Comparative Biochemical Analysis of Non-Diabetic Individuals with and without Metabolic Syndrome: A Cross-Sectional Study

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KEYWORDS
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ABSTRACT
Introduction: Non-communicable diseases (NCDs) increasingly threaten public health and economic well-being worldwide, leading to substantial shifts in healthcare demands. Metabolic syndrome (MetS)—characterized by central obesity, insulin resistance, dyslipidemia, and hypertension—is a significant risk factor for type 2 diabetes and cardiovascular diseases. Preventing and managing MetS effectively requires a comprehensive understanding of its underlying biochemical processes.
Objective: This study aims to identify key biochemical markers in non-diabetic individuals with MetS that may increase their risk for type 2 diabetes and cardiovascular diseases.
Materials and Methods: In this cross-sectional study, we investigated biochemical differences in non-diabetic individuals with MetS. Ethical approval was obtained, and 118 participants aged 30 to 60 years were recruited from an outpatient clinic, with 59 individuals in the MetS group and 59 as controls. Blood samples, taken after fasting overnight, were analyzed for serum insulin, lipid profiles, and fasting plasma glucose.
Results: The control group had an average age of 50.77 years, compared to 53.25 years in the MetS group. MetS participants exhibited significantly elevated postprandial blood sugar (PP2BS) (166.47 ± 21.89 mg/dL vs. 113.59 ± 18.11 mg/dL, $p < 0.001$) and fasting blood sugar (FBS) (113.57 ± 8.68 mg/dL vs. 103.02 ± 13.85 mg/dL, $p < 0.001$). Higher levels of triglycerides (214.16 ± 68.96 mg/dL vs. 118.55 ± 54.78 mg/dL, $p < 0.001$) and total cholesterol (203.35 ± 41.65 mg/dL vs. 183.0 ± 41.10 mg/dL, $p = 0.0086$) were also observed, alongside lower HDL levels (38.16 ± 6.50 mg/dL vs. 46.66 ± 12.18 mg/dL, $p < 0.001$). No significant differences were found in LDL cholesterol and HbA1c levels.
Conclusion: In non-diabetic individuals with metabolic syndrome, elevated glucose, triglycerides, total cholesterol, and reduced HDL indicate higher cardiometabolic risk. HbA1c and LDL showed no significant differences, but monitoring these markers could aid in early intervention.

1. Introduction

Non-communicable diseases (NCDs) significantly impact global health and economies, leading to shifts in healthcare priorities. Metabolic syndrome (MetS)—marked by central obesity, insulin resistance, dyslipidemia, and hypertension—is a key factor heightening the risk for cardiovascular disease and type 2 diabetes. As NCD rates continue to rise, a deep understanding of these mechanisms is crucial to devising effective prevention and treatment strategies. [1].

The World Health Organization reports that the rapid increase in NCDs is straining healthcare systems and threatening global economic and social development, affecting the lives of millions [2]. As the prevalence of these diseases continues to grow, it becomes increasingly essential to comprehend their underlying mechanisms and to devise effective prevention and management strategies.

The complexity of MetS arises from a multitude of factors, including lifestyle habits and genetic susceptibility. Research identifies MetS as a cluster of interrelated metabolic disorders—such as obesity, dyslipidemia, hyperglycemia, and hypertension—that collectively elevate the risk for type 2 diabetes and cardiovascular disease [3]. By pinpointing individuals with MetS, it is possible to implement targeted interventions that may lower the risk of serious health complications.

This study aims to explore the biochemical alterations in non-diabetic patients with MetS to develop effective preventive and therapeutic strategies. By understanding the mechanisms at play, it becomes feasible to identify high-risk individuals and carry out timely interventions, ultimately enhancing their health outcomes and quality of life [4,5].

2. Materials and Methods

This study aimed to assess biochemical variations in non-diabetic individuals with metabolic syndrome (MetS). This study received ethical approval from the Institutional Review Board. Prior to enrollment, all participants were fully informed about the study objectives and procedures, and written consent was obtained to ensure their voluntary participation. Based on the International Diabetes Federation's guidelines, 118 individuals aged 30 to 60 were recruited from an outpatient clinic. These individuals were divided into two equally sized groups: 59 participants meeting the diagnostic criteria for MetS and 59 non-MetS controls

In this cross-sectional study, participants were grouped based on essential diagnostic criteria, including central obesity, elevated triglyceride levels, low HDL cholesterol, high blood pressure, and increased fasting glucose levels [6]. To ensure accuracy and reliability in biochemical measurements, all participants underwent an overnight fast before blood sample collection. Blood was drawn into EDTA tubes, then centrifuged at 2000 rpm for 15 minutes at a temperature of 4°C. The separated plasma was stored at -80°C for later analysis [7].

The glucose oxidase-peroxidase method, a reliable protocol for plasma glucose analysis, was used to measure fasting plasma glucose levels [8]. Lipid profile assessments, covering total cholesterol, triglycerides, HDL, and LDL, were conducted using enzymatic techniques [9]. Serum insulin levels were measured through the enzyme-linked immunosorbent assay (ELISA), known for its high sensitivity and precision in quantifying insulin levels in human serum [10].

Statistical Analysis

Statistical analyses were performed using Stata software, version 15. Continuous variables were presented as mean ± standard deviation (SD). To compare the differences between the case and control groups, independent t-tests were used for normally distributed variables, including Fasting Blood Sugar (FBS), Postprandial Blood Sugar (PP2BS), Triglycerides, Total Cholesterol, HDL, BMI, Systolic Blood Pressure, and Diastolic Blood Pressure. For non-normally distributed variables, such as LDL and Uric Acid levels, the Mann-Whitney U test was applied. A p-value of less than 0.05 was considered statistically significant.[11].

3. Results:

This study comprised 118 participants, evenly split into two groups: 59 individuals diagnosed with metabolic syndrome (cases) and 59 without the condition (controls). The mean age of the control group was 50.77 years, while the case group had a slightly higher mean age of 53.25 years. Among the participants, there were 25 males (42.37%) and 34 females (57.63%) in the case group, and 31 males (52.54%) and 28 females (47.46%) in the control group.

Fasting Blood Sugar (FBS): The mean FBS level in the case group was significantly higher at 113.57 ± 8.68 mg/dL compared to the control group, which had a mean level of 103.02 ± 13.85 mg/dL. The difference between the two groups was statistically significant, with a p-value of less than 0.001. Additionally, postprandial blood sugar (PP2BS) levels were notably higher in cases (166.47 ± 21.89 mg/dL) than in controls (113.59 ± 18.11 mg/dL), also showing significance ($p < 0.001$).

HbA1c: The HbA1c levels did not demonstrate a significant difference between the case group, which had a mean level of 6.26 ± 0.66 %, and the control group, with a mean level of 6.01 ± 0.82 %. The p-value for this comparison was 0.074.

Urea: Urea levels were comparable between groups, with cases having a mean of 21.77 ± 6.29 mg/dL and controls at 21.72 ± 8.68 mg/dL ($p = 0.971$), indicating no significant difference.

Triglycerides and Total CholesterolThe case group exhibited significantly elevated triglyceride levels, with an average of 214.16 ± 68.96 mg/dL, compared to 118.55 ± 54.78 mg/dL in the control group ($p < 0.001$). This difference underscores the lipid dysregulation characteristic of MetS. Similarly, total cholesterol levels were higher in the case group at 203.35 ± 41.65 mg/dL compared to 183.0 ± 41.10 mg/dL in controls ($p = 0.0086$).

HDL and LDL: HDL cholesterol levels were significantly lower in the case group, measuring 38.16 ± 6.50 mg/dL, compared to the control group's 46.66 ± 12.18 mg/dL, with a p-value of less than 0.001. In contrast, there was no significant difference in LDL levels between the two groups.

BMI and Blood Pressure: Body mass index (BMI) was significantly higher in the case group, averaging 24.58

± 4.22, compared to 21.21 ± 2.09 in controls, with a highly significant p-value of less than 0.001. Additionally, both systolic (p = 0.0097) and diastolic blood pressures (p < 0.001) were significantly elevated in the case group compared to controls.

Table 1: Comparison of Parameters between Case and Control Groups

Test names	Mean ± SD (MetS Group)	Mean ± SD (Control Group)	p-value
Fasting Blood Sugar (FBS)	113.57 ± 8.68 mg/dL	103.02 ± 13.85 mg/dL	<0.001
Postprandial Blood Sugar (PP2BS)	166.47 ± 21.89 mg/dL	113.59 ± 18.11 mg/dL	<0.001
HbA1c	6.26 ± 0.66 %	6.01 ± 0.82 %	0.074
Urea	21.77 ± 6.29 mg/dL	21.72 ± 8.68 mg/dL	0.971
Total Cholesterol	203.35 ± 41.65 mg/dL	183.0 ± 41.10 mg/dL	0.0086
Triglycerides	214.16 ± 68.96 mg/dL	118.55 ± 54.78 mg/dL	<0.001
HDL	38.16 ± 6.50 mg/dL	46.66 ± 12.18 mg/dL	<0.001
LDL	120.65 ± 36.42 mg/dL	111.94 ± 33.15 mg/dL	0.2124
VLDL	42.83 ± 13.78 mg/dL	23.71 ± 10.34 mg/dL	<0.001
TotalCholesterol/HDL Ratio (TC/HDL)	5.32 ± 1.25	3.92 ± 1.02	<0.001
LDL/HDL Ratio	3.16 ± 0.85	2.40 ± 0.72	0.0003
Uric Acid	5.67 ± 1.32 mg/dL	5.08 ± 1.08 mg/dL	0.0125
Body Mass Index (BMI)	24.58 ± 4.22	21.21 ± 2.09	<0.001
Systolic Blood Pressure	120.06 ± 12.32 mmHg	114.67 ± 10.45 mmHg	0.0097
Diastolic Blood Pressure	77.86 ± 8.14 mmHg	71.01 ± 7.09 mmHg	<0.001

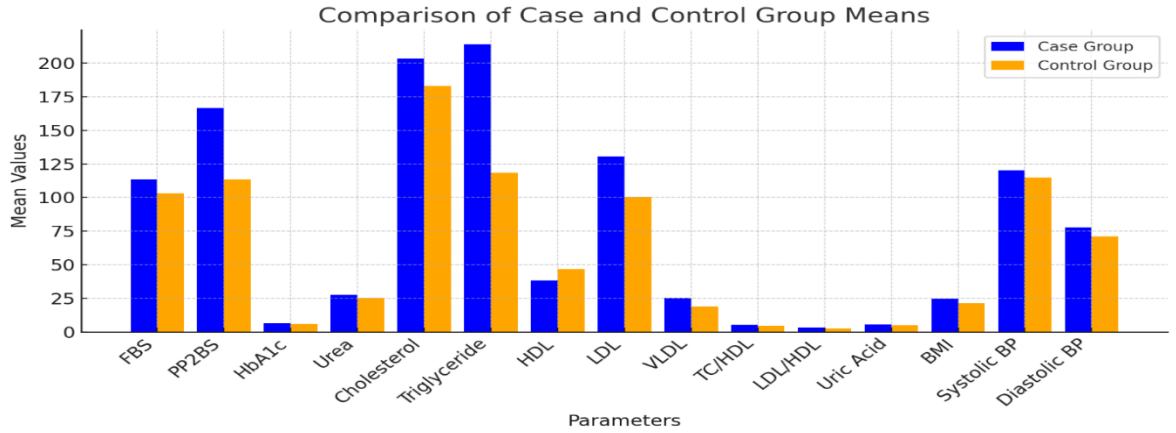

Figure 1: Comparison of Case and Control Group Means

4. Discussion:

The study involved a total of 118 participants, equally divided into two groups: 59 individuals diagnosed with metabolic syndrome (cases) and 59 healthy controls. The control group comprised 28 women and 31 men, while the case group consisted of 34 women and 25 men. A comprehensive evaluation was carried out on various parameters, including body mass index, diastolic and systolic blood pressure, uric acid, creatinine, HbA1c, total cholesterol, triglycerides, HDL cholesterol, LDL cholesterol, VLDL cholesterol, and the ratios of total cholesterol to HDL (TC/HDL) and LDL to HDL (LDL/HDL). Most parameters demonstrated significant differences between groups, except for urea, creatinine, uric acid, HbA1c, and LDL cholesterol.

Saravia et al. reported a mean age of 51.8 ± 5.2 years for cases and 47.5 ± 9.4 years for controls, with several biochemical parameters demonstrating positive correlations between individuals with metabolic syndrome and healthy individuals (p < 0.001) [12]. Significant positive correlations were found for parameters such as BMI, total cholesterol, triglycerides, HDL cholesterol, systolic and diastolic blood pressure, and fasting blood sugar (FBS), all with p-values < 0.001, except for LDL cholesterol and HbA1c, indicating no significant difference between groups [12].

Our findings align with those of Saravia et al., who similarly observed significant differences in parameters like BMI, total cholesterol, and triglycerides, while HbA1c and LDL cholesterol showed no marked difference between cases and controls [13]. Sutkovic et al. also reported elevated blood pressure, glucose, and lipid levels among cases, paralleling our findings and further emphasizing the risk profile in individuals with MetS. Our research indicated that fasting blood sugar (FBS) levels were 113.57 ± 8.68 mg/dL in the case group, compared to 103.02 ± 13.85 mg/dL in the control group (p < 0.001). Additionally, significant differences were observed in HDL, LDL, triglycerides, and total cholesterol levels between the two groups [13].

In Onkar Singh et al.'s study, male patients with metabolic syndrome were categorized based on fasting glucose levels, revealing differing values for HDL, triglycerides, total cholesterol, and LDL cholesterol compared to our results, where their mean FBS was noted as 121.33 ± 37.39 mg/dL. Our study includes a more diverse demographic, offering comparative insights across a broader spectrum of individuals and biochemical parameters, in contrast to Singh's study, which was limited to males and excluded certain comorbid conditions [14].

Furthermore, Chen LY et al. investigated the relationship between hyperuricemia and metabolic syndrome, finding significant associations between elevated triglycerides and increased waist circumference with higher uric acid levels in both genders [15]. In a distinct perspective, our study examined the relationships between individuals diagnosed with metabolic syndrome and healthy controls [15]. The findings revealed that the case group had significantly increased levels of serum uric acid, body mass index (BMI), systolic and diastolic blood pressure, as well as postprandial blood sugar (PP2BS) and VLDL cholesterol. Furthermore, the ratios of total cholesterol to HDL (TC/HDL) and LDL to HDL (LDL/HDL) were also markedly higher in the case group compared to their healthy counterparts [15,16].

In summary, These findings offer valuable insights into the biochemical profile linked with MetS, emphasizing markers in blood pressure, lipid, and glucose metabolism that could guide targeted clinical interventions. Identifying such markers can support early detection and personalized treatment strategies, potentially mitigating cardiometabolic risks in high-risk individuals.

5. Conclusions:

This study highlights key biochemical markers associated with MetS in non-diabetic individuals, such as elevated fasting/postprandial glucose, triglycerides, total cholesterol, and reduced HDL cholesterol, which may indicate a heightened risk for type 2 diabetes and cardiovascular diseases, aligning with our study's objective. While HbA1c and LDL levels did not show statistically significant differences between groups, their consistent presence across cases suggests they may still play a role in the metabolic profile associated with MetS. Ongoing monitoring of these biochemical markers, including both significant and non-significant findings, could support early detection and prompt intervention strategies. Such efforts are especially crucial in high-risk populations, including those in India, where the burden of MetS is on the rise.

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