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EXPLORING GENDER-BASED VARAITION IN GLYCEMIC CONTROL, METABOLIC SYNDROME BURDEN, AND CARDIOVASCULAR RISK IN AMONG ADULTS WITH TYPE 2 DIABETES MELLITUS: A CROSS-SECTIONAL STUDY

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Abstract

Background: *Type 2 diabetes mellitus (T2DM) is a complex metabolic condition associated with significant cardiovascular consequences, demonstrating clear gender-based differences in both clinical features and outcomes. Despite extensive research, has been conducted, important gaps remain in understanding the intersection of glycemic control, metabolic syndrome burden, and cardiovascular risk stratification vary between men and women.*

Methods: *In this cross-sectional study, 130 adults with T2DM (68 males, 62 females) who underwent detailed metabolic and cardiovascular profiling. We assessed the glycemic control (HbA1c), lipid profiles, blood pressure, anthropometric measurement, and cardiovascular complications. Advanced risk assessment tools were used including the Diabetes Complications Severity Index (DCSI), metabolic syndrome criteria, and a composite cardiovascular risk score. Gender-specific comparisons were conducted independent using the independent t-tests and chi-square analyses, with Pearson correlations analysis.*

Results: *The study revealed alarmingly poor glycemic control in the overall groups (mean HbA1c: 9.13% ± 1.83%), with only 27.7% of participants achieving the target <7% and 43.8% showing very poor control (≥9%). No significant in HbA1c was found between the gender (p=0.999). However, females had significantly higher BMI (27.6 vs 26.1 kg/m², p=0.038), LDL cholesterol (107.3 vs 96.0 mg/dL, p=0.028), and waist-to-height ratio (p=0.038). Males had significantly composite cardiovascular risk scores (12.9 vs 9.2, p<0.001). Metabolic syndrome was highly prevalent (72.3%), affecting 69.1% of males and 75.8% of females. Strong correlations were observer*

between HbA1c and systolic blood pressure (r=0.364, p<0.001), and between the diabetes duration and HbA1c (r=0.247, p<0.01). Overall, (78.5%) of patients had moderate to very high cardiovascular risk.

Conclusions: *This study highlights significant gaps in diabetes management, with suboptimal glycemic observer in both genders, alongside significant metabolic disparities. Females showed greater adiposity and more unfavorable lipid profiles, while males had higher overall cardiovascular risk. These findings emphasize the need for gender-sensitive diabetes care that addresses the full spectrum of cardiometabolic risk factors rather than focusing solely on glycemic control.*

1. Introduction

Type 2 diabetes mellitus (T2DM) has become one of the leading health issues of the 21 st century, and at present, the number of affected persons is estimated to be 537 million adults worldwide, with the number of cases to be projected as 783 million cases by the year 2045 (Hossain et al., 2024). The condition is not as simple as high hyperglycemia because T2DM is a multifactorial, complex, and metabolic disorder which predisposes to the cardiovascular disease significantly, as well as to the renal complications and mortality in general. The condition involves more than elevated hyperglycemia, T2DM constitutes a complex, multifactorial metabolic disorder that substantially increases the risk of the cardiovascular disease, renal complications, and overall mortality (Siam et al., 2024). Cardiovascular disease is the primary cause of morbidity and mortality among the individuals with diabetes patients (Zhang et al., 2010).

The association between diabetes and cardiovascular disease show important gender-based differenece that have garnered increasing research attention. While diabestes prevalence is similar in men and women, however women often experiences worse cardiovascular outcomes (Koutroumpakis and Aguilar, 2020). This "gender paradox" in diabetes outcomes has been attributed to biological mechanisms including body anthropometry, fat distribution, hormonal factors, and variation in risk factor management and therapeutic approaches (Kautzky-Willer et al., 2023). Metabolic syndrome represents a cluster of metabolic abnormalities that significantly elevate the risk of chornic condition partciulalry T2DM and cardiovasular characterized by central adiposity, high blood pressure, hyperglycemia, insulin resistance, iincreased triglyceride levels, and reduced high-density lipoprotein cholesterol (Patial et al., 2024). These abnormalities interact synegstically, promoting a chronic pro-infalamatory and pro-atherogenic environment which is characterized by the accelerates cardiometabolic deterioration, endothelial dysfunction, and the progression of atherosclerotic disease (Patial et al., 2024).Glycemic control, primarily measured by glycated hemoglobin (HbA1c), remains a key target in diabetes management (Nathan et al., 2009). However, the major clinical trials such as The Preterax and Diamicron Modified Release Controlled Evaluation (ADVANCE), Action to Control Cardiovascular Risk in Diabetes (ACCORD), Action in Diabetes and Vascular Disease: Veterans Affairs Diabetes Trial (VADT) results indicated that intensive glycemic control toward normal levels had little to no benefit or might even harm cardiovascular outcomes (Brown et al., 2010). While intensive glucose control reduces microvascular complications, their impact on macrovascular outcomes health is more limited, particularly in patients with established cardiovascular disease or long diabetes duration (Brown et al., 2010). More recent analyses have validated that intensive glucose-lowering reduces non-fatal myocardial infarction risk but has modest affects on overall cardiovascular events (Boussageon et al., 2011). Importantly, visit-to-visit HbA1c variability has emerged as an independent risk factor for cardiovascular outcomes, with systematic reviews demonstrating that the high glycemic variability linked with 27-35% high risk of the cardiovascular events and mortality, even when mean HbA1c levels are at target (Jang et al., 2019). This suggests that both degree and stability of the glycemic control contributes to

the long-term cardiovascular prognosis, offering a new precision-glycemia management target beyond the conventional mean HbA1c (Martinez et al., 2021).

The application of the composite risk scores, metabolic syndrome criteria, and the complications severity indices in gender-stratified analyses remains limited. This study aims adress important gaps by comprehensively evaluating gender-based differnece in glycemic control, the metabolic syndrome burden, and cardiovascular risk profiles among the adults with T2DM. By utalizing advanced novel risk stratification approaches, such as the Diabetes Complications Severity Index (DCSI), metabolic syndrome component analysis, and composite cardiovascular risk score. We aim to provide in detailed insights that can guide the personalized, and gender-sensitive diabetes care.

3. Methods

3.1 Study Design and Population

This was a cross-sectional observational study included 130 adults with established type 2 diabetes mellitus comprising 68 males and 62 females, recruited from the outpatient clinics. Participants were represented a consecutive sample of the enrolled patients with complete metabolic and cardiovascular evaluation. Patient were inclded if they confirmed T2DM diagnosis, age ≥18 years, and had complete clinical and laboratory data. Individuals with type 1 diabetes, gestational diabetes, or insufficient essential data were excluded. The study recieved ethical grant from the institutional Bioethical Committe review board, and all participants provide a written informed consent.

3.2 Data Collection and Variable Definitions

Detailed demographic, clinical, laboratory, and anthropometric data were obtained from electronic medical records and standardized assessment forms. Variables include age, gender, diabetes duration, family history of diabetes (binary: yes/no, random blood glucose (RBS), full lipid profile, blood pressure, BMI, waist-to-height ratio, estimated glomerular filtration rate (eGFR), and presence of cardiovascular complications **(Table 1-8) (Figure 1-5)**.

Derived Risk Scores includes the Metabolic Syndrome (MetS) based on the International Diabetes Federation criteria, defining by the presence of the latest three of the following, elevated blood pressure (≥130/85 mmHg), high triglycerides (≥150 mg/dL), low HDL (<40 mg/dL males, <50 mg/dL females), and obesity (BMI ≥30 kg/m²). The Diabetes Complications Severity Index (DCSI) summed of the present complications-HTN, CVD, Stroke, Angina, IHD), ranging from 0 to 5. Additionally, a Composite Cardiovascular Risk Score was calculated using the age, sex, HbA1c, blood pressure, lipids level, family history, and the existing complications with the scores from the 0 to 50 categorized as Low <10, Moderate 10-20, High 20-30 or Very High ≥30).

3.3 Statistical Analysis

Data analysis was performed using Python (v 3.12) with approriate statistical libraries incluing pandas, scipy, and seaborn. Continuous variables were asessed for normality with Shapiro-Wilk tests and expressed as mean ± standard deviation or median (interquartile range) as appropriate. The categorical variables were presented as frequencies and percentages. Three sample test including independent samples t-tests were used for normally distributed continuous variables, Mann-Whitney U tests for non-normally distributed variables and Chi-square tests or Fisher's exact tests for categorical variables were emplyed in this study. The correlation analysis was examined by the Pearson correlation coefficients for linear relationships between the continuous variables or Spearman rank correlations for the non-linear or ordinal relationships. A two-tailed p value < 0.05 were cosniderd statistically significant.

3.4 Data Quality Assurance

The rigorous quality checking was performed for data accuracy, logical consistency, and missing data assessment. Patients with >20% missing data were excluded, and the outliers were verified using the interquartile range method and verified against source documents.

4. Results

4.1 Baseline Demographics and Clinical Characteristics

The cohort comprised total 130 patients with T2DM, with a slight male predominance (52.3% male, 47.7% female). The duration averaged age was 49.6 ± 11.1 years, with no significant gender difference (Male: 50.1 ± 12.0 vs Female: 49.1 ± 10.2 years, p=0.607). Diabetes duration averaged 3.7 ± 4.7 years, with the males showing slightly longer but statistically non-significant duration (4.0 ± 5.0 vs 3.4 ± 4.4 years, p=0.441). Family history of diabetes was present in approxiamtely 53.8% of the males and 48.1% of females (p=0.349) participants (**Table 1**).

Table 1: Baseline Demographics and Clinical Characteristics

Characteristic	Male (n=68)	Female (n=62)	Total (n=130)	p-value
Age (years)	50.1 ± 12.0	49.1 ± 10.2	49.6 ± 11.1	0.607
Diabetes Duration (years)	4.0 ± 5.0	3.4 ± 4.4	3.7 ± 4.7	0.441
Family History, n (%)	29 (53.8%)	26 (48.1%)	55 (51.0%)	0.349

4.2 Glycemic Control Status

The study population exhibited alarmingly poor glycemic control overall (**Table 2**). However, the mean HbA1c was 9.13% ± 1.83%, with no significant difference between male and females (Male: 9.13% vs Female: 9.13%, p=0.999) (**Figure 1**). Only 27.7% of the patients achieved target HbA1c <7%, while 43.8% had very poor control (HbA1c ≥9%).

Control Category	Male n (%)	Female n (%)	Total n (%)	p-value
Optimal (<6.5%)	8 (11.8%)	6 (9.7%)	14 (10.8%)	0.872
Good (6.5-7.0%)	11 (16.2%)	11 (17.7%)	22 (16.9%)	
Fair (7.0-8.0%)	7 (10.3%)	9 (14.5%)	16 (12.3%)	
Poor (8.0-9.0%)	11 (16.2%)	10 (16.1%)	21 (16.2%)	
Very Poor (≥9.0%)	31 (45.6%)	26 (41.9%)	57 (43.8%)	

Table 2: The Glycemic Control Categories by Gender. The distribution across glycemic control categories was remarkably similar between the genders (p=0.872), indicating that factors beyond gender are driving the suboptimal glycemic control observed. Random blood glucose showed strong positive correlation with HbA1c (r=0.677, p<0.001), validating measurement consistency.

4.3 Gender Differences in Metabolic Parameters

Significant gender disparities emerged in anthropometric and lipid parameters (**Table 3**):

Parameter	Male (Mean ± SD)	Female (Mean ± SD)	p-value
BMI (kg/m²)	26.1 ± 4.2	27.6 ± 4.2	0.038
WHtR	0.51 ± 0.04	0.53 ± 0.04	0.038

Total Cholesterol (mg/dL)	176.1 ± 35.9	186.1 ± 38.4	0.132
LDL Cholesterol (mg/dL)	96.0 ± 30.3	107.3 ± 26.5	0.028
HDL Cholesterol (mg/dL)	36.1 ± 10.7	38.5 ± 8.4	0.160
Triglycerides (mg/dL)	196.7 ± 91.1	207.1 ± 103.2	0.547
Non-HDL Cholesterol (mg/dL)	140.0 ± 35.0	147.6 ± 37.5	0.234
TC/HDL Ratio	5.2 ± 1.6	5.1 ± 1.4	0.712
TG/HDL Ratio	6.1 ± 3.4	5.9 ± 3.6	0.762
LDL/HDL Ratio	2.9 ± 1.2	3.0 ± 1.1	0.628
Systolic BP (mmHg)	129.0 ± 13.5	130.6 ± 17.4	0.555
Diastolic BP (mmHg)	82.6 ± 7.6	84.3 ± 8.1	0.221
Pulse Pressure (mmHg)	46.4 ± 11.3	46.3 ± 13.0	0.964
eGFR (mL/min/1.73m²)	92.3 ± 15.2	94.1 ± 14.8	0.489

Table 3: Metabolic Parameters by Gender. Females had significantly higher BMI (27.6 vs 26.1 kg/m², p=0.038), waist-to-height ratio (p=0.038), and the LDL cholesterol (107.3 vs 96.0 mg/dL, p=0.028). These findings are clinically significant as both high BMI and the LDL level represent modifiable cardiovascular risk factors that disproportionately affect the female diabetic patients.

4.4 Metabolic Syndrome Analysis

Metabolic syndrome was present in 72.3% of all receruited patients (69.1% of males, 75.8% of females, p=0.558). However, the mean number of MetS components was 2.8 ± 1.0, with no significant gender differences (Male: 2.7 vs Female: 2.9, p=0.234) **(Table 4)**.

Component	**Male n** (%)	**Female n** (%)	**p-value**
Elevated BP (≥130/85)	38 (55.9%)	37 (59.7%)	0.815
Elevated TG (≥150)	38 (55.9%)	35 (56.5%)	1.000
Reduced HDL	52 (76.5%)	35 (56.5%)	**0.024**
Obesity (BMI ≥30)	17 (25.0%)	20 (32.3%)	0.507

Table 4: Metabolic Syndrome Component Prevalence. The Gender-specific thresholds: <40 mg/dL males, <50 mg/dL females. Notably, the males exhbiting a significantly higher prevalence of low HDL (76.5% vs 56.5%, p=0.024) chloestrol, despite the females having higher absolute LDL levels, suggesting the distinct patterns of dyslipidemia between males and females.

4.5 Cardiovascular Risk Stratification

The composite cardiovascular risk score revealed higher risk burden across the cohort **(Table 5)**. Overall, the mean score was 11.1 ± 7.8, with significant gender difference (Male: 12.9 ± 8.3 vs Female: 9.2 ± 6.6, p<0.001).

Risk Category	Male n (%)	Female n (%)	Total n (%)	p-value
Low Risk (<10)	24 (35.3%)	32 (51.6%)	56 (43.1%)	0.007
Moderate Risk (10-20)	25 (36.8%)	21 (33.9%)	46 (35.4%)	
High Risk (20-30)	15 (22.1%)	8 (12.9%)	23 (17.7%)	
Very High Risk (≥30)	4 (5.9%)	1 (1.6%)	5 (3.8%)	

Table 5: Cardiovascular Risk Categories by Gender. The males were significantly higher composite to be categorized as high risk (28.0% vs 14.5%, p=0.007), despite females having higher BMI and LDL cholesterol level. This apparent paradox reflects the composite nature of the risk score, which included the age, blood pressure, existing complications, and other factors where the males showed higher values.

4.6 Cardiovascular Complications and DCSI

Cardiovascular complications were prevalent, with hypertension the most common complication (46.9%), followed by stroke (23.1%), CVD (18.5%), angina (7.7%), and IHD (3.1%). The mean DCSI score value was 1.0 ± 1.1, with no significant gender difference were found in indviduals (Male: 1.0 vs Female: 0.9, p=0.612) **(Table 6)**.

Complication	Male n (%)	Female n (%)	p-value
Hypertension	30 (44.1%)	31 (50.0%)	0.661
CVD	14 (20.6%)	10 (16.1%)	0.625
Stroke	15 (22.1%)	15 (24.2%)	0.981
Angina	6 (8.8%)	4 (6.5%)	0.834
IHD	2 (2.9%)	2 (3.2%)	1.000

Table 6: Cardiovascular Complications by Gender. There is no statistically significant gender differences were observed in individual complication prevalence. However, the absolute burden remains concerning, with over half of all the recruited patients having hypertension and approximately one-quarter having experienced stroke.

4.7 Correlation Analyses

Variables	r	p-value	Interpretation
HbA1c - RBS	0.677	<0.001	Strong positive
HbA1c - SBP	0.364	<0.001	Moderate positive
HbA1c - CV Risk Score	0.262	0.003	Weak positive
HbA1c - Duration	0.247	0.005	Weak positive
Age - Duration	0.323	<0.001	Weak positive

LDL - TC/HDL Ratio	0.339	<0.001	Moderate positive
BMI - WHtR	0.891	<0.001	Very strong positive

Table 7: Key Correlation Coefficients. The strong correlation between the HbA1c and random blood glucose (r=0.677) level confirms the measurement consistency. The positive correlation between the HbA1c and systolic blood pressure (r=0.364), suggests the clustering of metabolic risk factors with poor glycemic control. Importanly, diabetes duration showed modest, but significant positive correlation with the HbA1c (r=0.247), indicating a progressive glycemic deterioration over time.

4.8 Glycemic Control Trajectory by Duration
Analysis of the glycemic control across the diabetes across the different duration groups revealed notable and concerning patterns. Despite the increase in the mean HbA1c with the duration of diabetes, the rate of patients with poor control was always high (>40%) in all the groups. This suggesting that elements other than the disease duration-such as treatment inertia, adherence issues, or progressive β-cell failure-plays a signinficant role **(Table 8) (Figure 5).**

Table 8: Glycemic Control by Duration Group

Duration	n	Mean HbA1c (%)	Poor Control (≥9%) n (%)
<1 year	20	8.43 ± 2.14	8 (40.0%)
1-5 years	54	9.13 ± 1.83	23 (42.6%)
5-10 years	26	9.15 ± 1.67	12 (46.2%)
10-20 years	20	9.58 ± 1.45	10 (50.0%)
>20 years	10	9.72 ± 1.38	4 (40.0%)

5. Discussion
This comprehensive cross-sectional study of the 130 adults, with the T2DM uncover several critical findings with important clinical implications **(Figure 1-5)**. First, the glycemic was alarmingly poor across the across the whole population, fewer than one-third of the patients reached the target HbA1c <7%, and nearly half showed very poor control (≥9%). Second, despite similar glycemic control between males and females, a significant metabolic disparity appeared, females exhibited the higher BMI, LDL cholesterol, and central adiposity, wherase the males show the composite cardiovascular risk scores. Third, the metabolic syndrome affected more than 70% of the patients, with distinct gender patterns in the component clustering. Fourth, the cardiovascular complications were highly prevalent, high blood pressure affecting approximately half, and stroke affecting nearly one-quarter of all the enrolled patients. In conlcusion, the diabetes duration showed a positive correlation with age and HbA1c, and indicating the progressive glycemic deterioration over time.

In 2006, acoss 28 health centers in KSA, 27.7% of the patients achieved targeted glycemic control, represents a significant clinical complication, and falls substantially below the optimal quality benchmarks. This rate is reported lower than the ~25–32% in Saudi Arabian research studies (Al-Rasheedi, 2015), highlighting a critical gap in the diabetes management gap that demands immediate attention. The positive relationship between diabetes duration and worsening glycemic control reflects the gradual decline in the β-cell function over time, a process well-established in type 2 diabetes (Saisho, 2015). This significant finding underscores the importance of early,

intensive intervention to prevent the progressive glycemic deterioration consistent with the UKPDS legacy effect demonstrating durable cardiovascular benefits from the early glycemic control (Bhattacharya et al., 2024).

Recent meta-analytic evidence showe that the intensive glucose control lower the risk of non-fatal myocardial infarction, and reduces the ocuurence of several microvascular complications, particularly retinopathy and nephropathy via effects on major adverse cardiovascular events are modest (Kunutsor et al., 2024). Although effective glycemic control are known reduces microvascular complications, approximately half of patients with type 2 diabetes fail to achieve the recommended HbA1c target of <7%, and 10–15% exhibiting the HbA1c levels ≥9%, placing them markedly high risk for microvascular complications (Abdul-Ghani and DeFronzo, 2018).

We noticed the biggest gender differences observed in body fats and lipid fat meausure. Women showed a noticevally higher BMI (27.6 vs 26.1 kg/m^2), waist-to-height ratio, and LDL cholesterol (107.3 vs 96.0 mg/dL). These findings line up with worldwide patterns that women with higher obesity rates, and have important health implications. The sex-specific differences in fat distribution are primarily driven by estrogen, resulting in women typically having storing more subcutaneous fat, while men accumulate more visceral adiposity (Kim et al., 2025). Mens has higher visceral and hepatic fat, combined with lower estrogen levels, promotes to greater insulin resistance, and faster progression to diabetes, while the women tend to maintain higher insulin sensitivity, and may stay in a prediabetic state longer (Geer and Shen, 2009). The elevated LDL-C levels are commonly observed in women with T2DM often the exceeding recommended targets, emphasizing the importance of the comprehensive lipid management, including statins and, when appropriate the additional therapies such as ezetimibe or PCSK9 inhibitors (Russo et al., 2015). The observation that men showed more prevalence of low level of HDL suggests different patterns of diabetic dyslipidemia between genders, with men exhibiting more harmful lipid profiles characterized by low HDL and small dense LDL particles (Kolovou et al., 2009).

The high prevalence of metabolic syndrome (~72%) in our cohort is consistent aligh with earlier reports that 45-70% of T2DM patients meet metabolic syndrome criteria, with the womens more affected and the low level of HDL and high triglyceriod are most common (Birarra and Gelayee, 2018). Metabolic syndrome double risk of cardiovascular events and represents a clustering of interconnected risk factors that amplify cardiovascular risk, beyond the simple sum of each factors (Shen et al., 2024). We found metabolic syndrome prevalence was similar between male and females, though the speific component differed, suggests that both male and female diabetic patients require thorogh risk factor management strategies. The HbA1c level were negatively correlated with HDL cholesterol (r=-0.27) indicates, that the patients with poorer glycemic control is accociated with lower protective HDL level, consequently high cardiovascular risk, consistent with pattern oberverd in insulin resistant dyslipidemia (Nnakenyi et al., 2022).

The composite cardiovascular risk score revealed that males exhibited significantly higher risk burdens than females (Fan et al., 2026). This apparent paradox reflects the multifactorial nature of the cardiovascular risk, wherein age, blood pressure, existing complications, and other factors contribute to overall risk (Bays et al., 2021). In our cohort males were slightly older and have higher rates of pre-existing cardiovascular complications, which elevated the risk scores.

We observerd that 56.9% of the patients were classified in the moderate to very high cardiovascular risk categry. This emphasizes the urgent need for comprehensive risk factor management, that goes beyond the glycemic control alone. The high rate of hypertension (46.9%) and stroke (23.1%) in our group indicates a substantial atherosclerotic burden that calls the aggressive trearment.

The Diabetes Complications Severity Index (DCSI) provides a numeric score of complication burden that links to healthcare utilization, costs, and mortality (Glasheen et al., 2017). In our cohort the mean DCSI score is 1.0 indicates a moderate complication burden, with no gender gap. However, the high prevalence of individual speicific complications especailly

stroke (23.1%) shows that many patients have already suffered serious cardiovascular events. However, there was a positive linked between HbA1c and systolic blood pressure highlight the clustering of metabolic risk factors typical of the Type 2 diabetes, which foster a pro-inflammatory, pro-thrombotic state that accelerate atherosclerosis and raises the cardiovascular risk (Kumar et al.). We did not see a strong HbA1c and lipid ratios correlation in our cohort which may reflect the high prevalence of dyslipidemia widespread across all glycemic control groups, suggesting lipid abnormalities are almost universal in this population, and need a systematic treatment regardless of glycemic control.

Our results both match and expand previous literature. A Saudi Arabian study by Almutairi et al. (2026) reported a similar rate of poor glycemic control, but noted a higher diabetes knowledge among women that did not translate into a better glycemic outcome. Our study likewise finding no female advantage in glycemic control, despite the potentially better health awareness, implyoing that knowledge alone is isnot enoguh to hit the glycemic targets, without proper healthcare access, medication adherence, and therapeutic support.

The UK Biobank study showed the observational data linked stronger type 2 diabetes and CVD risk in females than males, wherease the causal genetic effects were similar between sexes (de Ruiter et al., 2025). Our data revealed the equivalent complication rates between the genders implying that matched glycemic control and other risk factors leads to convergent cardiovascular outcomes. However, distinct metabolic risk profiles we observed suggest that the gender specific pathways to cardiovascular disease may differ, requiring tailored prevention strategies.The metabolic syndrome literature shows that the metabolic syndrome double cardiovascular events and mortality and *approximately a 1.5-fold increase in all-cause mortality* (Mottillo et al., 2010). Our finding shows that over 70% of the patients meet MetS criteria placing the most patients of our cohort in high-risk categories that demand the intensive risk factor modification.

These findings yield the key clinical implications:

1. Universal Glycemic Improvement Needed: The poor glycemic control in both sexes indicates that diabetes management strategies required fundamental re-evaluation. With < 30% achieving target HbA1c, systematic approachestrea tment intensification, education, and adherence support are needed urgently. Healthcare providers should adopt the treat-to-target protocol with regular monitoring as well as timely medication escalation.
2. Gender-Specific Risk Factor Modification: Higher females BMI and LDL suggest that cardiovascular risk prevention strategies should be gender-tailored. Women may benefit from structured weight management programs including structured lifestyle interventions, and anti-obesity drugs or metabolic surgery when appropriate. Moreover, the aggressive lipid-lowering therapy, should be considered also for women given their higher LDL levels.
3. Comprehensive Cardiovascular Risk Management: Nearly 80% of the patients have moderate to very high CVD risk, reqquiring management beyond the glycemic control to address hypertension, dyslipidemia, obesity, and lifestyle. The American Heart Association advises comprehensive evidence based risk factors control (Jacobs, 2022).
4. Early Intervention Imperative: The diabetes duration correlate with rising HbA1c supports early, intensive intervention to prevent progressive glycemic decline. The UKPDS legacy effect proves the early glycemic control yield lasting cardiovascular benefits (Holman et al., 2008).
5. Metabolic Syndrome-Focused Approaches: Metabolic syndrome prevalence is high, multiple components interventions-combined diet and exercise programs, or medications with pleiotropic effects (SGLT2 inhibitors, GLP-1 receptor agonists) are especially beneficial.

Strengths and Limitations

This study strengths, including the comprehensive metabolic phenotyping with novel parameters including the lipid ratios, visceral adiposity index, and eGFR. To validate the risk stratification, we have used the DCSI tools and composite cardiovascular risk scores to enhance the reliability of the study findings. Moreover, correlation analysis of the metabolic

syndrome components revealed the detailed geneder specific risk profiles. Moreover, the correlation analyses with appropriate statistical corrections to ensure the validity comparision.

Limitation must be acknowledged, such as the cross-sectional design prevent causal inference and temporal relationship assessment. The single-center convenience sample limits generalizability to broader populations and the lack of the longitudinal follow-up for outcome assessment. Morover, the missing data on medication regimens, adherence, lifestyle factors, and socioeconomic variables represents an essential unmeausred confounders. Some parameters were estimated rather than directly measured parameters (eGFR, WHtR, VAI) and no assessment was made of diabetes complications beyond the cardiovascular disease such as retinopathy, nephropathy, neuropathy. Ultimately, the relatively modest samples size may limit the power to detect small effect sizes.

Future studies should use longitudinal designs to determine the temporal relationships between glycemic control, risk factor modification, and the cardiovascular outcomes. Inlcuding continuous glucose reveals glycemic variability, an independent cardiovascular risk factor beyond mean HbA1c (Zhang et al., 2012). Additionally, the qualitative research on diabetes self-management barrier can guide targeted interventions.

Precision medicine including genetic profiling (genetic profilling and pharmacogenomic theraphy) can identify the patients who benefit most from intensive interventions. Evaluation of gender specific diabetes management programs would be valuable for informing clinical practice.

Conclusions

This comprehensive analysis exposes a critcial glycemic control situation in type 2 diabetes adults, with one-third of patients achivening the target HbA1c. Though, glycemic control was gendering neutral, significant metabolic disparities emerge, females exhibit higher BMI, LDL cholesterol, and central adiposity, wherease the males showed greater composite cardiovascular risk. A high metabolic syndrome (72.3%) burden and the cardiovascular complications-particularly hypertension (46.9%) and stroke (23.1%) highlight the need of urgent, comprehensive, and intensified diabetes care.

These findings support adopting gender-sensitive diabetes management, that acknowledge the distinct male and female risk profiles, while universally maintaining targeting the alarmingly low rates of the glycemic control. Thus, the link between diabetes duration and glycemic deterioration stresses the importance of the early intervention, and sustained optimal control to curb the metabolic decline. Systematic, evidence-based diabetes care reform is needed now before the poor glycemic control, and the cardiovascular complications becomes irreversible.

Healthcare providers, policymakers, and systems must be collaborated to launch comprehensive diabetes management programs, that covers the full cardiometabolic risk spectrum. Only, through integrated approaches can we reduces the substantial cardiovascular morbidity and mortality, linked with type 2 diabetes.

Declarations

Ethics approval and consent to participate

All procedures performed in this study involving human participants were conducted in accordance with ethical standards described in Helsinki 2013, and approved by Institutional Bioethics Committee of Governemnt Postgraduate College Dargai, Malakand, Khyber Pakhtunkhwa (Ref: GPGC/Zoo-102) Informed consent was obtained from all individual participants included in the study.

Clinical trial number: not applicable.

Consent to Publish:

Written informed consent for publication of anonymized data was obtained from all participants (or from their legal guardians, where applicable). No identifiable personal information is included in this manuscript.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

All authors contributed to the study conception and design. B.A., A.Q.A., M.A., W.K., A.M., G.G., S.J., H.U., A.A., M.K., S.M.S.A.S., Q.J., and Q.Z. contributed to the conception and design of the study. Data collection and experimental work were carried out by B.A., W.K., G.G., S.J., H.U., A.A., and M.K. Data analysis and interpretation were performed by B.A., A.Q.A., M.A., S.Z., and Q.Z. The manuscript was drafted by B.A. and Q.Z., and critically revised by A.Q.A., M.A., W.K., A.M., G.G., S.J., H.U., A.A., M.K., S.M.S.A.S., S.Z., and Q.J. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

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

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Figures

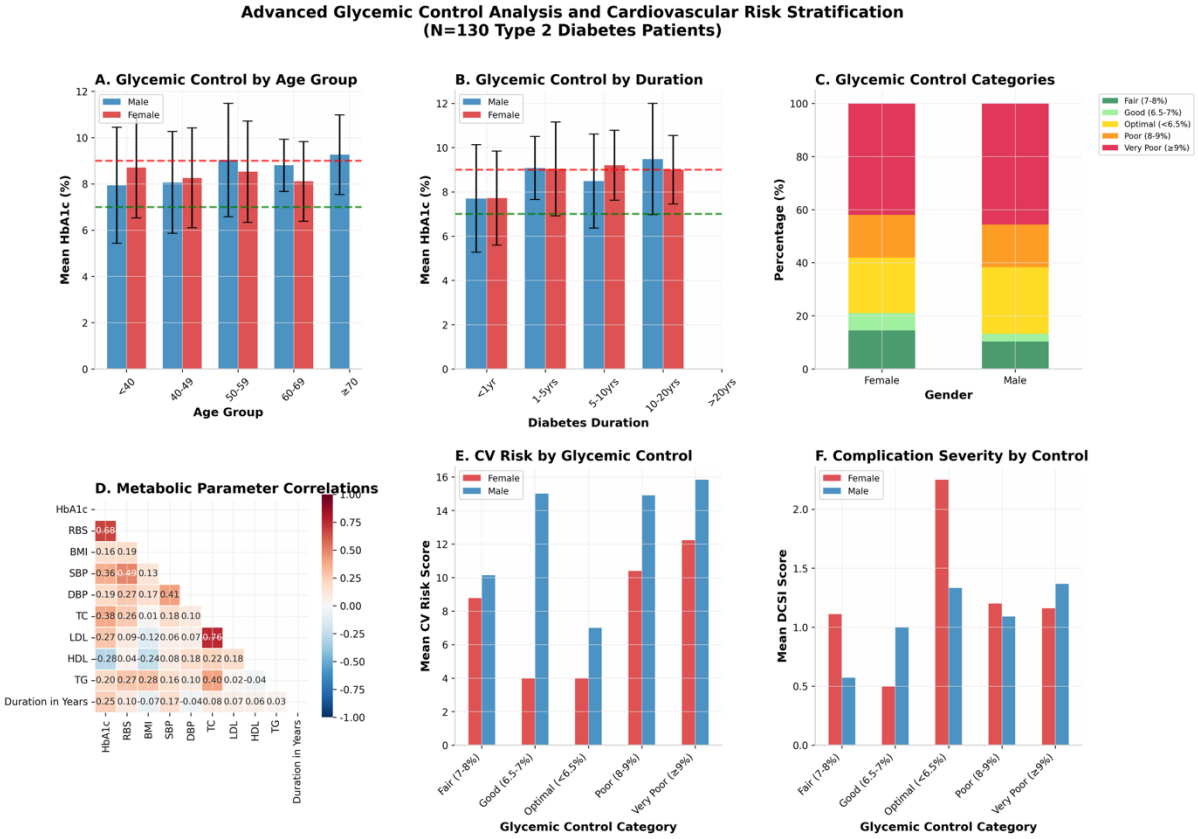

Figure 1: Highlights an Advanced Glycemic Control Analysis and Cardiovascular Risk Stratification (N=130 Type 2 Diabetes Patients)

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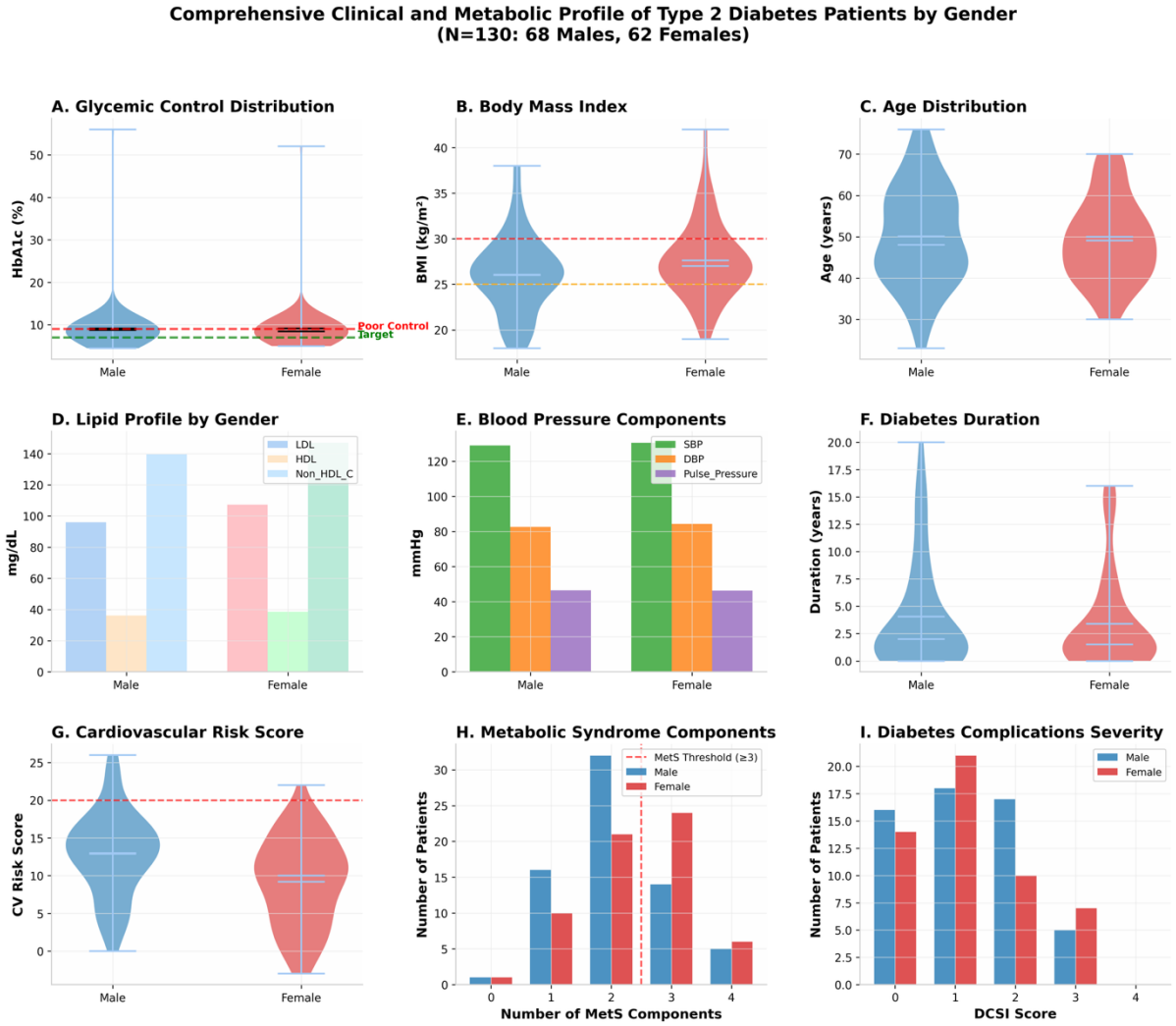

Figure 2: Comprehensive Clinical and Metabolic Profile of Type 2 Diabetes Patients by Gender (N=130: 68 Males, 62 Females)

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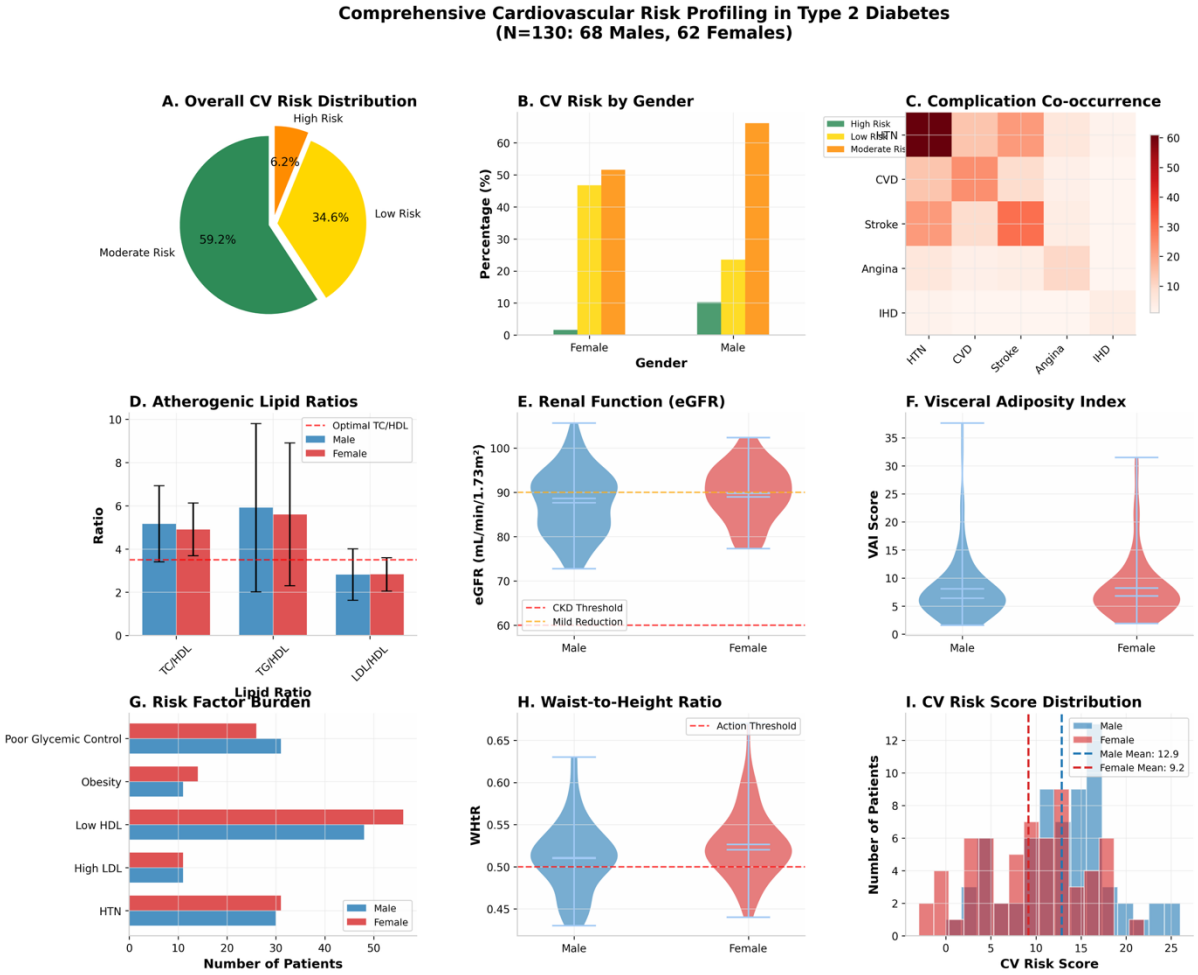

Figure 3: Illustrate the Comprehensive Cardiovascular Risk Profiling in Type 2 Diabetes (N=130: 68 Males, 62 Females)

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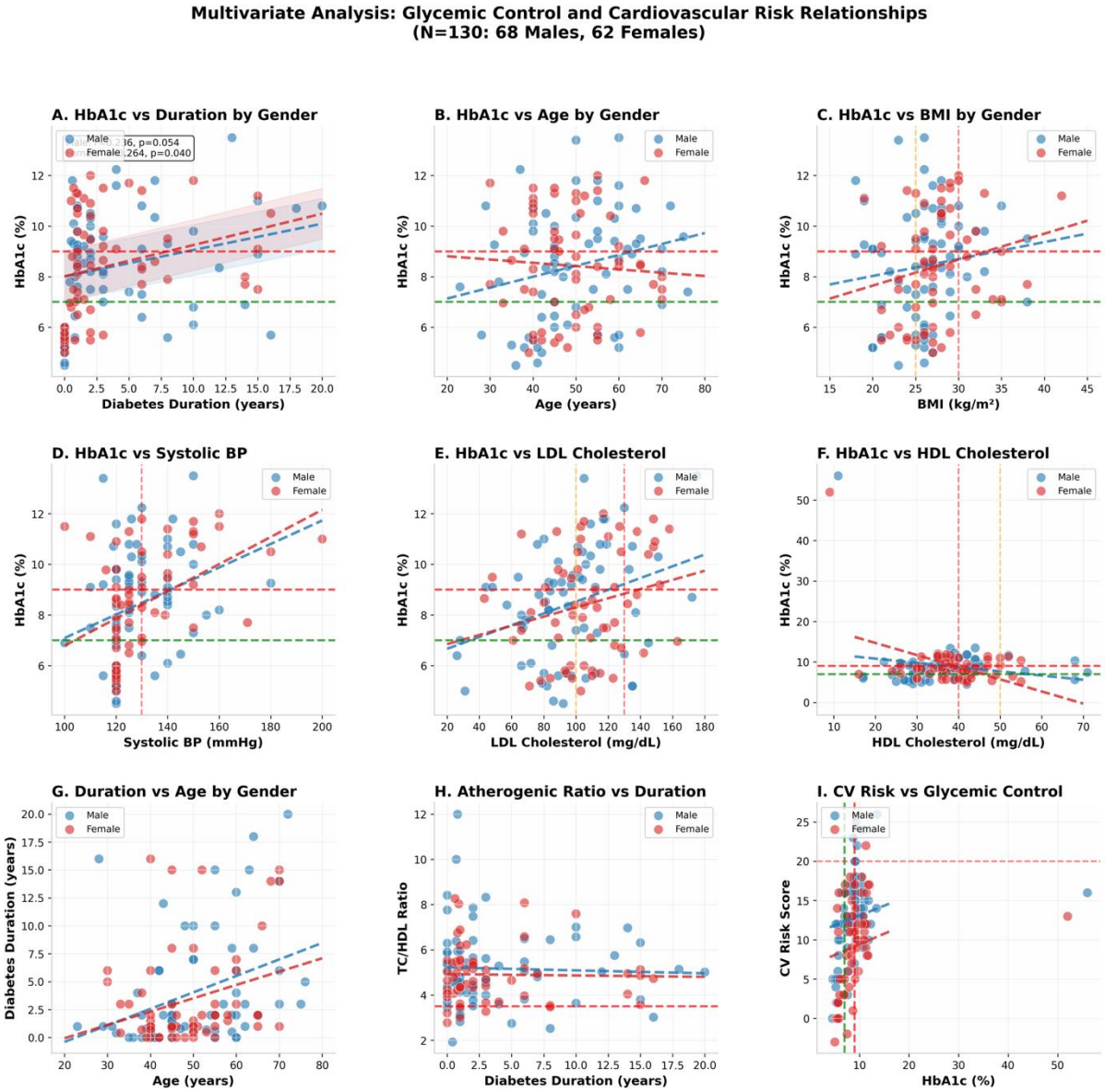

Figure 4: Represent the Multivariate Analysis: Glycemic Control and Cardiovascular Risk Relationships (N=130: 68 Males, 62 Females)

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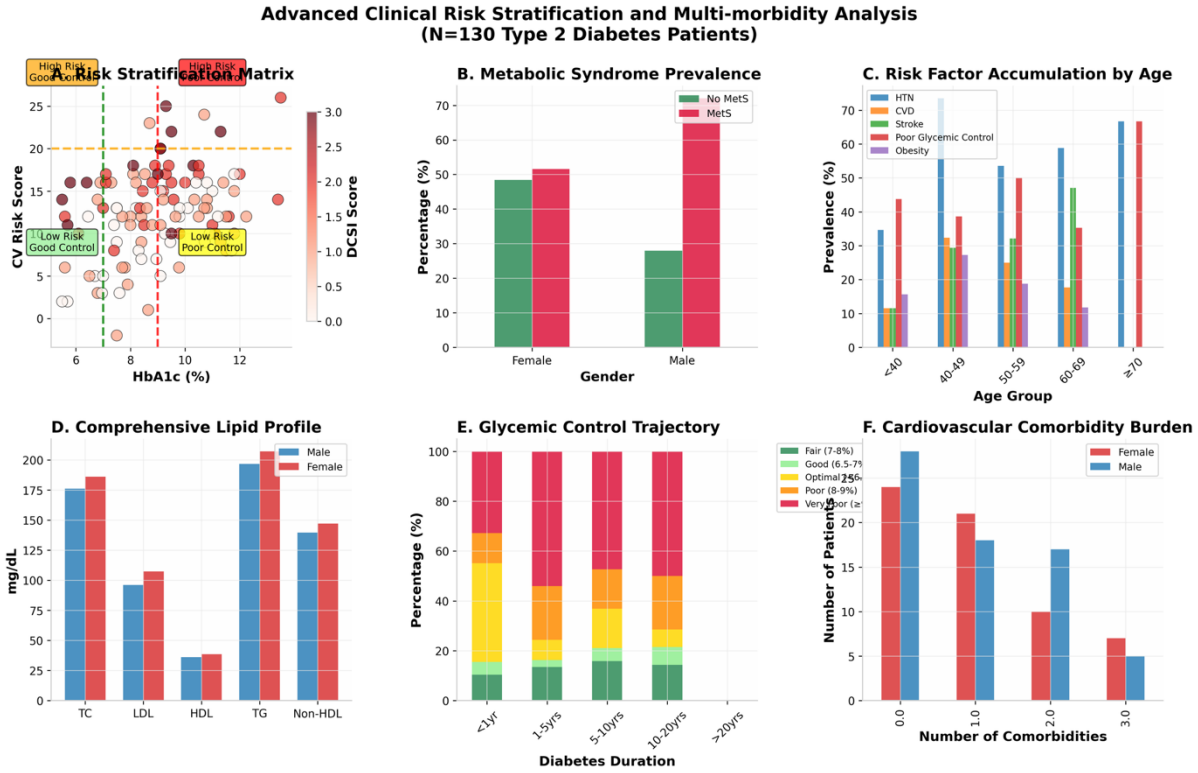

Figure 5: The Advanced Clinical Risk Stratification and Multi-morbidity Analysis (N=130 Type 2 Diabetes Patients)