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Research article

Evaluation of the Metabolic Profile in Patients with Diabetes Mellitus from Rural and Urban Areas and Theoretical Potential of a Therapeutic Swimming Program

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Abstract: Diabetes mellitus remains a major public health problem, with disparities in metabolic control influenced by environmental, lifestyle, and socioeconomic factors. To compare metabolic parameters and diabetes-related complications between patients from rural and urban areas and to outline a theoretical therapeutic swimming program that could support metabolic control. A cross-sectional observational study including 72 adults (19–83 years) with type 1 or type 2 diabetes was conducted in a tertiary diabetes center. Clinical and metabolic parameters assessed included HbA1c, BMI, blood pressure, hyperglycemia score, renal function (eGFR), and presence of nephropathy, hypertension, and coronary ischemic heart disease (CIHD). Descriptive statistics and Pearson correlations were used. The swimming program proposed represents a theoretical model and was not implemented in this cohort. Significant urban–rural differences were observed. Urban patients tended to have higher BMI and prevalence of hypertension, while rural patients showed higher HbA1c values and greater prevalence of nephropathy. Sex-specific differences were also present: women from rural areas exhibited the strongest correlation between HbA1c and hyperglycemia score (r=1.00), whereas in men the correlation was weak or absent. Renal impairment was more prevalent in rural populations and correlated strongly with elevated BMI, hypertension, and lower eGFR. The metabolic and cardiovascular risk profile differs substantially between rural and urban patients, suggesting the need for tailored prevention and intervention strategies. A structured swimming-based program may represent a feasible adjunct to metabolic control, but requires future interventional trials.

Keywords: diabetes mellitus, metabolic profile, hyperglycemia, rural–urban disparities, therapeutic swimming, nephropathy

1. Introduction

Diabetes mellitus (DM) is a major public health issue, affecting millions of individuals and being associated with increased morbidity and mortality [1]. The disease is characterized by hyperglycemia resulting from defects in insulin secretion or action [2]. Approximately 537 million adults are living with diabetes, a number that continues to rise, particularly in resource-limited settings. Type 2 diabetes mellitus (T2DM) is the most prevalent form, driven by insulin resistance and a relative deficiency of insulin secretion, and is frequently associated with obesity, dyslipidemia, and cardiovascular disease [3,4]. Comorbidities significantly increase mortality risk, and the progression of the disease in low-income countries underscores the critical importance of preventive strategies [6,7].

Recent research has enhanced the understanding of metabolic mechanisms and diagnostic approaches, including rapid and non-invasive techniques for detecting chronic kidney disease (CKD) in patients with T2DM [8,9]. Lifestyle interventions—dietary management, physical activity, and patient education—are essential components of disease control [10]. Physical activity improves insulin sensitivity, reduces glucose resistance, and lowers HbA1c levels [11,12]. Aerobic exercise attenuates oxidative stress and inflammation, key factors in the progression of T2DM [13].

Water-based training provides benefits comparable to land-based exercise, with reduced joint impact and improved cardiovascular workload management [14]. Studies demonstrate enhanced glucose response during aquatic circuit training [15] and positive effects of regular swimming on glycemic control and body composition [16]. Hydrotherapy programs may improve overall health status [17] and functional capacity [18]. Physical activity also offers psychological benefits, promoting greater treatment adherence [19]. Personalized exercise programs reduce the risk of hypoglycemia and optimize metabolic control [20,21]. Moderately intense, consistent, and supervised physical activity improves glycemic control and lowers cardiovascular risk [12].

Rural–urban differences in obesity and chronic disease prevalence are influenced by variations in physical activity levels and dietary patterns [22].

2. Results

For the group of women residing in urban areas (N = 21), the interpretation of the metabolic and anthropometric parameters is as follows: The study cohort consists of adult women aged 24 to 81 years (mean = 55.52 years), indicating a mature and heterogeneous population suitable for assessing natural variability in metabolic and clinical parameters.

The mean HbA1c value of 9.09% reflects suboptimal glycemic control. The quartiles show that 25% of the participants have HbA1c ≤ 7.78% (Q1) and 50% ≤ 8.6% (Q2), indicating that a subset of the group approaches the recommended target of 7%. Variability is moderate (SD = 1.60; CV% = 17.58%), suggesting substantial inter-individual differences.

The mean body mass index (BMI) of 28.3 kg/m² places most women in the overweight category, with values ranging from 17.2 to 52 kg/m². The BMI quartiles (Q1 = 23, Q2 = 26) show that 25% of the participants have a near-normal body weight, and half have a BMI ≤ 26 kg/m². The high variability (SD = 9.04; CV% = 31.94%) reflects the heterogeneity of the population with respect to body mass (Figure 1).

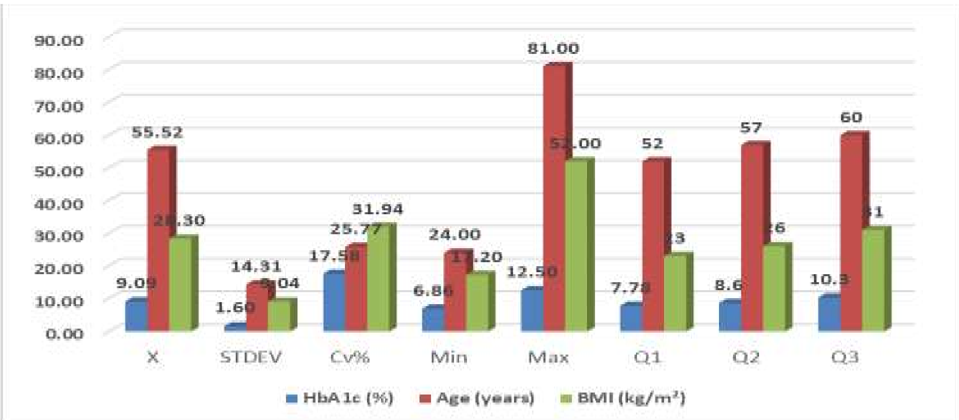

Figure 1. Analysis of metabolic and anthropometric parameters in urban-dwelling women (N = 21).

Regarding hyperglycemia, the mean score of 1.57 (range 0–3) indicates the presence of mild to moderate episodes within the group. The relatively high variability (SD = 0.75; CV% = 47.50%) reflects substantial inter-individual differences, with 25% of the participants having a score ≤ 1 and 75% ≤ 2, suggesting that most women do not experience severe hyperglycemia.

The prevalence of coronary ischemic heart disease (CIHD) was 57% (mean = 0.57, range 0–1), accompanied by high variability (CV% = 88.74%), indicating that approximately half of the participants have this comorbidity.

Arterial hypertension (HTN) was present in 76% of the women (mean = 0.76, range 0–1), with moderate variability (CV% = 57.28%). The quartile distribution shows that at least half of the participants have HTN, while one-quarter do not present this condition (Figure 2).

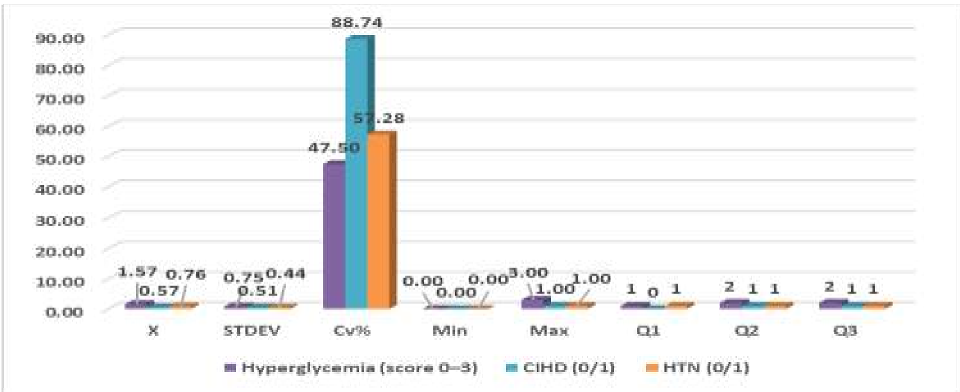

Figure 2. Analysis of clinical parameters and comorbidities in urban-dwelling women (N = 21).

Considering systolic (SBP) and diastolic blood pressure (DBP), the mean values of 140 mmHg for SBP and 78.48 mmHg for DBP indicate slightly elevated levels, characteristic of a group with increased cardiovascular risk. Relative variability is moderate (SD SBP = 24.12, CV% = 17.23%; SD DBP = 14.55, CV% = 18.53%), reflecting inter-individual differences in blood pressure values. The quartiles show that 25% of participants have SBP ≤ 120 mmHg and DBP ≤ 65 mmHg (Q1), 50% have values ≤ 140/80 mmHg (Q2, median), and 75% have values ≤ 160/90 mmHg (Q3), suggesting that most women exhibit mild to moderate hypertension.

Renal function, assessed through eGFR (ml/min/1.73 m²), had a mean value of 79.57, with high variability (SD = 31.12, CV% = 39.10%) and a wide range (min 10, max 112), indicating that while some participants present normal renal function, others exhibit significant impairment. The quartiles (Q1 = 65, Q2 = 94, Q3 = 100) show that half of the women have eGFR ≥ 94 ml/min/1.73 m², whereas one-quarter fall below 65, highlighting the heterogeneity of the group and the presence of individuals at increased risk for chronic kidney disease.

Diabetic nephropathy (coded as 0/1) was present in approximately 48% of the participants (mean = 0.48), with very high variability (SD = 0.51, CV% = 107.47%), indicating that nearly half of the women exhibit signs of renal impairment while the remainder do not. The quartile distribution shows that at least half of the participants present no evidence of nephropathy (Q2 = 0), while one-quarter are affected (Q3 = 1) (Figure 3).

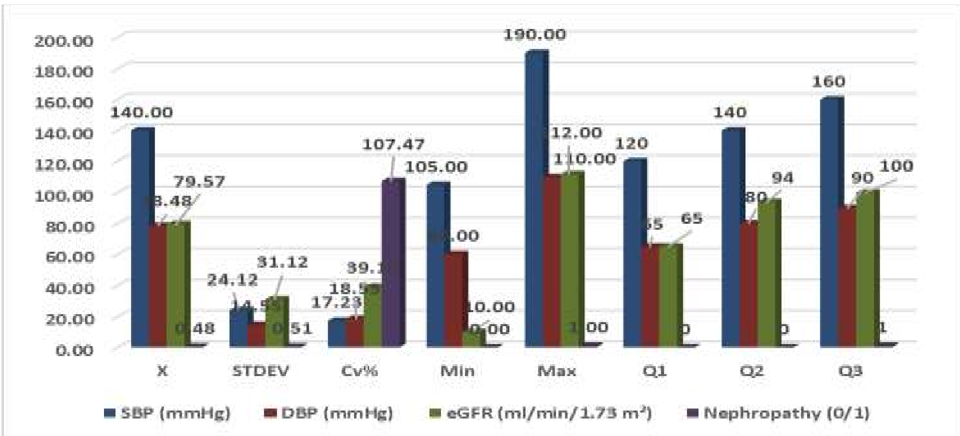

Figure 3. Cardiovascular and renal parameters in urban-dwelling women (N = 21).

For the group of women residing in rural areas (N = 18), the interpretation of metabolic and anthropometric parameters is as follows: Long-term glycemic control, assessed through HbA1c (%), shows a mean value of 9.58%, substantially above the recommended target of 7%, indicating insufficient glycemic control within the group. The relatively moderate variability (SD = 1.45, CV% = 15.11%) suggests that most participants exhibit elevated values, with only a few exceptions. The range was 7.09–12.10%, and the quartiles indicate that 25% of participants have HbA1c ≤ 8.35%, 50% ≤ 9.30%, and 75% ≤ 11.03%, showing that the majority present persistently high glycemic levels.

The mean age was 47.72 years, with high variability (SD = 15.42, CV% = 32.32%) and a range of 19–64 years, reflecting a heterogeneous sample that includes young adults as well as middle-aged and older women. The quartiles (Q1 = 37.25, Q2 = 53.50, Q3 = 59.75) indicate that half of the participants fall between 37 and 60 years, a range associated with increased risk of diabetes-related complications.

The mean body mass index (BMI) was 28.89 kg/m², corresponding to the overweight category, with moderate variability (SD = 6.14, CV% = 21.24%) and a range of 18.5–36 kg/m². Quartile values show that 25% of the women have BMI ≤ 23.13 (normal), half have BMI ≤ 30 (overweight), and 25% have BMI ≥ 34, indicating that the majority of women are overweight and at increased risk for metabolic and cardiovascular complications (Figure 4).

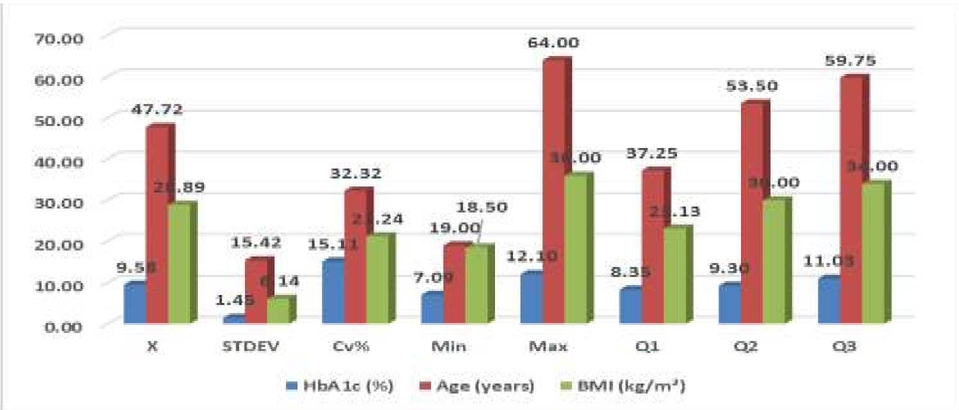

Figure 4. Analysis of metabolic and anthropometric parameters in rural-dwelling women (N = 18).

Hyperglycemia (score 0–3):
The mean score of 1.44 indicates the presence of mild to moderate hyperglycemic episodes within the group. The relatively high variability (SD = 0.62; CV% = 42.63%) suggests substantial inter-individual differences. The quartiles show that 25% of participants have a score ≤ 1 (Q1), the median is 1 (Q2), and 75% have a score ≤ 2 (Q3), indicating that most women do not experience severe hyperglycemia.

Coronary ischemic heart disease (CIHD, 0/1):
The mean prevalence of 37.17% reflects a moderate cardiovascular risk. The very high variability (SD = 49.43; CV% = 133.01%) indicates that approximately half of the women do not present CIHD, while one-quarter exhibit elevated levels of coronary impairment. The quartiles (Q1 = 0, Q2 = 17.5, Q3 = 56) confirm this heterogeneity.

Arterial hypertension (HTN, 0/1):
The mean value of 0.50 shows that approximately half of the participants are hypertensive. Variability is very high (SD = 0.51; CV% = 102.90%). The quartiles (Q1 = 0, Q2 = 0.50, Q3 = 1) indicate that half of the participants do not present hypertension, while at least one-quarter are hypertensive, highlighting the diversity within the group.

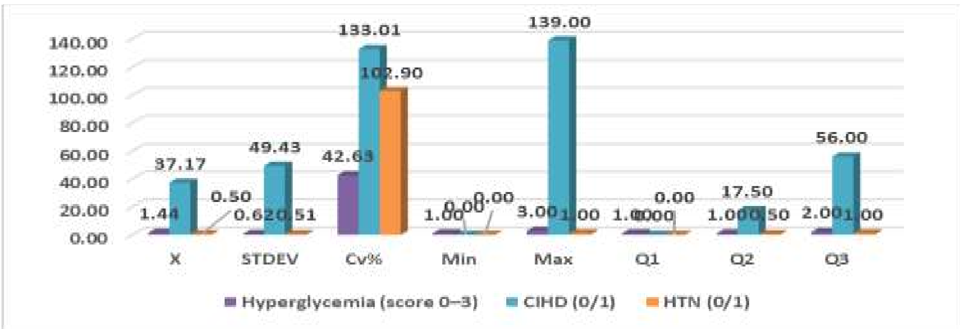

Figure 5. Analysis of clinical parameters and comorbidities in rural-dwelling women (N = 18).

Systolic (SBP) and diastolic blood pressure (DBP):
The mean SBP of 129.44 mmHg and DBP values of approximately 74–78 mmHg (the recorded value of 0.72 mmHg appears to be an error) indicate moderately elevated levels, characteristic of a group with mild to moderate cardiovascular risk. SBP variability is moderate (SD = 16; CV% = 12.36%). The SBP quartiles show that 25% of participants have SBP ≤ 120 mmHg (Q1), half have SBP ≤ 130 mmHg (Q2, median), and 75% have SBP ≤ 140 mmHg (Q3), suggesting that most women present mild to moderate hypertension.

Renal function (eGFR, ml/min/1.73 m²):
The mean eGFR of 74.94 indicates near-normal renal function, with some participants presenting moderate impairment. Variability is moderate (SD = 13.22; CV% = 17.65%), with a range of 60–110. The quartiles (Q1 = 65, Q2 = 72.5, Q3 = 82) show that half of the women have eGFR ≥ 72.5 ml/min/1.73 m², whereas one-quarter present values ≤ 65, indicating the presence of individuals at increased risk of renal involvement.

Diabetic nephropathy (0/1):
The mean prevalence of 85.28% and the quartile values (Q1 = 84.25, Q2 = 88.5, Q3 = 100) suggest that most participants exhibit signs of renal impairment. The variability (SD = 24.24; CV% = 28.42%) indicates some inter-individual differences; however, the overall prevalence of nephropathy is high within this rural cohort (Figure 6).

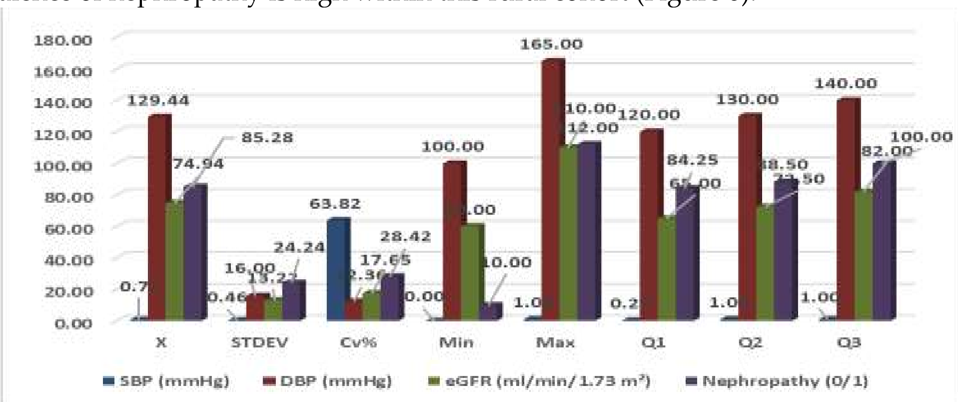

Figure 6. Cardiovascular and renal parameters in rural-dwelling women (N = 18).

For the group of men residing in urban areas (N = 20), the interpretation of metabolic and anthropometric parameters is as follows:

HbA1c (%):
The mean value of 8.64% indicates suboptimal glycemic control, exceeding the recommended target of 7%, suggesting that most patients experience chronic hyperglycemia. Variability is moderate (SD = 1.63; CV% = 18.88%), with a range of 5.4–11.3%, showing that while some individuals have near-normal values, others exhibit markedly poor

glycemic control. The quartiles (Q1 = 7.7; Q2 = 8.45; Q3 = 9.525) show that 25% of patients have HbA1c ≤ 7.7%, half have HbA1c ≤ 8.45%, and 75% ≤ 9.525%, indicating that the majority of men exceed the optimal glycemic threshold.

Age(years):

The mean age of 58.5 years reflects a mature cohort, predominantly characteristic of individuals with type 2 diabetes. Variability is moderate (SD = 15.02; CV% = 25.68%), with a wide range (23–83 years), suggesting the presence of both younger and older patients. The quartiles (Q1 = 50.5; Q2 = 62; Q3 = 68) show that half of the participants fall within the 50.5–68-year range.

Body mass index (BMI, kg/m²):

The mean BMI of 28.99 kg/m² places most men in the overweight category, associated with increased risk of metabolic and cardiovascular complications. Variability is relatively low (SD = 5.11; CV% = 17.62%), with values ranging from 20 to 41 kg/m². The quartiles (Q1 = 24.75; Q2 = 28.4; Q3 = 32.5) show that 25% of the patients have BMI ≤ 24.75 (normal or mildly overweight), half have BMI ≤ 28.4 (overweight), and 25% have BMI ≥ 32.5 (moderate to severe obesity).

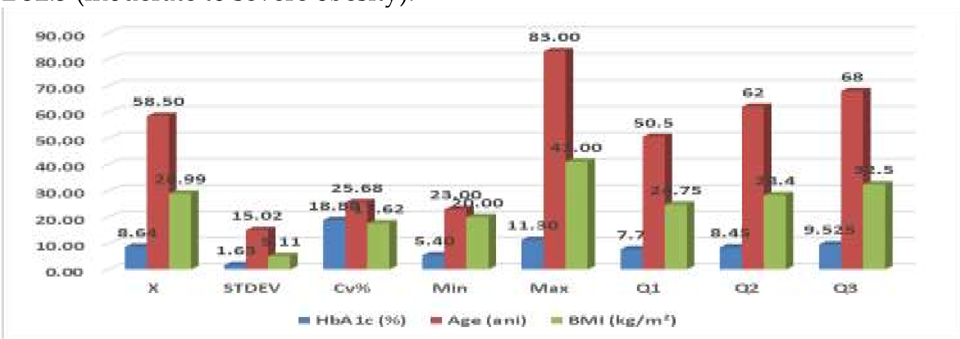

Figure 7. Mean values and distribution of HbA1c (%), age (years), and BMI (kg/m²) in urban-dwelling men (N = 20).

Hyperglycemia (score 0–3):

The mean score of 1.50 indicates the presence of mild to moderate hyperglycemic episodes. Variability is high (SD = 0.95; CV% = 63.06%), with values ranging from 0 to 3, reflecting substantial differences among patients—from normal glycemic levels to more severe episodes. The quartiles (Q1 = 1; Q2 = 1; Q3 = 2) show that 25% of participants have a score ≤ 1, half have a score ≤ 1, and 75% ≤ 2, indicating that most men exhibit mild to moderate hyperglycemia.

Coronary ischemic heart disease (CIHD, 0/1):

The mean value of 0.60 indicates that approximately 60% of patients present CIHD. Variability is high (SD = 0.50; CV% = 83.77%), reflecting that nearly half of the participants do not have coronary disease. The quartiles (Q1 = 0; Q2 = 1; Q3 = 1) show that half of the men present CIHD, while one-quarter have no evidence of the condition.

Arterial hypertension (HTN, 0/1):

The mean value of 0.70 indicates that 70% of the participants have hypertension. Variability is moderate (SD = 0.47; CV% = 67.17%), with values ranging from 0 to 1. The quartiles (Q1 = 0; Q2 = 1; Q3 = 1) indicate that at least half of the patients present HTN, while one-quarter do not, suggesting that most men in the group have mild to moderate hypertension (Figure 8).

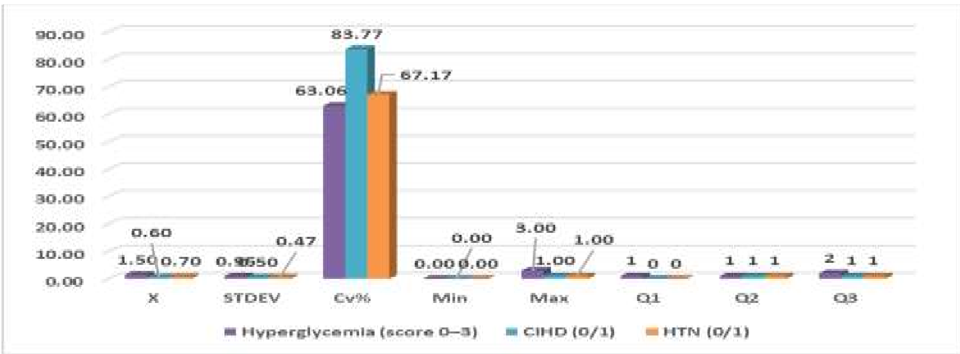

Figure 8. Metabolic and cardiovascular parameters in urban-dwelling men (N = 20).

Systolic blood pressure (SBP, mmHg) and diastolic blood pressure (DBP, mmHg):

The mean SBP of 129.3 mmHg and mean DBP of 73.9 mmHg indicate mildly elevated values, consistent with a moderate cardiovascular risk profile. Variability is moderate (SD SBP = 19.68, CV% = 15.22%; SD DBP = 11.42, CV% = 15.46%), demonstrating notable inter-individual differences in blood pressure levels. The quartiles show that 25% of patients have SBP ≤ 113.75 mmHg and DBP ≤ 65 mmHg (Q1), half have values ≤ 130/70 mmHg (Q2, median), and 75% ≤ 140.5/80 mmHg (Q3), suggesting that most men exhibit mild to moderate hypertension.

Renal function (eGFR, ml/min/1.73 m²):

The mean eGFR of 76.75 ml/min/1.73 m² indicates moderately preserved renal function, with high variability (SD = 25.40, CV% = 33.09%) and a wide range (min 10, max 110). This distribution shows that while some patients maintain normal renal function, others display significant impairment. The quartiles (Q1 = 62, Q2 = 86.5, Q3 = 93.75) demonstrate that half of the participants have eGFR ≥ 86.5, whereas one-quarter fall below 62, indicating the presence of individuals at elevated risk for chronic kidney disease.

Diabetic nephropathy (0/1):

The mean value of 0.50 indicates that approximately half of the patients present signs of diabetic nephropathy. Variability is very high (SD = 0.51, CV% = 102.6%), reflecting an almost equal distribution between those with and without renal involvement. The quartiles (Q1 = 0; Q2 = 0.5; Q3 = 1) confirm that 50% of participants show no evidence of nephropathy, while one-quarter exhibit clear renal impairment (Figure 9).

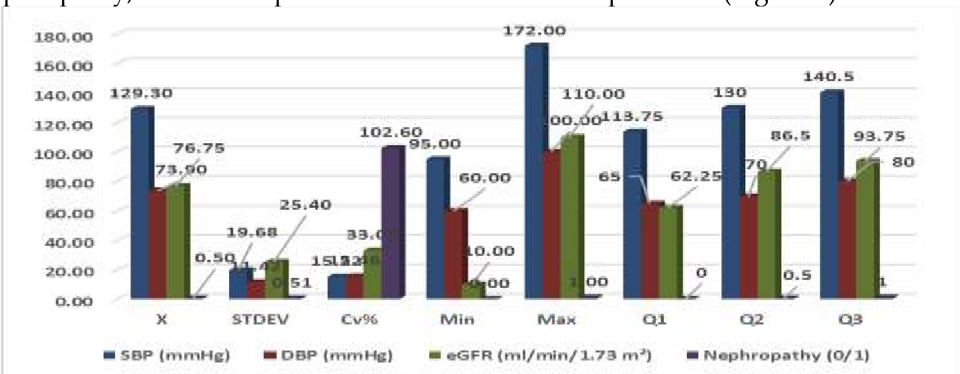

Figure 9. Cardiovascular and renal parameters in urban-dwelling men (N = 20).

For the group of men residing in rural areas (N = 13), the interpretation of anthropometric and metabolic parameters is as follows:

HbA1c (%):

The mean value of 8.78% indicates suboptimal glycemic control, exceeding the recommended target of 7%, suggesting the presence of chronic hyperglycemia in most patients. Variability is moderate (SD = 1.42; CV% = 16.22%), with a wide range (min 6.49 – max 16.22%), reflecting substantial inter-individual differences, from patients with near-normal values to those with very poor glycemic control. The quartiles (Q1 = 7.9;

Q2 = 8.73; Q3 = 9.2) show that 25% of patients have HbA1c ≤ 7.9%, half ≤ 8.73%, and 75% ≤ 9.2%, confirming that the majority exceed the optimal glycemic threshold.

Age (years):

The mean age of 48.31 years reflects a middle-aged cohort, typical of individuals with type 2 diabetes. Variability is moderate (SD = 13.90; CV% = 28.78%), with a range of 13.9–70 years, indicating that the sample includes both younger and older participants. The quartiles (Q1 = 44; Q2 = 52; Q3 = 57) show that half of the patients fall between 44 and 57 years.

Body mass index (BMI, kg/m²):

The mean BMI of 28.92 kg/m² places most men in the overweight category, associated with increased risk of metabolic and cardiovascular complications. Variability is relatively high (SD = 8.24; CV% = 28.49%), with values ranging from 21 to 45 kg/m², reflecting the heterogeneity of the group—from normal weight to severe obesity. The quartiles (Q1 = 22; Q2 = 26; Q3 = 34) show that 25% of participants have BMI ≤ 22 (normal weight), half ≤ 26 (overweight), and 25% ≥ 34 (severe obesity) (Figure 10).

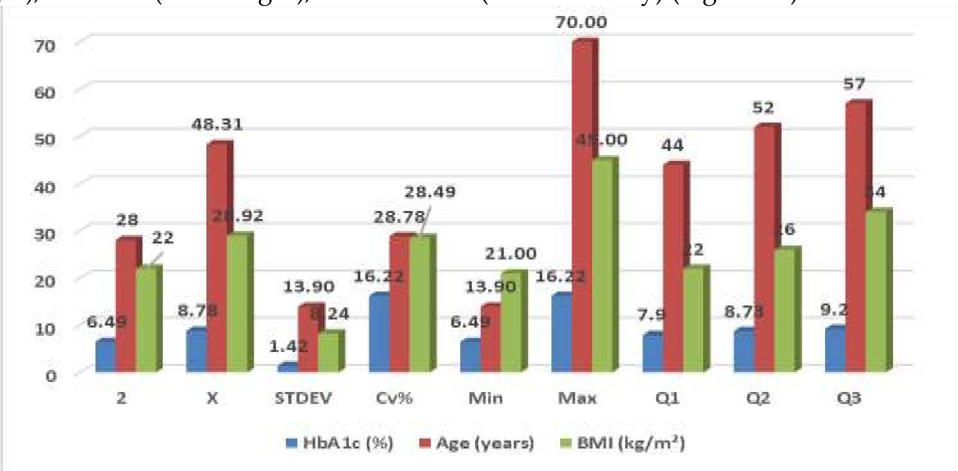

Figure 10. Anthropometric and metabolic profile of rural-dwelling men (N = 13).

Hyperglycemia (score 0–3):

The mean score of 1.31 indicates the presence of mild hyperglycemic episodes, with moderate values in most patients. Variability is moderate (SD = 0.48; CV% = 36.74%), and the quartiles (Q1 = 1; Q2 = 1; Q3 = 2) show that 25% of participants have a score ≤ 1, half ≤ 1, and 75% ≤ 2, suggesting that severe hyperglycemia is less common in this group.

Coronary ischemic heart disease (CIHD, 0/1):

The mean value of 0.62 indicates that approximately 62% of patients present CIHD. Variability is high (SD = 0.51; CV% = 82.29%), reflecting that nearly half of the participants do not have coronary disease. The quartiles (Q1 = 0; Q2 = 1; Q3 = 1) confirm that half of the patients have CIHD, while one-quarter present no evidence of this condition.

Arterial hypertension (HTN, 0/1):

The mean value of 0.54 shows that approximately 54% of patients are hypertensive. Variability is high (SD = 0.52; CV% = 96.36%), with values ranging from 0 to 1. The quartiles (Q1 = 0; Q2 = 1; Q3 = 1) indicate that half of the participants present hypertension, while one-quarter do not, suggesting that mild to moderate hypertension is common within this group (Figure 11).

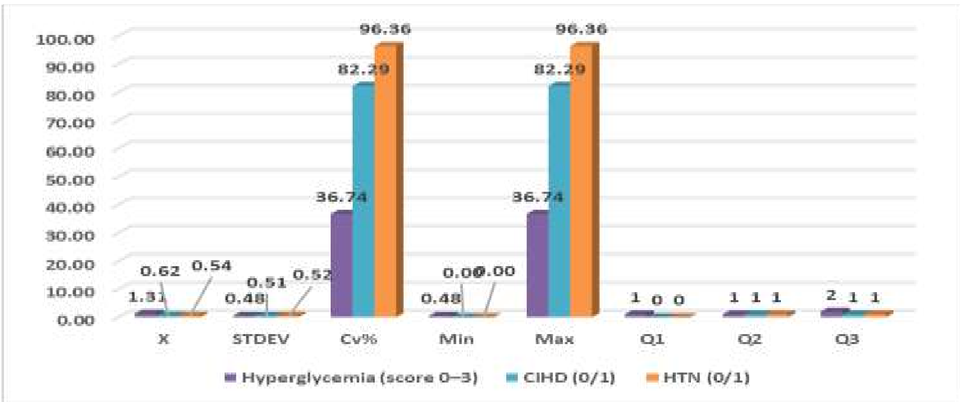

Figure 11. Prevalence of hyperglycemia, CIHD, and hypertension in rural-dwelling men (N = 13).

Systolic (SBP) and diastolic blood pressure (DBP):
The mean SBP of 142.31 mmHg and DBP of 80 mmHg indicate moderately to markedly elevated values, consistent with an increased cardiovascular risk profile. Variability is moderate (ST SBP = 25.13, CV% = 17.66%; ST DBP = 10.66, CV% = 13.33%), reflecting inter-individual differences. The quartiles show that 25% of patients have SBP ≤ 120 mmHg and DBP ≤ 70 mmHg (Q1), half have SBP ≤ 145 mmHg and DBP ≤ 80 mmHg (median, Q2), and 75% ≤ 170/88 mmHg (Q3), suggesting that most participants present mild to moderate hypertension.

Renal function (eGFR, ml/min/1.73 m²):
The mean eGFR of 86.62 indicates generally preserved renal function, but with substantial variability (SD = 26.58, CV% = 30.69%) and a wide range (min 6, max 105), showing that some patients exhibit significant renal impairment. The quartiles (Q1 = 81, Q2 = 98, Q3 = 102) indicate that half of the participants have eGFR values between 81 and 102 ml/min/1.73 m², while one-quarter fall below 81.

Diabetic nephropathy (0/1):
The mean value of 0.23 indicates that approximately 23% of patients present signs of diabetic nephropathy. Variability is very high (SD = 0.44, CV% = 190.03%), reflecting the fact that most patients do not show overt renal involvement. This pattern is confirmed by the quartiles (Q1 = 0, Q2 = 0, Q3 = 0), indicating that nephropathy is present only in a minority of cases (Figure 12).

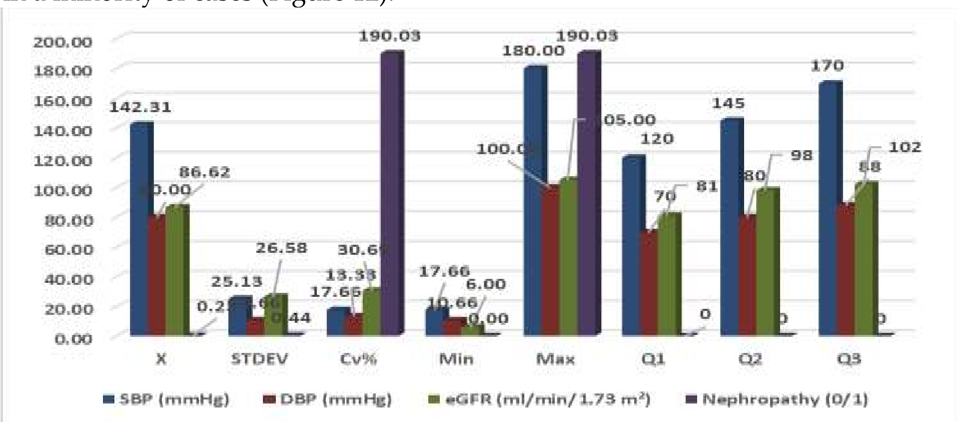

Figure 12. Cardiovascular and renal parameters in rural-dwelling men (N = 13).

In the group of urban-dwelling women, HbA1c (%) shows positive correlations with BMI (r = 0.48), arterial hypertension (HTN, r = 0.48), and coronary ischemic heart disease (CIHD, r = 0.54), suggesting that overweight patients and those with elevated blood pressure tend to exhibit higher glycemic levels and increased cardiovascular risk. Conversely, HbA1c decreases with age (r = –0.40).

Age is negatively correlated with BMI (r = –0.31), HTN (r = –0.55), and CIHD (r = –0.50), indicating that younger individuals tend to be more overweight and to present hypertension and coronary disease more frequently. However, age is positively correlated with short-term hyperglycemia scores (r = 0.33).

BMI increases in association with HbA1c, HTN, and CIHD, but decreases with age and short-term hyperglycemia scores (r = –0.49), highlighting the link between excess body weight and metabolic risk.

Coronary ischemic heart disease (CIHD) is more prevalent among patients with elevated HbA1c, higher BMI, and hypertension, but less common in older patients or those with higher short-term hyperglycemia scores.

HTN correlates strongly with systolic blood pressure (SBP, r = 0.64) and diastolic blood pressure (DBP, r = 0.55), and moderately with BMI and HbA1c, reinforcing the association between overweight status, glycemic control, and hypertension.

Renal function (eGFR) declines with the presence of nephropathy (r = –0.66), with increasing BMI (r = –0.54), and with higher HbA1c (r = –0.31), while nephropathy is more common among patients with elevated BMI and CIHD.

Table 1. Correlations among clinical and metabolic parameters in urban-dwelling women (n = 21

	HbA1c (%)	Age (years)	BMI (kg/m^2)	Hyperglycemia (score 0–3)	CIHD (0/1)	HTN (0/1)	SBP (mmHg)	DBP (mmHg)	eGFR (ml/min/1.73 m^2)	Nephropathy (0/1)
HbA1c (%)	1.00									
Age (years)	-0.40	1.00								
BMI (kg/m^2)	0.48	-0.31	1.00							
Hyperglycemia (score 0–3)	-0.12	0.33	-0.49	1.00						
CIHD (0/1)	0.54	-0.50	0.44	-0.64	1.00					
HTN (0/1)	0.48	-0.55	0.48	-0.33	0.42	1.00				
SBP (mmHg)	0.27	-0.43	0.09	0.00	0.16	0.64	1.00			
DBP (mmHg)	0.22	-0.38	-0.04	0.09	0.00	0.55	0.89	1.00		
eGFR (ml/min/1.73 m^2)	-0.31	0.25	-0.54	0.41	-0.46	-0.32	-0.51	-0.28	1.00	
Nephropathy (0/1)	0.17	-0.16	0.42	-0.36	0.44	0.31	0.09	-0.03	-0.66	1.00

In the group of rural-dwelling women, HbA1c values are strongly correlated with the hyperglycemia score (r = 1.00), confirming that the scoring system accurately reflects glycemic status. Age correlates positively with BMI (r = 0.85) and SBP (r = 0.85), suggesting that older women tend to be more overweight and have higher systolic blood pressure.

BMI shows positive correlations with arterial hypertension (HTN, r = 0.52) and SBP (r = 0.60), highlighting the relationship between excess body weight and hypertension.

Coronary ischemic heart disease (CIHD, 0/1) correlates negatively with HbA1c (r = –0.54), hyperglycemia score (r = –0.54), BMI (r = –0.37), and age (r = –0.41), indicating that, within this group, CIHD occurs more frequently among younger women with lower BMI and lower glycemic levels.

Renal function (eGFR) is negatively correlated with DBP (r = –0.53) and with the presence of nephropathy (r = –0.48). Nephropathy (0/1) shows a positive correlation with BMI (r = 0.29) and negative correlations with eGFR (r = –0.48) and DBP (r = –0.53).

Tabel 2. Corelații între parametrii clinici și metabolici la femei din mediul rural (n=18)

	HbA1c (%)	Age (years)	BMI (kg/m²)	Hyper-glycemia (score 0–3)	CIHD (0/1)	HTN (0/1)	SBP (mmHg)	DBP (mmHg)	eGFR (ml/min/1.73 m²)	Nephropathy (0/1)
HbA1c (%)	1.00									
Age (years)	0.03	1.00								
BMI (kg/m²)	0.06	0.85	1.00							
Hyperglycemia (score 0–3)	1.00	0.03	0.06	1.00						
CIHD (0/1)	-0.54	-0.41	-0.37	-0.54	1.00					
HTN (0/1)	0.21	0.47	0.52	0.21	-0.29	1.00				
SBP (mmHg)	0.01	0.85	0.60	0.01	-0.32	0.37	1.00			
DBP (mmHg)	-0.01	0.51	0.25	-0.01	-0.12	0.14	0.70	1.00		
eGFR (ml/min/1.73 m²)	-0.12	0.36	0.05	-0.12	-0.08	-0.04	0.62	0.80	1.00	
Nephropathy (0/1)	-0.06	-0.03	0.29	-0.06	0.06	-0.03	-0.23	-0.53	-0.48	1.00

In the group of urban-dwelling men, HbA1c (%) does not show strong correlations with other parameters (r = –0.24 with hyperglycemia, –0.08 with age, –0.07 with BMI), suggesting that glycemic variability is not closely linked to these characteristics in this sample.

Age correlates positively with CIHD (r = 0.42), HTN (r = 0.55), and DBP (r = 0.38), indicating that older men have a higher risk of hypertension and coronary heart disease. Age is also negatively correlated with eGFR (r = –0.35), suggesting a decline in renal function with advancing age.

BMI correlates positively with HTN (r = 0.46), SBP (r = 0.57), and DBP (r = 0.56), highlighting the association between overweight status and hypertension, and negatively with eGFR (r = –0.45), indicating that higher body mass is associated with reduced renal function.

Hyperglycemia (score 0–3) shows modest correlations: a positive correlation with nephropathy (r = 0.33) and weak positive correlations with SBP and DBP (~0.20).

CIHD (0/1) correlates positively with age (r = 0.42) and HTN (r = 0.36), indicating that coronary disease occurs more frequently in older and hypertensive men.

HTN (0/1) correlates positively with age (r = 0.55), BMI (r = 0.46), SBP (r = 0.37), and DBP (r = 0.38), confirming the association among overweight status, elevated blood pressure, and hypertension.

SBP and DBP are strongly correlated with each other (r = 0.87) and show moderate correlations with BMI, HTN, and age.

eGFR correlates negatively with BMI (r = –0.45), age (r = –0.35), and HTN (r = –0.41), while nephropathy correlates negatively with eGFR (r = –0.60) and positively with hyperglycemia (r = 0.33) and BMI (r = 0.30), indicating that reductions in renal function and higher body mass increase the likelihood of nephropathy.

Table 3. Correlations among clinical and metabolic parameters in urban-dwelling men (n = 20).

	HbA1c (%)	Age (years)	BMI (kg/m²)	Hyperglycemia (score 0–3)	CIHD (0/1)	HTN (0/1)	SBP (mmHg)	DBP (mmHg)	eGFR (ml/min/1.73 m²)	Nephropathy (0/1)
HbA1c (%)	1.00									
Age (years)	-0.08	1.00								
BMI (kg/m²)	-0.07	0.27	1.00							
Hyperglycemia (score 0–3)	-0.24	0.19	0.09	1.00						
CIHD (0/1)	0.27	0.42	0.00	0.11	1.00					
HTN (0/1)	0.12	0.55	0.46	-0.12	0.36	1.00				
SBP (mmHg)	-0.11	0.33	0.57	0.20	-0.10	0.37	1.00			
DBP (mmHg)	-0.05	0.38	0.56	0.20	0.08	0.38	0.87	1.00		
eGFR (ml/min/1.73 m²)	-0.13	-0.35	-0.45	-0.13	-0.21	-0.41	-0.14	-0.12	1.00	
Nephropathy (0/1)	0.04	0.13	0.30	0.33	0.00	0.22	0.00	0.13	-0.60	1.00

In the group of rural-dwelling men, HbA1c (%) correlates positively with age (r = 0.61) and BMI (r = 0.64), suggesting that older men and those with higher body weight tend to have higher glycemic levels. The hyperglycemia score shows weak negative correlations with HbA1c (r = –0.09), age (r = –0.14), and BMI (r = –0.27), indicating that this score does not directly reflect glycemic status in this sample.

BMI correlates positively with HTN (r = 0.40) and blood pressure (SBP r = 0.24; DBP r = 0.11), showing the association between overweight status and hypertension.

HTN (0/1) correlates strongly with SBP (r = 0.92) and DBP (r = 0.75), and moderately with CIHD (r = 0.54), confirming the established relationship between hypertension and coronary heart disease.

CIHD (0/1) presents moderate correlations with BMI (r = 0.41), HTN (r = 0.54), and blood pressure, but weaker correlations with HbA1c and age.

Renal function (eGFR) correlates negatively with DBP (r = –0.50), SBP (r = –0.33), and hyperglycemia (r = –0.40), indicating that higher blood pressure and elevated hyperglycemia scores are associated with reduced renal function.

Nephropathy (0/1) correlates negatively with eGFR (r = –0.59), slightly negatively with HTN (r = –0.23), and positively with hyperglycemia (r = 0.43), suggesting that declining renal function and increased hyperglycemia contribute to nephropathy risk.

Table 4. Correlations among clinical and metabolic parameters in rural-dwelling men (n = 20).

	HbA1c (%)	Age (years)	BMI (kg/m²)	Hyperglycemia (score 0–3)	CIHD (0/1)	HTN (0/1)	SBP (mmHg)	DBP (mmHg)	eGFR (ml/min/1.73 m²)	Nephropathy (0/1)
HbA1c (%)	1.00									
Age (years)	0.61	1.00								
BMI (kg/m²)	0.64	0.65	1.00							
Hyperglycemia (score 0–3)	-0.09	-0.14	-0.27	1.00						
CIHD (0/1)	0.07	0.21	0.41	0.18	1.00					
HTN (0/1)	0.28	0.28	0.40	-0.05	0.54	1.00				
SBP (mmHg)	0.09	0.18	0.24	0.01	0.57	0.92	1.00			
DBP (mmHg)	-0.03	0.06	0.11	0.00	0.39	0.75	0.92	1.00		
eGFR (ml/min/1.73 m²)	-0.02	0.24	0.24	-0.40	-0.15	-0.15	-0.33	-0.50	1.00	
Nephropathy (0/1)	-0.05	0.01	-0.04	0.43	0.06	-0.23	-0.05	0.00	-0.59	1.00

3. Discussion

The rising morbidity and mortality associated with type 2 diabetes mellitus (T2DM) and obesity-related cardiovascular diseases require comprehensive preventive and interventional strategies, particularly in developing countries. Community-based programs aimed at increasing physical activity and promoting healthy dietary choices are essential, especially for children [23].

A comparative analysis including 1,898 rural and 930 urban participants revealed significant metabolic differences: urban residents exhibited lower mean fasting glucose and reduced HOMA-IR indices but higher systolic and diastolic blood pressure values. These differences were not explained by helminth infections, suggesting an important contribution of lifestyle and socio-geographical factors [24].

Self-management strategies (SMS) implemented in urban primary care practices have proven effective for improving glycemic control. Social determinants—such as education level and basic diabetes knowledge (BDK)—play a crucial role in enhancing clinical outcomes [25]. In contrast, physical inactivity is more prevalent in rural areas, and evidence indicates that both the social and physical environments significantly influence activity levels, underscoring the need for context-specific interventions [26].

Existing data on preventing T2DM and its complications in developing countries are generally positive but limited in scale and scope, highlighting the need for larger, more robust studies [27]. Prevention and treatment strategies should therefore integrate lifestyle interventions, health education, and community-based physical activity programs to reduce the burden of diabetes and associated metabolic diseases.

Our study highlights clear differences between urban and rural environments in the distribution of metabolic and cardiovascular risk, with patterns also varying by sex. The findings indicate that in rural settings, the primary determinants of complication risk are hyperglycemia and renal function, whereas in urban settings, overweight status and hypertension are the dominant factors. Additionally, the hyperglycemia score correlates well with HbA1c only within certain subgroups (e.g., rural women) but not in others (urban or rural men), underscoring the importance of individualized assessment of metabolic and cardiovascular risk.

4. Materials and Methods

The aim of this study was to evaluate differences in metabolic parameters among patients with diabetes mellitus residing in rural and urban environments, and to identify the metabolic and cardiovascular risk factors relevant to each group.

Objectives of the study:

1. To conduct a comparative analysis of clinical and metabolic parameters (HbA1c, BMI, blood pressure, renal function, hyperglycemia) according to place of residence and sex.
2. To identify lifestyle-related differences (current or former smoking) and their impact on glycemic control.
3. To assess the prevalence of diabetic complications (nephropathy, coronary ischemic heart disease, hypertension) in rural versus urban populations.

Study hypothesis:

It is hypothesized that patients with diabetes mellitus living in rural and urban environments present significant differences in metabolic and clinical parameters, and that these parameters correlate with each other, highlighting meaningful relationships among glycemia, overweight status, blood pressure, and renal function.

Inclusion criteria:

Patients with type 1 or type 2 diabetes mellitus, registered at the Suceava Diabetes Clinic, aged 19 to 83 years, with low levels of physical activity, without major contraindications to clinical evaluation, and who provided informed consent for participation.

Sample:

The study included 72 adults, distributed as follows: 21 urban women, 18 rural women, 20 urban men, and 13 rural men.

Measured parameters and their descriptions:

- **HbA1c (%)** – glycated hemoglobin, an indicator of mean glycemia over the previous 2–3 months.
- **Age (years)** – chronological age of the patient.
- **BMI (kg/m²)** – body mass index, an indicator of nutritional status.
- **Hyperglycemia (score 0–3)** – a score reflecting the severity of hyperglycemic episodes (0 = no hyperglycemia, 3 = severe hyperglycemia).
- **CIHD (0/1)** – coronary ischemic heart disease (0 = absent, 1 = present).
- **HTN (0/1)** – arterial hypertension (0 = absent, 1 = present).
- **SBP (mmHg)** – systolic blood pressure.
- **DBP (mmHg)** – diastolic blood pressure.
- **eGFR (ml/min/1.73 m²)** – estimated glomerular filtration rate, an indicator of renal function.
- **Nephropathy (0/1)** – presence of diabetic nephropathy (0 = absent, 1 = present).

Methods:

- Review of relevant scientific literature;
- Observational methodology;
- Measurement of metabolic and clinical parameters;
- Graphical and tabular representation of data.

Mathematical and statistical analysis:

Mean, standard deviation, coefficient of variation, minimum and maximum values, and quartile distributions were calculated. Correlations among variables were assessed using Pearson correlation coefficients to identify relationships among HbA1c, BMI, blood pressure, renal function, and other metabolic complications. All statistical computations were performed using Microsoft Excel.

Tabel 1. Program propus de înot terapeutic – 12 săptămâni

Swimming Technique / Exercise	Duration (Women)	Duration (Men)	Intensity	Breaks	Objectives	Monitoring
Freestyle	10 min	12 min	Light	1 min every 2 laps	Cardiovascular endurance	Blood glucose before/after
Backstroke	10 min	12 min	Moderate	1 min every 2 laps	Back toning, posture correction	-
Breaststroke	10 min	12 min	Moderate	1 min every lap	Arm and leg toning	-
Walking in water	5 min	5 min	Light	-	Peripheral circulation	-
Exercises with kickboard / dumbbells	5-10 min	5-10 min	Moderate	30 sec between sets	General toning	2–3 sets
Stretching and relaxation	5 min	5 min	Light	-	Muscle relaxation	Deep breathing
Freestyle / Backstroke / Breaststroke (intervals)	20 min	25 min	Moderate	1 min between laps	Endurance and coordination	HbA1c and pulse
Walking in water / arm and leg exercises	5 min	5 min	Light	-	Mobility and balance	-
Stretching and relaxation	5 min	5 min	Light	-	Muscle relaxation	-
Freestyle / Backstroke / Breaststroke	25 min	30 min	Moderate	1-2 min between laps	Cardiovascular and muscular endurance	Technical observation
Exercises with kickboard / dumbbells	5-10 min	5-10 min	Moderate	30 sec between sets	General toning	2-3 sets
Stretching and relaxation	5 min	5 min	Light	-	Relaxation, cramp prevention	Deep breathing

Note: The swimming program was not implemented within this study; it represents a theoretical proposal based on the analysis of preliminary data.

Conclusions

The study highlights significant differences between rural and urban environments in the distribution of metabolic and cardiovascular risk, as well as sex-related variations. In rural settings, hyperglycemia and impaired renal function emerge as the main risk factors, whereas in urban environments, overweight status and hypertension predominate. HbA1c levels are generally above the recommended target, and the hyperglycemia score reflects glycemic status in certain subgroups, such as rural women, but not consistently across all groups.

Overweight status and hypertension are associated with increased cardiovascular risk, while reduced renal function and the presence of nephropathy elevate the risk of complications in rural populations. These findings underscore the need for individualized assessment of metabolic and cardiovascular risk, taking into account residence, sex, BMI, blood pressure, and renal function.

To address the identified risks, we propose the implementation of a therapeutic swimming program tailored to each group, which may contribute to lowering blood glucose levels, improving cardiovascular function, supporting weight management, and promoting regular physical activity. Integrated prevention and management strategies should include health education, routine physical activity, and individualized monitoring of metabolic parameters.

The limitations of this study include the lack of actual implementation of the swimming program, the small sample size, the observational nature of the data, and the absence of long-term follow-up, all of which restrict the generalizability of the findings and limit the ability to determine causal effects on metabolic parameters.

Future research should implement adapted swimming programs for patients with diabetes, using larger samples and longitudinal monitoring, in order to assess their impact on metabolic outcomes and the reduction of complication risk.

6. Patents

It is not the case

Supplementary Materials: It is not the case

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, Cobuz Claudiu and Vizitiu Lakhdari Elena.; methodology, Cobuz Claudiu.; software, Vizitiu Lakhdari Elena; validation, Silișteanu Sînzîiana Călina and Vizitiu Lakhdari Elena; formal analysis, Vizitiu Lakhdari Elena.; investigation, Cobuz Claudiu; resources, Silișteanu Sînzîiana Călina; data curation, Vizitiu Lakhdari Elena.; writing—original draft preparation, Silișteanu Sînzîiana Călina.; writing—review and editing, Cobuz Claudiu.; visualizationCobuz Claudiu.; supervision, Silișteanu Sînzîiana Călina.; project administration, Vizitiu Lakhdari Elena; funding acquisition, Cobuz Claudiu.

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