycémie modérée à jeun (IFG) a été définie par une glycémie à jeun comprise entre 6,1 et 6,9 mmol/L et l’intolérance au glucose (IGT) par une glycémie deux heures après glucose comprise entre 7,8 et 11,0 mmol/L. La valeur prédictive du score FINDRISC a été évaluée transversalement, en utilisant les caractéristiques opératoires de la surface sous courbe (AUROC).

* Corresponding author. Tel.: +30 213 2061061; fax: +30 210 7791839.
E-mail address: kmakrila@med.uoa.gr (K. Makrilakis).

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Résumé

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Résultats. – Un total de 869 sujets (379 hommes, âgés de 56,2 ± 10,8 ans) a été sélectionné parmi la population générale de la ville et des environs d’Athènes. L’HGPO a révélé un diabète méconnu chez 94 sujets (10,8 %), une IFG chez 85 sujets (9,8 %) et une IGT chez 109 sujets (12,6 %). La sensibilité du score FINDRISC supérieur ou égal à 15 (45 % de la population) pour la prédiction d’un diabète méconnu était de 81,9 % et sa spécificité de 59,7 %. L’AUROC pour le dépistage d’un diabète méconnu était de 0,716 (0,680–0,752), l’AUROC pour la mise en évidence du syndrome métabolique de 0,733 (0,699–0,767).

Conclusion. – Cette étude montre que le questionnaire FINDRISC s’avère être un outil performant pour le dépistage du diabète, de l’hyperglycémie modérée à jeun, de l’intolérance au glucose et du syndrome métabolique dans un échantillon de la population grecque.

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Mots clés : Dépistage du diabète ; Questionnaire FINDRISC ; Diagnostic ; Intolérance au glucose ; Hyperglycémie modérée à jeun ; Prévention du diabète ; Diabète de type 2 ; Grèce

1. Introduction

The frequency of type 2 diabetes (T2D) is increasing worldwide to nearly epidemic proportions as the general population becomes older, less active and more obese. Its future burden is expected to increase dramatically, with increases in both long-term morbidity and mortality. Furthermore, it is estimated that approximately one-third of all people with diabetes may be undiagnosed [1]. The economic burden of treating diabetes and its complications is likewise enormous. For this reason, effective primary prevention programmes for T2D are urgently needed to reduce the clinical and economic healthcare burden.

The disease is characterized by a long prediabetic period, during which impaired fasting glucose (IFG), impaired glucose tolerance (IGT) and many of the components of the metabolic syndrome (MetS) interact to finally end with overt clinical diabetes [2]. Many studies have shown that interventions at the prediabetic state using either lifestyle modifications [3,4] or medications [5,6] can prevent, or at least delay, progression of the disease. This means that the identification of those at high risk for T2D is warranted to allow for a more timely implementation of preventative action aimed at reducing their risk [7]. This has been recently shown to be cost-effective as well [8].

Measuring plasma glucose (either fasting or 2 h after an oral glucose tolerance test [OGTT]) and glycosylated haemoglobin (HbA1c) levels are the recommended methods for screening the general population [9]. However, these are invasive procedures, costly and time-consuming (especially OGTT) and, thus, not suitable for mass screening. Furthermore, as they are based solely on measuring glycaemia, they may diagnose the disease too late, when complications have already occurred [10].

The MetS is a cluster of metabolic risk factors for cardiovascular disease (CVD) that are associated with insulin resistance. The presence of the MetS predicts the future development of both T2D and CVD. Diagnosing the syndrome, however, requires measuring five clinical and biochemical parameters, whereas its predictive ability does not appear to surpass other, simpler risk-assessment tools, such as the Framingham risk score (for predicting CVD) or simple plasma glucose measurement (for predicting T2D) [11].

Recently, many attempts have been made to develop simple, fast, non-invasive and practical screening tools for identifying individuals at high risk of future development of T2D [12–21]. Of these tools, the Finnish Type 2 Diabetes Risk Score (FINDRISC) questionnaire [12] is widely used, and has already been validated in different, but mostly Caucasian [12,22–27], populations for detecting unknown diabetes, abnormal glucose tolerance and the MetS.

It is questionable, however, to what extent screening protocols, such as risk-score assessment followed by blood glucose measurements, that have been developed in one population can be applied in other countries’ populations [28]. As the effectiveness of the FINDRISC questionnaire has not yet been studied in Greece, the aim of the present study was to validate the questionnaire in a population-based, cross-sectional setting in Greece, and to study its performance as a screening tool for undetected T2D, other abnormalities of glucose homeostasis and the MetS in middle-aged individuals.

2. Subjects and methods

Validation was performed using the baseline data from a cross-section of participants in a T2D prevention program in Greece, using both the FINDRISC questionnaire and OGTT [29]. The main aim of this EU-funded project (Diabetes in Europe–Prevention using Lifestyle, Physical Activity and Nutritional Intervention, DE–PLAN) was to establish a model for the efficient identification of community-living individuals at high risk of T2D in EU member countries, as well as to test the feasibility and cost-effectiveness of translating the interventional concepts learned from prevention trials to the currently used healthcare systems [30].

The project was approved by the participating hospital’s ethics committee and the National Drug Organization of Greece. All participants gave their informed consent according to the general recommendations of the Declaration of Helsinki.

The study has been described in detail elsewhere [29]. In brief, the FINDRISC questionnaire was distributed to around 7900 individuals, aged 35–75 years, with no known diabetes and residing in the metropolitan areas of Athens. The questionnaire comprises eight items: age; body mass index (BMI); waist circumference; physical activity; dietary consumption of fruits, vegetables and berries; use of antihypertensive medications; history of high blood glucose; and family history of diabetes (see www.diabetes.fi/english/risktest). The total test score (maximum: 26) provides a measure of the probability of developing T2D, with a score greater or equal to 15 being indicative of a high probability [12].

Of the 3240 completed questionnaires, 869 respondents agreed to undergo an OGTT. On the day of the test, the partic-
ipant's weight, height, waist circumference and blood pressure were measured, and their medical histories recorded. Plasma glucose, total and high-density lipoprotein (HDL) cholesterol, and triglyceride levels were also measured from fasting blood samples at a central, accredited university research laboratory, using enzymatic assays. Low-density lipoprotein (LDL) cholesterol was calculated using the Friedewald formula [31].

Based on the OGTT results, participants were categorized as having either normal glucose tolerance (NGT, fasting plasma glucose less than 6.1 mmol/L and 2-h plasma glucose less than 7.8 mmol/L), impaired fasting glucose (IFG, fasting plasma glucose 6.1–6.9 mmol/L), impaired glucose tolerance (IGT, 2-h plasma glucose 7.8–11.0 mmol/L) or diabetes (fasting plasma glucose greater or equal to 7.0 mmol/L and/or 2-h plasma glucose greater or equal to 11.1 mmol/L) [32]. The MetS was defined according to National Cholesterol Education Program Adult Treatment Panel III (NCEP–ATP III) criteria [33].

2.1. Statistical analysis

Continuous variables were presented as means ± 1 standard deviation (SD), and qualitative variables as absolute and relative frequencies (%). Comparisons between normally distributed continuous variables were performed with calculations of Student’s t test. Associations between categorical variables were tested with the use of contingency tables and calculations of the Chi² test. Patients’ characteristics according to their FINDRISC scores were compared by one-way analysis of variance (ANOVA) for continuous variables. Those with IFG, IGT and T2D were analyzed all together as a combined “dysglycaemia” group. Associations and correlation coefficients between the FINDRISC and clinical parameters were evaluated by Pearson’s correlation test. The predictive value of FINDRISC to detect diabetes, dysglycaemia and the MetS was cross-sectionally evaluated using the area under the receiver operating characteristic (AUROC) curve method. Sensitivity was plotted against the y axis, and false-positive rates (1–specificity) against the x axis, followed by plotting of the AUROC curve. The optimal cutoff levels used were the peaks of the curve, where the sum of sensitivity and specificity is at maximum. The AUROC curve (for example, for detection of diabetes) can be regarded as reflecting the probability that a randomly chosen subject with undiagnosed diabetes is more likely to be classified as diabetic than a randomly chosen subject without diabetes and, therefore, is indicative of the overall ability of the risk score to correctly identify those with undiagnosed diabetes. All reported P values were derived from two-sided tests and compared with a significance level of 5%. Data were analyzed using SPSS version 16.0 software (SPSS Inc, Chicago, IL, USA).

3. Results

The demographic, clinical and laboratory characteristics of our study participants are presented in Table 1. The prevalence of undiagnosed diabetes (based on OGTT results) was 10.8%, while that of dysglycaemia (IFG + IGT + T2D) was 33.6%, with significant differences between genders (higher in men). However, the prevalence of the MetS (38.4%) did not differ between men and women.

Of the total 869-screened participants, 840 had complete FINDRISC data, and a marked increase in the prevalence of undiagnosed diabetes and dysglycaemia was observed as FINDRISC score values increased (Table 2). The prevalence of unknown diabetes in those with a FINDRISC score greater than 15 (44.5% of the study population) was 19.3% whereas, for any degree of dysglycaemia (IFG + IGT + T2D), the prevalence was 51.1%.

The AUROC curve for detecting unknown diabetes (Fig. 1A) was 0.724 (95% CI: 0.677–0.770) overall, with 0.731 (0.667–0.794) for men and 0.726 (0.659–0.793) for women (NS, not significant). The AUROC curve for any degree of dysglycaemia was 0.716 (0.68–0.752), with 0.721 (0.668–0.724) for men and 0.720 (0.671–0.770) for women (NS; Fig. 1B).

The optimal cutoff value for detecting unknown diabetes was a FINDRISC greater or equal to 15, at which the sensitivity was 81.1% and specificity was 59.8% (Table 3). With a FINDRISC greater or equal to 10 (73% of the population), the sensitivity was 96.7% and the specificity was 29.5%, whereas with a score greater or equal to 7 (93.5% of the population), the sensitivity was 100%, but its specificity was only 10.7%.

The best cutoff value for detecting any dysglycaemia was again, a FINDRISC greater or equal to 15, with sensitivity of 67.7% and specificity of 67.2%.

With the exception of total and LDL cholesterol, all other measured CVD risk factors had strong, significant associations with FINDRISC values (Table 2). Specifically, the FINDRISC was significantly correlated with systolic (r = 0.28, P < 0.001) and diastolic (r = 0.12, P = 0.001) blood pressure, HDL cholesterol (r = –0.12, P < 0.001) and triglycerides (r = 0.16, P < 0.001). Also, there was an inverse association between the FINDRISC and smoking (r = –0.26, P < 0.001).

The prevalence of the MetS was also positively correlated with the FINDRISC (r = 0.39, P < 0.001). The AUROC curve for detecting the MetS was 0.733 (95% CI: 0.699–0.767) overall, with 0.707 (0.653–0.760) for men and 0.757 (0.713–0.801) for women. Yet again, the optimal cutoff value for detecting the MetS was a FINDRISC greater or equal to 15, with sensitivity of 67.3% and specificity of 70.6% (Table 3).

4. Discussion

The American Diabetes Association (ADA) recommends screening for T2D at 3-year intervals, beginning at age 45 years, especially in those with a BMI greater or equal to 25 kg/m² [34]. However, these recommendations are not widely followed, as indicated by the fact that one-third of those who have diabetes go undiagnosed [1]. As the main reason for this problem is the cost and inconvenience of diabetes testing [35], one way to address the issue is to develop a simple, inexpensive tool that can identify those at high risk of having either pre-diabetes or undiagnosed diabetes [36]. However, although a number of investigators have developed diabetes risk-assessment tools [12–21], most of these have not been tested in populations other than those in which they were originally developed [28].
Table 1
Clinical, demographic and laboratory characteristics of the study participants by gender.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Men</th>
<th>Women</th>
<th>P*</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants (n)</td>
<td>379</td>
<td>490</td>
<td></td>
<td>869</td>
</tr>
<tr>
<td>Age (years)</td>
<td>56.0 (10.7)</td>
<td>56.4 (10.9)</td>
<td>NS</td>
<td>56.2 (10.8)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>29.4 (4.0)</td>
<td>29.8 (5.7)</td>
<td>NS</td>
<td>29.6 (5.0)</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>103.3 (10.8)</td>
<td>94.0 (12.4)</td>
<td>&lt;0.001</td>
<td>98.0 (12.6)</td>
</tr>
<tr>
<td>Smoking (never/ex/current) (%)</td>
<td>28/37/35</td>
<td>58/6/36</td>
<td>&lt;0.001</td>
<td>45/20/35</td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>128.3 (17.2)</td>
<td>124.1 (19.9)</td>
<td>0.001</td>
<td>126.0 (18.8)</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>79.9 (11.2)</td>
<td>76.0 (11.7)</td>
<td>&lt;0.001</td>
<td>77.7 (11.6)</td>
</tr>
<tr>
<td>Fasting glucose (mg/dL)</td>
<td>5.83 (1.18)</td>
<td>5.61 (1.05)</td>
<td>0.004</td>
<td>5.71 (1.12)</td>
</tr>
<tr>
<td>Glucose at 120 min (mg/dL)</td>
<td>6.28 (2.91)</td>
<td>6.57 (2.79)</td>
<td>NS</td>
<td>6.44 (2.84)</td>
</tr>
<tr>
<td>Total cholesterol (mmol/L)</td>
<td>5.61 (1.01)</td>
<td>5.82 (1.08)</td>
<td>0.003</td>
<td>5.73 (1.06)</td>
</tr>
<tr>
<td>Triglycerides (mmol/L)</td>
<td>1.47 (0.78)</td>
<td>1.25 (0.69)</td>
<td>&lt;0.001</td>
<td>1.34 (0.74)</td>
</tr>
<tr>
<td>HDL cholesterol (mmol/L)</td>
<td>1.20 (0.19)</td>
<td>1.36 (0.24)</td>
<td>&lt;0.001</td>
<td>1.29 (0.24)</td>
</tr>
<tr>
<td>LDL cholesterol (mmol/L)</td>
<td>3.76 (0.92)</td>
<td>3.90 (0.96)</td>
<td>0.026</td>
<td>3.84 (0.95)</td>
</tr>
<tr>
<td>FINDRISC value</td>
<td>12.6 (4.9)</td>
<td>13.6 (4.9)</td>
<td>0.005</td>
<td>13.1 (4.9)</td>
</tr>
<tr>
<td>Undiagnosed diabetes (%)</td>
<td>11.9</td>
<td>10.0</td>
<td>&lt;0.001</td>
<td>10.8</td>
</tr>
<tr>
<td>Dysglycaemia (%)</td>
<td>36.0</td>
<td>31.7</td>
<td>&lt;0.001</td>
<td>33.6</td>
</tr>
<tr>
<td>MetS (%)</td>
<td>39.1</td>
<td>37.9</td>
<td>NS</td>
<td>38.4</td>
</tr>
</tbody>
</table>

Data are presented as means (± SD) unless otherwise specified; NS: not significant; BMI: body mass index; BP: blood pressure; HDL: high-density lipoprotein; LDL: low-density lipoprotein; MetS: the metabolic syndrome; Dysglycaemia = combined impaired fasting glucose, impaired glucose tolerance and type 2 diabetes.

* Men vs women.

Table 2
Characteristics of the study participants by FINDRISC.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Finnish Type 2 Diabetes Risk Score (FINDRISC)</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0–3</td>
<td>4–6</td>
</tr>
<tr>
<td>n (%)</td>
<td>18 (2.1)</td>
<td>63 (7.4)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>46.5 (5.2)</td>
<td>48.6 (9.9)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.6 (2.6)</td>
<td>25.7 (2.7)</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>79.3 (10.4)</td>
<td>89.1 (9.9)</td>
</tr>
<tr>
<td>Smoking (never/ex/current) (%)</td>
<td>43/14/43</td>
<td>29/21/50</td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>106.4 (19.4)</td>
<td>119.0 (15.5)</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>68.7 (13.5)</td>
<td>76.6 (10.4)</td>
</tr>
<tr>
<td>Fasting glucose (mmol/L)</td>
<td>5.08 (0.53)</td>
<td>5.16 (0.53)</td>
</tr>
<tr>
<td>Glucose at 120 min (mmol/L)</td>
<td>4.49 (1.53)</td>
<td>4.85 (1.51)</td>
</tr>
<tr>
<td>Total cholesterol (mmol/L)</td>
<td>5.66 (1.22)</td>
<td>5.68 (1.17)</td>
</tr>
<tr>
<td>Triglycerides (mmol/L)</td>
<td>0.92 (0.41)</td>
<td>1.22 (0.80)</td>
</tr>
<tr>
<td>HDL cholesterol (mmol/L)</td>
<td>1.41 (0.27)</td>
<td>1.33 (0.24)</td>
</tr>
<tr>
<td>LDL cholesterol (mmol/L)</td>
<td>3.83 (1.10)</td>
<td>3.83 (1.08)</td>
</tr>
<tr>
<td>Undiagnosed diabetes (%)</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Dysglycaemia (%)</td>
<td>5.6</td>
<td>9.5</td>
</tr>
<tr>
<td>MetS (%)</td>
<td>11.1</td>
<td>9.8</td>
</tr>
</tbody>
</table>

Data are presented as means (± SD) unless otherwise specified; BMI: body mass index; BP: blood pressure; HDL: high-density lipoprotein; LDL: low-density lipoprotein; NS: not significant; MetS: the metabolic syndrome; Dysglycaemia = combined impaired fasting glucose, impaired glucose tolerance and type 2 diabetes. * One-way ANOVA or Chi² test.
Nevertheless, the present study has demonstrated that the FINDRISC questionnaire can perform reasonably well in predicting undiagnosed T2D, glucose homoeostasis abnormalities and the MetS in cross-sections of the Greek population, and at least as well as it has in the other Caucasian populations studied so far [12,22–26]. Using an optimal cutoff value of greater or equal to 15, the questionnaire was able to identify 81.1% of those with unknown diabetes and 67.7% of those with any dysglycaemic condition (pre-diabetes and unknown diabetes).

In the original FINRISK studies [12], the FINDRISC questionnaire was developed as a predictor of future drug-treated diabetes in the Finnish population (in 1987), and was validated 5 years later (in 1992). The AUROC curve for a cross-sectional evaluation of the questionnaire to predict undiagnosed diabetes was 0.80 (compared with 0.72 in the present study). It is well known that models generally perform best with the data on which they were initially developed, and that they perform better on training rather than test data [37]. However, as the original questionnaire comprised only seven items (excluding a family history of diabetes) for a possible maximum score of 20 [12], direct comparisons with the present study data are difficult.

Nevertheless, the FINDRISC questionnaire was subsequently cross-sectionally validated in 2002 by a similar FINRISK survey in Finland, using the full questionnaire of eight items and a possible maximum score of 26 [22], thereby allowing direct comparison with the present study. The AUROC curves for the prevalence of unknown diabetes (0.722 in men and 0.732 in women) in that study were almost identical to those found in the present study for a similar cutoff value greater or equal to 9, although the specificity (4%) and AUROC curve (65%) were somewhat lower [25].

Two other studies evaluated the FINDRISC questionnaire and then compared it with other available screening tools for the detection of unknown diabetes [25,26]. The Cooperative Health Research in the Region of Augsburg (KORA) study used the tool in a German population (aged 55–77 years; n = 1353), and found that its sensitivity (82%) and positive predictive value (12%) were similar to those reported in the FINRISK survey (using a cutoff value greater or equal to 9), although the specificity (4%) and AUROC curve (65%) were somewhat lower [25]. The FINDRISC also performed equally as well as the Rotterdam Diabetes Study tool [14] and the San Antonio Heart Study diabetes-prediction model [15] in terms of AUROC curves, all of which were lower than that of the present study. Validation

<table>
<thead>
<tr>
<th>SDM</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
<th>Study sample %</th>
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<tbody>
<tr>
<td>Cutoff = 7</td>
<td>100</td>
<td>10.7</td>
<td>11.7</td>
<td>100</td>
<td>90.5</td>
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<td>Cutoff = 10</td>
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<td>29.5</td>
<td>14.0</td>
<td>98.7</td>
<td>73.3</td>
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<tr>
<td>Cutoff = 15</td>
<td>81.1</td>
<td>59.8</td>
<td>19.3</td>
<td>96.4</td>
<td>44.5</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Dysglycaemia</th>
<th>Cutoff = 7</th>
<th>97.5</th>
<th>13.1</th>
<th>36.2</th>
<th>91.4</th>
<th>90.5</th>
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<tbody>
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<td>87.4</td>
<td>33.9</td>
<td>40.0</td>
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<td>73.3</td>
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<tr>
<td></td>
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<td>67.7</td>
<td>67.2</td>
<td>51.1</td>
<td>80.5</td>
<td>44.5</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>MetS</th>
<th>Cutoff = 7</th>
<th>97.6</th>
<th>13.8</th>
<th>41.9</th>
<th>89.9</th>
<th>90.5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cutoff = 10</td>
<td>89.0</td>
<td>37.0</td>
<td>47.4</td>
<td>84.1</td>
<td>73.3</td>
</tr>
<tr>
<td></td>
<td>Cutoff = 15</td>
<td>67.3</td>
<td>70.6</td>
<td>59.3</td>
<td>77.2</td>
<td>44.5</td>
</tr>
</tbody>
</table>

PPV: positive predictive value; NPV: negative predictive value.

a National Cholesterol Education Program Adult Treatment Panel III criteria.
A higher FINDRISC was also associated with a poorer CVD risk-factor profile (Table 2), as shown in other studies as well [22,23]. Smoking was the only risk factor negatively associated with the FINDRISC. Although the prevalence of smoking was rather high in our present population (35%) – which is consistent with the rest of Greece (around 40%) [38] – smoking is not part of the FINDRISC or any other questionnaire so far used to predict dysglycaemia. However, this observation should perhaps be further examined in larger studies, as smoking has also been implicated in the development of T2D [39].

One limitation of the present study is that participants were drawn from a limited population survey carried out in healthcare centers and occupational settings around Athens [29] and, thus, the results may not be applicable to the rest of Greece. Also, the number of participants was relatively small (n = 869), although the results were similar to those of other studies in different populations and larger cohorts [12,22–26], which supports the validity of our present findings. However, in our study, the diagnosis of diabetes and dysglycaemia was based on only one OGTT value, not two as recommended. On the other hand, the strengths of our study were that the diagnosis of diabetes was not self-reported, and that the age distribution of the participants was wide and included the vast majority of the high-risk population (aged 35–75 years).

5. Conclusion

The present study has validated the FINDRISC questionnaire as a useful screening tool to identify unknown diabetes, abnormal glucose homoeostasis and the MetS in a cross-section of the Greek population. The questionnaire was originally developed in a prospective setting to identify those at high risk of developing T2D in the future. The performance of the questionnaire in the present study was good, and comparable to its performance in the other Caucasian populations tested [22–26]. This confirms that the FINDRISC tool is indeed also valid for Southern European populations, despite having lifestyles that are very different from Northern European ones, and supports the fact that risk factors for T2D are similar in different European populations. The FINDRISC tool is simple, inexpensive and non-invasive [36], and has been specifically recommended as a European and global screening tool by the European IMAGE project, a programme for the “Development and Implementation of a European Guideline and Training Standards for Diabetes Prevention”, which aims to improve the management and reduce the impact of T2D across Europe [7,40]. Another advantage of the FINDRISC is that it can also identify those considered to be at high risk for the development of T2D, but who currently have normal blood glucose levels. This means that implementing lifestyle interventional programmes in such cases will be a true attempt at primary prevention of hyperglycaemia.

Fig. 1. Receiver operating characteristic (ROC) curves for the prevalence of unknown type 2 diabetes (a), Dysglycaemia (b), and the metabolic syndrome (c), in Greek men and women.
Conflict of interest statement

None of the authors have any conflict of interest to declare.

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