

Article

Determinants of Health Status in Adult Diabetic Patients: From Anthropometric and Biological Indicators to Individual Perception

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Abstract

Background/Objectives: In Romania, diabetes mellitus remains a significant public health challenge, characterized by high prevalence and significant undiagnosed cases. This study assessed the prevalence of elevated glycated hemoglobin (HbA1c) levels within the adult population participating in the European Health Examination Survey (EHES) and examined their associations with major cardiometabolic risk factors, subjective health perception, and patient awareness of previously diagnosed chronic conditions. **Methods:** This cross-sectional study analyzed data from the EHES in Romania, including systematic, population-weighted sample of adults aged 25–64 years. Data were analyzed using the Complex Samples module in SPSS, version 29.0 (IBM Corp., Armonk, NY, USA). HbA1c levels were measured through standardized clinical examination, with values of 5.7–6.4% classified as at risk for diabetes mellitus, and values $\geq 6.5\%$ as diabetes mellitus. **Results:** Among 5380 representative adults, the prevalence of elevated HbA1c ($\geq 6.5\%$) was 7.1%, while prediabetes (HbA1c 5.7–6.4%) affected 35.4% of participants; both conditions were significantly more prevalent in men than in women. Elevated HbA1c and prediabetes were substantially more frequent among individuals with hypertension and hypercholesterolemia, and glycemic control among participants with previously diagnosed diabetes was generally poor (all $p \leq 0.05$). Individuals who are aware of having a chronic health condition appear to engage more actively in self-care practices, including increased physical activity and more frequent monitoring of key biological parameters. **Conclusions:** Elevated HbA1c and prediabetes were more prevalent than estimates reported in other studies using HbA1c-based diagnostic criteria. These observations highlight the importance of early detection and timely diagnosis, as awareness of one's health status may facilitate healthier behaviors that mitigate metabolic complications.



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This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.**Keywords:** elevated HbA1c level; predictability; individual perception

1. Introduction

Globally, it is estimated that approximately 589 million adults aged 20 to 79 years live with diabetes. Effective management of diabetes has become a global public health priority, in the context of the continued increase in mortality caused by complications of these pathologies.

The current prevalence of diabetes (9.8%) and the number of people with diabetes (66 million) in the EU Region will increase by 10% by the year 2050. In 2024, it was estimated that USD 193 billion was spent on diabetes in the Region, representing 19% of total global expenditure [1].

A major problem driven by determinants such as weak health systems and low awareness among both the population and health professionals is the high proportion of undiagnosed diabetes mellitus. This pathology can remain undiagnosed for a long period, leading to the subsequent development of micro- and macrovascular complications, some of which may be irreversible [2–6].

Some studies highlight that undiagnosed diabetes mellitus represents a significant and underestimated mortality risk, comparable to that associated with diagnosed diabetes and other major chronic diseases [7–12].

In 2022, it was estimated that more than half of adults aged 30 years and older with diabetes (59%) [13,14] were not taking medication. Moreover, treatment coverage for diabetes was lower in low- and middle-income countries. Although medication adherence is an important factor influencing metabolic control, it remains suboptimal.

Multiple evidence-based studies have confirmed that good treatment adherence is extremely important for improving glycemic control, preventing complications, and reducing the economic burden on the health system. However, a recent study highlighted poor treatment adherence, pointing out that 21.2% of patients showed a low level of adherence [15–19].

In Romania, diabetes mellitus represents a major public health challenge. In 2024, the number of registered patients with diabetes mellitus reached 1,485,087, with 114,904 new cases diagnosed annually. The prevalence of diabetes mellitus among the adult population is 9.1%.

A significant challenge for Romania is the low rate of diagnosed diabetes related to its estimated prevalence, with only 21.4% of total cases being identified [20]. Poor early detection contributes significantly to the adverse outcomes, and is associated with an annual number of 10,034 deaths among the adult population [20].

The consensus report prepared by the American Diabetes Association (ADA) and the American Cancer Society (ACS) concluded that individuals with type 2 diabetes are at increased risk for several types of cancer, particularly colorectal, breast, endometrial, liver, pancreatic, and bladder cancers [21–28].

Diabetes mellitus, particularly the asymptomatic progression of undiagnosed cases, promotes the development of vascular complications and increases the risk of premature mortality [29,30]. Possible macrovascular complications include myocardial infarction, stroke, renal failure, and peripheral arterial disease [31–38], and microvascular complications include retinopathy, nephropathy, and neuropathy [39–43]. Macrovascular complications account for the majority of diabetes-related deaths [44–48].

Diabetes management relies primarily on anthropometric and biological indicators, which represent the gold standard in evaluating treatment outcomes and assessing the risk of vascular complications [49–53]. At the same time, the patient's individual perception of health status and the impact of the disease on usual daily activity are also important, as they influence motivation and self-management behavior, including glycemic monitoring, treatment adherence and long-term prognosis.

Health perception reflects an individual's perceived health status and well-being. It is influenced by a complex set of factors, including physical, emotional and mental state, as well as previous experiences with illness, previous medical care, psychological, social and cultural influences [54–58].

Diabetes management remains focused on objective indicators such as biological and anthropometric parameters of treatment success. However, disease management also depends on the patient's perspective on daily behaviors and on how individuals perceive their own health status [59,60].

The European Health Examination Survey (EHES) in Romania provided reliable data on the health status of the adult population and on the prevalence of major risk factors associated with chronic diseases. It also assesses the need for health promotion and disease prevention by evaluating the population's self-perceived health status.

Considering the high prevalence of diabetes in Romania, the substantial proportion of undiagnosed cases, and the diverse determinants contributing to disease occurrence, the main objective of this study is to assess the prevalence of elevated glycated hemoglobin levels in the adult population included in the EHES and to examine the relationship among the elevated HbA1c levels and the major cardiometabolic risk factors, subjective health perception and the awareness of previously diagnosed chronic diseases.

2. Materials and Methods

2.1. Planning of the National European Health Examination Survey (EHES)

This study was conducted within the framework of the European Health Examination Survey (EHES) in Romania, representing the first nationwide implementation of the survey. The purpose of the EHES in Romania was to assess the prevalence of major chronic diseases and their associated risk factors. Following the EHES recommendations to incorporate the methodology into the local context, the survey was completed with the assessment of self-perceived health status and an extensive panel of biological measurements. Data collection, including questionnaire administration, clinical examinations, and biological sample collection, was conducted between 5 August 2022 and 1 November 2022. Prior to nationwide implementation, a pilot study involving 400 participants was carried out to evaluate study procedures and ensure data quality, achieving an expected response rate of 50%.

In Romania, the EHES was coordinated by the National Institute of Public Health through Project PDP1/NT2311/13.05.2020, funded by the EEA Financial Mechanism 2014–2021. The project was implemented under the title “Strengthening the national network of primary health care providers to improve the health status of the population, children and adults (including vulnerable populations)”.

To ensure the scientific rigor and quality of the collected data, the following stages were systematically followed: (1) survey design and definition of objectives; (2) survey planning and preparation; (3) pre-testing and piloting; (4) sampling design and logistical preparation; (5) field research and data collection; (6) database development, data analysis and reporting [61–64]. The target population comprised men and women aged 25–64 years. This age range was selected in accordance with the EHES Manual recommendations, considering the generally lower response rates among younger adults and the specific medical assessment requirements of individuals aged over 65 years. Eligible participants were non-institutionalized civilian residents of Romania, both insured and uninsured, who were registered with a family physician and met the national residency criteria. Participants were stratified into four age groups: 25–34, 35–44, 45–54, and 55–64 years.

Exclusion criteria included individuals who had resided in Romania for less than six months during the previous 12 months (e.g., tourists and short-term visitors), military personnel and members of public order, national security, and judicial authority institutions covered by the dedicated health insurance system of the Ministry of National Defense, as well as institutionalized individuals residing in hospitals, prisons, or long-term care facilities.

Data were collected using the standardized EHES questionnaire, which comprised four modules: (1) socio-demographic characteristics, including sex, age, marital status, educational attainment; (2) health perception including self-rated health status, self-reported chronic conditions, and the impact of these conditions on daily activities; (3) health care utilization, including the use of medications for diabetes, hypertension, and hypercholesterolemia, healthcare-seeking behavior, and preventive health examinations; and (4) health determinants, including body weight status, smoking habits, alcohol consumption, physical activity, and sedentary behavior. In addition to questionnaire data, clinical examinations and biological measurements were performed according to the EHES protocol [61,62]. Biological samples were collected for laboratory assessment of glycated hemoglobin (HbA1c), high-density lipoprotein (HDL) cholesterol, triglycerides (TG), and other predefined biomarkers.

All personnel involved in participant recruitment, data collection, clinical examinations, and biological sample collection received standardized training in accordance with the Romanian EHES implementation protocol [65–67].

2.2. Population Sampling

A two-stage stratified sampling design was employed in accordance with the recommendations of the EHES Manual.

In the first stage, family physicians were selected as the primary sampling units. To ensure national coverage, family physicians were sampled from all counties and from both urban and rural areas, proportionally to the distribution of the target population within each county. The number of family physicians selected per county was determined according to the proportion of the county population relative to the national target population. Using a probability-proportional-to-size sampling method, 120 family physicians were selected nationwide. In the second stage, participants were selected from the capitation lists of the sampled family physicians. Eligible individuals were chosen using systematic sampling. The number of participants selected from each capitation list was determined according to predefined strata based on age group, sex, and area of residence.

Population weights by eligible age group, area of residence and sex were established for each county and the necessary samples were calculated. For each primary sampling unit, the required number of participants was established per stratum. In order to compensate for the various causes of the imbalance between the selected sample and the national representativeness, the dataset was adjusted according to the characteristics of interest, using the Horvitz-Thompson weighting [68–70].

The selection process is shown in Figure 1.

2.3. Data Collection Methodology

The data collection process followed a standardized protocol to ensure accuracy and consistency across all sampling units. The EHES questionnaire was administered by trained interviewers prior to the clinical examination. Clinical assessments, including blood pressure measurements and anthropometric evaluations, were performed by family physicians and nurses. Following the clinical examination, biological samples were collected for laboratory analysis.

Blood pressure was measured three times, and the average of the three readings was used for analysis. Elevated blood pressure was defined as a mean systolic blood pressure ≥ 140 mmHg and/or a mean diastolic blood pressure ≥ 90 mmHg. Glycemic status was assessed using fasting plasma glucose levels. Blood samples for glucose determination were collected from participants after a fasting period of at least 8 h. Questionnaire data, clinical examination findings, and laboratory results were subsequently integrated into a

dedicated study database. To ensure data integrity and participant confidentiality, each participant was assigned a unique identification code, which was used throughout the data collection and management process.

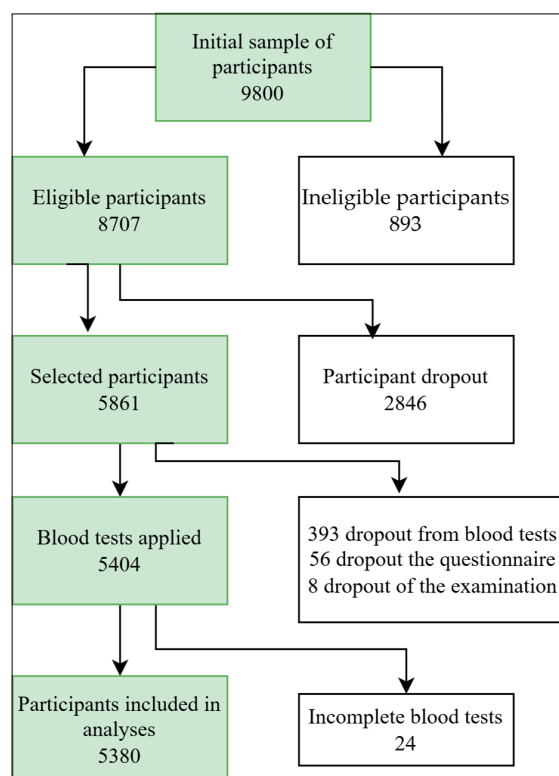


Figure 1. Flowchart of the participant selection process for EHES Romania.

All participants provided written informed consent, which was mandatory, prior to enrollment. The study protocol and informed consent were approved by the Ethics Committee of the National Institute of Public Health (Approval No. 2857 of 17 February 2022). The consent form covered all study components, including the processing of personal data, questionnaire administration, clinical examinations, and biological sample collection. Participants were free to participate only in those study components for which they had provided explicit consent.

2.4. Data Analysis

Data analysis was performed using IBM SPSS Statistics for Windows, Version 29.0 (IBM Corp., Armonk, NY, USA). Population weights were calculated following the EHES methodology using the Horvitz–Thompson approach. The initial sampling weight (w_i) was defined as the inverse of the overall inclusion probability and incorporated both stages of the sampling design: the probability of selecting a family physician as the primary sampling unit and the probability of selecting an individual from the physician’s capitation list as the secondary sampling unit. To account for differential participation and reduce potential non-response bias, a non-response adjustment factor (g_i) was applied. This factor was computed within strata defined by county, sex, age group, and area of residence (urban/rural), based on the ratio of eligible individuals selected to those who completed the survey. The final analysis weight was obtained by multiplying the sampling weight (w_i) by the corresponding non-response adjustment factor (g_i), in accordance with EHES recommendations [70]. The final weights were determined by calculating the ratio between the national population distribution and the sample distribution across key representativeness variables: development region, area of residence, gender, and five-year age

groups. To account for the complex survey design, variance estimation was performed using the Complex Samples module in SPSS, version 29.0 (IBM Corp., Armonk, NY, USA). Strata, physician-level clusters (as primary sampling units), and sampling weights were incorporated into the analysis design plan. Standard errors and 95% confidence intervals (95% CI) for prevalence estimates and logistic regression models were calculated using Taylor series linearization to adjust for clustering effects.

Diabetes mellitus status was determined based on glycated hemoglobin (HbA1c) levels, which reflect average blood glucose concentrations over the preceding 8–12 weeks. For the HbA1c level, the reference values used were as follows: $\leq 5.6\%$ normal level; 5.7–6.4% at risk for diabetes mellitus; $\geq 6.5\%$ diabetes mellitus [71–73]. The HbA1c levels were categorized according to clinical reference thresholds (at risk for diabetes mellitus and diabetes mellitus). Metabolic risk factors were defined based on the following clinical thresholds [74]: elevated blood pressure (SBP ≥ 130 mmHg and/or DBP ≥ 85 mmHg) [75]; abdominal obesity (waist circumference >102 cm for men and >88 cm for women) [76]; HDL cholesterol (<50 mg/dL for women and <40 mg/dL for men) [77], elevated triglycerides (≥ 150 mg/dL), and elevated fasting plasma glucose (≥ 110 mg/dL).

Descriptive statistics were used to summarize the data, and weighted analyses were conducted to provide accurate assessment of HbA1c level prevalence and its associated risk factors within the Romanian adult population. The distribution of continuous variables (age, BMI, systolic blood pressure [SBP], diastolic blood pressure [DBP], abdominal circumference [AC], HDL cholesterol, triglycerides [TG], and fasting blood glucose [FBG]) was assessed using the Kolmogorov–Smirnov test. Continuous variables are presented as means and standard deviations (SD). Comparison of the mean values of these variables across the three HbA1c categories (normal glycemic status, prediabetes, and diabetes mellitus) was performed using the General Linear Model univariate analysis tailored for complex samples. For continuous variables statistical significance was evaluated using the design-adjusted Wald F test. Associations between categorical variables were assessed using the adjusted as a variant of Rao–Scott adjusted chi-square test.

HbA1c levels were correlated with a wide range of indicators, including anthropometric and biological factors, socio-demographic variables (age, area of residence), and behavioral determinants (alcohol consumption, smoking status, and physical activity levels), as well as self-perceived health status. Design-based multiple linear regression analysis was performed using the Complex Samples General Linear Model procedure to identify independent predictors of HbA1c levels, treated as a continuous variable, and to develop prediction equations. Additionally, multivariable logistic regression analyses for complex samples were conducted to assess factors associated with elevated HbA1c categories.

A p -value < 0.05 was considered statistically significant.

2.5. Ethical Approval

The study protocol was approved by the Ethics Committee of the National Institute of Public Health (Approval No. 2857 of 17 February 2022).

Written informed consent was obtained from all participants prior to enrollment and participation in the survey, which was mandatory. Investigators, including family physicians and nurses, provided detailed information regarding the study objectives, procedures, clinical examinations, biological sample collection, and the processing and protection of personal and medical data. Participants were informed about all aspects of the study in clear and accessible language and were given sufficient time to review the informed consent form, ask questions, and consider their participation. Contact information was provided to allow participants to seek additional clarification before or after the study visit. All information communicated verbally was also included in the written informed

consent document. The participants could leave the survey and withdraw their informed consent any time, for any reason and without any penalty.

3. Results

The socio-demographic characteristics, health perception, awareness, and self-management behaviors of the study population regarding their health status are summarized in Table 1.

Table 1. Socio-demographic characteristics, awareness and perception of the population on health status according to the HbA1c level.

Variable	HbA1c (≤5.6%) (n = 3100)	HbA1c (5.7–6.4%) (n = 1896)	HbA1c (≥6.5%) (n = 384)	p-Value
Prevalence by HbA1c category	57.4 (55.8–59.0)	35.4 (33.9–36.8)	7.1 (6.5–7.9)	<0.001
Sex % (95% CI)				
male	55.4 (53.1–57.7)	35.6 (33.5–37.8)	9.0 (7.8–10.3)	<0.001
female	59.5 (57.3–61.7)	35.1 (33.1–37.2)	5.4 (4.6–6.3)	
Age group % (95% CI)				
25–34 years	80.5 (77.5–83.2)	18.9 (16.3–21.8)	0.56 (0.3–1.4)	<0.001
35–44 years	69.6 (66.9–72.2)	28.1 (25.7–30.7)	2.2 (1.6–3.2)	
45–54 years	48.6 (45.8–51.4)	42.4 (39.7–45.2)	8.9 (7.5–10.6)	
55–64 years	33.1 (30.2–36.2)	50.0 (46.9–53.1)	16.9 (14.9–19.1)	
Residence % (95% CI)				
Urban	58.3 (56.1–60.4)	34.9 (32.9–36.9)	6.9 (5.9–7.9)	0.447
Rural	56.5 (54.1–58.9)	35.9 (33.8–38.2)	7.6 (6.5–8.8)	
Education % (95% CI)				
≤12	51.9 (49.8–54.0)	38.7 (36.8–40.7)	9.4 (8.3–10.5)	<0.001
>12	65.2 (63.0–67.4)	30.7 (28.6–32.8)	4.1 (3.3–5.1)	
Income % (95% CI)				
Low	56.5 (54.5–58.6)	35.6 (33.7–37.5)	7.9 (6.9–8.9)	<0.001
Over basic living expenses	64.7 (61.2–68.1)	31.1 (27.8–34.6)	4.1 (2.9–5.8)	
Do not declare	55.1 (51.8–58.4)	37.6 (34.6–40.8)	7.3 (5.7–9.3)	
Marital status				
Single % (95% CI)	71.2 (67.6–74.7)	24.6 (21.4–28.0)	4.2 (2.9–6.1)	<0.001
Married % (95% CI)	55.8 (54.0–57.6)	36.8 (35.1–38.5)	7.4 (6.6–8.3)	
Widower % (95% CI)	36.7 (29.7–44.2)	48.9 (41.8–56.0)	14.5 (10.4–19.7)	
Divorced % (95% CI)	54.2 (48.5–59.9)	37.7 (32.3–43.5)	8.0 (5.5–11.6)	
Patient perception of health status % (95% CI)				
Very good	73.8 (70.9–76.5)	25.0 (22.3–27.9)	1.2 (0.6–2.2)	<0.001
Good	57.1 (55.1–59.0)	36.3 (34.5–38.1)	6.7 (5.8–7.7)	
Medium	43.3 (39.9–46.8)	43.1 (39.9–46.3)	13.6 (11.6–15.9)	
Bad	36.5 (26.9–47.2)	40.7 (31.0–51.1)	22.9 (15.5–32.3)	
Very bad	60.3 (37.5–79.4)	28.2 (12.9–51.0)	11.4 (2.8–37.0)	
Patient’s awareness about their own health status				
Existence of chronic health problems (>6 months) % (95% CI)	42.7 (40.3–45.1)	43.0 (40.7–45.3)	14.3 (12.8–16.0)	<0.001
Self-reported chronic diseases % (95% CI)				
HBP **	34.3 (31.5–37.1)	47.5 (44.8–50.3)	18.2 (16.2–20.4)	<0.001
T2DM *	8.2 (5.5–12.0)	27.2 (22.3–32.7)	64.7 (58.8–70.1)	<0.001
HC ***	37.0 (34.2–39.8)	46.7 (43.9–49.5)	16.4 (14.4–18.5)	<0.001
Prescribed medication % (95% CI)				
HBP **	30.5 (27.6–33.6)	49.3 (46.2–52.5)	20.1 (17.8–22.7)	<0.001
T2DM *	7.1 (4.5–11.0)	25.6 (20.4–31.5)	67.3 (61.0–73.0)	<0.001
HC ***	28.8 (25.4–32.4)	48.4 (44.7–52.1)	22.8 (19.8–26.2)	<0.001

Table 1. Cont.

Variable	HbA1c ($\leq 5.6\%$) (n = 3100)	HbA1c (5.7–6.4%) (n = 1896)	HbA1c ($\geq 6.5\%$) (n = 384)	p-Value
Biological measures % (95% CI)				
Blood pressure measurement				
In the last year	54.3 (52.5–56.1)	37.2 (35.6–38.9)	8.4 (7.6–9.4)	<0.001
1–5 years ago	66.3 (63.1–69.3)	30.1 (27.2–33.1)	3.6 (2.5–5.2)	
Over 5 years ago	72.5 (63.9–79.6)	25.0 (18.4–32.9)	2.6 (0.8–7.7)	
Cholesterol measurement				
In the last year	52.1 (50.0–54.2)	38.8 (36.8–40.7)	9.2 (8.1–10.3)	<0.001
1–5 years ago	61.6 (59.2–64.1)	33.0 (30.7–35.4)	5.3 (4.3–6.5)	
Over 5 years ago	67.4 (62.4–72.0)	27.8 (23.6–32.5)	4.8 (3.0–7.5)	
Blood glucose measurement				
In the last year	52.4 (50.4–54.5)	38.3 (36.4–40.3)	9.2 (8.2–10.4)	<0.001
1–5 years ago	62.0 (59.5–64.4)	33.2 (30.9–35.6)	4.8 (3.8–6.0)	
Over 5 years ago	68.3 (63.0–73.1)	26.8 (22.3–31.8)	5.1 (3.1–7.9)	
Family physician evidence % (95% CI)				
HBP **	32.6 (29.9–35.4)	48.7 (45.9–51.6)	18.7 (16.7–21.0)	<0.001
T2DM *	7.9 (5.3–11.8)	27.1 (22.2–32.7)	65.0 (59.1–70.4)	<0.001
HC ***	33.5 (30.6–36.5)	48.5 (45.8–51.5)	18.0 (15.8–20.4)	<0.001

* T2DM = diabetes mellitus type 2; ** HBP = high blood pressure; *** HC = hypercholesterolemia; HbA1c—Glycated hemoglobin. Data were analyzed using the Complex Samples module in SPSS, version 29.0 (IBM Corp., Armonk, NY, USA). Associations between categorical variables were assessed using the adjusted as a variant of Rao–Scott adjusted chi-square test. Family physician evidence refers to diagnoses of hypertension, type 2 diabetes mellitus, and hypercholesterolemia documented in the participants' family physician records at the time of the survey.

The prevalence of participants at risk for type 2 diabetes mellitus (T2DM) and those with elevated HbA1c levels was significantly higher among men compared to women (35.6% vs. 35.1% for participants at risk for T2DM and 9.0% vs. 5.4% for elevated HbA1c, respectively; $p < 0.001$).

Furthermore, the mean age of individuals with elevated HbA1c levels (55.0 ± 7.2 years) was significantly higher than that of individuals at risk for diabetes (49.3 ± 9.9 years; $p < 0.001$). The prevalence of both participants at risk for diabetes mellitus and elevated HbA1c values increased significantly with age ($p < 0.001$). The lowest prevalence rates were observed in the 25–34 age group for both risk categories (18.9% and 0.56%, respectively). Conversely, the highest prevalence rates were recorded in the 55–64 age group, reaching 50.0% for those at risk and 16.9% for those with elevated HbA1c levels. Individuals with lower educational levels and lower income levels exhibited elevated HbA1c levels and a significantly higher risk of developing diabetes compared to those with higher education ($p < 0.001$) and higher income ($p < 0.001$). The participants' self-perceived health status differed significantly based on the presence of diabetes risk or above-target HbA1c levels ($p < 0.001$).

Specifically, participants at risk for diabetes mellitus perceived their health as “good” or “very good” in 36.3% and 25.0% of cases, respectively, while 40.7% and 28.2% reported “bad” or “very bad” health status. In contrast, participants with elevated HbA1c levels showed a markedly lower health perception; only 6.7% and 1.2% perceived their health as “good” or “very good,” respectively. Conversely, a significant proportion of this group reported their health status as “bad” (22.9%) or “very bad” (11.4%). Regarding patient awareness of their own health status, significant differences were observed across the three groups ($p < 0.001$). Among participants with normal HbA1c levels, 42.7% were aware of a chronic health condition diagnosed more than six months prior. This awareness level was

similar among those at risk for diabetes (43.0%), but dropped sharply to only 14.3% in the group with above-target HbA1c levels.

Conversely, when asked specifically about diabetes, 27.2% of those at risk and 64.7% of those with elevated HbA1c levels were aware of its status as a chronic disease ($p < 0.001$). In terms of self-management behavior, significant disparities were found in glycemic monitoring ($p < 0.001$). While 52.4% of individuals with normal HbA1c levels and 38.3% of those at risk for diabetes had measured their blood glucose within the past year, only 9.2% of participants with elevated HbA1c levels had performed this check. The prevalence of diabetes risk factors was notably high among participants with pre-existing cardiovascular comorbidities. Among patients registered with their family physicians for hypertension, 48.7% were categorized as being at risk for diabetes, while 18.7% exhibited elevated HbA1c levels.

Similarly, for those diagnosed with hypercholesterolemia, 48.5% were at risk for diabetes, and 18.7% had confirmed diabetes mellitus based on HbA1c values ($p < 0.001$). Regarding patients with a prior clinical diagnosis of Type 2 Diabetes Mellitus (T2DM), registered with their family physician, the biochemical analysis revealed varying levels of glycemic control: 7.9% maintained normal HbA1c levels, 27.1% were at risk for diabetes based on HbA1c values, and 65.0% had elevated HbA1c values consistent with active diabetes mellitus ($p < 0.001$).

The behavioral, clinical, and laboratory parameters of the study population, stratified by glycated hemoglobin (HbA1c) levels, are summarized in Table 2.

Table 2. Behaviors, clinical, and laboratory characteristics of the study population, stratified by glycated hemoglobin (HbA1c).

Variable	HbA1c ($\leq 5.6\%$)	HbA1c (5.7–6.4%)	HbA1c ($\geq 6.5\%$)	<i>p</i> Value
Smoking status % (95% CI)				
Current smokers	19.1 (17.0–21.0)	23.2 (20.9–25.7)	29.1 (23.9–35.0)	<0.001
Non-smokers	80.9 (79.0–82.7)	76.8 (74.3–79.1)	78.7 (77.2–80.1)	
Alcohol consumption % (95% CI)				
Never	34.9 (33.0–37.0)	38.4 (35.8–41.1)	40.5 (35.3–46.0)	0.034
Occasionally	35.0 (33.1–37.0)	35.2 (32.8–37.8)	31.8 (27.1–36.9)	
Frequent	30.0 (28.1–32.0)	26.3 (24.1–28.7)	27.7 (23.2–32.6)	
Binge drinking	36.8 (34.3–39.3)	37.5 (34.4–40.8)	40.3 (33.4–47.5)	
Light physical activity % (95% CI)				
Never	4.6 (3.8–5.6)	5.6 (4.5–6.9)	5.9 (4.0–8.6)	0.313
Daily	83.3 (81.8–84.8)	81.6 (79.5–83.5)	79.0 (74.3–83.1)	
1–3 days/week	6.5 (5.6–7.5)	7.8 (6.6–9.3)	8.7 (6.4–11.8)	
4–7 days/week	5.1 (4.3–6.0)	4.6 (3.7–5.8)	6.1 (3.9–9.6)	
<20 min	11.6 (10.4–12.9)	11.6 (10.0–13.3)	15.8 (16.7)	0.064
>20 min	87.2 (85.8–88.5)	87.7 (86.0–89.3)	83.2 (79.1–86.7)	
Moderate physical activity % (95% CI)				
Never	8.0 (6.9–9.2)	9.8 (8.2–11.6)	9.5 (6.9–12.9)	<0.001
Daily	67.2 (65.1–69.1)	63.7 (61.1–66.2)	66.4 (61.0–71.3)	
1–3 days/week	13.9 (12.6–15.2)	16.7 (15.0–18.6)	14.6 (13.5–15.7)	
4–7 days/week	10.4 (9.2–11.7)	8.8 (7.5–10.3)	13.2 (9.9–17.5)	
<20 min	11.2 (10.0–12.5)	18.8 (11.2–14.5)	17.3 (13.7–21.7)	0.018
>20 min	87.5 (86.1–88.8)	86.2 (84.4–87.8)	81.5 (77.1–85.3)	
Intense physical activity % (95% CI)				
Never	53.2 (51.1–55.4)	58.2 (55.6–60.8)	68.5 (63.3–73.4)	<0.001
Daily	15.0 (13.4–16.8)	15.6 (13.7–17.7)	9.9 (7.3–13.4)	
1–3 days/week	14.7 (13.3–16.2)	11.7 (10.2–13.4)	10.3 (7.2–14.4)	
4–7 days/week	13.0 (11.7–14.4)	10.4 (9.0–12.0)	9.2 (6.5–12.9)	
<20 min	22.0 (19.8–24.5)	26.6 (23.3–30.2)	35.7 (27.5–44.9)	<0.005
>20 min	70.9 (68.2–73.4)	65.2 (61.2–68.9)	59.2 (49.9–67.8)	

Table 2. Cont.

Variable	HbA1c ($\leq 5.6\%$)	HbA1c (5.7–6.4%)	HbA1c ($\geq 6.5\%$)	p Value
BMI * (kg/m ²) (mean $\pm$ SE)	26.5 $\pm$ 0.1	29.6 $\pm$ 0.14	33.05 $\pm$ 0.32	<0.001
Ponderal status % (95% CI)				
Underweight	2.6 (2.1–3.2)	0.6 (0.4–1.0)	0.2 (0.0–1.4)	<0.001
Normal	38.9 (37.0–40.8)	19.1 (17.3–21.0)	5.5 (3.6–8.4)	
Overweight	36.6 (34.8–38.4)	37.4 (35.1–39.7)	26.8 (22.4–31.7)	
Obese	22.0 (20.5–23.6)	42.9 (40.5–45.3)	67.5 (62.3–72.2)	
Metabolic syndrome				
SBP *** (mmHg) (mean $\pm$ SE)	128.0 $\pm$ 0.38	134.6 $\pm$ 0.46	143.6 $\pm$ 1.08	<0.001
DBP **** (mmHg) (mean $\pm$ SE)	78.9 $\pm$ 0.27	82.3 $\pm$ 0.32	85.8 $\pm$ 0.65	<0.001
BP ** (SBP > 130 mmHg; DBP > 85 mmHg) % (95% CI)	45.6 (43.5–47.7)	61.6 (59.3–63.9)	80.6 (76.6–84.6)	<0.001
AC ***** (mean $\pm$ SE)				
Female	86.2 $\pm$ 0.38	95.9 $\pm$ 0.49	109.2 $\pm$ 1.31	<0.001
Male	96.8 $\pm$ 0.39	103.2 $\pm$ 0.54	111.3 $\pm$ 0.93	<0.001
AC ***** % (95% CI)				
Female (>88 cm)	41.7 (39.1–44.3)	69.8 (66.8–72.6)	94.7 (90.4–97.1)	<0.001
Male (>102 cm)	31.1 (28.3–34.1)	49.6 (45.9–53.3)	74.6 (67.7–80.4)	<0.001
HDL ***** (mean $\pm$ SE)				
Female	56.7 $\pm$ 0.4	52.5 $\pm$ 0.4	46.5 $\pm$ 0.8	<0.001
Male	48.4 $\pm$ 0.4	44.9 $\pm$ 0.4	40.2 $\pm$ 0.8	<0.001
HDL ***** % (95% CI)				
Female (>50 mg/dL)	34.7 (32.5–36.9)	46.0 (42.8–49.2)	64.0 (56.4–70.9)	<0.001
Male (>40 mg/dL)	27.9 (25.4–30.5)	36.7 (33.4–40.0)	54.8 (47.5–61.9)	<0.001
HDL ***** % (95% CI)	31.4 (29.7–33.1)	41.3 (39.0–43.6)	58.2 (52.9–63.4)	<0.001
TG ***** (mean $\pm$ SE)	113.7 $\pm$ 1.63	137.9 $\pm$ 2.2	200.5 $\pm$ 9.1	<0.001
TG ***** (>150 mg/dL) % (95% CI)	20.0 (18.6–21.6)	30.7 (28.5–33.0)	52.3 (47.2–57.3)	<0.001
Fasting plasma glucose (mean $\pm$ SE)	91.9 $\pm$ 0.2	99.6 $\pm$ 0.4	163.8 $\pm$ 3.4	<0.001
Fasting plasma glucose (≥ 100 mg/dL) % (95% CI)	5.2 (4.4–6.1)	18.9 (17.1–20.9)	89.1 (85.2–92.2)	<0.001
Metabolic syndrome % (95% CI)	17.4 (16.0–18.9)	39.2 (36.8–41.6)	83.3 (78.8–87.0)	<0.001

* BMI = Body Mass Index, ** BP = Blood pressure, *** SBP = Systolic blood pressure, **** DBP = diastolic blood pressure, ***** AC = Abdominal Circumference, ***** HDL = High-density lipoprotein, ***** TG = Triglycerides, HbA1c = Glycated hemoglobin. Data were analyzed using the Complex Samples module in SPSS, version 29.0 (IBM Corp., Armonk, NY, USA). For continuous variables statistical significance was evaluated using the design-adjusted Wald F test. Associations between categorical variables were assessed using the adjusted as a variant of Rao–Scott adjusted chi-square test.

Regarding smoking status, a higher prevalence of ex-smokers was observed in the group with elevated HbA1c levels (19.8%) compared to both the group at risk for diabetes (16.4%) and the group with normal HbA1c levels (12.9%; $p < 0.001$). Regarding alcohol consumption, the prevalence of binge drinking increased with increasing HbA1c levels. However, the proportion of participants who never consumed alcohol is higher for those with elevated HbA1c levels (40.53%) compared to those at risk of type 2 diabetes (38.2%) and those with normal HbA1c levels (34.9%). In contrast, physical activity frequencies were strongly associated with HbA1c levels ($p < 0.001$). Furthermore, among participants who devoted more than 20 min to intense physical activity on a typical day, 65.2% were identified as being at increased risk for diabetes, while 59.2% exhibited abnormal HbA1c levels ($p < 0.001$). The body mass index mean was significantly higher in prediabetes and diabetes groups ($p < 0.001$). Moreover, the prevalence of obesity is higher in prediabetes and diabetes groups $p < 0.001$). Consistent with these findings, all components of the metabolic syndrome exhibited a significantly higher prevalence among participants at high risk of

diabetes and those with abnormal HbA1c levels compared to individuals with normal glycemic status ($p < 0.001$). The relationship between HbA1c levels and associated factors was assessed using Spearman's rho correlation coefficient. The results are presented in Supplementary Table S1.

The HbA1c level is correlated with some socio-demographic characteristics of the participants (positively with age, male gender and negatively with education level). Also, the HbA1c level correlated negatively with the perception of health status and with accessibility at health services for clinical (blood pressure) and paraclinical (serum cholesterol and fasting blood glucose) monitoring; participants with higher HbA1c levels monitored these parameters at shorter period of time. The awareness of the chronic diseases and the use of prescription medications for these diseases correlated with the HbA1c level. The correlation between chronic diseases and HbA1c level was further supported by the Spearman coefficient, which demonstrated a significant correlation. The HbA1c level is correlated with the metabolic syndrome components (positively with blood pressure, abdominal circumference, triglycerides, and fasting blood sugar, and negatively with HDL cholesterol).

Paradoxically, the HbA1c level correlated negatively with alcohol consumption frequency (the HbA1c level increases when the alcohol consumption frequency decreases). The HbA1c level is correlated with the frequency of intense physical activity and with moderate and intense physical activity duration (>20 min). Also, it is correlated with the ponderal status; the higher HbA1c level is associated with a higher body mass index.

The relationship between factors associated with HbA1c levels was assessed using odds ratios (ORs). A multinomial logistic regression model was fitted with HbA1c categories as the dependent variable (normal HbA1c $< 5.7\%$, prediabetes $5.7\text{--}6.4\%$, and diabetes $\geq 6.5\%$). Participants with HbA1c $< 5.7\%$ served as the reference category. Adjusted odds ratios (ORs) and 95% confidence intervals (95% CI) were estimated simultaneously for the prediabetes and diabetes categories. The results are presented in Figures 2 and 3 and in Supplementary Figures S1 and S2. The presence of metabolic syndrome was significantly associated with higher HbA1c levels (OR = 3.06, 95% CI: 2.67–3.52, $p < 0.001$). Abdominal circumference was associated with higher odds of prediabetes in both sexes; however, the magnitude of the association was greater among women (OR = 3.23, 95% CI: 2.74–3.81) than among men (OR = 2.17, 95% CI: 1.79–2.64). Participants reporting better perceived health had lower odds of HbA1c $\geq 6.5\%$, whereas awareness of diabetes, the use of prescribed medication for diabetes, and recent measurements of blood pressure were associated with higher odds of elevated HbA1c levels. Weight status, as a consequence of unhealthy dietary behaviors and a sedentary lifestyle, was associated with higher glycated hemoglobin (HbA1c) levels.

A multiple linear regression analysis was performed to identify the key predictors associated with glycated hemoglobin (HbA1c) levels. Fasting plasma glucose (FPG) emerged as the strongest predictor. Consequently, three distinct models were developed to evaluate the influence of various clinical and demographic parameters: Model 1 evaluated the isolated impact of fasting glycemia as a primary predictor of HbA1c levels. Model 2 excluded fasting glycemia to assess the cumulative effect of other statistically significant parameters. This model included age, ponderal status, sex and metabolic syndrome. Model 3: integrated fasting glycemia alongside other significant variables, specifically age, ponderal status, sex and metabolic syndrome, to provide a comprehensive predictive framework (Table 3).

Statistical significance was assessed using design-adjusted t -tests. Using variables that are significantly associated with glycated hemoglobin levels, we can obtain prediction scores for the glycated hemoglobin category. It is possible to accurately predict a person's glycated hemoglobin level based on fasting blood glucose. The regression equation for fasting blood glucose is $= 3.524 + 0.012 \times \text{fasting blood glucose}$. The glycated hemoglobin pre-

diction score for model 2 excludes fasting blood glucose. The regression model utilized to estimate the Score for Model 2 is expressed as: $\text{Score model 2} = 5.558 + 0.017 \times \text{age (years)} + 0.078 \times \text{weight status (1 = underweight; 2 = normal weight; 3 = overweight; 4 = obese)} - 0.442 \times \text{metabolic syndrome (2 = no; 1 = yes)}$. The regression equation for model 3 = $3.197 + 0.021 \times \text{fasting blood glucose (mg/dL)} + 0.007 \times \text{age (years)} + 0.049 \times \text{weight status (1 = underweight; 2 = normal weight; 3 = overweight; 4 = obese)} + 0.087 \times \text{sex (2 = female; 1 = male)} - 0.077 \times \text{metabolic syndrome (2 = no; 1 = yes)}$.

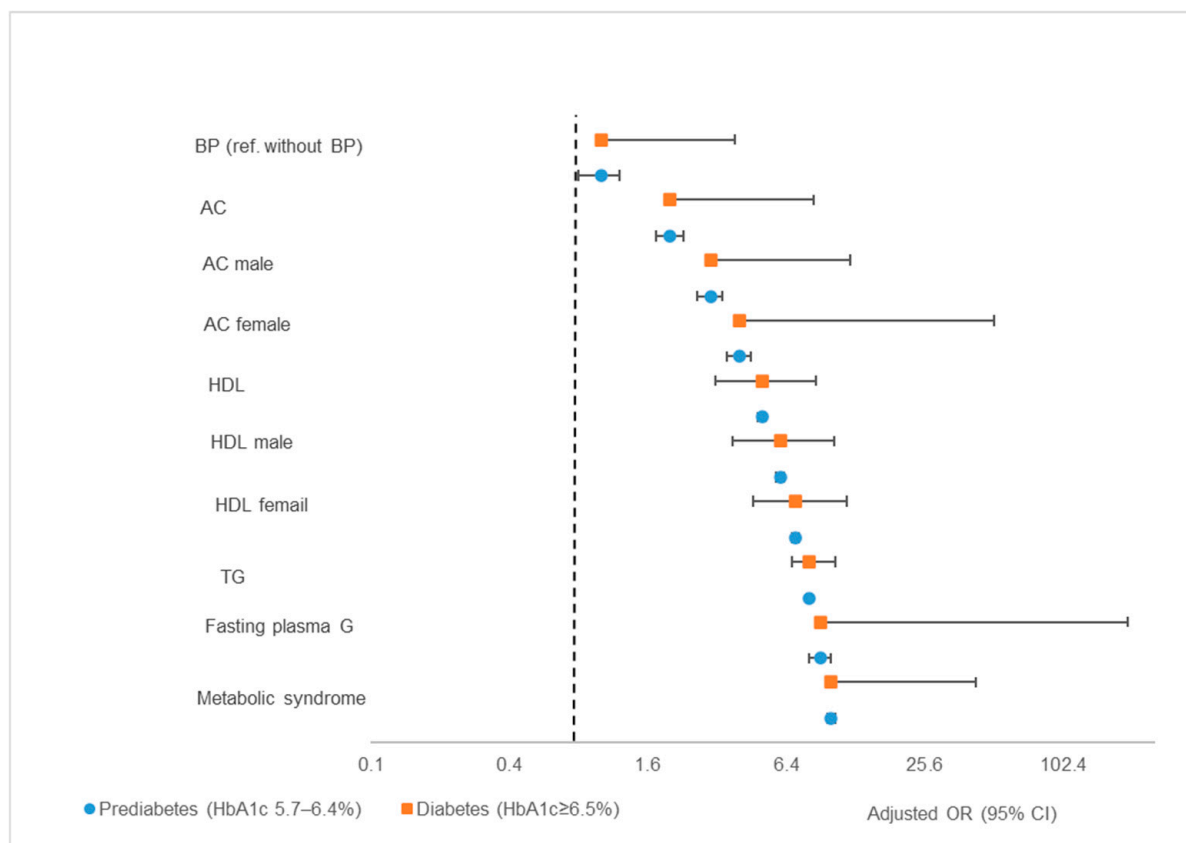


Figure 2. Adjusted odds ratios (95% CI) for metabolic syndrome predictors of prediabetes (HbA1c 5.7–6.4%) and diabetes (HbA1c $\geq$ 6.5%) from the multinomial logistic regression model.

Table 3. Logistic regression models predicting HbA1c level.

Parameter	* B	** SE	<i>p</i> Value	95% CI ***	
				Lower	Upper
Model 1					
Fasting blood sugar	0.022	0.001	<0.001	0.020	0.024
Model 2					
Age	0.017	0.001	<0.001	0.015	0.019
Ponderal status	0.078	0.013	<0.001	0.053	0.103
Sex	−0.065	0.021	0.002	−0.106	−0.023
Metabolic syndrome	−0.442	0.029	<0.001	−0.499	−0.386
Model 3					
Fasting blood sugar	0.021	0.001	<0.001	0.019	0.023
Age	0.007	0.001	<0.001	0.005	0.009
Ponderal status	0.049	0.010	<0.001	0.030	0.068
Sex	0.087	0.016	<0.001	0.056	0.118
Metabolic syndrome	−0.077	0.022	0.001	−0.121	−0.033

* B = unstandardized coefficient; ** SE = standard error; *** CI = confidence interval for B.

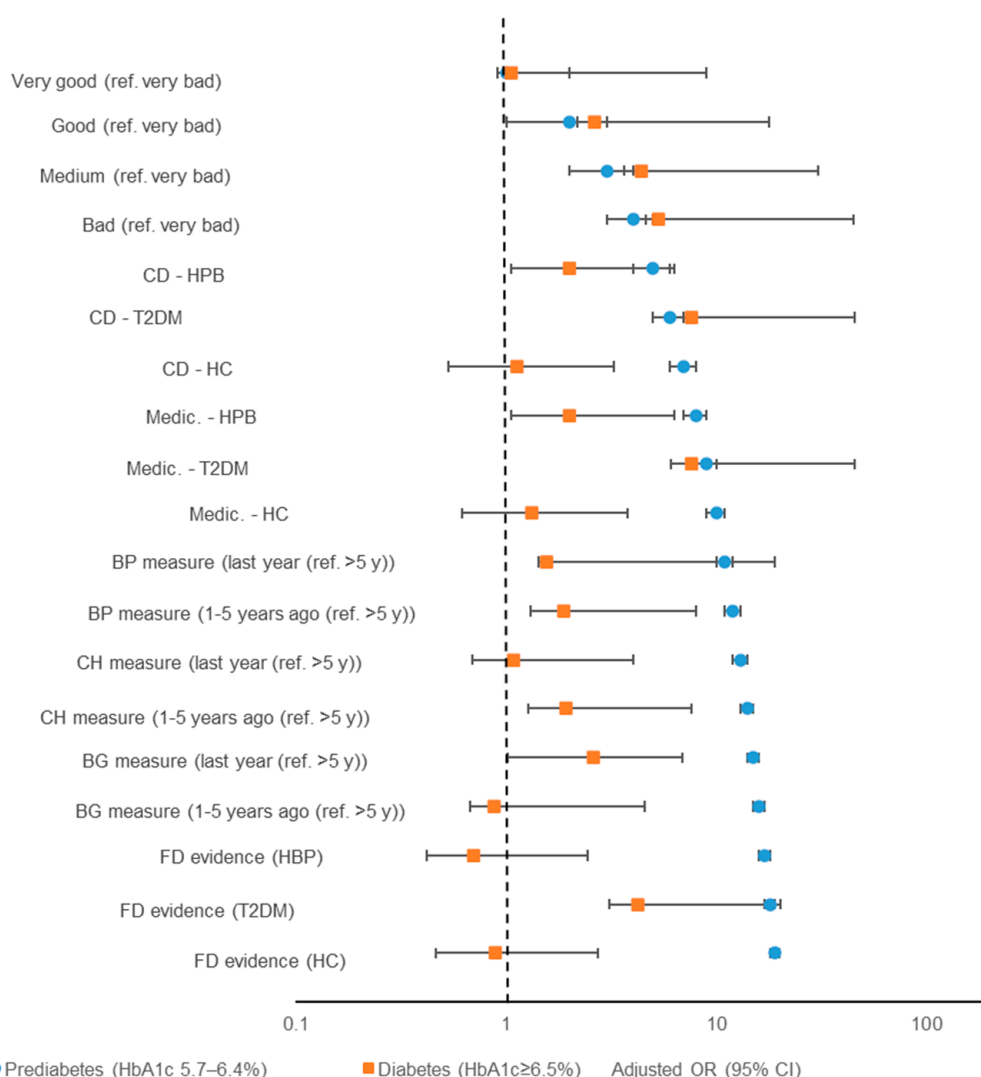


Figure 3. Adjusted odds ratios (95% CI) for patient perception of health status predictors of prediabetes (HbA1c 5.7–6.4%) and diabetes (HbA1c $\geq$ 6.5%) from the multinomial logistic regression model.

4. Discussion

In this representative sample of 5380 Romanian adults aged 25–64 years, the prevalence of elevated HbA1c ($\geq$ 6.5%) was 7.1%, while prediabetes (5.7–6.4%) reached 35.4%, with consistently higher values among men [71,78].

These estimates align broadly with national diabetes prevalence data [20]; however, some individuals with clinically diagnosed diabetes exhibited HbA1c values below the diagnostic threshold, misclassifying them into high-risk or normoglycemic categories. This diagnostic discordance is well documented, as HbA1c-based definitions may shift population prevalence estimates relative to fasting glucose-based criteria [79].

The prevalence observed in the Romanian population in this analysis, compared with the results of the cross-sectional study from UK Biobank that assessed the prevalence of diabetes and prediabetes using the HbA1c levels, is approximately ten times higher for prediabetes, and about twice as high for diabetes [80].

Because diabetes prevalence is typically estimated using fasting glucose and HbA1c, studies employing different diagnostic criteria often report markedly different prevalence rates across populations [81,82].

Self-perceived health status showed a clear gradient across glycemic categories: only 1.2% of individuals with elevated HbA1c reported good health, whereas 73.8% of those

rating their health as very good had normal HbA1c values. To our knowledge, this study is among the first to evaluate the association between self-perceived health and HbA1c levels in a Romanian adult population. Better self-perceived health was independently associated with lower odds of HbA1c ($\geq 6.5\%$), a finding consistent with evidence indicating that individuals who perceive their health positively tend to have fewer comorbidities, healthier behaviors, and higher treatment adherence, all contributing to improved glycemic control [83–86]. Conversely, poor self-rated health may reflect underlying metabolic risk, psychological distress, or early symptoms of dysglycemia, which are associated with higher HbA1c levels [87,88].

Awareness of chronic conditions such as hypertension, diabetes, or hypercholesterolemia was also linked to normal HbA1c values, likely reflecting greater engagement with healthcare services, adherence to medical recommendations, and motivation to adopt healthier behaviors. This interpretation is supported by the lower prevalence of smoking and the higher frequency and duration of high-intensity physical activity among individuals with normal HbA1c [89–91].

The sole exception was alcohol consumption, which appeared associated with normal HbA1c; this counterintuitive pattern may be explained by underreporting, particularly among individuals previously advised to reduce intake [67].

Furthermore, participants with normal HbA1c also demonstrated more proactive health monitoring behaviors, especially regarding blood pressure, glucose, and cholesterol measurements. In contrast, individuals registered with their family physician as having hypertension, diabetes, or hypercholesterolemia exhibited higher HbA1c levels, likely reflecting symptomatic disease prompting medical consultation and diagnosis, consistent with findings from other populations [92,93].

Body mass index (BMI) was a strong predictor of elevated HbA1c levels in our study. Although BMI is widely used in epidemiological research and remains a practical and internationally accepted indicator for assessing obesity and diabetes risk at the population level, it does not distinguish between fat mass and lean mass, which may lead to misclassification of metabolic risk. Therefore, variations in body composition and skeletal frame size should be considered when interpreting the association between BMI and glycemic status [94–97].

Components of the metabolic syndrome were consistently associated with dysglycemia, each increasing the likelihood of being classified either as high risk or as having elevated HbA1c. Abdominal obesity showed strong effects, with individuals being 2.6 times more likely to fall within the high-risk HbA1c range and 8.3 times more likely to exhibit HbA1c $\geq 6.5\%$. Elevated fasting glucose was the strongest predictor of abnormal HbA1c (OR = 84.72), a physiologically expected finding given that HbA1c reflects mean glycemia over the preceding 8–12 weeks. Abdominal circumference captures visceral adiposity—a key driver of insulin resistance—while fasting hyperglycemia reflects impaired glucose metabolism. These associations are consistent with established pathophysiological mechanisms and previous evidence [98,99].

Urban-rural differences also emerged. Rural residents exhibited a lower prevalence of elevated HbA1c, a pattern that is aligned with their substantially higher levels of daily physical activity across all intensity categories—light (88.1% vs. 77.5%), moderate (76.8% vs. 56.4%) and vigorous (19.9% vs. 10.5%)—compared with urban residents. In our analysis, regular vigorous physical activity was strongly associated with reduced odds of high-risk HbA1c and abnormal glycemia, suggesting that the more active lifestyle characteristic of rural populations may contribute to improved glucose metabolism. These findings are consistent with extensive evidence linking physical activity to lower type 2 diabetes risk.

Nevertheless, urban-rural differences in glycemic status are likely multifactorial and may also reflect variations in socioeconomic conditions, dietary habits, healthcare access, and other health-related behaviors [100–103].

Although dietary habits were not assessed in the present study, nutrition is a well-established determinant of type 2 diabetes risk and glycemic control. Previous studies have shown that healthy dietary patterns—particularly those rich in fruits, vegetables, whole grains, and other plant-based foods—are associated with a lower risk of developing type 2 diabetes and with improved metabolic outcomes. However, the present study examined only the association between metabolic factors, without considering nutritional status or its potential impact on these metabolic determinants [104–106].

The findings of this study have important public health implications. The relatively high prevalence of undiagnosed diabetes and elevated HbA1c levels indicates that a substantial proportion of Romanian adults may remain unaware of their glycemic status, potentially delaying diagnosis and increasing the risk of diabetes-related complications. These results highlight the need to strengthen population-based screening and early detection strategies, particularly among individuals with established risk factors such as older age, obesity, hypertension, and low levels of physical activity.

The strong association observed between physical activity and HbA1c levels further highlights the importance of lifestyle-based prevention measures. Public health interventions that promote regular physical activity, healthy dietary habits, weight management, and cardiovascular risk reduction may contribute to lowering the burden of type 2 diabetes. Moreover, targeted health promotion programs should prioritize high-risk groups identified in this study, with particular attention to individuals with obesity and other metabolic risk factors.

5. Conclusions

This comprehensive epidemiological assessment reveals a disproportionately high prevalence of elevated HbA1c and prediabetic states among Romanian adults compared to an international study using identical diagnostic criteria. Our findings suggest that awareness of chronic conditions serves as a critical catalyst for health-seeking behaviors, including enhanced physical activity and proactive metabolic monitoring. Furthermore, this study identifies key modifiable determinants of dysglycemia, positioning abdominal obesity, metabolic syndrome components, and physical inactivity as primary drivers of adverse glycemic status. The robust associations observed underscore an urgent need for targeted, multi-sectoral public health interventions focused on weight management, active lifestyle promotion, and early metabolic screening to mitigate the future burden of type 2 diabetes and its associated complications in Romania.

Limitations

Relying solely on HbA1c to estimate diabetes prevalence introduces several limitations, as its accuracy is affected by laboratory standardization issues and non-glycemic factors (e.g., age, anemia, hemoglobinopathies, and renal disease), potentially leading to misclassification and an underestimation of early or isolated postprandial hyperglycemia. Methodologically, the generalizability of our findings is limited by the exclusion of individuals over 65 years, a demographic with a higher risk for metabolic conditions. Furthermore, this study did not evaluate dietary behaviors, a critical factor influencing glycated hemoglobin levels. Consequently, future population-based research in Romania should incorporate comprehensive assessments of nutritional habits, aligning with public health prevention strategies.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/diabetology7070138/s1>. Supplementary Table S1. Correlation between factors associated with glycated hemoglobin values (HbA1c). Figure S1. Adjusted odds ratios (95% CI) for socio-demographic predictors of prediabetes (HbA1c 5.7–6.4%) and diabetes (HbA1c $\geq$ 6.5%) from the multinomial logistic regression model. Figure S2. Adjusted odds ratios (95% CI) for behaviors predictors of prediabetes (HbA1c 5.7–6.4%) and diabetes (HbA1c $\geq$ 6.5%) from the multinomial logistic regression model.

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Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of the National Institute of Public Health, number 2857 from 17 February 2022.

Informed Consent Statement: Mandatory informed consent was obtained from all subjects involved in this study.

Data Availability Statement: The data presented in this study are available on request from the first author (lacramioara.brinduse@umfcd.ro).

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Abbreviations

The following abbreviations are used in this manuscript:

EHES	European Health Examination Survey
HbA1c	Glycated hemoglobin
T2DM	Type 2 Diabetes Mellitus

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