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Detailed Evaluation of Finnish Diabetes Risk Score Questionnaire in Diabetes, Hypertension, and Chronic Diseases

ABSTRACT

Objective: The Finnish Diabetes Risk Score (FINDRISC) questionnaire, developed to determine the future risk of type 2 diabetes, is a simple, fast, inexpensive, non-invasive, and reliable tool. We aimed to evaluate the FINDRISC questionnaire in detail not only for diabetes but also for predicting hypertension or any chronic disease. Thus, we contributed to the national health system and literature.

Methods: The FINDRISC scale, comprising 8 questions, was administered to 347 individuals for adaptation to Turkish. The questionnaire was applied to 51 subjects twice at 15-day intervals to examine invariance over time. Reliability, validity, and sensitivity tests were analyzed, and positive/negative predictive values and likelihood ratios were calculated.

Results: In the reliability analysis of FINDRISC, the Cronbach's alpha coefficient was found suitable for the whole scale ($\alpha = 0.71$). Evaluating the receiver operating characteristic curves revealed that the area under the curve with 95% CI was 0.896, 0.864-0.928 for diabetes; 0.855, 0.815-0.894 for any chronic disease; and 0.855, 0.810-0.890 for hypertension ($P < .001$ for all). In those with a total risk score ≥15.50, the sensitivity and specificity for diabetes were calculated as 92% and 71%, respectively. The corresponding sensitivity and specificity at a 13.5 cutoff risk score yielded 74% and 85%, respectively, for chronic disease and 87% and 67%, respectively, for hypertension.

Conclusion: Our study has shown that the FINDRISC scale can be used reliably in people in Turkey. We think this scale may also be beneficial in assessing the risk of hypertension or any chronic disease beyond determining the risk of type 2 diabetes.

Keywords: Adaptation, chronic disease, diabetes, FINDRISC questionnaire, reliability

Introduction

The most recent edition of the diabetes atlas revealed that over half a billion adults (20-79 years old) worldwide had diabetes in 2021. Projections show that this figure will increase by approximately 50% by 2045 to exceed 3/4 billion. In this process, it is estimated that the diabetes prevalence, which was 10.5% in 2021, will increase to 12.2% in 2045.[1] The prevalence of diabetes is also on the rise in our country. According to the population-based Turkish Diabetes Epidemiology (TURDEP-I) survey conducted in 1998 and its 12-year-later repeated version, the TURDEP-II (performed in 2010), the prevalence of diabetes increased from 7.2% to 13.7% in the adult population of Turkey.[2] Diabetes is among the top 10 causes of death in adults worldwide, and the economic burden of diabetes on countries is quite high.[3] It is thought that global healthcare expenditures related to diabetes were 966 billion USD in 2021.[1]

The prevention of diabetes can considerably contribute to increasing the quality of life, prolonging life expectancy, and improving the economic situation of people at risk.[4] Numerous attempts are being made to create strategies that endorse appropriate and cost-effective screening of individuals, particularly those at high risk of developing type 2 diabetes.[5] Various screening tools are available to assess the likelihood of diabetes within the upcoming 5-10 years without requiring invasive tests.[4]

The Finnish Diabetes Risk Score (FINDRISC), developed by Lindström and Tuomilehto to determine the risk of type 2 diabetes, is defined as a simple, fast, inexpensive, non-invasive, and reliable tool.[6] The FINDRISC has been accepted as a valid scale in many countries, such as Spain, Greece, Norway, and Germany.[7-10] In 2017, we used the FINDRISC scale in over 20 000 participants of the aforementioned cross-sectional TURDEP-II study by Satman et al[11] and

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evaluated the sensitivity and specificity of the screening tool by calculating the areas under the receiver operating curve (ROC-AUC). In addition, the FINDRISC scale's validity was evaluated in a doctoral thesis, and the findings were published as an article in our country.[12,13] However, there is a need for a study in which more detailed statistical analyses are carried out, including language adaptation, content validity, test–retest, concurrent validity, and reliability.

In this study, we aimed to perform the Turkish translation and adaptation and a detailed analysis comprising the reliability, validity, and sensitivity tests and positive predictive value (PPV) and negative predictive value (NPV) and likelihood ratios of the FINDRISC diabetes risk questionnaire. Thus, we hope to contribute to the national health research and literature. Moreover, we also investigated the validity of this scale in the presence of hypertension or any chronic disease.

Materials and Methods

Setting, Sample Size Determination, and Samples

Volunteers aged 18 and over were invited to participate in this study, with flyers posted in various hospital outpatient clinics as part of a diabetes awareness campaign. The research was carried out by the outpatient clinic staff of the Division of Endocrinology and Metabolic Diseases, İstanbul University, İstanbul Faculty of Medicine between March 1, 2023, and April 30, 2023.

The sample size for diabetes and hypertension was calculated with 80% power. For diabetes, we took the sensitivity as 0.90, type I error as 0.05, margin of error as 7%, and disease prevalence as 0.20. Therefore, we attained a sample size of 353 people, deemed sufficient based on calculations. Similarly, when we took the sensitivity as 0.90, the type I error as 0.05, the margin of error as 7%, and the disease prevalence as 0.25, the sufficient sample size was 282 for hypertension. Thus, the power of the study was at least 80% or more for the sample size determined in both conditions.[14,15]

Eligible individuals who agreed to participate in this study were invited to the outpatient clinic, face-to-face interviews were conducted, and fasting plasma glucose (FPG) levels were measured using a glucometer (*ACCU-CHEK Performa, ROCH*) calibrated according to plasma glucose. The 8-question scale was applied to 347 individuals to adapt the FINDRISC to Turkish. The FINDRISC scale was applied to 51 subjects twice, with an interval of 15 days, to examine invariance over time. The "World Health Organization Well-Being Index (WHO-5)" questionnaire was applied to these individuals to make comparisons. In addition, all participants filled out a "Patient Identification Form," questioning their demographic characteristics and medical history.

MAIN POINTS

- The Finnish Diabetes Risk Score (FINDRISC) questionnaire, developed to determine the risk of type 2 diabetes, is a simple, fast, inexpensive, non-invasive, and reliable tool.
- In our country, there is no detailed study on the FINDRISC scale covering the terms "language adaptation, content validity, test and retest, concurrent validity, and reliability."
- Our study found that this scale can also evaluate the risk of diabetes, hypertension, and chronic diseases.

Individuals who met any of the following criteria were excluded from the study: being younger than 18 years of age; illiterate; having the difficulty of hearing, speaking, or understanding; currently pregnant or lactating women; professional athletes; persons with type 1 diabetes or decompensated liver disease or those undergoing bariatric surgery; and people currently on renal replacement therapy.

Instruments

Three instruments, including the Patient Identification Form, the WHO-5 Well-Being Index, and the FINDRISC, were used in this study.

Patient Identification Form: Through the Patient Information Form developed by the authors, sociodemographic characteristics of the participants, such as age, gender, educational status, social status, and chronic disease status, were questioned.

Finnish Diabetes Risk Score: The FINDRISC tool comprises 8 comprehending questions such as age, body mass index (BMI), waist circumference, physical activity level, fruit, vegetable, and berry intakes, using antihypertensive medications, history of any hyperglycemia, and a family history of diabetes.[6] The English version of the Finnish Diabetes Risk Score (FINDRISC-EN) and estimating the risk of developing type 2 diabetes within a 10-year time frame are given in Supplementary Table 1.[16] The evaluation of the scale is as follows: <7 points, low; 7-11 points, mild; 12-14 points, moderate; 15-20 points, high (33%); and >20 points, very high-risk level (50%).

World Health Organization Well-Being Index: This is one of the most widely used scales to evaluate subjective well-being, consisting of 5 items about the emotions of the participant in the last 2 weeks. Since this index was first published by the WHO Regional Office for Europe in 1998, it has been translated into more than 30 languages and used in many studies. The 5 items in the index are as follows: "I have felt cheerful and in good spirits," "I have felt calm and relaxed," "I have felt active and vigorous," "I woke up feeling fresh and rested," and "My daily life has been filled with things that interest me." The total points range from 0 (absence of well-being) to 25 (maximal well-being) on this scale. The raw score obtained is multiplied by 4, and the evaluation is made out of 100.[17,18] A group of researchers translated the scale into Turkish in 1999 and then conducted a study to assess its validity and reliability.[19]

Procedures and Data Collection

Participants filled out the forms in a quiet, well-lit patient education room located in the diabetes outpatient clinic, where they could concentrate on completing the questionnaires undisturbed. One of the researchers accompanied the participants to assist in the calculation of BMI and measurement of waist circumference.

The scale was applied to 347 individuals, and for test–retest stability, participants who were able to visit the outpatient clinic within 2 weeks after the initial evaluation were invited. Fifty-five individuals who agreed to make a second visit to the outpatient clinic were called 2 days before the scheduled date to remind them of their appointment. Fifty-one out of 55 participants completed the scale again in the outpatient clinic. Participants completed the scale within 3-10 minutes, and 95.0% completed the survey in 8 minutes or less.

Statistical Analysis

The categorical data are presented in numbers and percentages, while the continuous data are expressed as mean, SD, and median (minimum–maximum). Since the total risk scores were not normally

distributed, paired groups were compared using the Mann–Whitney *U*-test, while groups consisting of more than 2 were analyzed using the Kruskal–Wallis 1-way analysis of variance.

Reliability Analysis: *The* "test–retest" method was used to evaluate the invariance with respect to time, and the *t*-test was chosen for independent groups for the differences in the total scores obtained. The Spearman correlation coefficient was calculated for the relationship between test and retest scores. The Cronbach's alpha reliability coefficient was calculated for the internal consistency of the scale.

Validity Analysis: The content validity ratio (Lawshe technique) and the content validity index (CVI) were calculated in the evaluation of expert opinions.

Concurrent Validity: The concurrent validity analysis is a type of criterion validity. It shows how well a new test compares to a well-established test. The Spearman correlation coefficient was calculated for the correlation of the scores obtained from the 2 tests.

Sensitivity Analysis: Knowing how accurately the scale can distinguish diseased individuals from healthy individuals is very important. We used ROC analysis and calculated the AUC with 95% CIs to determine the best-fit sensitivity and specificity of the scale. The calculation of terms used to evaluate the adequacy of the diagnostic test in comparison with the gold standard test [i.e., sensitivity, specificity, false positive rate (FPR), false negative rate (FNR), PPV, NPV], positive likelihood ratio [LR+], negative likelihood ratio [LR–], and accuracy] has been omitted from the main manuscript but is summarized in Supplementary Table 2.[20-22]

The data obtained from the study were analyzed using the Statistical Package for Social Science Statistics software, version 21.0 (IBM Corp.; Armonk, NY, USA). A *P*-value of less than .05 was considered to determine the level of statistical significance.

Ethical Committee Approval

Before starting the study, ethical approval was obtained from the Institutional Review Board of İstanbul University, İstanbul Faculty of Medicine Clinical Research Ethics Committee (date: March 6, 2023, no. 165724). The study was conducted in accordance with the Declaration of Helsinki. A written consent was obtained from the participants. In addition, written permission was obtained from Professor Jaakko Tuomilehto via e-mail on behalf of the study group, which owns the scale, to adapt FINDRISC to Turkish.

Results

General Characteristics of Participants

Table 1 presents the general characteristics of the study group. The participants' mean age (SD) was 46.7 ± 15.5 years, ranging from 19 to 73 years. More than half of the participants were women (64.8%), married (69.2%), and individuals whose household income level was above the minimum wage (74.6%). Of them, 60.1% had an education above the primary school level. Most of the individuals did not use any tobacco products (68.6%) or alcohol (86.2%). While two-thirds of the participants had at least 1 chronic disease (66.6%), the most common diseases were hypertension (38.0%) and diabetes (28.8%).

The participants' responses to the FINDRISC scale are shown in Table 2. Based on the answers given to the questionnaire, more than half of the participants (55.9%) were over 45 years old, 71.8% were overweight or obese, more than half were not performing regular physical activity (59.9%), and the majority of them had diabetes in their first- and/or second-degree relatives (69.3%).

Table 1. Distribution of Participants According to Sociodemographic and Disease Characteristics

	Number (n)	Percent
Gender		
Female	225	64.8
Male	122	35.2
Household income status		
Minimum wage and below	88	25.4
Above minimum wage	259	74.6
Education level		
Primary education	142	40.9
High school	76	21.9
University-doctorate	129	37.2
Marital status		
Married	240	69.2
Single	89	25.6
Widow	18	5.2
Working status		
Employed	142	40.9
Unemployed	153	44.1
Retired	52	15.0
Smoking		
Yes	109	31.4
No	238	68.6
Alcohol		
Yes	48	13.8
No	299	86.2
Chronic diseases		
Yes	231	66.6
No	116	33.4
Diseases*		
Diabetes mellitus	100	28.8
Cardiovascular disease	66	19.0
Hypertension	132	38.0
Hyperlipidemia	57	16.4
Gastrointestinal disease	34	9.8
Kidney disease	21	6.1

*Multiple options are marked.

According to the data obtained from the "Patient Identification Form," the mean scores of the FINDRISC scale according to the age groups, gender, social status, presence of diabetes, chronic diseases, and hypertension are shown in Table 3. The mean scores of the FINDRISC scale were statistically higher in older people than in younger age groups ($P < .001$). The mean scores did not differ between men and women participants. The mean FINDRISC scores were statistically different by social status. The mean score in single participants was significantly lower than in married ($P < .05$) and widowed/divorced individuals ($P < .001$). The mean FINDRISC scores in those with diabetes, chronic disease, and hypertension were statistically higher than those without ($P < .001$ for all).

Language Adaptation: In our study, the original FINDRISC-EN scale was translated to Turkish by an English instructor and a faculty

Table 2. Answers to the Finnish Diabetes Risk Score Questions

	Number (n)	Percent
Q1. Age		
Under 45 years	153	44.1
45-54 years	72	20.7
55-64 years	67	19.3
Over 64 years	55	15.9
Q2. Body mass index		
Lower than 25 kg/m^2	98	28.2
25-30 kg/m^2	120	34.6
Higher than 30 kg/m^2	129	37.2
Q3. Waist circumference		
Men Women		
<94 cm <80 cm	84	24.2
94-102 cm 80-88 cm	91	26.2
>102 cm >88 cm	172	49.6
Q4. Physical activity (≥30 min/day)	139	40.1
Yes	208	59.9
No		
Q5. Eating vegetables, fruit/berries	226	65.1
Every day	121	34.9
Not every day		
Q6. Antihypertensive medication		
No	200	57.6
Yes	147	42.2
Q7. High blood glucose		
No	181	52.2
Yes	166	47.8
Q8. Diabetes in relatives		
No	106	30.5
Yes (first degree)	174	50.1
Yes (second degree)	67	19.3

member of the Faculty of Foreign Languages. After the Turkish translation of the scale was reviewed by a literature teacher, it was retranslated to English by a specialist in endocrinology and metabolic diseases, who lived abroad for years and was fluent in English. The scale, which was translated into English, was later translated back into Turkish by 2 faculty members from the Faculty of Foreign Languages. After all these processes, the original FINDRISC scale was compared with its translated version. Then, necessary arrangements were made, and it was sent to Jaakko Tuomilehto by e-mail on behalf of the working group. The final version of the scale was presented to 10 specialists in the Division of Endocrinology and Metabolic Diseases. Finally, we decided that there is no significant difference between the original and semantic scales. The final Turkish version of the scale (FINDRISC-TR) and its evaluations are given in Supplementary Table 3.

Content Validity: After the validity of the FINDRISC scale was completed, its scope validity was determined via consultation with 10 experts. Experts have been asked to evaluate the suitability of each scale item with a score between 1 and 4. With the Lawshe method, the differences between the experts' opinions have been determined, and the data obtained was evaluated with the CVI.[23] The calculated CVI of the items was 0.95.

Reliability Study: *Internal Consistency Reliability Coefficient*:In the reliability analysis of FINDRISC, the Cronbach's alpha reliability coefficient was found to be satisfactory for the whole scale ($\alpha = 0.71$) (Table 4).

Test and Retest: The FINDRISC scale was reapplied to 51 people with an interval of 2 weeks, and the paired sample *t*-test revealed a clinically significant difference of 0.22 points between the mean values of the test and retest (10.98 ± 7.05 and 10.76 ± 7.17, respectively; $t = -2.11$, $P = .04$). Spearman correlation analysis showed a highly significant, strong positive correlation coefficient between the test and retest, indicating that there was a complete relationship ($r = 0.98$; $P < .001$).

Validity Study

Concurrent Validity: The relationship between FINDRISC and the WHO-5 scale was examined for concurrent validity. A weak negative but statistically significant correlation was found ($r = -0.11$; $P = .03$) between the 2 scales since the WHO-5 scale shows general well-being, whereas the FINDRISC scale estimates the potential for diabetes.

Receiver Operating Characteristic Analysis

In order to evaluate the predictive accuracy of FINDRISC in determining the risk of future diabetes development, we employed ROC analysis. The analysis involved calculating the AUC with a 95% CI

Table 3. The Distribution of the Finnish Diabetes Risk Scores by Age, Gender, Social Status, and Presence of Diseases

		Mean ± SD	Median	Minimum–Maximum	Significance
Age	≤45	8.74 ± 6.08	7	0-22	$z = 11.25$ $P < .001$
	>45	17.64 ± 5.49	18	3-26	
Gender	Female	14.04 ± 7.48	15	0-26	$z = 1.16$ $P = .24$
	Male	13.12 ± 6.81	13	0-25	
Social status	Married	14.92 ± 6.62	16	0-26	KW = 58.23 $P < .001$ *$P < .05$
	Single	9.09 ± 6.89	6*	0-26	
	Widowed/divorced	20.56 ± 5.32	23	8-26	
Diabetes	Yes	20.69 ± 3.50	21	11-26	$z = 11.52$ $P < .001$
	No	10.89 ± 6.43	10	0-24	
Chronic diseases	Yes	16.73 ± 6.21	18	1-26	z = 10.79 p<0.001
	No	7.72 ± 5.17	7	0-21	
Hypertension	Yes	19.14 ± 4.84	20	3-26	$z = 10.96$ $P < .001$
	No	10.39 ± 6.44	9	0-26	

*The FINDRISC scale total score was found to be significantly lower in those who were single compared to those who were married/divorced.

Table 4. Reliability Test of the 8-Item FINDRISC

FINDRISC Question No.	Mean ± SD	Corrected Item: Total Correlation	Cronbach's Alpha if the Item is Deleted	Cronbach's Alpha General Test
Q1	1.62 ± 1.57	0.487	0.669	0.707
Q2	1.46 ± 1.25	0.542	0.665	
Q3	2.77 ± 1.62	0.583	0.646	
Q4	1.20 ± 0.98	0.201	0.719	
Q5	0.35 ± 0.48	0.020	0.731	
Q6	0.85 ± 0.99	0.532	0.677	
Q7	2.39 ± 2.50	0.610	0.638	
Q8	3.09 ± 2.18	0.338	0.715	

FINDRISC, The Finnish Diabetes Risk Score

to determine the ROC-AUC value. Additionally, we estimated the sensitivity and specificity of the FINDRISC scale. The sensitivity and specificity of the (best) optimal cutoff score for each condition (e.g., diabetes mellitus, any chronic disease, or hypertension) are shown in Table 5.

Diabetes Mellitus

Sensitivity and specificity for diabetes were evaluated at each possible cutoff value (total FINDRISC score). The ROC curve according to the presence of diabetes is shown in Figure 1. The AUC for diabetes is calculated as 0.896 (95% CI, 0.864-0.928; $P < .001$).

In participants with a total risk score ≥15.5, the sensitivity and specificity for diabetes were 92% and 71%, respectively. This means that a 15.50 total score has the power to distinguish 92% of individuals with diabetes and 71% of controls. In contrast, a ≥14.5 total risk score yielded 95% sensitivity and 67% specificity. In other words, a 14.50 total score has the power to distinguish 95% of individuals with diabetes and 67% of controls.

When the total FINDRISC score was taken as 15.50, the LR+ was calculated as 3.21, which means the probability of the test result being positive in the presence of diabetes is 3.21 times higher than in the absence of diabetes. Thus, if the best total score was 14.5, the calculated LR+ can be found to be 2.90, which means the probability of the test result being positive in the presence of diabetes is 2.90 times higher than in the absence of the disease (Table 6).

Chronic Diseases

The ROC curve according to the presence of any chronic diseases is shown in Figure 2. The AUC for chronic disease is calculated as 0.855 (95% CI, 0.815-0.894; $P < .001$).

When considering the optimal cutoff value of ≥13.50 for determining any chronic disease, the sensitivity and the specificity were 74% and 85%, respectively, which means a total FINDRISC score ≥13.50 has the power to distinguish 74% of patients with chronic disease and 85% of controls. In this case, LR+ is calculated as 5.01. The probability of the test result being positive in the presence of the disease was 5.01 times higher than in the absence of the disease.

Hypertension

The ROC curve according to the presence of hypertension is shown in Figure 3. As seen, the AUC for hypertension is calculated as 0.855 (95% CI, 0.810-0.890; $P < .001$).

If the optimal cutoff value in the determination of hypertension was considered to be ≥13.50, the sensitivity and specificity were calculated at 87% and 67%, respectively. It means a total FINDRISC score of ≥13.5 has the power to distinguish 87% of patients with hypertension and 67% of controls. In this case, the LR+ was calculated as 2.60. The probability of the test result being positive in the presence of hypertension is 2.60 times higher than in the absence of the disease (Table 6).

Discussion

The FINDRISC questionnaire was designed to identify individuals who are at a high risk of developing type 2 diabetes without needing invasive laboratory tests;[6] then, it is translated into different languages, and several validation studies have been performed to use this tool in many countries or populations.[7-10] In the validation study for use in Brazilian and Portuguese populations, the Cronbach's alpha was determined as 0.84.[5] Pertiwi et al, who validated the Indonesian version, obtained a Cronbach alpha of 0.727.[24] In the present study, the Cronbach's alpha reliability coefficient was found to be reasonable for the whole FINDRISC scale ($\alpha = 0.71$). Since the generally accepted lower limit for Cronbach's alpha is 0.7,[25] the Cronbach's alpha score we found in our study was categorized as reliable.

The ROC curves were evaluated in FINDRISC validation studies conducted in various countries. The results for AUC were as follows: 0.78

Table 5. Sensitivity and Specificity Values According to Different Total Score Values for the Presence of Diabetes, Chronic Disease, and Hypertension

Cutoff score	Sensitivity	1 - Specificity	Specificity	Sensitivity + Specificity	LR+	LR−
Diabetes mellitus						
≥14.50	0.95	0.33	0.67	1.62	2.90	0.07
≥15.50	0.92	0.29	0.71	1.63	3.21	0.11
Chronic disease						
≥13.50	0.74	0.15	0.85	1.59	5.01	0.31
≥14.50	0.70	0.12	0.88	1.58	5.79	0.34
≥15.50	0.65	0.10	0.90	1.55	6.35	0.39
Hypertension						
≥13.50	0.87	0.34	0.67	1.54	2.60	0.19
≥14.50	0.83	0.31	0.69	1.52	2.65	0.25
≥15.50	0.80	0.27	0.73	1.53	2.94	0.28

LR+, positive likelihood ratio; LR−, negative likelihood ratio.

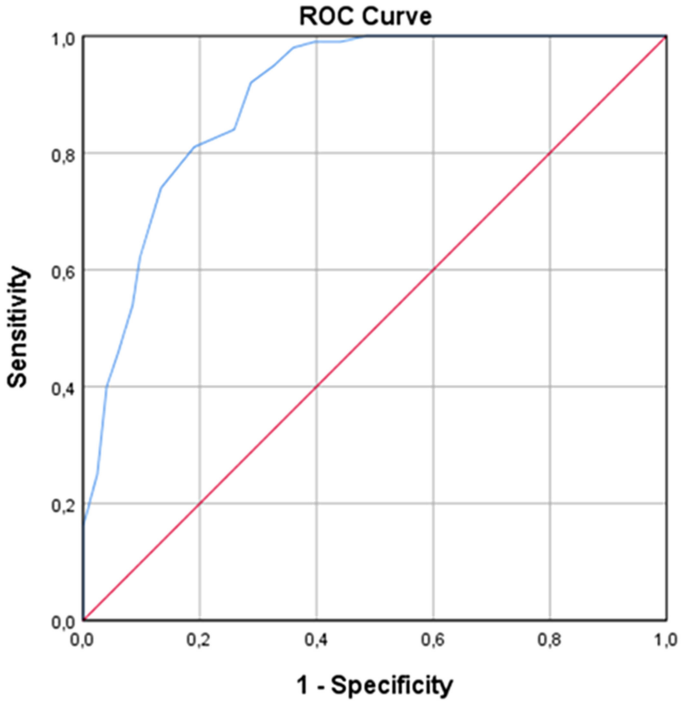

Figure 1. Receiver operating characteristics (ROC) curve according to the presence of diabetes (AUC, 95% CI, 0.896, 0.864-0.928; *P* < .001).

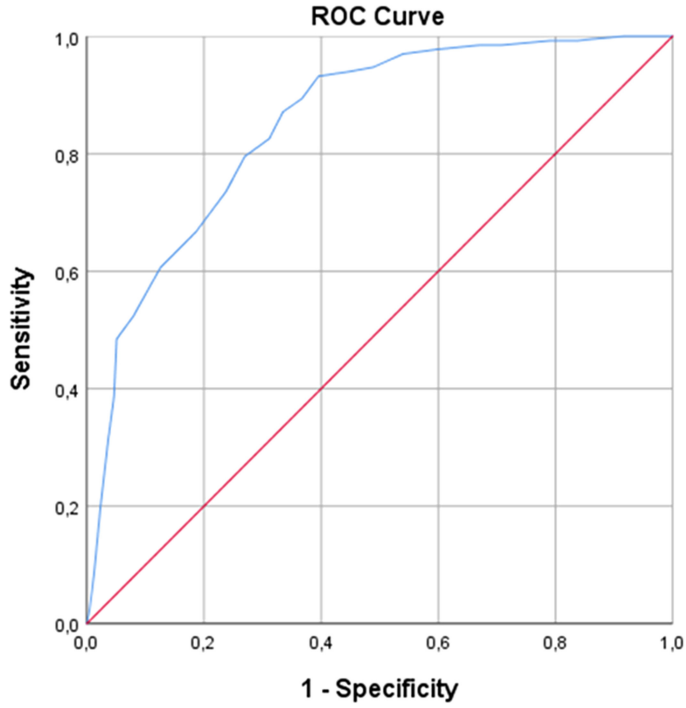

Figure 3. Receiver operating characteristic (ROC) curve according to the presence of hypertension (AUC, 95% CI, 0.855, 0.810-0.890; *P* < .001).

in the rural population of China,[26] 0.78 in Slovenia,[27] 0.77 in India,[28] and 0.77 in Norway.[9] In the Pizarra study conducted in Spain, which evaluated the ability of the FINDRISC scale to detect undiagnosed type 2 diabetes and predict the incidence of type 2 diabetes, the

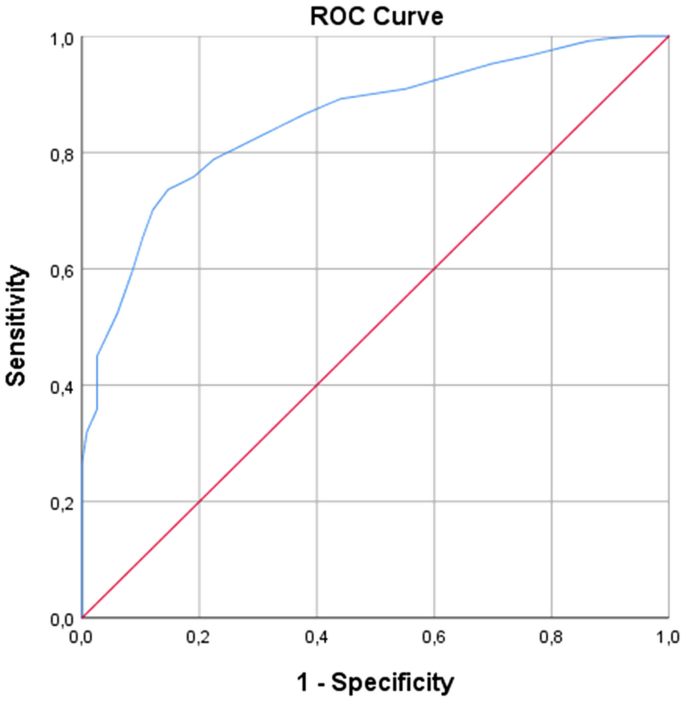

Figure 2. Receiver operating characteristic (ROC) curve according to the presence of chronic disease (AUC, 95% CI, 0.855, 0.815-0.894; *P* < .001).

AUC values were 0.74 and 0.75, respectively.[7] In our country, the AUC value for the prevalence of undiagnosed diabetes was found to be 0.67 in the study of Satman et al.[11] In Tarı Selçuk's[13] doctoral thesis and Demirağ and Boyraz's[12] studies, the area under the ROC curve for the predictive power of the FINDRISC score for newly diagnosed type 2 diabetes was found to be 0.84 and 0.80, respectively.

The FINDRISC questionnaire has been proven to be a valuable tool in predicting various health outcomes beyond just type 2 diabetes and impaired glycemia. It has been utilized to evaluate the risk of hypertension, coronary artery disease, stroke, and overall mortality. In a study conducted in the middle-aged group of Finnish men with metabolic syndrome (METSIM cohort), the FINDRISC scale demonstrated its effectiveness as a reliable predictor for incident type 2 diabetes, drug-treated hypertension, cardiovascular events, and total mortality.[29] In a study that included low-middle-income women from Peru, using the FINDRISC scale, the AUC calculated for the presence of diabetes and hypertension was 0.81 and 0.75, respectively.[30] In the present study, we found the AUC for diabetes was 0.896, chronic disease was 0.855, and hypertension was 0.855. The AUC value can range from 0 to 1.0 and indicates the discrimination ability of the diagnostic test studied. As an AUC above 0.8 indicates that the diagnostic test has good accuracy,[31] we can say that the Turkish version of the FINDRISC scale has very good accuracy.

Sensitivity and specificity analyses were performed in translation studies of the FINDRISC scale in various countries. For example, the optimal cutoff score of ≥9 (63.0% sensitivity and 67.3% specificity) was determined for detecting undiagnosed type 2 diabetes in Indonesia.[32] According to the Pizarra study conducted in Spain, the best estimate of the risk of incident type 2 diabetes was found in subjects with fasting glucose >100 mg/dL and FINDRISC ≥9.[7] In the

above-mentioned Perugia study, the FINDRISC cutoff point calculated for diabetes was 10.5 (81.5% sensitivity and 72.1% specificity), 8.5 for hypertension (83.9% sensitivity and 51.1% specificity), and 10.5 for any comorbidity (81.6% sensitivity and 74.1% specificity).[30] In our study, the optimal cutoff points best fit for detecting diabetes were 15.5 (92% sensitivity and 71% specificity), chronic disease 13.5 (74% sensitivity and 85% specificity), and hypertension 13.5 (87% sensitivity and 67% specificity).

This information about diabetes confirms the classification as having a high risk of developing type 2 diabetes if the result obtained from the FINDRISC scale is 15 or higher.[16] We think that it is appropriate to perform more advanced diagnostic tests, such as the oral glucose tolerance test (OGTT) or hemoglobin A1c (HbA1c) measurement, for individuals with a score above 15. In addition, although this tool is a scale for determining diabetes risk, screening individuals with a score above 13 points in terms of hypertension and other chronic diseases will be beneficial in individual and public health settings.

When the time-invariance principle was evaluated, the Spearman correlation coefficient was calculated as $r = 0.98$; $P < .001$ was highly significant, indicating a complete relationship between the 2 tests. Since the correlation was positive and close to 1, we decided the test was highly reliable. When we examined the reason for a 0.22-point decrease between the test and retest average scores, which we conducted at a 2-week interval, we found that some participants increased their consumption of vegetables, fruits, and berries immediately after the first test and also started doing regular physical activity. This shows that applying the FINDRISC scale only once can positively affect individuals' lifestyles.

When we compared the data of the "Patient Identification Form" that was filled out by the participants with the FINDRISC scores, we found that the average FINDRISC scores increased significantly, especially in people older than 45 years, in those with a chronic disease, diabetes, or hypertension ($P < .001$). These results support the reliability of the questionnaire, as the high mean FINDRISC scores are highly correlated with known comorbid diseases of the participants.

The risk of depression increases with the presence of diabetes. It is stated in various studies that the WHO-5 can be used as a screening test for depression in individuals with diabetes.[33,34] For this reason, we found a weak negative but statistically significant correlation between the FINDRISC and WHO-5 scales in our study, as expected ($r = -0.11$, $P = .03$). When the correlations between the FINDRISC and WHO-5 scales were analyzed separately for those who answered the seventh question in the FINDRISC scale (Have you ever been found to have high blood glucose?) "yes" and those who answered "no," there was no significant correlation between the 2 questionnaires (yes: $r = -0.11$, $P = .154$ vs. no: $r = 0.07$, $P = .297$).

One of the limitations of this study is that participants' glucose tolerance status is based on a single FPG value. This may lead to an underestimation of diabetes prevalence in the study. However, according to the American Diabetes Association and other authorities, the FPG test provides a highly accurate and reliable diagnosis of diabetes, equal to OGTT or HbA1c.[35] Therefore, we believe that the results of our study are guiding and add value for future research that will guide policymakers.

In validation studies of the FINDRISC scale carried out in several populations, the performance of the questionnaire is evaluated in a group diagnosed with a gold standard test. Although 2-hour plasma glucose (2hPG) in OGTT was used as the gold standard tests in the earlier studies, FPG and HbA1c are also being used as the gold standard test to evaluate glucose status (diabetes or prediabetes) in recent studies. Mavrogianni et al,[36] Agarwal et al,[37] and Mugume et al[38] used a single FPG as a gold standard test in their studies. Jin et al[39] used the 3 tests to validate the FINDRISC questionnaire in the Shanghai population and evaluated them separately. Fasting plasma glucose (AUC-ROC: 0.785, Sp: 65.2%, Se: 88.1%) resulted in a higher discriminative power in type 2 diabetes mellitus screening compared to 2hPG (AUC-ROC: 0.731, Sp: 69.0%, Se: 72.7%) and HbA1c (AUC-ROC: 0.704, Sp: 45.9%, Se: 89.6%) tests.

As a result, the FINDRISC scale, adapted and used in many countries worldwide, can be a fast and low-cost screening method in our country. In addition to determining the risk of type 2 diabetes, we think that it is a scale that can be predictive in terms of hypertension and chronic diseases.

Ethics Committee Approval: This study was approved by Ethics Committee of İstanbul University (Approval No: 165724, Date: March 6, 2023).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

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Supplementary Table 1. English Version of the Finnish Diabetes Risk Score (FINDRISC-EN) and Estimating the Risk of Developing Type 2 Diabetes

1. Age
- 0 p. Under 45 years
- 2 p. Between 45 and 54 years
- 3 p. Between 55 and 64 years
- 4 p. Over 64 years

2. Body mass index
- 0 p. Lower than 25 kg/m^2
- 1 p. Between 25 and 30 kg/m^2
- 3 p. Higher than 30 kg/m^2

3. Waist circumference measured below the ribs (usually at the level of the navel)
- MEN WOMEN
- 0 p. Less than 94 cm Less than 80 cm
- 3 p. Between 94 and 102 cm Between 80 and 88 cm
- 4 p. More than 102 cm More than 88 cm

4. Do you usually have daily at least 30 min of physical activity at work and/or during leisure time (including normal daily activity)?
- 0 p. Yes
- 2 p. No

5. How often do you eat vegetables, fruit, or berries?
- 0 p. Every day
- 1 p. Not every day

6. Have you ever taken antihypertensive medication regularly?
- 0 p. No
- 2 p. Yes

7. Have you ever been found to have high blood glucose (e.g., in a health examination, during an illness, during pregnancy)?
- 0 p. No
- 5 p. Yes

8. Have any of the members of your immediate family or other relatives been diagnosed with diabetes (type 1 or type 2)?
- 0 p. No
- 3 p. Yes: grandparent, aunt, uncle, or first cousin (but no own parent, brother, sister or child)
- 5 p. Yes: parent, brother, sister, or own child

• **SCORE**	• **ESTIMATED RISK OF TYPE 2 DIABETES WITHIN 10 YEARS**
• Lower than 7 points	• Low risk: 1 in 100 (1%)
• Between 7 and 11 points	Mild risk: 1 in 25 (4%)
• Between 12 and 14 points	Moderate risk: 1 in 6 (16%)
• Between 15 and 20 points	• High risk: 1 in 3 (33%)
• Higher than 20 points	• Very high risk: 1 in 2 (50%)

Supplementary Table 2. Situations that may be Encountered while Evaluating the Diagnostic Test

		Real situation / (Gold standard)		
		Diseased	**Not diseased**	
Diagnostic test	Diseased	A	B	A + B
	Not diseased	C	D	C + D
		A + C	B + D	A + B + C + D

Sensitivity - The ability of the test to distinguish patients from real patients.
Sensitivity = A / (A + C) = TP / (TP + FN)
Specificity - The ability of the test to distinguish healthy from real healthy.
Specificity = D / (B + D) = TN / (TN + FP)
The erroneous judgments of the test, which are the inverse of the sensitivity and specificity ratios, can also be calculated as follows:
FPR - These are the cases that the test incorrectly calls patients among the true healthy people.
FPR = (1 - Specificity) = B / (B + D) = FP / (FP + TN)
FNR - These are the cases in which the test erroneously says healthy among real patients.
FNR = (1 - Sensitivity) = C / (A + C) = FN / (FN + TP)
PPV - It is the ratio of true positives among positives determined according to the test result.
PPV = A / (A + B) = TP / (TP + FP)
NPV - It is the ratio of true negatives among the negatives determined according to the diagnostic test results.
NPV = D / (C + D) = TN / (TN + FN)
LR+ - It is the accuracy rate of diagnosing the disease. It is the ratio of the probability of a positive test result in the presence of the disease to the probability of being positive in the absence of the disease.
LR+ = Sensitivity / (1 - Specificity)= A (B + D) / B (A + C) = TP (FP+TN) / FP (TP + FN)
The higher this ratio, the better differentiated real patients.
LR− - It is the accuracy rate of the diagnosis of not diseased. It is the ratio of the probability of the test result being negative in the presence of the disease to the probability of being negative in the absence of the disease.
LR− = (1 - Sensitivity) / (Specificity) = C (B + D) / D (A + C) = FN (FP + TN) / TN (TP + FN)
(TP, true positive; TN, true negative; FP, false negative; FN, false negative)
Accuracy - One of the measures used when it is desired to obtain a single measure by combining sensitivity and specificity is the probability of an accurate test result. The total correct diagnosis rate of the test in patient and healthy is calculated as "accuracy" (Zou et al, 2007; Kanık & Erden, 2003; Güven Tezcan, 2017).

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Supplementary Table 3. The Turkish Version of the FINDRISC Questionnaire (FINDRISC-TR) and Estimating Risk of Developing Type 2 Diabetes

1. Yaş
- 0 puan: <45 yaş
- 2 puan: 45-54 yaş
- 3 puan: 55-64 yaş
- 4 puan: >64 yaş

2. Beden kütle indeksi (BKİ)
- 0 puan: <25 kg/m^2
- 1 puan: 25-30 kg/m^2
- 3 puan: >30 kg/m^2

3. Bel çevresi
- ERKEK KADIN
- 0 puan: <94 cm <80 cm
- 3 puan: 94-102 cm 80-88 cm
- 4 puan: >102 cm >88 cm

4. Ekseri günlerde işte veya boş zamanlarınızda çoğunlukla günde en az 30 dakika egzersiz yapıyor musunuz?
- 0 puan: Evet
- 2 puan: Hayır

5. Hangi sıklıkta sebze-meyve tüketiyorsunuz?
- 0 puan: Her gün
- 1 puan: Her gün değil

6. Kan basıncı yüksekliği için düzenli ilaç kullandınız mı veya sizde yüksek tansiyon bulundu mu?
- 0 puan: Hayır
- 2 puan: Evet

7. Daha önce (check-up, hastalık veya gebelik sırasında) kan şekerinizin yüksek veya sınırda olduğu söylendi mi?
- 0 puan: Hayır
- 5 puan: Evet

8. Aile bireylerinizden herhangi birisine diyabet tanısı konulmuş muydu?
- 0 puan: Hayır
- 3 puan: Evet: İkinci derece yakınlarda (amca, hala, dayı, teyze, kuzen ya da yeğen) (birinci derece yakınlar hariç)
- 5 puan: Evet: Birinci derece yakınlarda (biyolojik baba, anne, kardeş ya da çocuk)

• TOPLAM PUAN	• RİSK DERECESİ VE 10 YILLIK TİP 2 DİYABET RİSKİ
• <7 puan	• Düşük risk: 1/100 (%1)
• 7-11 puan	• Hafif risk: 1/25 (%4)
• 12-14 puan	• Orta risk: 1/6 (%16)
• 15-20 puan	• Yüksek risk: 1/3 (%33)
• >20 puan	• Çok yüksek risk: ½ (%50)