Prevalence and correlates of undiagnosed, diagnosed, and total type 2 diabetes among adults in Morocco, 2017

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The study aimed to estimate the prevalence and associated factors of undiagnosed type 2 diabetes (T2D) among adults in Morocco. Cross-sectional data were analyzed from 4779 people (≥ 18 years, mean age 41.7 years) who participated in the Morocco STEPS nationally representative survey in 2017 and had completed fasting blood glucose measurement. The results indicate that the prevalence of undiagnosed T2D was 5.9% (44.7% of total T2D), diagnosed T2D 7.3% and total T2D 13.2%. In the adjusted multinomial logistic regression analysis, older age (≥ 50 years), receipt of health care advice, and obesity were positively associated with undiagnosed T2D. Older age (≥ 50 years), urban residence, receipt of health care advice, ever cholesterol screening, moderate sedentary behaviour, obesity, hypertension, and elevated total cholesterol were positively associated with diagnosed T2D. In adjusted logistic regression analysis, older age (≥ 50 years), receipt of health care advice and cholesterol screening were negatively associated with undiagnosed T2D versus diagnosed T2D. A significant proportion of adults in Morocco had undiagnosed T2D and several associated factors were identified that can help guide interventions.

According to the World Health Organization, more than one and a half million people died from diabetes in 2019; however, diabetes can be treated with diet, physical activity, medication and regular screening and management of complications. Untreated undiagnosed type 2 diabetes (T2D) may have serious consequences, including microvascular and macrovascular complications and an increased risk of mortality, highlighting the crucial importance of early diagnosis. In 2021, worldwide 44.7% of adults with T2D did not know they had T2D. In an earlier review of studies in 29 low- and middle-income countries (LMICs), the prevalence of undiagnosed T2D was 4.9%, and in a review of 55 studies in the eastern Mediterranean region, the pooled prevalence of undiagnosed T2D was 5.45%, for example, in Tunisia 7.7% and in Iraq 6.2%. In a small sample of urban Sahraoui women in South Morocco, the prevalence of undiagnosed T2D was 6.4% in 2001/2002. Due to 44% of the diabetes population being undiagnosed in Morocco, the Moroccan Ministry of Health launched a public awareness campaign in 2015 on the different types of diabetes, its risk factors, warning signs and complications, the importance of screening and the adoption of a healthy lifestyle, involving health professionals and other lay persons in awareness and health education and involving the media in information and awareness on diabetes and its complications. There is a lack of national data on undiagnosed T2D and its correlates in Morocco. These data may help to assess public health interventions related to the screening and diagnosis of T2D in Morocco.

Predisposing factors associated with undiagnosed T2D included in some studies younger adults, older adults, male sex, living alone, and family history of diabetes. Enabling/disabling factors associated with undiagnosed T2D include rural residence, in some studies lower economic status, food insecurity, and lower education, and in other studies higher economic status, education, and lower education. Other enabling/disabling factors associated with undiagnosed T2D include knowing symptoms of diabetes, no health care visit in the past 12 months, health insurance status (having medical insurance), and not having private insurance and health risk behaviours (high sedentary behaviour, heavy alcohol use, and high level of physical activity).

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The need factors associated with undiagnosed T2D include other chronic diseases, hypertension status (not hypertension, hypertension), obesity, low HDL-C, high triglycerides, dyslipidaemia, cardiovascular disease status (not heart disease, cardiovascular disease), and perceived poor health. The study aimed to estimate the prevalence and associated factors of undiagnosed T2D among people 18 years and older in Morocco.

Methods

Study design and participants. Secondary data from the ‘STEPwise approach to NCD risk factor Surveillance’ (STEPS) cross-sectional survey in Morocco in 2017 with complete measurements of fasting blood glucose were analyzed; the overall response rate was 89.0%. STEPS focus is on “obtaining population-based data on the established risk factors that determine the major disease burden on a regular basis”. Participants were randomly selected from the target population (18 years and older), using a multi-stage stratified sampling procedures. Following the STEP-wise survey procedures, in Step 1 behavioural and sociodemographic data were collected. In Step 2, physical measurements and blood pressure were assessed, and in Step 3 biochemical measurements were collected to assess blood glucose and cholesterol. Blood glucose, total cholesterol and triglycerides were measured in peripheral (capillary) blood at the data collection site; equipment used was the Cardiochek PA (pts Diagnostics, Indianapolis, Indiana, USA) with a Chip MeMo, Blood Glucose Strips and lipids.

Ethics approval was provided by the Biomedical Research Ethics Committee, Faculty of Medicine and Pharmacy of Rabat, Morocco, and participants provided written informed consent. All methods were performed in accordance with the relevant guidelines and regulations.

Measures

Outcome variable. Undiagnosed T2D was defined as fasting plasma glucose level ≥126 mg/dL among people who responded “no” to the question “Have you ever been told by a doctor or other health worker that you have raised blood sugar or diabetes?” Diagnosed T2D was defined as those who answered “yes” to the question of ever having been told by a health care worker that they had diabetes, and total T2D included those with undiagnosed T2D (with not having T2D as reference category). Logistic regressions were calculated to estimate differences in proportion.

Sample size calculations and data analysis

Sample size calculation. This data set had an overall N = 5429 and 4779 (88%) persons from the total sample who completed fasting blood glucose measurement. From a review in the study region, the pooled prevalence of undiagnosed T2D was 5.45%. We calculated the sample size with Epi-Info with population 100,000, expected frequency 5.45, acceptable margin of error 5% confidence level 99.99, minimum sample size is 317. In our study we calculated that based on the existing data set of 4799 people, the sample size is sufficient.

All statistical analyses were conducted with STATA software version 14.0 (Stata Corporation, College Station, TX, USA). Analysis weights were calculated by taking the inverse of the probability of selection of each participant adjusted for differences in the age-sex composition of the sample population compared to the target population. Descriptive statistics are used to describe the sample. Pearson chi-square statistics were used to calculate differences in proportion. Multinomial logistic regression was used to estimate factors associated with undiagnosed T2D and diagnosed T2D (with not having T2D as reference category). Logistic regressions were used to assess the associations with undiagnosed T2D versus diagnosed T2D. Covariates in the logistic regression models included predisposing factors (age, gender, and marital status), enabling, or disabling factors (residence status, reported receipt of health care advice, cholesterol screening, education, smoking status, physical activity, and sedentary behaviour) and need factors (BMI, hypertension, heart attack or stroke, and elevated total cholesterol). Variables significant in univariable analyses were subsequently included in the multivariable models. To account for the multi-stage sample design, Taylor linearization methods were used. P-values <0.05 were considered significant and missing values were discarded.
Results
Sample characteristics. The sample with complete fasting blood glucose measurement included 4779 persons (≥18 years), with a mean age of 41.7 years (SD = 16.5 years) in 2017. The prevalence of undiagnosed T2D was 5.9% (44.7% of total T2D), diagnosed T2D 7.3%, and total T2D 13.2%. Further sociodemographic and health characteristics of the sample by T2D status are described in Table 1.

Associations with undiagnosed and diagnosed T2D versus non-diabetic. In the adjusted multinomial logistic regression analysis, older age (≥50 years) (ARRR: 2.80, 95% CI: 1.80–4.35), receipt of health care advice (ARRR: 1.79, 95% CI: 1.32–2.41), and obesity (ARRR: 1.71, 95% CI: 1.19–2.46) were positively associated with undiagnosed T2D. Older age (≥50 years) (ARRR: 6.64, 95% CI: 3.81–11.60), urban residence (ARRR: 1.50, 95% CI: 1.12–2.00), receipt of health care advice (ARRR: 2.92, 95% CI: 2.32–3.82), ever cholesterol screening (ARRR: 2.64, 95% CI: 1.99–3.50), moderate sedentary behaviour (ARRR: 1.33, 95% CI: 1.01–1.75), obesity (ARRR: 1.56, 95% CI: 1.11–2.19), hypertension (ARRR: 1.47, 95% CI: 1.13–1.92), and elevated total cholesterol (ARRR: 2.64, 95% CI: 1.99–3.50) were positively associated with diagnosed T2D. In addition, in unadjusted analyses, male sex, higher education, and high physical activity were negatively associated, and hypertension and elevated total cholesterol were positively associated with undiagnosed T2D (see Tables 2 and 3).

Associations with undiagnosed T2D versus diagnosed T2D. In adjusted logistic regression analysis, older age (≥50 years) (AOR: 0.32, 95% CI: 0.16–0.64), receipt of health care advice (AOR: 0.51, 95% CI: 0.36–0.72), and ever cholesterol screening (AOR: 0.31, 95% CI: 0.20–0.47) were negatively associated with undiagnosed T2D versus diagnosed T2D. Furthermore, in the unadjusted analysis, urban residence, sedentary behaviour, obesity, hypertension, and heart attack or stroke were negatively associated with undiagnosed T2D versus diagnosed T2D (see Table 4).

Discussion
The study found a national prevalence of undiagnosed T2D (5.9%, 44.7% of total T2D), which is similar to recent global Figs. (44.7% of total T2D)6, higher than in an earlier review of studies in 29 LMICs (4.9%)7, higher than in a review of studies in the Eastern Mediterranean region (5.4%)6, and lower than in a local study among women in Morocco (6.4%)3. People with undiagnosed T2D versus diagnosed T2D showed fewer diabetes-related risk factors, such as younger age, no obesity, and no hypertension than those with diagnosed T2D. This may be explained by people with undiagnosed T2D being generally younger and healthier than those with diagnosed T2D, mostly at an earlier stage of T2D9.

Consistent with some previous research14–19, some predisposing factors (older age) were associated with undiagnosed T2D versus no T2D. According to some previous studies13,16, enabling/disabling factors associated with undiagnosed T2D versus diagnosed T2D included no receipt of health care advice (to lose weight) in the past three years, and had never been screened for cholesterol. People with receipt of health care advice and cholesterol screening are more likely to use health services and may consequently reduce the odds of undiagnosed T2D.16 Following the T2D management guidelines in Morocco, patients with diabetes are expected to attend health care services more often41, which may explain that people diagnosed T2D visit health care providers more often than people with undiagnosed T2D15. While some studies13,16 found an association between rural residence and undiagnosed T2D, we only found this association in unadjusted analysis. Previous studies14,23,25 found mixed results regarding the association between educational status and undiagnosed T2D, while we found no significant association.

Consistent with previous research17–19,21,22,28, need factors associated with undiagnosed T2D included other chronic diseases, such as obesity. Obesity is a known risk factor for diabetes41. Consistent with some research13–15, in unadjusted analysis, we found a negative association between hypertension, cardiovascular disease, and undiagnosed T2D versus diagnosed T2D. Unlike some previous studies12,13,21, we did not find an association between elevated total cholesterol and undiagnosed T2D. However, we found a statistically significant positive association between elevated total cholesterol and diagnosed T2D. This may be explained by people with diagnosed T2D who are generally older and less healthy, mostly at a later stage of T2D than those with undiagnosed T2D10.

Strengths and limitations. The study strengths include the use of nationally representative adult sample of all ages and standardized STEPS methodology and measures. The limitation of the study is using peripheral (capillary) blood instead venous plasma glucose42. However, Priya et al.43 showed that capillary blood glucose is a feasible alternative for screening for diabetes in epidemiological studies in developing countries where obtaining venous samples may be difficult. Some variables were evaluated by self-report, which may have biased responses, and the cross-sectional design precludes causative conclusions between the evaluated variables. The sample only included those persons who were non-institutionalized, while the inclusion of institutionalized persons would have given different estimates. Furthermore, certain variables, such as knowledge of diabetes symptoms and a family history of diabetes, were not evaluated and should be included in future research.

Implications for public health research and practice. Policy implications are that increased public awareness campaigns, and screening of T2D are needed to reduce undiagnosed T2D in Morocco. The Morocco national NCD programme includes community awareness campaigns on diabetes, screening/early detection, and integrated care for diabetes44.

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Table 1. Characteristics and predisposing, enabling/disabling and risk factors in a sample of 4779 adults screened for diagnosed and undiagnosed diabetes in Morocco, 2017. *Based on chi-square statistics.

| Variable                      | Sample | No diabetes | Undiagnosed T2D | Diagnosed T2D | p-value* |
|-------------------------------|--------|-------------|------------------|---------------|----------|
| N                             | 4779   | 4003        | 333              | 443           |          |
| N (%)                         |        | %           | %                | %             |          |
| All                           | 86.8   | 5.9         | 7.3              |               |          |
| Predisposing factors          |        |             |                  |               |          |
| Age (years)                   |        |             |                  |               |          |
| 18–34                         | 1343 (38.9) | 95.1       | 3.4              | 1.6           | <0.001   |
| 35–49                         | 1546 (30.4) | 89.3       | 5.5              | 5.1           |          |
| 50 or more                    | 1890 (30.7) | 73.8       | 9.7              | 16.6          |          |
| Gender                        |        |             |                  |               |          |
| Female                        | 3139 (50.9) | 84.4       | 7.1              | 8.5           | <0.001   |
| Male                          | 1640 (49.1) | 89.2       | 4.8              | 6.0           |          |
| Marital status                |        |             |                  |               |          |
| Not married                   | 1250 (31.1) | 87.9       | 5.8              | 6.3           | 0.266    |
| Married                       | 3525 (68.9) | 86.4       | 6.0              | 7.7           |          |
| Enabling/disabling factors    |        |             |                  |               |          |
| Residence                     |        |             |                  |               |          |
| Rural                         | 1909 (36.3) | 90.5       | 5.3              | 4.2           | <0.001   |
| Urban                         | 2870 (63.7) | 84.7       | 6.3              | 9.0           |          |
| Receipt of health care advice |        |             |                  |               |          |
| No                            | 3329 (71.3) | 91.4       | 4.8              | 3.7           | <0.001   |
| Yes                           | 1450 (28.7) | 75.3       | 8.7              | 16.0          |          |
| Ever cholesterol screening    |        |             |                  |               |          |
| No                            | 4099 (88.5) | 89.4       | 5.8              | 4.8           | <0.001   |
| Yes                           | 680 (11.5) | 66.7       | 6.9              | 26.3          |          |
| Education                     |        |             |                  |               |          |
| None                          | 2468 (41.1) | 82.3       | 7.7              | 10.0          | <0.001   |
| Primary                       | 1003 (23.1) | 88.5       | 5.4              | 6.1           |          |
| > Primary                     | 1305 (35.9) | 90.9       | 4.3              | 4.8           |          |
| Smoking tobacco               |        |             |                  |               |          |
| Never                         | 4076 (80.6) | 86.0       | 6.4              | 7.6           | 0.002    |
| Past                          | 346 (8.5) | 87.1       | 4.0              | 8.9           |          |
| Current                       | 357 (10.9) | 92.3       | 4.4              | 3.3           |          |
| Physical activity             |        |             |                  |               |          |
| Low                           | 1249 (24.8) | 82.8       | 7.3              | 9.9           | <0.001   |
| Moderate                      | 1037 (21.8) | 83.5       | 7.0              | 9.5           |          |
| High                          | 2476 (53.4) | 90.0       | 4.9              | 5.1           |          |
| Sedentary behaviour           |        |             |                  |               | <0.001   |
| Low                           | 3180 (66.3) | 88.3       | 5.8              | 5.9           |          |
| Moderate                      | 1291 (27.6) | 84.4       | 6.3              | 9.3           |          |
| High                          | 299 (6.0) | 81.5       | 5.6              | 5.6           |          |
| Need factors                  |        |             |                  |               |          |
| Body mass index               |        |             |                  |               |          |
| Underweight                   | 187 (5.6) | 95.8       | 3.1              | 1.1           | <0.001   |
| Normal                        | 1681 (40.6) | 91.2       | 4.7              | 4.1           |          |
| Overweight                    | 1635 (33.3) | 85.6       | 6.0              | 8.5           |          |
| Obesity                       | 1142 (20.4) | 76.7       | 9.7              | 13.6          |          |
| Hypertension                  | 1083 (19.9) | 76.0       | 8.4              | 15.6          | <0.001   |
| Heart attack or stroke        | 169 (3.3) | 78.5       | 5.7              | 15.8          | <0.001   |
| Elevated total cholesterol    | 421 (7.4) | 76.4       | 8.7              | 14.9          | <0.001   |
## Conclusion

A significant proportion of adults in Morocco had undiagnosed T2D. Predisposing factors (older age), enabling factors (receipt of health care advice) and need factors (obesity) were identified as associated with undiagnosed T2D versus no T2D, and predisposing factors (younger age), and enabling / enabling factors (no receipt of health care advice, never been screened for cholesterol) were identified as associated with undiagnosed T2D versus diagnosed T2D, which can be targeted in interventions.

### Table 2. Relative risk ratios for factors associated with undiagnosed and diagnosed type 2 diabetes (T2D) in Moroccan adults, 2017.

| Variable                   | Undiagnosed T2D | Diagnosed T2D |
|----------------------------|-----------------|---------------|
| **Predisposing factors**   |                 |               |
| Age (years)                |                 |               |
| 18–34                      | 1 (Reference)   | 1 (Reference) |
| 35–49                      | 1.75 (1.15–2.66)** | 3.70 (2.54–5.40)** |
| 50 or more                 | 3.70 (2.54–5.40)*** | 13.74 (8.28–22.79)*** |
| Gender                     |                 |               |
| Female                     | 1 (Reference)   | 1 (Reference) |
| Male                       | 0.65 (0.49–0.85)** | 0.66 (0.53–0.84)*** |
| Marital status             |                 |               |
| Not married                | 1 (Reference)   | 1 (Reference) |
| Married                    | 1.04 (0.78–1.39) | 1.24 (0.97–1.60) |
| **Enabling/disabling factors** |               |               |
| Residence                  |                 |               |
| Rural                      | 1 (Reference)   | 1 (Reference) |
| Urban                      | 1.27 (0.97–1.66) | 2.32 (1.81–2.98)*** |
| Receipt of health care advice |             |               |
| No                         | 1 (Reference)   | 1 (Reference) |
| Yes                        | 2.21 (1.69–2.87)*** | 5.21 (4.16–6.53)*** |
| **Ever cholesterol screening** |             |               |
| No                         | 1 (Reference)   | 1 (Reference) |
| Yes                        | 1.61 (1.12–2.31)** | 7.39 (5.86–9.33)*** |
| Education                  |                 |               |
| None                       | 1 (Reference)   | 1 (Reference) |
| Primary                    | 0.65 (0.46–0.91)* | 0.57 (0.42–0.76)*** |
| > Primary                  | 0.50 (0.36–0.70)*** | 0.44 (0.33–0.58)*** |
| Smoking tobacco            |                 |               |
| Never                      | 1 (Reference)   | 1 (Reference) |
| Past                       | 0.62 (0.36–1.06) | 1.14 (0.79–1.66) |
| Current                    | 0.64 (0.37–1.14) | 0.39 (0.23–0.65)*** |
| Physical activity          |                 |               |
| Low                        | 1 (Reference)   | 1 (Reference) |
| Moderate                   | 0.94 (0.67–1.32) | 0.94 (0.71–1.25) |
| High                       | 0.61 (0.45–0.83)*** | 0.47 (0.37–0.62)*** |
| Sedentary behaviour        |                 |               |
| Low                        | 1 (Reference)   | 1 (Reference) |
| Moderate                   | 1.13 (0.85–1.50) | 1.64 (1.29–2.09)*** |
| High                       | 1.05 (0.63–1.75) | 2.34 (1.61–3.40)*** |
| Need factors               |                 |               |
| Body mass index            |                 |               |
| < 25 kg/m²                 | 1 (Reference)   | 1 (Reference) |
| Overweight                 | 1.45 (1.04–2.01)* | 2.39 (1.78–3.21)*** |
| Obesity                    | 2.62 (1.89–3.61)*** | 4.32 (3.23–5.77)*** |
| Hypertension               | 2.82 (1.40–2.40)*** | 3.55 (2.84–4.44)*** |
| Heart attack or stroke     | 1.05 (0.51–2.14) | 2.51 (1.60–3.92)*** |
| Elevated total cholesterol | 1.77 (1.19–2.63)*** | 2.50 (1.84–3.40)*** |

*RRR Relative, CI/Confidence intervals. *p < 0.05; **p < 0.01; ***p < 0.001.
Table 3. Relative risk ratios for factors associated with undiagnosed and diagnosed type 2 diabetes (T2D) in Moroccan adults, 2017, adjusted for age, gender, RRR Relative risk ratio, CI Confidence intervals. *p < 0.05; **p < 0.01; ***p < 0.001.

| Variable                  | Undiagnosed T2D | Diagnosed T2D |
|---------------------------|-----------------|---------------|
|                           | Adjusted RRR (95% CI) | Adjusted RRR (95% CI) |
| **Predisposing factors**  |                 |               |
| Age (years)               |                 |               |
| 18–34                     | 1 (Reference)   | 1 (Reference) |
| 35–49                     | 1.44 (0.92–2.24) | 2.58 (1.46–4.57)*** |
| 50 or more                | 2.80 (1.80–4.35)*** | 6.64 (3.81–11.60)*** |
| Gender                    |                 |               |
| Female                    | 1 (Reference)   | 1 (Reference) |
| Male                      | 0.84 (0.59–1.21) | 1.02 (0.73–1.43) |
| **Enabling/disabling factors** |                 |               |
| Residence                 |                 |               |
| Rural                     | 1 (Reference)   | 1 (Reference) |
| Urban                     | 1.13 (0.83–1.54) | 1.50 (1.12–2.00)*** |
| Receipt of health care advice |             |               |
| No                        | 1 (Reference)   | 1 (Reference) |
| Yes                       | 1.79 (1.32–2.41)*** | 2.92 (2.23–3.82)*** |
| Ever cholesterol screening |             |               |
| No                        | 1 (Reference)   | 1 (Reference) |
| Yes                       | 0.84 (0.55–1.27) | 2.64 (1.99–3.50)*** |
| Education                 |                 |               |
| None                      | 1 (Reference)   | 1 (Reference) |
| Primary                   | 0.94 (0.65–1.37) | 0.95 (0.67–1.35) |
| > Primary                 | 0.75 (0.51–1.09) | 0.75 (0.53–1.05) |
| Smoking tobacco           |                 |               |
| Never                     | 1 (Reference)   | 1 (Reference) |
| Past                      | 0.59 (0.32–1.09) | 0.80 (0.49–1.29) |
| Current                   | 0.87 (0.45–1.68) | 0.64 (0.35–1.18) |
| Physical activity         |                 |               |
| Low                       | 1 (Reference)   | 1 (Reference) |
| Moderate                  | 1.09 (0.77–1.56) | 1.14 (0.83–1.56) |
| High                      | 0.82 (0.60–1.13) | 0.94 (0.69–1.26) |
| Sedentary behaviour       |                 |               |
| Low                       | 1 (Reference)   | 1 (Reference) |
| Moderate                  | 1.03 (0.77–1.38) | 1.33 (1.01–1.75)* |
| High                      | 0.82 (0.48–1.40) | 1.53 (0.99–2.37) |
| Need factors              |                 |               |
| Body mass index           |                 |               |
| < 25 kg/m²                | 1 (Reference)   | 1 (Reference) |
| Overweight                | 1.14 (0.81–1.61) | 1.29 (0.93–1.80) |
| Obesity                   | 1.71 (1.19–2.46)** | 1.56 (1.11–2.19)** |
| Hypertension              | 1.21 (0.89–1.64) | 1.47 (1.13–1.92)** |
| Heart attack or stroke    | 0.92 (0.45–1.91) | 1.57 (0.92–2.69) |
| Elevated total cholesterol | 1.39 (0.89–2.15) | 2.64 (1.99–3.50)*** |
### Table 4. Unadjusted and adjusted Odds Ratios (OR) for factors associated with diagnosed or undiagnosed type 2 diabetes (T2D) in Moroccan adults, 2017.

| Variable                        | Unadjusted OR (95% CI) | Adjusted OR (95% CI) |
|---------------------------------|------------------------|----------------------|
| **Predisposing factors**        |                        |                      |
| **Age (years)**                 |                        |                      |
| 18-34                           | 1 (Reference)          | 1 (Reference)        |
| 35-49                           | 0.50 (0.25-0.98)*      | 0.43 (0.20-0.92)*    |
| 50 or more                      | 0.27 (0.15-0.50)****   | 0.32 (0.16-0.64)****  |
| **Gender**                      |                        |                      |
| Female                          | 1 (Reference)          | –                    |
| Male                            | 0.97 (0.69-1.37)       |                      |
| **Marital status**              |                        |                      |
| Not married                     | 1 (Reference)          | –                    |
| Married                         | 0.84 (0.58-1.21)       |                      |
| **Enabling/disabling factors**  |                        |                      |
| **Residence**                   |                        |                      |
| Rural                           | 1 (Reference)          | 1 (Reference)        |
| Urban                           | 0.55 (0.38-0.78)****   | 0.81 (0.55-1.19)     |
| **Receipt of health care advice**|                        |                      |
| No                              | 1 (Reference)          | 1 (Reference)        |
| Yes                             | 0.42 (0.31-0.59)****   | 0.51 (0.36-0.72)****  |
| **Ever cholesterol screening**  |                        |                      |
| No                              | 1 (Reference)          | 1 (Reference)        |
| Yes                             | 0.22 (0.15-0.33)****   | 0.31 (0.20-0.47)****  |
| **Education**                   |                        |                      |
| None                            | 1 (Reference)          | –                    |
| Primary                         | 1.15 (0.75-1.76)       |                      |
| > Primary                       | 1.15 (0.77-1.73)       |                      |
| **Smoking tobacco**             |                        |                      |
| Never                           | 1 (Reference)          | –                    |
| Past                            | 0.54 (0.29-1.01)       |                      |
| Current                         | 1.66 (0.79-3.48)       |                      |
| **Physical activity**           |                        |                      |
| Low                             | 1 (Reference)          | –                    |
| Moderate                        | 1.00 (0.66-1.50)       |                      |
| High                            | 1.29 (0.88-1.89)       |                      |
| **Sedentary behaviour**         |                        |                      |
| Low                             | 1 (Reference)          | 1 (Reference)        |
| Moderate                        | 0.69 (0.48-0.98)*      | 0.74 (0.50-1.11)     |
| High                            | 0.45 (0.25-0.81)**     | 0.52 (0.27-1.01)     |
| **Need factors**                |                        |                      |
| **Body mass index**             |                        |                      |
| < 25 kg/m²                      | 1 (Reference)          | 1 (Reference)        |
| Overweight                      | 0.60 (0.39-0.92)*      | 0.83 (0.52-1.32)     |
| Obesity                         | 0.61 (0.40-0.91)*      | 1.07 (0.67-1.70)     |
| Hypertension                    | 0.51 (0.37-0.71)****   | 0.80 (0.56-1.14)     |
| Heart attack or stroke          | 0.42 (0.19-0.93)*      | 0.61 (0.23-1.61)     |
| Elevated total cholesterol      | 0.71 (0.44-1.12)       | –                    |

*OR Odds ratio, CI: Confidence intervals. *p < 0.05; **p < 0.01; ***p < 0.001.
Data availability
The data source is publicly available at the World Health Organization NCD Microdata Repository (URL: https://extranet.who.int/ncdsmicrodata/index.php/catalog).

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References
1. World Health Organization (WHO). Diabetes fact sheet. https://www.who.int/news-room/fact-sheets/detail/diabetes (2021).
2. Fowler, M. Microvascular and macrovascular complications of diabetes. Clin. Diabetes 29, 116–122 (2011).
3. Vinik, A. & Flemmer, M. Diabetes and macrovascular disease. J. Diabetes Complicat. 16, 235–245 (2002).
4. Wild, S. H., Smith, F. B., Lee, A. J. & Fowkes, F. G. Criteria for previously undiagnosed diabetes and risk of mortality: 15-year follow-up of the Edinburgh artery study cohort. Diabet. Med. 22(4), 490–496. https://doi.org/10.1111/j.1464-5491.2004.01433.x (2005).
5. Valdés, S., Botas, P., Delgado, E. & Díaz, C. F. Mortality risk in Spanish adults with diagnosed diabetes, undiagnosed diabetes or pre-diabetes. The Asturias study 1998–2004. Rev. Esp. Cardiol. 62(5), 528–34. https://doi.org/10.1016/s1885-5857(09)71835-3 (2009).
6. Ogurtsova, K. et al. IDF diabetes atlas: Global estimates of undiagnosed diabetes in adults for 2021. Diabetes Res. Clin. Pract. 183, 101918. https://doi.org/10.1016/j.diabres.2021.101918 (2022).
7. Seiglie, J. A. et al. Diabetes prevalence and its relationship with education, wealth, and BMI in 29 low- and middle-income countries. Diabetes Care 43(4), 767–775. https://doi.org/10.2337/dc19-1782 (2020).
8. Mirahmadizadeh, A. et al. The prevalence of undiagnosed type 2 diabetes and pre-diabetes in Eastern Mediterranean region (EMRO): A systematic review and meta-analysis. Diabetes Res. Clin. Pract. 160, 107931. https://doi.org/10.1016/j.diabres.2019.107931 (2020).
9. Rguibi, M. & Belahsen, R. Prevalence and associated risk factors of undiagnosed diabetes among adult Moroccan Sahraoui women. Public Health Nutr. 9(6), 722–727. https://doi.org/10.1079/phn2005866 (2006).
10. World Health Organization Regional Office for the Eastern Mediterranean. Sattaquer au diabete en tant que défi de santé publique dans la Région de la Méditerranée orientale. 2021. https://applications.emro.who.int/docs/EMR687-If.pdf (accessed 6 August 2022).
11. Université Mohammed VI des Sciences de la Santé. Le ministère de la Santé lance un vaste plan d'action contre le diabète au Maroc, 2015. https://um6ss.ma/le-ministere-de-la-sante-lance-un-vaste-Plan-action-contre-le-diabete-au-maroc/ (accessed 6 August 2022).
12. Ben Abdelaziz, A. et al. Profile and evolution of the Global Burden of Morbidity in the Maghreb (Tunisia, Morocco, Algeria). The Triple burden of morbidity. Tunis Med. 96(10–11), 760–773 (2018).
13. Lee, S. et al. Examining social determinants of undiagnosed diabetes in Namibia and South Africa using a behavioral model of health services use. Diabetes Res. Clin. Pract. 175, 108814. https://doi.org/10.1016/j.diabres.2021.108814 (2021).
14. Claypool, K. T., Chung, M. K., Deonarine, A., Gregg, E. W. & Patel, C. J. Characteristics of undiagnosed diabetes in men and women under the age of 50 years in the Indian subcontinent: The National Family Health Survey (NFHS-4)/Demographic Health Survey 2015–2016. BMJ Open Diabetes Res. Care 8(1), e000965. https://doi.org/10.1136/bmjdrcc-2019-000965 (2020).
15. Du, Y. et al. Factors associated with undiagnosed type 2 diabetes in Germany: results from German health interview and examination survey for adults 2008–2011. BMJ Open Diabetes Res. Care 8(1), e001707. https://doi.org/10.1136/bmjdrcc-2020-001707 (2020).
16. Mou, C., Xu, M. & Lyu, J. Predictors of undiagnosed diabetes among middle-aged and seniors in China: Application of Andersen's Behavioral model. Int. J. Environ. Res. Public Health 18(16), 8396. https://doi.org/10.3390/ijerph18168396 (2021).
17. Islam, R. M. et al. Prevalence of undiagnosed diabetes and the relative importance of its risk factors among adults in Bangladesh: Findings from a nationwide survey. Diabetes Res. Clin. Pract. 185, 109228. https://doi.org/10.1016/j.diabres.2022.109228 (2022).
18. Hellberg, A. et al. Predictors of undiagnosed prevalent type 2 diabetes - The Danish general suburban population study. Prim. Care Diabetes. 12(1), 13–22. https://doi.org/10.1016/j.pcd.2017.08.005 (2018).
19. Mohammad, A., Ziyab, A. H. & Mohammad, T. Prevalence of prediabetes and undiagnosed diabetes among Kuwaiti adults: A cross-sectional study. Diabetes Metab. Syndr. Obes. 14, 2167–2176. https://doi.org/10.2147/DMSO.s296848 (2021).
20. Heinanza, Y. et al. Association of living alone with the presence of undiagnosed diabetes in Japanese men: the role of modifiable risk factors for diabetes: Toranomon hospital health management center study 13 (TOPICS 13). Diabet. Med. 30(11), 1355–1359. https://doi.org/10.1111/dme.12255 (2013).
21. Bantie, G. M. et al. Prevalence of undiagnosed diabetes mellitus and associated factors among adult residents of Bahir Dar city, northwest Ethiopia: a community-based cross-sectional study. BMJ Open 9(10), e030158. https://doi.org/10.1136/bmjopen-2019-030158 (2019).
22. O’Connor, J. M., Millar, S. R., Buckley, C. M., Kearney, P. M. & Perry, I. J. The prevalence and determinants of undiagnosed and diagnosed type 2 diabetes in middle-aged Irish adults. PLoS One 8(11), e80504. https://doi.org/10.1371/journal.pone.0080504 (2013).
23. Hasan, M. M., Tasnim, F., Tariqujaman, M. & Ahmed, S. Socioeconomic inequalities of undiagnosed diabetes in a resource-poor setting: Insights from the cross-sectional Bangladesh demographic and health survey 2011. Int. J. Environ. Res. Public Health 16(1), 115. https://doi.org/10.3390/ijerph16010115 (2019).
24. Walker, R. J., Garacci, E., Ozieh, M. & Egede, L. E. Food insecurity and glycemic control in individuals with diagnosed and undiagnosed diabetes in the United States. Prim. Care Diabetes 15(3), 813–818. https://doi.org/10.1016/j.pcd.2021.05.003 (2021).
25. Ruiz, P. L. et al. Undiagnosed diabetes based on HbA1c, by socioeconomic status and healthcare consumption in the Tromso study 1994–2016. BMJ Open Diabetes Res. Care 9(2), e002432. https://doi.org/10.1136/bmjdrcc-2021-002432 (2021).
26. Leamy, S. et al. Prevalence and correlates of diagnosed and undiagnosed type 2 diabetes mellitus and pre-diabetes in older adults: Findings from the Irish longitudinal study on ageing (TILDA). Diabetes Res. Clin. Pract. 110(3), 241–249. https://doi.org/10.1016/j.diabres.2019.101053 (2015).
27. Dugue, O. et al. Adapting existing diabetes risk scores for an Asian population: A risk score for detecting undiagnosed diabetes in the Mongolian population. BMC Public Health 15, 938. https://doi.org/10.1186/1471-2458-9 (2015).
28. Echosofu-Tchegui, J. B. et al. Prevalence and determinants of undiagnosed diabetes in an urban sub-Saharan African population. Prim. Care Diabetes 6(3), 229–234. https://doi.org/10.1016/j.pcd.2012.05.002 (2012).
29. Pramono, L. A. et al. Prevalence and predictors of undiagnosed diabetes mellitus in Indonesia. Acta Med. Indones. 42(4), 216–223 (2010).
30. Nguyen, V. D. et al. Prevalence of undiagnosed diabetes and pre-diabetes and its associated risk factors in Vietnam. J. Glob. Health Sci. 1(1), e7. https://doi.org/10.35500/jghs.2019.1.e7 (2019).
31. Bjarko, V. V. et al. Undiagnosed diabetes: Prevalence and cardiovascular risk profile in a population-based study of 52,856 individuals. The HUNT Study, Norway. Diabet. Med. 48, 29. https://doi.org/10.1111/dme.14829 (2022).
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Author contributions
All authors fulfil the criteria for authorship. S.P. and K.P. conceived and designed the research, performed statistical analysis, drafted the manuscript, and made critical revision of the manuscript for key intellectual content. All authors read and approved the final version of the manuscript and have agreed to authorship and order of authorship for this manuscript.

Competing interests
The authors declare no competing interests.

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