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ORIGINAL RESEARCH

Improving Diabetes and Pre-Diabetes Detection in the UK: Insights From HbA1c Screening in an Acute Hospital's Emergency Department

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ABSTRACT

Introduction: Many individuals in the community have undiagnosed glucose intolerance, type 2 diabetes (T2D), and pre-diabetes (Pre-DM). This study explored screening for unknown glucose intolerance in the emergency department (ED) in an acute hospital.

Methods: 1382 persons attending the ED without T2D were screened using HbA1c. T2D and Pre-DM were classified using American Diabetes Association (ADA) and National Institute for Health and Care Excellence (NICE) criteria. The Finnish Diabetes Risk Score (FINDRISC) was calculated in all patients.

Results: According to NICE criteria, 80.1% (1107 individuals) exhibited normal glucose tolerance, 11.6% (160 individuals) exhibited pre-diabetes, and 8.3% (115 individuals) exhibited diabetes. Each unit increase in FINDRISC score, using multinomial regression, corresponded to an 8% (5–12%; $p<0.001$) higher risk for pre-diabetes and a 16% (10–23%; $p<0.001$) higher risk for diabetes (NICE). The risk remained elevated

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even after adjusting for age, sex, and ethnicity. South-Asians had higher glucose intolerance rates than white British (34.8% versus 18.5%) using the NICE criteria, and even greater at 50.0% versus 37.6% using ADA criteria. The adjusted relative risk of having pre-diabetes in people of color compared with white British individuals was 1.77 (1.04–3.00; $p=0.034$, ADA) and 2.84 (1.41–5.65; $p=0.003$, NICE). The multinomial relative-risk ratio (RRRs) for having diabetes by ethnicity was 2.97 (1.73–5.08; $p<0.0001$, ADA) and 2.80 (1.59–4.94; $p<0.0001$, NICE).

Conclusions: Routine HbA1c screening in the ED, with FINDRISC scoring, successfully identifies individuals with diabetes and pre-diabetes. This approach could enable early intervention, particularly in groups at higher risk of glucose intolerance.

Trial registration: ClinicalTrials.gov identifier, NCT04653545.

Keywords: HbA1c screening; Emergency department; Type 2 diabetes; Pre-diabetes; FINDRISC; Undiagnosed diabetes; Ethnic disparities; Cost-effectiveness

Key Summary Points

What was the aim of this study?

To assess the prevalence of undiagnosed pre-diabetes and type 2 diabetes among emergency department (ED) attendees using HbA1c testing and to evaluate the effectiveness of the Finnish Diabetes Risk Score (FINDRISC) in predicting glucose intolerance. This was conducted in the context of UK data suggesting that approximately 30% of adults with type 2 diabetes were undiagnosed between 2013 and 2019.

What was found?

Among 1382 adults aged ≥ 30 years without known diabetes, 30.4% had pre-diabetes and 8.3% had diabetes based on American Diabetes Association (ADA) criteria, with similarly high detection rates using NICE criteria. A one-point increase in FINDRISC score was associated with a 9% higher risk of pre-diabetes and a 12% higher risk of diabetes. These findings align with prior evidence of high rates of undiagnosed diabetes among ED attendees.

What are the implications of the findings?

Routine HbA1c screening in the ED, combined with FINDRISC scoring, effectively identifies a substantial burden of undiagnosed glucose intolerance, particularly in ethnically diverse and high-risk populations. This strategy facilitates earlier diagnosis and intervention and may help reduce long-term healthcare costs and complications associated with diabetes.

How might this influence clinical practice or policy?

Opportunistic HbA1c screening during ED visits could complement existing primary care-based diabetes screening programs, particularly for underserved populations with low primary care engagement. The cost per case detected was lower than in community pharmacy models, supporting ED-based screening as a scalable and potentially cost-effective public health strategy. Early identification in the ED also offers the opportunity to reduce health inequalities and improve timely linkage to outpatient care.

INTRODUCTION

Type 2 diabetes represents a significant public health issue, with its global prevalence expected to reach 643 million by 2030 [1]. The Centres for Disease Control and Prevention's 2020 National Diabetes Statistics Report highlighted that approximately 13% of US adults have diabetes, and 34.5% have pre-diabetes, with a higher prevalence observed in older adults [2]. Among those with diabetes, 21.4% were unaware of their condition, and only 15.3% of individuals with pre-diabetes had been informed by a healthcare professional [2]. Individuals with type 2 diabetes face more than double the risk of experiencing a heart attack or developing heart failure compared with those without diabetes [3–5]. They also have a higher risk of kidney failure and are more likely to suffer from new cases of blindness among adults in the USA [6, 7]. Furthermore, type 2 diabetes is associated with increased risks of nonalcoholic fatty liver disease, and nonalcoholic steatohepatitis [8]. In 2021, it was estimated to be the eighth leading cause of death in the USA [9]. Early identification of hyperglycemia can lead to a more comprehensive evaluation of cardiovascular risk and prompt, appropriate treatment of CVD risk factors. While the direct impact of early hyperglycemia treatment on reducing CVD risk remains debatable, effective management of associated risk factors through early detection can significantly contribute to reducing the long-term risks of microvascular and macrovascular complications [10].

Many public health organizations advocate for diabetes risk assessment and the screening of asymptomatic individuals. Countries such as Australia, Canada, and Singapore advocate for diabetes screening for adults over 40 years of age, while the American Diabetes Association (ADA) recommends screening for adults aged 40–70 years who are overweight or obese [11]. However, actual uptake rates for such a diabetes screening approaches have been suboptimal. A cross-sectional study in the USA from 2005 to 2012 reported diabetes screening rates of 46.2% for those in the recommended screening category and 29.6% for those not recommended for screening [12]. Similarly, participation rates in health examinations for cardiovascular disease and diabetes in Sweden ranged between 48% and 67% [13].

In the UK, recent data estimate that approximately 30% of adults living with type 2 diabetes between 2013 and 2019 were undiagnosed, which equates to around 1 million individuals [14]. In addition, many individuals present with complications at the point of diagnosis owing to the long latent phase of the disease [15]. These factors present strong arguments for the implementation of screening programs. Despite these arguments, the UK National Screening Committee (NSC) currently advises against systematic population screening for type 2 diabetes in adults [16]. This stance is based on findings from a 2013 review by the University of Warwick, funded by the Health Technology Assessment (HTA) programme [17]. The ADDITION-Cambridge trial concluded that screening high-risk individuals for type 2 diabetes did not lead to significant reductions in mortality related to all causes, cardiovascular disease, quality of life, or diabetes over a 10-year period [18]. However, screening did not appear to be associated with psychological harm or provide false reassurance to those with negative results [18]. A recent systematic review by Cochrane accentuated the limited evidence supporting or negating the effectiveness of broad population screening for type 2 diabetes [7], and more targeted screening in high risk populations might be more beneficial.

Traditionally, diabetes has been diagnosed using the fasting blood glucose level or 75 g oral glucose tolerance test (OGTT) [20, 21]. However, the recent adoption of glycated hemoglobin (HbA1c) testing as a diagnostic tool for high-risk individuals has simplified the diagnostic process, as extra visits in a fasting state are not necessary [22, 23]. Targeted HbA1c testing in high-risk populations could therefore increase the detection of both diabetes and pre-diabetes, potentially leading to better patient outcomes [9, 24, 25]. The Finnish Diabetes Risk Score (FINDRISC) questionnaire has been used to identify individuals who are at high risk for developing type 2 diabetes [27].

This study primarily aimed to determine the prevalence of undiagnosed glucose intolerance in an emergency department (ED) setting and to assess the utility of the Finnish Diabetes Risk Score (FINDRISC) in identifying high-risk individuals. The study did not include ambient (non-fasting) glucose values as a comparison but focused instead on the measurement of HbA1c, which has several advantages to provide a long-term indicator of glucose control, which might offer a more comprehensive risk assessment in the ED population.

METHODS

Study Overview and Setting

The study data was collected prospectively over 1 year, from December 2021 to December 2022, at the Emergency Department (ED) of Tameside General Hospital, located in the eastern region of Manchester, UK. This ED is the largest within the healthcare organization, handling a high volume of patient visits daily, including urgent care, primarily serving a diverse and underserved population.

Data Collection

All individuals aged 30 years and older presenting to the ED were approached for participation, irrespective of their presenting complaint. Patients who were pregnant or had a known diagnosis of diabetes were excluded. Only those willing to provide informed consent were included. An age cutoff of 30 years was selected to focus on an ED population at meaningful risk for glucose intolerance while still capturing younger adults where early detection could be beneficial. This threshold also reflects UK epidemiological trends showing increasing diabetes prevalence from age 30 years [26]. This strategy aimed to opportunistically identify undiagnosed diabetes and assess diabetes risk among a broad patient population. Demographic information such as age, gender, and ethnicity were recorded for each participant. In addition, data on lifestyle factors such as smoking status and history of diabetes and hypertension were gathered. Physical measurements, including height, weight (used to calculate body mass index [BMI]), waist circumference, and blood pressure, were systematically documented for all patients. These measurements were necessary for calculating the Finnish Diabetes Risk Score (FINDRISC), which was assessed by trained nurses or assistants who had received specific training for this evaluation.

Data Handling and Storage

The collected data were stored in a secure, password-protected database on a hospital server with standard National Health Service (NHS) encryption and firewalls. Patient demographic details were extracted from their clinical notes and electronic patient records (EPR) and then entered a specific data collection form designed for this study. To ensure anonymity, each participant was assigned a unique study number, and personal identifiable information was kept separate from the anonymized dataset. This separation was maintained to protect patient privacy and ensure compliance with data protection regulations.

Ensuring Data Completeness and Accuracy

Data completeness and accuracy were ensured through cross-validation by two independent investigators. This process involved checking the data entries for any discrepancies or missing information, which were then resolved through consensus. Regular audits and checks were also performed throughout the study period to maintain data quality and integrity.

Finnish Diabetes Risk Score (FINDRISC)

In order to further to evaluate the risk of diabetes, the Finnish Diabetes Risk Score (FINDRISC) was calculated for each patient without a history of diabetes [27]. FINDRISC is a widely endorsed tool that effectively predicts future and prevalent undiagnosed diabetes, particularly in European populations. This scoring system was developed through a Finnish study

of individuals aged 45–64 years over a decade, from 1987 to 1997 (Supplementary Table). In this system, a score of ≥ 9 out of 26 indicates a 13% 10-year risk of developing type 2 diabetes, while a score of ≥ 13 suggests a 30% 10-year risk [28]. The scoring system has been updated to include factors such as family history of diabetes and an age category of ≥ 65 years [27]. According to revised guidelines, particularly those used in Norway, a score of ≥ 15 out of 26 indicates a greater than 30% 10-year risk of diabetes [27].

Diagnostic Criteria and Classification

Patients were categorized as normal glucose tolerance, having pre-diabetes, or having diabetes according to both the National Institute for Health and Care Excellence (NICE) and American Diabetes Association (ADA) guidelines. The ADA defines diabetes with an HbA1c level of ≥ 48 mmol/mol and pre-diabetes with HbA1c levels between 39 and 47 mmol/mol [29]. NICE guidelines classify pre-diabetes with HbA1c levels between 42–47 mmol/mol and diabetes at HbA1c levels of ≥ 48 mmol/mol [30]. Participants with HbA1c levels diagnostic of diabetes (≥ 48 mmol/mol) were referred to their GP for further evaluation and management. Those with pre-diabetes (based on ADA and/or NICE criteria) were provided with verbal lifestyle advice and encouraged to follow up with their GP, but formal referral was not mandated.

Blood Sample Collection and HbA1c Measurement

Blood samples were drawn from the antecubital vein to assess blood glucose levels, lipid profiles, and renal function. In addition, HbA1c levels were measured using point-of-care testing (POCT). The POCT was conducted with the HemoCue® HbA1c 501 system (HemoCue AB, Sweden), certified by the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC) and the NGSP [31]. This method involved taking 5 µL of blood from the fingertip, preparing it with a reagent pack, and inserting it into the HemoCue cartridge for analysis, with results available in 5 min. The HemoCue® HbA1c 501 has a coefficient of variation (CV) of 3.4% [31].The HbA1c results were available within approximately 5 min via the HemoCue® HbA1c 501 point-of-care testing system, enabling results to be available during the ED visit.

The POC analyzer underwent daily internal quality control checks in accordance with manufacturer guidelines, and regular calibration was conducted by trained biomedical staff. In cases where the HbA1c result was unexpectedly elevated or inconsistent with clinical presentation, repeat testing was performed to rule out user or machine error. A subset of individuals with newly detected dysglycemia also had venous samples sent to the hospital laboratory for confirmation of HbA1c levels, with high concordance observed. However, the primary diagnostic tool remained POC HbA1c testing. However, all HbA1c samples were obtained via capillary fingerprick testing using the POC analyzer. No venous samples were used for initial HbA1c assessment.

Health Economic Evaluation

The costs to screen the patients, mainly the HbA1c diagnostic test kit, apportioned cost of the diagnostic machine, calibration kit, and electricity needed to operate the POCT device, were estimated on the basis of the 2024 market price, available from the distributor's website. The time needed to administer the test by a band 6 nurse within the NHS was obtained on the basis of 2023 NHS cost standards [32]. The additional staff time per participant for conducting HbA1c testing and risk scoring was approximately 10 min, primarily involving nursing staff. Other costs such as physician time, overheads, etc. were omitted as they are already included in patient care regardless of whether the test was performed or not. The cost of conducting the research was also omitted from the calculation, as the analysis assumes screening being part of normal ED practice.

Data Management and Ethical Considerations

This study was reviewed and approved by the Health Research Authority Ethics Committee in the UK (ID 287393). All participants gave written informed consent prior to inclusion. The study was conducted in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments. Further information about the methods is presented in ClinicalTrials.gov under the identifier NCT04653545.

Project Team and Risk Documentation

The multidisciplinary project team included physicians, nurse practitioners, physician associates (PAs), and registered nurses (RNs). Participants meeting the inclusion criteria were given the FINDRISC test upon their arrival in ED. Nurse practitioners then recorded the FINDRISC score in each patient's medical chart, providing a detailed account of their diabetes risk status.

Handling Missing Data

Missing data were identified through systematic reviews of patient record and data entry logs. Any missing information was noted and tracked. Where feasible, missing data were obtained by revisiting patient files or re-collecting information from the EPR. If data could not be retrieved, those cases were excluded from specific analyses where the missing data would affect the results. The amount of missing data and the variables affected were recorded. Overall, less than 5% of the data were missing for critical variables such as HbA1c levels, FINDRISC scores, and demographic information.

Statistical Analyses

For the statistical analysis, descriptive statistics were first employed to calculate the mean and standard error (SE) for variables such as age, HbA1c levels, weight, and BMI across the three groups (normal glucose tolerance, pre-diabetes, and diabetes). To compare these variables between groups, one-way analysis of variance (ANOVA) was used for continuous variables. In addition, *t*-tests were used to compare the means of continuous variables between pairs of groups when applicable. Categorical variables were analyzed using chi-squared tests to evaluate the distribution of diabetes statuses across different demographic categories.

In addition, the incidence of glucose intolerance among different ethnic groups was examined using chi-squared tests to compare proportions across ethnicities. Multinomial logistic (ML) regression analyses using the Stata module *mlogit*, which fits models for a categorical dependent variable with outcomes that have no natural ordering, were then applied to assess the association between the Finnish Diabetes Risk Score (FINDRISC) and the likelihood of being classified as having pre-diabetes or diabetes compared with those with normoglycemia, with adjustments for confounding factors such as age, sex, geographic ethnicity, and clustering by postcode.

The relative-risk ratios (RRRs) presented from the ML regression analyses are the exponentiated values of the derived coefficient. The RRR represents a one-unit change in the corresponding variable (risk is measured as the risk of the outcome relative to the base outcome). We estimated the risks associated with each unit increase in the FINDRISC score and compared the relative risk ratios of being classified as having pre-diabetes or diabetes among South Asian and other ethnic minorities combined versus individuals who identified ethnically as white British.

We also employed logistic regression modeling with diabetes or glucose intolerance (defined as having both diabetes and pre-diabetes) as the dependent variables in models, which included the FINDRISC score, age, sex, and ethnicity as independent variables. We then computed the area under the receiver-operating characteristic (ROC) curve to examine the predictive ability of the models, followed by the Hosmer–Lemeshow (H–L) model post-estimation Pearson chi-squared goodness-of-fit test. A *p*

value > 0.05 indicates good fit [33]. For the H–L test, a *p* value > 0.05 indicates good fit [33].

Finally, we used the Stata module *margins* to produce the graphics that show the contrasting risk by gender and ethnicity per FINDRISC score on the probability of having diabetes. Margins are statistics calculated from predictions of the logistic regression models at fixed values of covariates in the models employed. Data analysis was conducted using STATA (version 16, StataCorp LLC, College Station, Texas, USA) [34].

RESULTS

Of the estimated 1800 eligible ED attendees during the study period (aged ≥ 30 years, excluding known diabetes and pregnancy), 1382 (80%) consented and were included: 623 males (45.1%) and 759 females (54.9%). Among the patients screened, 118 individuals, constituting 8.6% of the sample, were identified as minorities. All participants underwent HbA1c measurement using the specified methodology. Notably, female participants represented 54.9% of the cohort.

Table 1 Participant demographics characteristics. This table summarizes the demographics characteristics of the study participants, including the distribution of gender, ethnicity, diabetes status, and smoking habits

Category	Details	*N*	Percentage (%)
Total Individuals		**1382**	
Gender	Male	623	45.1
	Female	759	54.9
Ethnicity	White	1264	91.5
	Other ethnicities	118	8.5
Pre-DM/DM	White	234	18.5
	Other ethnicities	41	34.8
Smoking	Current/previous	548	40.1
	Never	819	59.9

Table 1 offers a comprehensive descriptive analysis, illustrating the distribution of ethnicity, the prevalence of pre-diabetes (Pre-DM) and diabetes (DM) among various groups, as well as smoking status. A total of 418 patients (20%) declined to participate, most commonly citing lack of time or feeling unwell.

Tables 1 and 2 provide a detailed analysis of the participants' characteristics, including their age, sex, BMI, and hypertension status. In addition, it presents measurements of HbA1c and glucose organized according to three HbA1c groups based on NICE criteria: less than 42 mmol/mol (indicating normal glucose tolerance), between 42 and 47 mmol/mol (indicating pre-diabetes), and 48 mmol/mol or greater (indicating diabetes). Within this classification, most participants, 80.1% (1107 individuals), exhibited normal glucose tolerance. On the basis of the Hba1c levels, pre-diabetes was observed in 11.6% (160 individuals), and diabetes was diagnosed in 8.3% (115 individuals), with similar proportions across both men and women. HbA1c levels showed a significant gradation across these groups, with mean (SE) values of 35.5 (0.17) mmol/mol for normal glucose tolerance, 43.6 (0.45) mmol/mol for pre-diabetes, and 57.2 (0.55) mmol/mol for diabetes ($p < 0.0001$). When examining age distributions, the mean (SE) ages for these groups were 52.3 (0.44) years for those with normal glucose tolerance, 57.4 (1.16) years for those with pre-diabetes, and 55.9 (1.38) years for those diagnosed with diabetes ($p < 0.0001$). BMI also varied significantly, with means (SE) of 28.6 (0.21) for patients within the normal glucose tolerance group, 29.1 (0.55) for the pre-diabetes group, and 32.4 (0.68) for the diabetes group ($p < 0.0001$).

NICE criteria analyses: a multinomial logistic regression analysis revealed that each unit increase in the FINDRISC score was associated with an 8% higher relative-risk ratio of pre-diabetes (RRR 1.08, 95% CI: 1.05–1.12) and a 16% higher risk of diabetes (RRR 1.16, 95% CI: 1.10–1.23). In age, sex, and ethnicity adjusted models the RRRs were 1.06 (95% CI: 1.01–1.10) for pre-diabetes and 1.16 (95% CI: 1.10–1.23) for diabetes (both $p < 0.0001$). These findings are from the analysis using the NICE criteria, with further details available in Table 3. Figure 1

Table 2 Clinical characteristics by glycemic status. This table presents the clinical characteristics of participants, categorised by their glycemic status based on the National Institute for Health and Care Excellence (NICE) and the American Diabetes Association (ADA) criteria

Category	NICE		ADA		NICE/ADA	*p*-Value
	Normal (< 42)	42–47	Normal (< 39)	39–47	≥ 48	
N	1107	160	847	420	115	
(%)	80.1	11.6	61.3	30.4	8.3	
Age (years)	52.3	57.4	51.0	56.9	55.9	< 0.0001
(SE)	0.44	1.16	0.50	0.71	1.38	
Male sex	501	68	379	195	47	0.62
(%)	45.7	42.7	44.7	46.4	42.0	
HbA1c (mmol/mol)	35.5	43.6	34.2	41.3	57.2	< 0.0001
(SE)	0.17	0.45	0.20	0.26	0.55	
Glucose (mmol/L)	5.8	6.4	5.8	6.2	6.8	< 0.0001
(SE)	0.05	0.13	0.06	0.08	0.16	
BMI	28.6	29.1	28.6	28.9	32.4	< 0.0001
(SE)	0.21	0.55	0.23	0.34	0.68	
HTN (yes)	236	56	156	132	32	0.001
(%)	21.4	35.0	18.8	31.7	28.3	

shows the discrete changes (or contrasts) in the probability of having diabetes (based on the NICE guidelines) by sex (left panel) or ethnicity (right panel) as the FINDRISC score increases in 4-unit increments. The probability of having diabetes is greater in male ED attendees, and people of color seem to have a greater propensity of diabetes compared with white individuals.

ADA criteria analyses: the study also classified patients according to the ADA criteria, revealing different distributions, with a relatively large increase in the number of people with pre-diabetes (Table 4). Under this classification, 61.3% (847 individuals) of the cohort exhibited normal glucose tolerance, 30.4% (420 individuals) had pre-diabetes, and 8.3% (115 individuals) were diagnosed with diabetes. The mean (SE) HbA1c levels for these ADA groups were 34.2 (0.2) mmol/mol for normal, 41.3 (0.26) mmol/mol for pre-diabetes, and 57.3 (0.52) mmol/mol for diabetes ($p < 0.0001$). The age distribution for these groups showed mean (SE) values of 51.1 (0.50) years for normal glucose tolerance, 56.9 (0.71) years for pre-diabetes, and 55.9 (1.35) years for diabetes, with a significant overall difference across groups ($p < 0.0001$). Furthermore, the mean (SE) BMI for these groups were 28.6 (0.23) for normal glucose tolerance, 28.9 (0.34) for pre-diabetes, and 32.4 (0.70) for diabetes, with marked differences between groups ($p < 0.0001$).

The unadjusted multinomial logistic regression analysis within the ADA framework indicated that each unit increase in the FINDRISC score was linked to a 9% higher risk of pre-diabetes (RRR 1.09, 95% CI: 1.06–1.11) and a 12% higher risk of diabetes (RRR 1.12, 95% CI: 1.10–1.22). Effect modification was noted after adjustments for age, sex, and ethnicity resulted in per unit attenuation of the relative risk ratios at 1.06 (95% CI: 1.04–1.10) for pre-diabetes and 1.16 (95% CI: 1.10–1.23) for diabetes, both statistically significant ($p < 0.001$). An important finding from the study was that British South

Table 3 Adjusted relative-risk ratios for pre-diabetes and diabetes by Finnish Diabetes Risk Score and Criteria. This table shows the RRRs for pre-diabetes and diabetes based on the Finnish Diabetes Risk Score (FINDRISC) categories according to the criteria set by the National Institute for Health and Care Excellence (NICE) and the American Diabetes Association (ADA)

Category	FINDRISC score	Pre-diabetes	*p*-Value	Diabetes	*p*-Value
NICE Criteria	Per unit	1.06 (1.02, 1.10)	0.008	1.18 (1.11, 1.24)	< 0.0001
	By category				
	7–11	0.82 (0.51, 1.32)	0.41	2.91 (1.22, 6.87)	0.015
	12–14	1.16 (0.69, 1.96)	0.56	6.63 (2.46, 17.90)	< 0.0001
	15–20	1.38 (0.66, 2.91)	0.38	6.95 (2.58, 18.71)	< 0.0001
	> 20	5.56 (2.01, 15.42)	0.001	16.14 (2.31, 112.58)	0.005
ADA Criteria	Per unit	1.07 (1.04, 1.09)	< 0.0001	1.19 (1.13, 1.26)	< 0.0001
	By Category				
	7–11	1.00 (0.70, 1.40)	0.96	2.95 (1.24, 7.02)	0.014
	12–14	1.32 (0.86, 2.04)	0.20	7.12 (2.70, 18.73)	< 0.0001
	15–20	1.42 (0.98, 2.07)	0.064	7.47 (2.79, 20.02)	< 0.0001
	> 20	19.89 (2.78, 142.45)	0.003	71,81 (5.91, 872.53)	0.001

Adjusted for age, sex, ethnicity, and smoking status, and were clustered by postcode

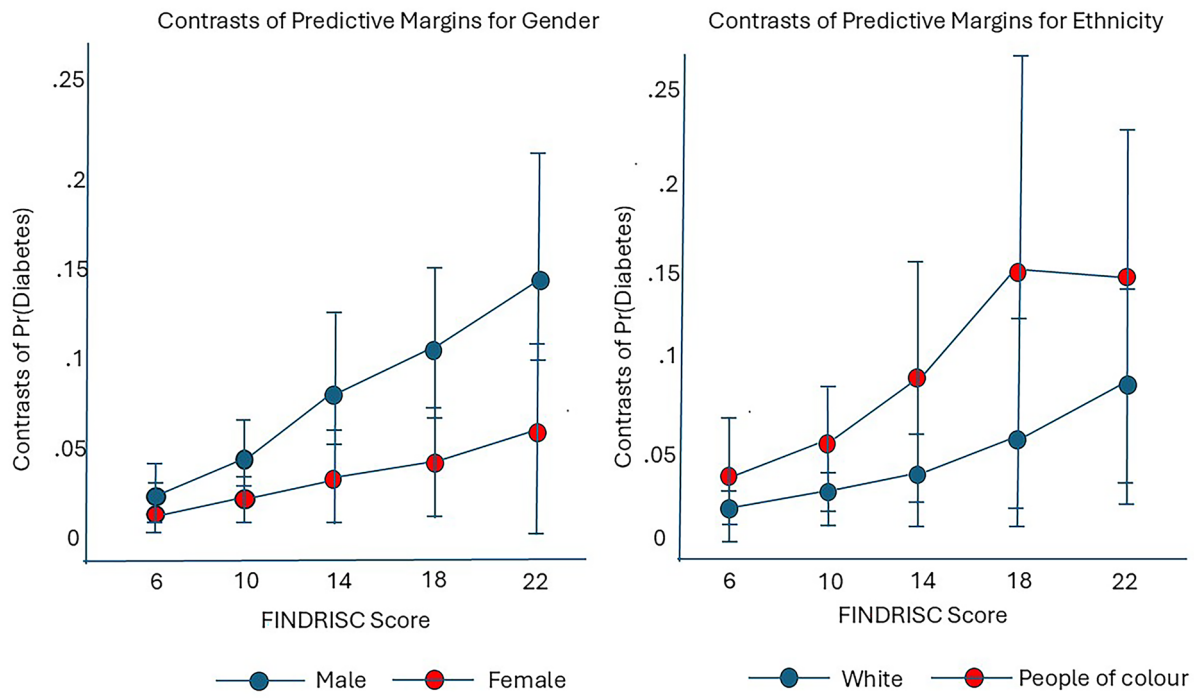

Fig. 1 Changes (or contrasts) in the probability of having diabetes (based on the NICE guidelines) by sex (left panel) or ethnicity (right panel) as the FINDRISC score increases in 4-unit increments

Table 4 Clinical characteristics by glycemic status (American Diabetes Association Criteria). This table presents the clinical characteristics of participants, categorized by their glycemic status based on the American Diabetes Association (ADA) criteria using hemoglobin A1c (HbA1c) levels. Characteristics include the number of participants, age, gender distribution, hemoglobin A1c (HbA1c) levels, glucose levels, body mass index (BMI), and prevalence of hypertension (HTN)

Category	Normal	39–47	≥ 48	*p*-Value
N	847	420	115	
(%)	61.3	30.4	8.3	
Age (years)	51.0	56.9	55.9	< 0.0001
(SE)	0.50	0.71	1.35	
Male	379	195	49	0.63
(%)	44.7	46.4	42.6	
HbA1c (mmol/mol)	34.2	41.3	57.2	< 0.0001
(SE)	0.20	0.26	0.52	
Glucose (mmol/L)	5.8	6.2	6.8	< 0.0001
(SE)	0.06	0.08	0.15	
BMI	28.6	28.9	32.4	< 0.0001
(SE)	0.23	0.34	0.7	
HTN (yes)	156	132	31	0.0001
(%)	18.8	31.7	28.3	

Table 5 Unadjusted and adjusted odds ratios for pre-diabetes and diabetes mellitus. This table presents the unadjusted and adjusted odds ratios for pre-diabetes and diabetes mellitus based on the criteria established by the National Institute for Health and Care Excellence (NICE) and the American Diabetes Association (ADA) from multinomial logistic regression models. The adjustments were made for age, sex, and ethnicity in models clustered by postcode

Criteria	Category	OR (unadjusted)	OR (adjusted)
NICE Criteria	Pre-DM	1.08 (1.05, 1.12)	1.06 (1.01, 1.10)
	DM	1.16 (1.10, 1.23)	1.16 (1.10, 1.23)
ADA Criteria	Pre-DM	1.09 (1.06, 1.11)	1.06 (1.04, 1.10)
	DM	1.12 (1.06, 1.18)	1.16 (1.10, 1.23)

Adjusted for age, sex, ethnicity, and smoking, and clustered by postcode

Asian and other people of color exhibited a higher prevalence of glucose intolerance—both pre-diabetes and diabetes—compared with white individuals (50.0% versus 37.6%, respectively). These minority groups were also nearly twice as likely to be classified as having pre-diabetes (RRR = 1.94, 95% CI: 1.11–3.38) or three times as likely to have diabetes (RRR = 2.80, 95% CI: 1.61–4.84). This emphasizes the importance of ethnicity in the risk assessment for glucose intolerance. For detailed statistics and further insights, please refer to Tables 3, 4, and 5.

Finally, in multivariable logistic regression analyses we estimated each unit increase in the FINDRISC score was associated with a 16% increase in the risk of having diabetes versus normoglycemia or pre-diabetes (OR 1.16 [1.10–1.23], C-statistic = 0.72 for model goodness-of-fit, H–L $\chi^2 = 8.66$, $p = 0.37$ indicating good model fit; ADA criteria). In the ED, for this population, the risk of having glucose intolerance (T2DM/pre-DM) compared with normoglycemia was around 10%, regardless of the criteria used for diagnosis (ADA: OR = 1.09 [1.07–1.12], H–L $\chi^2 = 6.77$, $p = 0.56$. NICE: OR = 1.10 [1.06–1.14], H–L $\chi^2 = 15.23$, $p = 0.06$) with similar estimates of the goodness-of-fit of the models with a modest C-statistic of 66.3% and 67.3%, respectively.

For the health economic assessment, the average material cost to screen for HbA1c was estimated to be £12 and the time cost for a nurse to administer the test was £8.3, resulting in a total cost of £20.3 per test performed. These were calculated from annual inpatient care to treat short and long-term complications of diabetes, and is estimated at between £1800 and £2500 per patient [35]. Given these long-term costs, this additional test in the ED may result in significant savings and quality of life.

DISCUSSION

This is the largest study to investigate the efficacy of utilizing HbA1c testing in the emergency department (ED) for diagnosing pre-diabetes and diabetes in a population without a known diagnosis of diabetes. Applying the NICE and ADA criteria, the study revealed a considerable detection rate of nearly 1 in 10 and an even higher 30% for pre-diabetes, respectively, and 8% for newly diagnosed diabetes with both criteria. This finding aligns with other research suggesting a high incidence of undiagnosed diabetes among ED patients [36, 37]. For example, a study by Hng et al. in Australia, involving 1267 emergency department patients, identified 157 individuals with available HbA1c samples who were diagnosed with diabetes [37].

The success of using HbA1c testing in the ED setting extends beyond just high detection rates. In Melbourne's tertiary referral hospital ($N = 725$), Jelinek et al. observed similar rates of dysglycemia [38]. However, their study's dependency on a 75 g oral glucose tolerance test (OGTT) for diagnosis proved less practical compared with the more straightforward HbA1c testing employed by Hng et al. and as used in our current study [37]. The OGTT's requirement for patient preparation and multiple blood samples poses logistical challenges, whereas HbA1c testing offers a simpler, more efficient approach, requiring only a single blood sample without pre-test preparation. Our study's findings are particularly valuable because they highlight the hidden burden of diabetes within the hospital population. With many people with T2D unaware of their condition, the potential for early detection and intervention in the ED is significant. This supports the case for routine HbA1c testing in individuals presenting to the ED—a population evidently enriched with undiagnosed diabetes cases. In addition, the HbA1c test circumvents the issue of "stress hyperglycemia" often encountered with blood glucose testing in the ED, providing a more reliable diagnosis [37].

The utility of HbA1c testing extends to pre-diabetes identification, supported by ADA guidelines [22]. Early identification of pre-diabetes allows for timely lifestyle interventions, which are proven to prevent progression to diabetes, as demonstrated by the Diabetes Prevention Program and the Finnish Diabetes Prevention Program [39, 40].

A novel aspect of our study is the application of HbA1c testing in a non-primary care setting. While previous research has confirmed the feasibility of diabetes screening in outpatient and general practice environments [41], our study capitalizes on the unique opportunity presented by the ED to catch diabetes in individuals who might otherwise evade routine medical care. The ED visit serves as a critical point for detecting pre-diabetes and diabetes in patients who present with non-glycemic issues, capturing a broader and potentially less health-conscious population. Our data also revealed that patients with glucose intolerance tended to be older, had higher body mass indices (BMI), and elevated admission blood glucose levels. Hypertension prevalence was notably higher in this group. Moreover, the Finnish Diabetes Risk Score (FINDRISC), used to identify individuals at risk for diabetes, showed a significant correlation with elevated risk scores in our cohort. Specifically, a FINDRISC score greater than 20 was associated with a six to tenfold increased risk of pre-diabetes and diabetes under NICE criteria, and a higher 22–45-fold increase under ADA criteria. However, it is important to note that FINDRISC does not account for ethnicity, and our findings indicate that individuals of South Asian (SA) or African Caribbean (AFC) ethnicity exhibited a two to threefold greater risk of developing pre-diabetes and diabetes.

The benefits of screening for diabetes in the ED is that the patients are already at the point of care premises and hence do not incur additional cost other than the cost of testing and the time needed to administer the test. Given the high rate of previously undiagnosed diabetes and pre-diabetes found in this study (12–30% depending on criteria used and 9%, respectively), the expected cost to find one additional individual with diabetes and pre-diabetes was about £228 and £173, respectively. These figures were calculated from the estimated unit cost per test divided by undiagnosed and pre-diabetes rates from the sample. The relatively high prevalence of patients with undiagnosed diabetes attending

the ED reduces the cost to find one additional individual with diabetes.

The question is then whether conducting such a screening test is cost effective and worth doing in light of resource-constrained environments in the healthcare sector. Annual screening to detect type 2 diabetes is not cost effective [42], but screening in a setting with high expected prevalence might yield different cost effectiveness findings [43].

Screening for undetected diabetes in the ED and referring the patients to their GP for further treatment as reported in our study (£228) is much cheaper than screening through community pharmacists, with the cost being more than £3795 per patient detected [44]. The much lower case-finding cost in our context was due to: (1) the high chance of detecting positive cases, and (2) the lower cost of providing the test without the need to develop specific skills and procedures in the community pharmacy setting.

Given the low uptake of community-based diabetes screening programs, our results advocate for the opportunistic testing of diabetes in the ED with the straightforward, inexpensive HbA1c blood test. The high prevalence of glucose intolerance identified in our ED patients emphasizes the need for such initiatives. Incorporating routine HbA1c screening into ED guidelines could facilitate early diagnosis and treatment, ultimately alleviating long-term burdens on healthcare services and improving patient outcomes. As the prevalence of these conditions continues to rise, implementing effective screening protocols in high-traffic, non-primary care settings such as the ED becomes increasingly crucial for public health.

Although our results align with the existing literature on diabetes detection, the demographic and clinical characteristics of patients can vary significantly across different geographic locations. This variation may result in different rates of undiagnosed diabetes in other regions. Therefore, it is important to consider these factors when applying HbA1c testing protocols in diverse ED settings. Moreover, the use of HbA1c in diagnosing diabetes is complicated by ethnic variability in the measurement, which is not necessarily reflective of glycemic status or hemoglobin structure and quantity. Studies have shown that HbA1c levels can vary among different ethnic groups independently of actual blood glucose levels. This variability is particularly pertinent in our population, where slight elevations in HbA1c may disproportionately indicate diabetes in some ethnicities compared with others [45–47]. Such discrepancies necessitate cautious interpretation of HbA1c results and highlight the need for considering ethnic-specific reference ranges or supplementary diagnostic criteria.

It is important to address several limitations that may affect the broader applicability of our findings. Firstly, the accuracy of HbA1c as a diagnostic tool can be compromised by conditions that alter the quality or quantity of hemoglobin, such as anemia, hemoglobinopathies, or recent blood transfusions (though no patient was tested post-transfusion in this ED setting) [48]. These factors were not specifically controlled in our study and could lead to an underestimation of diabetes prevalence. Secondly, there is a potential selection bias since our study focused on patients who underwent bloodwork in the ED. These patients might differ from those who did not receive bloodwork, possibly having more comorbidities or symptoms that prompted testing, thereby affecting the generalizability of our results to all ED patients. In addition, our study was conducted at a single center, which may limit the generalization of our findings. Furthermore, while we included sex as a covariate in all models and presented disaggregated results by sex, we did not collect data on gender identity, nor conduct a gender-based analysis. Future studies should consider incorporating gender-related variables, as social roles and access to care may influence diabetes risk and screening uptake.

CONCLUSIONS

Our findings robustly support the implementation of HbA1c testing in the emergency department (ED) for diabetes case finding. The considerable prevalence

of undiagnosed diabetes within our patient population highlights the critical need for routine HbA1c screening in this setting, which may be the only place where hard-to-reach individuals may attend for healthcare. The integration of HbA1c testing into standard ED protocols could substantially improve diabetes diagnosis and care. A limitation of our study is that while point-of-care (POC) HbA1c testing offers significant convenience, particularly in resource-poor settings, it is not without its drawbacks. These include reduced accuracy, potential bias, and the risk of human error due to lack of proficiency in testing at sites where this waived test is performed. Consequently, while POC HbA1c testing has the potential to enhance diabetes diagnosis in the ED, clinicians must be mindful of these limitations [49]. In addition, the long-term health benefits of incorporating POC HbA1c testing into ED protocols have yet to be fully determined. We also acknowledge that alternative diabetes risk assessment tools, such as the Diabetes UK "Know Your Risk" score (https://riskscore.diabetes.org.uk/), incorporate ethnicity into risk calculation and may offer complementary predictive value. However, for this study, FINDRISC was selected owing to its established validation in European populations and its practicality within the ED setting. Lastly, while FINDRISC was originally developed for individuals aged 45–64 years [27], subsequent studies have explored its application in broader adult populations. In our study, no formal score adjustment was made for participants aged 30–44 years.

Furthermore, integrating ED-based diabetes screening presents a scalable and affordable solution to address disparities in diabetes prevalence and ensure timely linkage to outpatient care for newly identified patients. Future research should focus on refining screening criteria tailored to the ED environment to maximize diagnostic yield and develop robust follow-up systems to support ongoing management for those newly diagnosed with diabetes.

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Data Availability. The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of Interest. Edward Jude has received travel and research grants from Novo Nordisk, Sanofi, AstraZeneca, and Menarini. Sushant Saluja, Nicolaas Schaper, Simon G. Anderson, Adrian Heald, and Dono Widiatmoko have no conflicts of interest to declare.

Ethical Approval. This study was reviewed and approved by the Health Research Authority Ethics Committee in the UK (ID 287393). The study was conducted in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments. All participants provided written informed consent before participation. Further methodological details are available on ClinicalTrials.gov (Identifier: NCT04653545).

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