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DISCUSSION PAPER

PREVALENCE, DIAGNOSIS OF DIABETES AMONG OLDER EUROPEANS: RESULTS FROM THE SURVEY OF HEALTH, AGEING AND RETIREMENT IN EUROPE (SHARE)

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Prevalence, diagnosis of diabetes among older Europeans: Results from the Survey of Health, Ageing and Retirement in Europe (SHARE)

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Abstract:

This study compares the prevalence of pre-, diagnosed and undiagnosed diabetes (preDM, dDM and uDM) among people aged 50+ in 11 European countries plus Israel, and investigates factors associated with preDM and uDM. We combine dried blood spot data with self-reports from SHARE Wave 6. Participants are classified into four groups: normal A1c, preDM, uDM, and dDM. Multinomial regressions were applied to study associations with sociodemographic, lifestyle and health factors. The overall diabetes prevalence is 21.2% (14.0% dDM; 7.2% uDM, which are 34.2% of all diabetics), 54.0% of the study population exhibit pre-diabetic A1c values. The undiagnosed tend to have fewer symptoms and better general health than the diagnosed. Significant disparities in prevalence are observed across countries, with Mediterranean countries showing higher rates. Given the high prevalence of preDM and uDM, timely screening and detection are crucial for early lifestyle changes to delay or reverse disease progression. Our study provides insights into how countries could allocate healthcare resources between prevention and treatment, emphasizing the need for wider diagnostic strategies to capture less symptomatic preDM and uDM.

Keywords: diabetes prevalence rate, prediabetes, undiagnosed diabetes, dried blood spots, international comparisons

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1. Introduction

Diabetes is a chronic metabolic disease responsible for substantial morbidity and mortality, which is imposing a heavy burden on individuals and high financial cost on healthcare systems. Due to its asymptomatic character, diabetes can remain undetected for up to 10 years [1]. Studies have shown that a person may spend several years in the asymptomatic phases of preDM and/or uDM. Without timely screening and early intervention during these stages, elevated blood sugar levels can irreversibly affect blood vessels and organs, and induce a variety of severe complications, including kidney, nerve and eye damage, diabetic foot syndrome, and increase the risk of cardiovascular disease and cognitive decline [2,3]. In fact, initial diabetes diagnosis may come at the same time as diagnosis of diabetes complications [4]. In addition, if people in the pre-diabetes state can be early captured through intervention and change of lifestyle, they may remain prediabetic or even return to normal without progressing eventually to full diabetes [5]. Therefore, improving the risk communication, implementing diabetes screening in health systems for early detection will help prediabetic and newly diagnosed individuals to develop healthy habits from early on, and ensure timely medical intervention to reduce the occurrence of diabetes-related complications.

The precise estimation of diabetes prevalence and incidence are essential for assessing public health efforts, developing prevention strategies and evaluating their effectiveness. The sources of diabetes information commonly rely on social surveys, clinical records or insurance claims and may have shortcomings: social surveys dependent on self-reported diagnostic histories, which are susceptible to memory bias [6-8]. Clinical records face variations in diagnostic criteria across different health systems. Insurance data may potentially lead to over-reporting, inflating the reported prevalence [9,10]. Still, these data sources primarily capture information on dDM and overlook the uDM group, thereby underestimating the overall prevalence [11,12].

To better evaluate participants' health in population surveys, an increasing number of studies incorporate biomarker collection as objective health measurements, such as Health and Retirement Study (HRS) in the US [13], English Longitudinal Study of Ageing (ELSA) in England [14], The Irish Longitudinal Study on Ageing (TILDA) in Ireland [15], SHARE in continental Europe [16], and Chinese Health Aging Retirement Longitudinal Study (CHARLS) in China [17]. The European Health Examination Survey (EHES), collaboration among organizers of national health examination surveys (HES) in Europe, also conducts blood sampling for health assessments across EU countries [18]. However, comparing the diabetes prevalence from different surveys is challenging. Different surveys use different study design, target different age ranges and may be conducted in different years. In addition, blood biomarkers may be analyzed from different blood specimen types e.g., venous blood (VB) vs. dried blood spots (DBS) samples in different laboratories, which will impact the biomarkers levels [16,19,20] and complicate the comparisons or make it impossible [21]. This issue becomes particularly critical when disease or risk is defined by clinical cut-off points, as exemplified by the widely used HbA1c blood level exceeding 6.5% for diagnosing diabetes.

SHARE tries to minimize these shortcomings by employing a harmonized blood collection strategy for all countries, collecting the blood samples during the same time period, using a single laboratory for analyses, and validating the survey-collected DBS for the impact of field conditions [16, 22]. Hence, the laboratory results are comparable across countries. In this paper, we use self-reported diabetes diagnosis and HbA1c blood levels measured in DBS samples from the biomarker data set from SHARE to estimate the prevalence of preDM, uDM and dDM in 11 European countries and Israel. Further, combining the biomarker data with the wealth of information in the regular SHARE data set, we explore the reasons for country disparities in diabetes prevalence at the macro level and investigate how demographic and socioeconomic characteristics, lifestyle behaviours and health status influence diabetes status, with a specific focus on preDM and uDM. Our objective is to identify factors that differentiate individuals with preDM and uDM from normoglycemics, aiming to target potential diabetes cases among asymptotic “seemingly healthy” individuals for more effective diabetes screening. Furthermore, a comparison between uDM and dDM cases allows us to discern which groups of diabetics are more prone to being overlooked.

2. Methods

2.1 SHARE and SHARE DBS Data

The data sets used in the following analysis are from SHARE, a longitudinal study launched every two years since 2004, interviewing people aged 50+ in 27 continental European countries and Israel. In all waves, SHARE collects information on demographic and socioeconomic circumstances, self-reported health, wealth and income [23]. In its Wave 6 in 2015, SHARE collected DBS samples from 27,000 respondents in 12 countries (Belgium, Switzerland, Germany, Denmark, Estonia, Spain, France, Greece, Israel, Italy, Sweden, Slovenia), in order to obtain objective information of the health status [24].

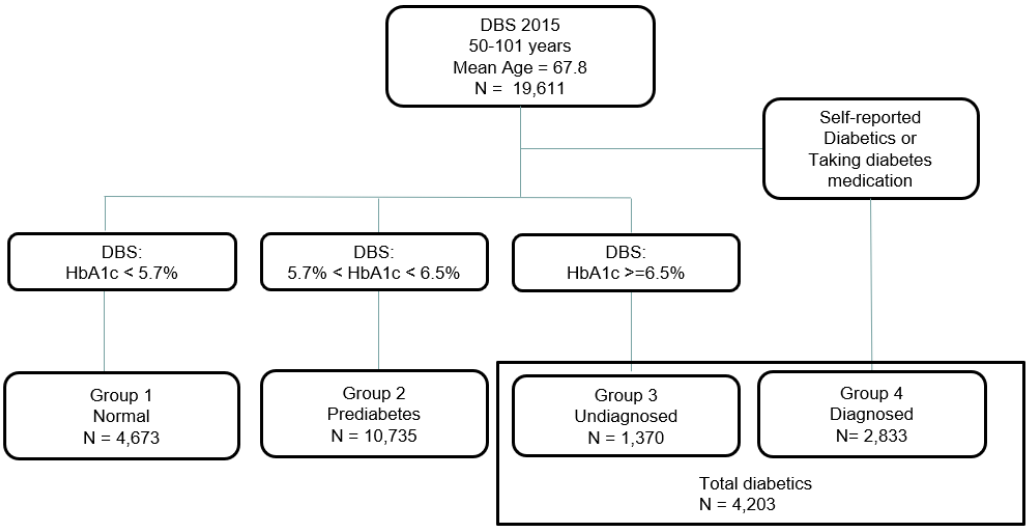
All eligible respondents in panel households were asked to consent to the blood collection; participation was voluntary in all countries. Among all individuals interviewed (52,374) in Wave 6, 39,483 were eligible, of which 27,373 (67.18%) consented. In France, eligibility was restricted to only four districts due to logistical reasons. Greece started blood collection only in late summer of 2015 and had the lowest DBS participation rate (33.47%) followed by Israel (52.78%). Finally, 19,611 DBS samples could be analysed for Hemoglobin A1C (HbA1c). The selection of the sample and the collection and analysis of DBS for biomarkers (HbA1c amongst others) is described in Börsch-Supan, M et al., 2024 [16].

2.2 The HbA1c and Diabetes Group Classification

Hemoglobin A1C (HbA1c) is a marker which reflects blood glucose levels over the past two to three months. It is commonly used as a blood glucose test in diabetes patients, but also in population screening for diabetes [25]. According to the clinical guidelines of the American Diabetes Association (2013), normal A1c values are

< 5.7%; values between 5.7%-6.5% are considered prediabetic and HbA1c values ≥ 6.5% define diabetes [26].

Our study groups DBS participants into four categories by the SHARE-measured HbA1c level or a self-reported diabetes diagnosis. Those who never have self-reported being diagnosed by a doctor nor are taking diabetes medication are categorized in Group 1 (normoglycemics, HbA1c < 5.7%) and Group 2 (preDM, HbA1c > 5.7% to 6.5%). Those with HbA1c blood levels ≥ 6.5% but never diagnosed by a doctor nor taking related medications are called undiagnosed (uDM, Group 3). The dDM (Group 4) either has a self-reported diabetes diagnosis or is taking diabetes medication. Only 130 individuals deny a diabetes diagnosis but report taking diabetes medication in the SHARE sample. They are included in Group 4. In 2023, Mose et al. using SHARE data from Denmark have shown that self-reports on diabetes diagnosis and related medication were very reliable [8]. Our focus is on Type 2 diabetes. With the data available in the SHARE sample, we cannot distinguish between Type 2 and Type 1 or other types of diabetes. According to the literature, Type 1 diabetes comprises about 5–10% of all diabetes cases and is usually diagnosed in childhood or adolescence [27]. Figure 1 shows the flowchart for the classification of the diabetes groups.



Source: The Survey of Health, Ageing and Retirement in Europe, Wave 6 in 2015

Figure 1. Sample selection and diabetes group classification flowchart in SHARE Sample

2.3 Statistical methods

The prevalence is estimated using a weighted logistic regression with a DBS-specific weighting factor. The weights include corrections for non-response in the entire SHARE questionnaire and are additionally adjusted for non-response in the blood-sampling module. The derivation of DBS weights is described in detail in Börsch-Supan, M. et al., 2024 [16]. Briefly, the weighting factors correct for biases in gender, age and education between the survey sample and the national population. To ensure fair comparisons across

countries, we report both unadjusted and adjusted prevalence rates, the latter assuming equal distribution across countries in terms of age, gender and education.

To identify the factors associated with preDM, uDM and dDM compared to normoglycemia, we used multinomial logistic regression, setting normoglycemia as the reference group and reporting the relative risk ratios (RRRs), which can be interpreted as odds ratios (ORs). Additionally, to identify the factors associated with the diagnosis of diabetes, we applied logistic regression among individuals with diabetes, setting dDM as 1 and uDM as 0, which allowed us to identify the factors associated with dDM compared to uDM, and reported the odds ratios. Initially, we controlled for demographic characteristics, then added controls for immigration status, income, BMI, lifestyle, and health conditions, all modeled with country-fixed effects. Due to missing some control variables, 350 observations were omitted in the regression analysis. We considered p-values below 5% as significant. All statistical analyses are conducted using STATA, version 14.

3. Results

3.1 The prevalence rates of preDM, uDM, dDM, and tDM across countries

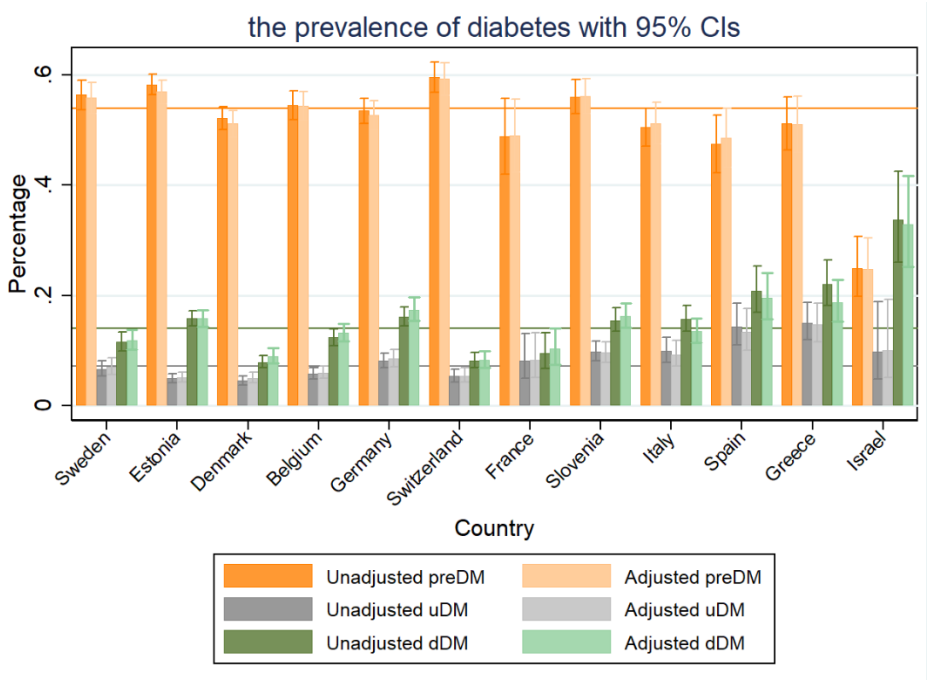
Table 1 and Figure 2 show the unadjusted and adjusted estimated prevalence of preDM, uDM and dDM, as well as total diabetes mellitus (tDM) across the 12 SHARE countries, all of which belong to high-income countries [28]. The adjusted prevalence rate changed only slightly after correcting for age, gender and education across countries. Overall, the total diabetes prevalence (tDM=uDM+dDM) among individuals aged 50+ in these SHARE countries is 21.2%: 7.2% uDM, 14% dDM, indicating that 34.2% of all individuals with diabetes in our sample were undiagnosed in 2015. Notably, approximately half of the population has prediabetic A1c blood levels. Significant disparities in diabetes prevalence are observed between countries, even after adjustment for age, gender, education (see Figure 2): northern and central European countries have lower rates of uDM and dDM compared to the Mediterranean countries. Specifically, Sweden, Denmark, Belgium, Switzerland have an estimated prevalence of both uDM and dDM below the average across all countries. In contrast, Mediterranean countries such as Italy, Israel, Slovenia, Spain, and Greece have a higher prevalence of both, uDM and dDM, than the cross-countries average. Denmark and Switzerland have the lowest tDM prevalence at around 14%, while Spain and Greece have overall diabetes prevalence rates of approximately 33%. Israel records the highest prevalence in the older population among the SHARE countries at 43,6%. These findings underscore that approximately one in three individuals aged 50+ in Spain and Greece have diabetes and almost every second in Israel.

The rate of undiagnosed diabetes among total diabetics (uDM/tDM) varies, with Israel showing a relatively low rate of 22.4%, comparable to Estonia with 23.8%. Conversely, France and Greece exhibit the highest uDM/tDM rates, each around 45%. However, some results need careful interpretation considering the small sample sizes of France, Greece and Israel.

Table 1: The estimated prevalence rate of prediabetes, undiagnosed and diagnosed diabetes, and the rate of diabetes diagnosis across 11 European countries and Israel (in %)

Country	preDM		uDM		dDM		tDM		uDM among tDM	
	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted	Unadjusted	Adjusted
Sweden	56.4	55.8	6.6	7.0	11.5	11.9	18.2	18.9	36.5	36.4
	[53.7 - 59.1]	[53.0 - 58.6]	[5.2 - 8.0]	[5.5 - 8.4]	[9.9 - 13.2]	[10.2 - 13.6]	[16.0 - 20.2]	[16.7 - 21.1]	[30.1 - 42.5]	[29.9 - 42.5]
Estonia	58.2	56.8	5.0	5.1	15.8	15.8	20.8	20.9	23.9	23.8
	[56.4 - 60.2]	[54.9 - 59.1]	[4.1 - 5.8]	[4.2 - 6.0]	[14.5 -17.2]	[14.3 - 17.3]	[19.2 - 22.3]	[19.3 - 22.6]	[20.2 - 27.3]	[19.7 - 27.5]
Denmark	52.0	50.9	4.5	5.0	7.9	9.0	12.4	14	36.4	36.2
	[50.1 - 54.2]	[48.6 - 53.3]	[3.7 - 5.4]	[4.0 - 6.0]	[6.8 - 9.0]	[7.7- 10.3]	[11.1 - 13.8]	[12.4 - 15.6]	[30.8 - 41.9]	[30.1 - 42.3]
Belgium	54.5	54.3	5.7	6.0	12.3	13.2	18.1	19.2	31.8	31.3
	[51.9 - 57.0]	[51.6 - 56.8]	[4.7 - 6.8]	[4.9 - 7.1]	[10.8 - 13.8]	[11.6 - 14.8]	[16.3 - 19.9]	[17.3 - 21.0]	[26.9 - 36.6]	[26.4 - 36.2]
Germany	53.6	52.6	8.1	8.5	16.1	17.4	24.2	26.0	33.6	32.5
	[51.4 - 55.9]	[50.2 - 55.3]	[6.8 - 9.4]	[7.0 - 10.1]	[14.4 - 17.8]	[15.3 - 19.5]	[22.2 - 26.2]	[23.5 - 28.4]	[29.1 - 38.1]	[27.5 - 37.4]
Switzerland	59.6	59.1	5.4	5.4	8.2	8.3	13.5	13.6	39.6	41.6
	[56.9 - 62.4]	[56.3 - 62.2]	[4.2 - 6.5]	[4.1 - 6.7]	[6.8 - 9.6]	[6.8 - 9.8]	[11.7 - 15.3]	[11.8 - 15.5]	[32.7 - 46.4]	[34.2 - 49.0]
France	48.9	49.0	8.1	8.3	9.5	10.3	17.6	18.6	46.1	47.9
	[42.3 - 56.1]	[42.6 - 56.0]	[4.2 - 12.1]	[4.3 - 12.2]	[6.3 - 12.7]	[71 - 3.6]	[12.8 - 22.5]	[13.7 - 23.5]	[30.9 - 61.3]	[34.7 - 61.1]
Slovenia	56.1	56.1	9.7	9.6	15.5	16.3	25.2	25.8	38.6	36.8
	[53.1 - 59.3]	[53.1 - 59.5]	[8.0 - 11.6]	[7.8 - 11.4]	[13.3 - 17.6]	[14.0 - 18.5]	[22.6 - 27.9]	[23.1 - 28.6]	[32.9 - 44.6]	[31.1 - 42.7]
Italy	50.7	51.6	9.9	9.3	15.7	13.5	25.6	22.8	38.7	40.7
	[47.1 - 54.0]	[47.6 - 55.1]	[7.7 - 12.1]	[7.0 - 11.5]	[13.3 - 18.0]	[11.3 - 15.7]	[22.6 - 28.6]	[19.9 - 25.7]	[31.9 - 45.6]	[34.0 - 47.5]
Spain	46.8	48.1	14.4	13.4	20.9	19.6	35.2	33.0	40.8	38.4
	[40.9 - 51.3]	[42.0 - 52.8]	[10.6 - 18.1]	[9.7 - 17.1]	[16.7 - 25.0]	[15.4 - 23.8]	[30.3 - 40.2]	[28.0 - 38.0]	[32.1 - 49.5]	[29.7 - 47.1]
Greece	51.1	51.0	15.1	14.8	22.0	18.8	37.1	33.6	40.6	44.2
	[46.3 - 56.0]	[46.0 - 56.1]	[11.7 - 18.4]	[11.3 - 18.3]	[17.9 - 26.2]	[15.0 - 22.6]	[32.4 - 41.8]	[29.1 - 38.1]	[32.9 - 48.4]	[35.7 - 52.7]
Israel	24.6	24.5	9.9	10.1	33.8	32.9	43.6	43.0	22.6	22.4
	[19.0 - 29.9]	[19.1 - 29.5]	[3.2 - 16.6]	[3.3 - 16.9]	[25.4 - 42.1]	[24.6 - 41.2]	[35.1 - 52.1]	[34.6 - 51.5]	[8.5 - 36.7]	[8.6 - 36.3]
Average	54.0		7.2		14.0		21.2		34.2	
	[51.1 - 56.7]		[5.8 - 9.0]		[12.1 - 16.0]		[19.0 - 23.6]		[28.6 - 40.2]	

Source: The Survey of Health, Ageing and Retirement in Europe, Wave 6 in 2015
Note: preDM: prediabetes mellitus, uDM: undiagnosed diabetes mellitus, dDM: diagnosed diabetes mellitus, tDM: total diabetes mellitus, encompassing both undiagnosed and diagnosed diabetes mellitus. The uDM among tDM indicates the rate of undiagnosed diabetes within the total diabetes mellitus. The unadjusted prevalence rates were estimated based on the existing demographic characteristics of the country. Adjusted prevalence rates were calculated by standardizing for age, gender and education levels to the average levels observed across multiple countries, thereby holding these factors constant across different populations.



Source: The Survey of Health, Ageing and Retirement in Europe, Wave 6 in 2015
Note: Prevalence estimates were adjusted for age, gender and education levels. Orange represents preDM (prediabetes mellitus), defined as HbA1c >5.7% but <6.5%. Gray indicates uDM (undiagnosed diabetes mellitus), defined as HbA1c measurement ≥ 6.5%, but no self-reported diabetes and taking no diabetes medication. Green represents dDM diagnosed by a doctor and/or taking diabetes medication. The orange horizontal line is the average prevalence of preDM (54.0%) across countries, the grey horizontal line is the average prevalence of uDM (7.2%) across countries, the dark green line is the average prevalence of dDM (14.0%) across countries.

Figure 2. The estimated prevalence rate of preDM, uDM and dDM across countries with 95% CIs.

The disparities in the prevalence and diagnosis of diabetes across countries can be associated with differences in lifestyle and/or health status between countries, as well as in the effectiveness and cost of the healthcare system (here measured by the proportion of patients forgoing care due to waiting times and costs). Table 2 illustrates differences in sample characteristics across countries. Compared to Mediterranean countries (Italy, Spain, Greece, and Israel), northern countries show generally better performance in income, BMI, health conditions, and healthcare system. Denmark and Switzerland, which have the lowest uDM and dDM rates, also exhibit the highest household incomes, lowest obesity rates, better health conditions, and more efficient healthcare systems. Israel, having the highest prevalence of diabetes, shows a very high obesity rate (26.3%) and a significant portion of the population being physically inactive (26.1%). Additionally, Israel faces worse health conditions with high prevalence rates of hypertension (52.1%), high blood cholesterol (44.9%), stroke (4.4%), mental health problems (3%), and chronic kidney disease (3.9%). Israel's population has a very diverse ethnic background differing from European countries with more homogenous population composition. Some of the ethnic groups have higher genetic predispositions to diabetes. Studies in Israel have shown that the Arabic population has a higher risk for diabetes than the Jewish population [29]. Furthermore, challenges in healthcare efficiency are also observed in Italy and Greece, with higher reports of unmet healthcare needs due to cost (10.4%; 23.5% respectively) and time constraints (19.4%; 21.6% respectively).

Table 2: Sample characteristics across 11 Europeans countries and Israel

Baseline Characteristics	Total %	Sweden %	Estonia %	Denmark %	Belgium %	Germany %	Switzerland %	France %	Slovenia %	Italy %	Spain %	Greece %	Israel %
N	19261	2079	3157	2464	2554	2421	1567	301	1568	1298	968	483	401
Gender													
Male	42.7	44.5	33.9	44.9	43.9	46.9	47.0	42.6	41.6	44.5	40.0	44.1	44.4
Age Group													
Age (mean, years)	67.8	69.5	70.3	65.5	66.1	65.8	68.3	68.5	67.3	67.9	69.0	69.6	70.8
50-59	22.2	12.8	15.1	31.3	29.2	29.4	20.6	22.0	23.6	21.2	19.2	9.7	7.8
60-69	36.8	39.5	32.6	37.4	38.5	35.5	37.7	36.1	36.4	36.3	35.4	45.2	43.4
70-79	28.1	34.0	33.9	22.4	21.2	27.3	27.3	24.9	27.3	31.5	28.4	28.0	30.2
>=80	13.0	13.7	18.4	8.9	11.1	7.8	14.4	17.0	12.7	11.0	17.0	17.1	18.5
ISCED Group													
Year of Education (mean, years)	11.4	11.8	11.7	13.6	12.7	12.7	8.6	12.1	10.4	8.6	7.9	9.0	12.6
Low Edu	33.1	34.3	28.3	17.0	38.4	11.0	20.2	39.3	33.3	71.7	80.8	57.1	36.6
Medium Edu	40.2	33.9	49.1	37.9	26.4	57.2	63.2	34.4	49.9	21.7	10.1	26.4	26.8
High Edu	26.8	31.7	22.7	45.0	35.2	31.9	16.7	26.2	16.8	6.6	9.2	16.5	36.6
Born Native													
Yes	88.6	92.0	78.9	96.7	92.1	87.9	83.1	90.5	87.9	98.2	97.4	97.5	40.5
Income Quartiles													
Household Income (mean, euro)	35992	41577	8424	46844	52471	34203	92011	35140	16011	22702	17967	13177	34339
1st quantiles	25.2	3.4	83.5	3.6	4.6	8.8	2.1	7.9	44.9	19.8	35.8	61.4	19.3
2nd quantiles	24.9	19.8	14.4	19.0	27.3	28.6	4.5	30.5	40.7	47.1	44.3	26.4	26.1
3rd quantiles	25.0	39.8	1.9	33.1	33.4	39.6	20.1	38.7	11.6	26.8	16.5	10.1	32.2
4th quantiles	24.9	36.9	0.2	44.3	34.8	23.1	73.3	23.0	2.8	6.4	3.4	2.1	22.4
BMI Group													
BMI (mean, kg/m^2)	27.0	26.3	28.1	26.1	26.6	27.3	25.9	26.5	27.8	27.0	27.7	27.2	27.8
Normal (<25)	36.8	43.2	31.1	45.2	38.1	34.9	45.5	42.6	27.9	35.7	27.7	30.3	27.6
Overweight (25-30)	40.8	38.3	37.6	38.8	41.9	41.5	38.8	35.4	44.4	42.7	47.2	49.3	46.1
Obese (>30)	22.4	18.5	31.3	16.0	20.0	23.6	15.7	22.0	27.7	21.7	25.1	20.4	26.3
Lifestyle													
Physical Inactivity	8.5	4.0	9.9	4.2	9.8	4.9	4.4	10.8	7.4	20.9	14.4	5.6	26.1
Alcohol*	58.1	66.2	31.4	81.3	69.4	63.9	75.2	73.4	49.1	49.5	36.6	53.6	19.5
Ever Smoked	47.1	55.1	40.3	58.6	49.8	48.6	46.9	40.7	38.3	43.3	40.0	47.0	32.2
Health Condition**													
Hypertension	42.3	40.0	53.8	34.4	34.1	43.2	31.9	37.9	47.9	47.9	44.4	49.4	52.1
High Blood Cholesterol	25.5	16.9	22.5	25.1	32.3	19.9	17.7	23.8	28.5	29.8	33.9	44.5	44.9
Stroke	3.3	3.7	4.6	3.2	3.4	2.7	1.7	2.3	4.2	2.3	2.2	2.9	4.4
Mental health problem***	1.2	1.1	1.5	0.6	1.0	1.0	0.6	0.3	1.9	1.3	1.8	2.0	3.0
Chronic Kidney Disease	2.0	0.7	4.1	1.1	1.6	2.0	0.8	1.9	2.2	2.0	1.6	1.2	3.9
Depression	40.6	32.7	48.0	31.2	41.3	47.4	38.8	45.2	40.1	43.4	39.8	33.0	42.4
Sleep problem	37.9	32.5	51.2	31.5	35.1	38.0	33.4	40.0	41.2	34.7	34.7	30.7	46.1
Healthcare system													
Forgo care - cost	2.9	0.2	3.6	0.2	2.5	2.4	0.8	2.6	2.1	10.4	1.6	19.4	4.4
Forgo care – time	9.5	5.9	24.0	4.1	4.7	4.6	0.9	4.6	5.8	23.5	4.7	21.6	12.0

*: At least one alcoholic beverage the last 7 days.
**: Have you ever been diagnosed with any of the following health conditions.
***: Alzheimer's disease, dementia, senility
Source: The Survey of Health, Ageing and Retirement in Europe, Wave 6 in 2015

3.2 Factors associated with Diabetes

Table 3: Descriptive statistics of the study sample by diabetes classification

Baseline Characteristics	Group 1 **normalA1c**		Group 2 **preDM**		Group 3 **uDM**		Group 4 **dDM**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
N	4583		10564		1349		2765	
Gender								
Female	2650	57.8	6184	58.5	776	57.5	1410	51.0
Male	1933	42.2	4380	41.5	573	42.5	1355	49.0
Age Group								
Age (mean, years)	65.8		68.0		68.4		70.2	
50-59	1341	29.3	2265	21.4	283	21.0	361	13.1
60-69	1730	37.7	3901	36.9	481	35.7	987	35.7
70-79	1071	23.4	2990	28.3	395	29.3	958	34.6
>=80	441	9.6	1408	13.3	190	14.1	459	16.6
Born Native								
No	486	10.6	1108	10.5	148	11.0	436	15.8
Yes	4097	89.4	9456	89.5	1201	89.0	2329	84.2
ISCED Group								
Year of Education (mean, years)	12.0		11.4		10.8		10.5	
Low Edu	1245	27.2	3390	32.1	541	40.1	1187	42.9
Medium Edu	1835	40.0	4324	40.9	517	38.3	1064	38.5
High Edu	1503	32.8	2850	27.0	291	21.6	514	18.6
Income Quartiles								
Household Income (mean, euro)	40994		36118		32464		28939	
1st quantiles	921	20.1	2670	25.3	373	27.7	904	32.7
2nd quantiles	988	21.6	2585	24.5	393	29.1	823	29.8
3rd quantiles	1215	26.5	2661	25.2	320	23.7	619	22.4
4th quantiles	1459	31.8	2648	25.1	263	19.5	419	15.2
BMI Group								
BMI (mean, kg/m^2)	25.9		26.8		27.5		29.5	
Normal (<25)	2088	45.6	4038	38.2	421	31.2	527	19.1
Overweight (25-30)	1830	39.9	4347	41.1	588	43.6	1100	39.8
Obese (>30)	665	14.5	2179	20.6	340	25.2	1138	41.2
Physical Inactivity								
No	4298	93.8	9787	92.6	1225	90.8	2324	84.1
Yes	285	6.2	777	7.4	124	9.2	441	15.9
Alcohol*								
No	1549	33.8	4348	41.2	652	48.3	1522	55.0
Yes	3034	66.2	6216	58.8	697	51.7	1243	45.0
Ever Smoked								
No	2421	52.8	5616	53.2	711	52.7	1433	51.8
Yes	2162	47.2	4948	46.8	638	47.3	1332	48.2
Hypertension								
No	3074	67.1	6349	60.1	748	55.4	936	33.9
Yes	1509	32.9	4215	39.9	601	44.6	1829	66.1
High Blood Cholesterol								
No	3682	80.3	8107	76.7	1024	75.9	1543	55.8
Yes	901	19.7	2457	23.3	325	24.1	1222	44.2
Stroke								
No	4446	97.0	10210	96.6	1305	96.7	2572	93.0
Yes	137	3.0	354	3.4	44	3.3	193	7.0
Mental Health Problem**								
No	4538	99.0	10450	98.9	1337	99.1	2709	98.0
Yes	45	1.0	114	1.1	12	0.9	56	2.0
Chronic Kidney Disease								
No	4517	98.6	10390	98.4	1322	98.0	2655	96.0
Yes	66	1.4	174	1.6	27	2.0	110	4.0
Depression								
No	2734	59.7	6316	59.8	825	61.2	1569	56.7
Yes	1849	40.3	4248	40.2	524	38.8	1196	43.3
Sleep Problem								
No	2928	63.9	6573	62.2	897	66.5	1571	56.8
Yes	1655	36.1	3991	37.8	452	33.5	1194	43.2

*: At least one alcoholic beverage the last 7 days

**: Alzheimer's disease, dementia, senility

Source: The survey of health, aging, and retirement in Europe, wave 6 in 2015

Note: PreDM: prediabetes mellitus, uDM: undiagnosed diabetes mellitus, dDM: diagnosed diabetes mellitus. The 12 countries studied include Sweden, Estonia, Denmark, Belgium, Germany, Switzerland, France, Slovenia, Italy, Spain, Greece, and Israel.

Table 3 presents the characteristics of the four diabetes groups. Group 4 (the diabetics) has the highest average age (70.2 years), lowest level of education (10.5 years), lowest annual household income (€28,939), highest average body mass index (BMI; 29.5 kg/m^2), and the highest proportion of hypertensive patients (66.1%), yet the lowest alcohol consumption. Next is group 3 (uDM), being younger (68.4 years), slightly higher educated (10.8 years) with higher annual household income (€32,464) and lower BMI (27.55 kg/m2). In group 2 (preDM), the average age is 68.0 years, education level 11.4 years, annual household income €36,118, and BMI 26.85 kg/m^2. Compared to the normoglycemics (group 1), more individuals in groups 2-4 are physically inactive. Smoking rates are similar across all groups, around 47%. For high blood cholesterol, stroke, mental health problems, and declining kidney function, the prevalence is similar between the preDM and uDM groups compared to the normal A1c group, but much higher in the dDM group.

Table 4 reports the odds ratios from multinomial logistic regression for preDM, uDM and dDM compared to those with normoglycemia (columns 1-6). Additionally, columns 7-8 explore factors associated with dDM compared to uDM using logit regression.

Columns 1 and 2 indicate that older age groups consistently show higher odds of being preDM instead of normoglycemic. After controlling for additional characteristics (Column 2), we also find that overweight or obese adults, and individuals with hypertension exhibit increased odds of having preDM. There is no significant association between education, immigration status and adherence to a healthy lifestyle, health conditions (except for hypertension) with the odds of having preDM. Columns 3 and 4 reveal the factors associated with uDM compared to being normoglycemic. We found that higher education is associated with lower odds of being in the uDM group. However, after controlling for additional characteristics (Column 4), the association with education disappears (only marginally significant at the 10% level). We find that people with obesity and hypertension have higher odds of being in the uDM group. Notably, there was no significant difference in the odds of having uDM compared to being normoglycemic among people of different genders, ages, income levels, lifestyles, and health conditions, except for hypertension. Columns 5 and 6 examine factors associated with dDM compared to being normoglycemic, confirming existing literature findings such as being male, older, of lower education, with unhealthy lifestyle, higher BMI, and the presence of chronic diseases (i.e., hypertension, high blood cholesterol and stroke) are more likely to have dDM [30-32]. Additionally, people with sleep problems also have higher odds for dDM. The one exception is alcohol drinking, people drinking alcohol are less likely to have dDM, as alcohol interacts with diabetes medication, impacts the blood sugar and interferes with diabetes management. dDM patients are advised to decrease or better give up drinking.

Columns 7 and 8 present the factors associated with dDM compared to uDM. Our primary aim is to investigate the key characteristics of diabetics that are associated with a higher likelihood of being diagnosed. In column 7, we observe that males and older individuals have higher odds of being diagnosed, while no significant association is evident concerning education level. After controlling for other characteristics in column 8, we

find that native-born individuals have lower odds of being diagnosed. Individuals with well-known diabetes risk factors or comorbidities, such as overweight or obesity, physical inactivity, high blood cholesterol and stroke, are associated with higher odds of getting diagnosed. Conversely, those with fewer risk factors and fewer symptoms tend to be overlooked and remain undiagnosed.

Table 4: Factors associated with preDM, uDM and dDM, reported Odd ratios

VARIABLES	(1) PreDM	(2) PreDM	(3) uDM	(4) uDM	(5) dDM	(6) dDM	(7) dDM among tDM	(8) dDM among tDM
Gender (baseline: Female)								
Male	0.942	0.912	1.056	1.054	1.649***	1.813***	1.656***	1.744***
	0.096	0.0979	0.166	0.180	0.195	0.232	0.242	0.279
Age Group (baseline:50 - 59)								
60-69	1.448***	1.351***	1.184	1.025	2.158***	1.905***	1.976***	2.004***
	0.168	0.155	0.228	0.203	0.340	0.305	0.405	0.432
70-79	1.778***	1.642***	1.361	1.083	3.461***	2.820***	2.821***	2.806***
	0.216	0.208	0.271	0.234	0.567	0.478	0.588	0.616
>=80	1.908***	1.822***	1.576*	1.214	3.596***	2.888***	2.393***	2.497***
	0.310	0.313	0.387	0.332	0.718	0.622	0.565	0.635
ISCED Group (baseline: Low Edu)								
Medium Edu	1.023	1.088	0.887	1.041	0.829	1.118	0.894	0.985
	0.130	0.139	0.191	0.229	0.137	0.191	0.180	0.209
High Edu	0.835	0.945	0.479***	0.634*	0.404***	0.686**	0.724	0.974
	0.123	0.145	0.111	0.154	0.0705	0.128	0.151	0.215
Born Native								
Yes		1.074		1.344		0.700		0.501**
		0.220		0.402		0.161		0.147
Income Quartiles (baseline: income 1st quantiles)								
income 2nd quantiles		1.407*		1.295		1.176		0.922
		0.212		0.324		0.213		0.214
income 3rd quantiles		1.288		0.970		0.815		0.805
		0.202		0.286		0.155		0.219
income 4th quantiles		1.163		0.615		0.785		1.079
		0.219		0.241		0.190		0.430
BMI Group (Baseline: Normal (>25)								
Overweight (25-30)		1.262**		1.266		2.183***		1.822***
		0.139		0.212		0.338		0.327
Obese (>30)		1.703***		1.714**		5.948***		3.505***
		0.257		0.389		1.084		0.747
Lifestyle								
Physical inactivity		0.919		0.938		1.444*		1.620**
		0.170		0.238		0.287		0.345
Ever Smoked		1.134		1.120		1.481***		1.216
		0.117		0.189		0.179		0.182
Alcohol[1]		0.889		0.774		0.516***		0.690**
		0.095		0.125		0.0671		0.105
Health Condition[2]								
Hypertension		1.276**		1.870***		2.097***		1.193
		0.138		0.321		0.278		0.186
High Blood Cholesterol		1.275*		0.939		2.477***		2.537***
		0.166		0.180		0.360		0.464
Stroke		1.132		1.300		1.716**		1.525
		0.285		0.574		0.474		0.518
Mental Health[3]		1.202		0.799		0.961		1.533
		0.433		0.427		0.433		0.701
Chronic Kidney Disease		1.151		1.096		1.754		1.423
		0.377		0.518		0.626		0.566
Depression		0.949		0.920		0.866		0.858
		0.0985		0.146		0.110		0.132
Sleep Problem		1.192		1.067		1.351**		1.222
		0.130		0.201		0.174		0.207
Constant	1.745***	0.969	0.281***	0.181***		0.0963***	0.825	0.496*
	0.239	0.289	0.0675	0.0796		0.0339	0.196	0.205
Country fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	19,261	19,261	19,261	19,261	19,261	19,261	4,114	4,114

*** indicates p<0.01, ** indicates p<0.05, * indicates p<0.1.

1: At least one alcoholic beverage the last 7 days

2: Have you ever been diagnosed with any of the following health conditions.

3: Alzheimer's disease, dementia, senility

Source: The Survey of Health, Aging, and Retirement in Europe, Wave 6 in 2015

Note: preDM: prediabetes mellitus uDM: undiagnosed diabetes mellitus, dDM: diagnosed diabetes mellitus, tDM indicates total diabetes mellitus, encompassing both undiagnosed and diagnosed diabetes mellitus. The dDM among tDM indicates the rate of diagnosed diabetes within the total diabetes mellitus. The 12 countries studied include Sweden, Estonia, Denmark, Belgium, Germany, Switzerland, France, Slovenia, Italy, Spain, Greece, and Israel.

4. Discussion

The study reveals that over a fifth of the individuals aged 50 and older across 11 European countries plus Israel in 2015 had diabetes, with a significant portion undiagnosed. Higher rates of both diagnosed and undiagnosed diabetes are observed in Mediterranean countries, particularly Spain, Greece and Israel, compared to northern and central Europe. Additionally, nearly half of the study population has prediabetic A1c blood levels, indicating a likely increase in diabetes incidence in the near future. In fact, Elek & Bíró (2021) using SHARE self-reported data from Waves 4 and 7 found varying transition rates from no-diabetes to diabetes across countries, with higher-than-average incidence in Spain and lower rates in Denmark and Switzerland [11]. These findings align with the uDM prevalence disparities observed in our study as some preDM and uDM cases identified in SHARE Wave 6 through blood biomarker analysis evolved into dDM by Wave 7. The disparities between countries in prevalence and diagnosis of diabetes may be attributed to heterogeneity in the effectiveness and cost of the healthcare systems, and lifestyle differences described in Table 2. Genetic variation may also explain part of the disparity between populations in northern and southern Europe [33].

Among all diabetics of the SHARE DBS participants, approximately 34.2% had remained undiagnosed. This rate is comparable to 36.6% undiagnosed (aged 20-79) among diabetic groups in European high-income countries (IDF estimates, 2013) [34]. Compared with two harmonized population studies targeting middle-aged and older adults, the undiagnosed rate among all diabetics in the SHARE sample (in 2015) is lower than, for example in CHARLS (2011/12) 59.3% representing 10.3% of the Chinese target population [30], but higher than in ELSA (2012/13) representing 22.2% or 3.4% of the English target population [31]. ELSA and CHARLS measure HbA1c values in venous blood, while SHARE measures in capillary blood. However, studies have shown that HbA1c results obtained from the fingertip capillary blood are comparable and highly correlated with those obtained from venous samples [35,36].

The prevalence of uDM among the SHARE sample (from 2015) is higher compared to many other national health studies in Europe. For instance, GESUS (the Danish General Suburban Population Study, aged 20-100 years, HbA1c measured, from 2011) in Denmark reported 1.4% uDM (31.9%% among all diabetics) compared 4.5% uDM (36.4% among all diabetes) in SHARE [37], BELHES (Belgian Health Examination Survey, aged ≥18 years, fasting blood glucose or HbA1C measured, from 2018) in Belgium reported 3.2% uDM(37% among all diabetics) compared to 5.7% uDM (31.8% among all diabetics) in SHARE [38]. DEGS (German health interview and examination survey, aged 40–79 years, HbA1c measured, from 2008-2011) in Germany found 2.9% uDM (20.7% among all diabetics) compared to 8.1% uDM (33.6% among all diabetics) in SHARE [12], the Di@bet.es Study (a national diabetes study, aged ≥18 years, glucose tolerance test, from 2009-2011) in Spain observed 6.8% uDM (43.7% among all diabetes) compared to 14.4% uDM (40.8% among all diabetics) in SHARE [39]. SHARE measured A1c blood levels in older adults 50+ (50–100yrs), while national HES surveys include individuals from 18 years old. Moreover, the majority of national HES surveys

were conducted before 2015. Therefore, both the older population and the increasing incidence rate of diabetes may have driven the higher rate of uDM in SHARE DBS countries. This comparison also highlights that due to differences in target populations, survey years and measurement methods, cross-survey comparisons should be interpreted with care. However, a similar ranking of prevalence rates across countries is also observed in the national health studies, with Mediterranean countries showing the higher and northern and central Europe showing the lower prevalence of uDM.

Given the constraints on healthcare resources, it is imperative for public health departments to strategically allocate medical resources among the prevention, screening and treatment of diabetes. Our findings indicate that some northern and central European countries, such as Sweden, Estonia and Switzerland, exhibit a higher proportion of preDM. Consequently, these countries might benefit from concentrating more healthcare resources on preventing and screening diabetes to identify prediabetic individuals early and implement appropriate measures to prevent or slow the progression to full diabetes. Conversely, in Mediterranean countries (e.g., Spain, Greece, Israel) a higher proportion of the populations already has diabetes. While continuing to emphasize diabetes screening in these countries, increasing the treatment and management of diabetes to prevent further deterioration of the condition and mitigate the risk of complications for the individual, might also relieve the healthcare systems.

Our study found that obesity and hypertension are significantly associated with all three diabetes groups, consistent with previous studies in Ireland [32] and Germany [12]. Obesity is identified as the factor with the strongest independent association with the three groups of diabetes. Hypertension frequently coexists with diabetes as part of the metabolic syndrome, which can substantially elevate the risk of vascular complications.

Moreover, individuals with preDM and uDM show similar lifestyle and health status to normoglycemic individuals. Those in the uDM category are younger, have healthier lifestyles and exhibit better general health than those with dDM. These characteristics may contribute to the fact that they often remain unnoticed in European countries. Consequently, focusing diabetes screening only on individuals with apparent risk factors leaves many older adults unaware of their condition. Without timely detection and lifestyle changes, many preDM individuals may eventually progress to full T2DM. Those with uDM may progressively develop more serious diabetic symptoms or even complications such as retinopathy, CVD or kidney disease [40]. Therefore, enhancing diabetes-risk communication, expanding population screenings, and providing testing incentives could raise awareness and offer early intervention opportunities. Community-based screening, particularly for hard-to-reach populations with unfavorable risk profiles, could complement clinical-based screening systems effectively [41,42]. The significant association between hypertension and both preDM and uDM supports the strategy of combined testing for diabetes and hypertension as an effective approach to early disease detection [43,44].

Limitations of our study should be noted. First, as in many population surveys, the diabetes status was assessed using a single HbA1c test, but neither a fasting glucose (FPG) nor an oral glucose tolerance test

(OGTT) was conducted. Multiple testing and different tests are imperative for a clinical diabetes diagnosis [45]. Therefore, the prevalence of preDM and uDM may be less precise [46]. Secondly, the seasonality (e.g., in food consumption or activity behaviour) and field conditions (environmental impact, blood-sample handling by the interviewers and shipment times to the Biobank, etc.) during blood-sample collection may have influenced the HbA1c analysis results more than our corrections could account for [16]. Thirdly, the dDM is based on respondents' self-reports, and reporting errors by the respondents as well as the interviewers may lead to some measurement error, though Mose et al. (2023) using Danish SHARE data to show that self-reported diabetes and related medications in SHARE was very reliable [8]. Finally, France, Greece and Israel have small sample sizes in our study. Therefore, the interpretation of the results from these three countries may require careful consideration and warrant further investigation.

This study is the first collection of DBS samples for blood biomarker assessment across multiple European countries. Blood collection methods were harmonized and collected in parallel in 2015, the samples were analyzed in a single laboratory and the resulting blood marker values corrected for field conditions. This enables cross-national comparison of blood values [16]. Easy measurement of the diabetes marker HbA1c from DBS allows assessment of pre- and undiagnosed diabetes cases in a population survey, which is not only highly important for individuals but also for entire national health systems. The comparison of the SHARE results with existing surveys supports the use of HbA1c measurement in population surveys for understanding the diabetes status of a country.

Our findings underscore the importance of identifying individuals with uDM to more accurately assess the prevalence of the disease and highlight the necessity for early diagnostic testing, particularly considering that more than half of our study population is in preDM and uDM stages.

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