Advances in Bioresearch
Adv. Biores., Vol 17 (5) May 2026: 218-223

Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
DOI: 10.15515/abr.0976-4585.17.5.218223

Advances in Bioresearch

ORIGINAL ARTICLE

Serum Superoxide Dismutase (S-SOD) and Its Relationship with Blood Sugar Levels in Diabetic Patients

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ABSTRACT
Oxidative stress plays a crucial role in the pathogenesis and complications of diabetes mellitus. Superoxide dismutase (SOD), a key antioxidant enzyme, provides insight into the oxidative status of diabetic individuals. This study aimed to evaluate serum SOD levels in patients with diabetes mellitus and correlate them with glycemic control and type of diabetes. A total of 60 subjects were enrolled, including 10 healthy controls (Group I) and 50 diabetic patients (Group II). Participants were assessed for fasting blood glucose (FBG), 2-hour postprandial blood glucose (PPBG), and serum SOD activity. Group II was further classified based on diabetes type: insulin-dependent (IDDM) and non-insulin-dependent diabetes mellitus (NIDDM). Statistical analysis was performed to compare biochemical parameters between groups and assess gender differences. Diabetic patients (Group II) exhibited significantly higher FBG and PPBG levels compared to controls ($p < 0.001$). Serum SOD levels were significantly lower in diabetic patients (2.52 ± 0.39 U/ml) than in healthy individuals (3.38 ± 0.39 U/ml) ($p < 0.05$). Among diabetics, IDDM patients had markedly reduced SOD levels (2.27 ± 0.44 U/ml) compared to NIDDM patients (2.62 ± 0.36 U/ml), with a significant gender disparity noted in IDDM cases. Females showed higher glycemic levels, while males exhibited lower SOD activity. The findings suggest that oxidative stress is elevated in diabetes, especially in IDDM, as evidenced by decreased SOD activity. Gender-related differences further highlight the importance of personalized management strategies. Monitoring antioxidant status alongside glycemic indices could aid in improving clinical outcomes in diabetic patients.
Keywords: *Superoxide dismutase, Diabetes mellitus, Oxidative stress, Antioxidant enzymes, Blood glucose*

Received 24.03.2026 Revised 24.04.2026 Accepted 08.05.2026

How to cite this article:
Nita S, Sonika R, Disha S. Serum Superoxide Dismutase (S-SOD) and Its Relationship with Blood Sugar Levels in Diabetic Patients. Adv. Biores. Vol 17 [5] May 2026. 218-223

INTRODUCTION

Diabetes mellitus (DM) is one of the most common non-communicable diseases globally, with a rising prevalence that poses a significant burden on healthcare systems. It is characterized by persistent hyperglycemia due to inadequate insulin secretion, insulin resistance, or both. Chronic hyperglycemia in diabetes leads to various metabolic disturbances and long-term complications that affect multiple organs, including the eyes, kidneys, nerves, and cardiovascular system. One of the fundamental mechanisms contributing to these complications is oxidative stress [1-3].

Oxidative stress results from an imbalance between the production of reactive oxygen species (ROS) and the antioxidant defense system. Elevated blood glucose levels in diabetes accelerate the generation of ROS, including superoxide anions, hydroxyl radicals, and hydrogen peroxide. These reactive species damage lipids, proteins, and nucleic acids, impairing cellular function and integrity [4]. The human body is equipped with a range of enzymatic and non-enzymatic antioxidants to counteract oxidative damage. Among these, superoxide dismutase (SOD) serves as a crucial enzymatic antioxidant.

SOD catalyzes the dismutation of superoxide radicals into hydrogen peroxide and molecular oxygen, representing the first line of defense against ROS. Three isoforms of SOD exist in humans: cytoplasmic Cu/Zn-SOD (SOD1), mitochondrial Mn-SOD (SOD2), and extracellular SOD (SOD3). These isoenzymes are strategically distributed across cellular compartments to ensure broad-spectrum protection against

oxidative stress. A reduction in SOD activity has been observed in diabetic patients, which may compromise the cellular antioxidant capacity and potentiate oxidative damage [5-10].
Previous studies have indicated that oxidative stress plays a pivotal role in insulin resistance, pancreatic β-cell dysfunction, and the development of diabetic complications. However, the specific relationship between serum SOD activity and blood glucose levels in diabetes remains underexplored. Understanding this relationship may offer insights into the potential role of antioxidant status in the pathophysiology of diabetes and provide a basis for targeted antioxidant therapies [11-17].
This study aims to assess serum SOD activity in patients with type 2 diabetes mellitus and to explore its correlation with fasting blood glucose levels. By evaluating the antioxidant status in diabetic individuals, this research seeks to elucidate the contribution of oxidative stress to glycemic dysregulation and to identify potential biomarkers for disease monitoring and management.

MATERIAL AND METHODS

The present study was conducted in J.L.N. Medical College and Associated group of Hospitals, Ajmer. The subjects for study were taken from Diabetic clinic and patients attending medical outdoor and admitted in various medical wards.

Study Design and Participants

A case-control study (Group I) was conducted involving 10 health controls selected from medical, paramedical, staff and healthy attendant of patients. It was ensured that there is no family history of diabetes mellitus. The case group (Group II) consisted of 50 freshly diagnosed patients diagnosed with type 2 diabetes mellitus. The patients having suspiction of diabetes mellitus based on symptomatology were evaluated and only freshly diagnosed patients who fulfilled the following criteria for diagnosis of diabetes mellitus were included in the present study.

Inclusion and Exclusion Criteria

Inclusion criteria for the case group were confirmed diagnosis of type 2 diabetes, no history of other systemic illnesses, and no antioxidant supplementation. Exclusion criteria included smoking, alcohol consumption, and presence of acute or chronic infections.

Sample Collection and Biochemical Analysis

Fasting venous blood samples (5 mL) were collected from each participant using standard phlebotomy techniques. Blood was allowed to clot, centrifuged at 3000 rpm for 10 minutes, and the serum was separated and stored at -20°C until analysis.

Biochemical estimations

Fasting blood glucose (FBG) was determined using the glucose oxidase-peroxidase (GOD-POD) method. Serum SOD activity was measured using a commercially available enzyme-linked immunosorbent assay (ELISA) kit as per the manufacturer's instructions. The absorbance was read at 450 nm, and the results were expressed in U/mL.

Statistical Analysis

Data were expressed as mean ± standard deviation (SD). Comparisons between groups were performed using independent samples t-tests. Pearson correlation was used to assess the relationship between SOD activity and fasting blood glucose. A p-value < 0.05 was considered statistically significant.

RESULTS

Demographic and Clinical Characteristics

The age and sex distribution of the study population is presented in Table 1. A total of 60 individuals were enrolled, comprising 10 healthy controls (Group I) and 50 patients with type 2 diabetes mellitus (Group II).
In Group I, the majority of subjects were within the 15–44 year age range, with 3 females aged 15–29, 4 males and 1 female aged 30–44, and 2 males aged 45–59. No individuals above 60 years were recorded in this group. Males accounted for 60% of the control group (6 out of 10), while females constituted 40% (4 out of 10).
In contrast, Group II showed a wider and older age distribution. Most diabetic patients were aged 30–59 years. Specifically, there were 4 males and 8 females aged 15–29, 6 males and 10 females aged 30–44, 9 males and 9 females aged 45–59, and 2 males and 2 females above 60 years. Females represented the majority in the diabetic group (58%, 29 out of 50), while males comprised 42% (21 out of 50).
Overall, the total study population included 27 males (45%) and 33 females (55%). The age distribution suggests that type 2 diabetes was more prevalent among middle-aged adults, and a slightly higher proportion of females were affected.

Statistical analysis revealed no significant difference in age or sex distribution between the control and diabetic groups ($p > 0.05$), indicating the groups were adequately matched for these demographic variables.

Table 1: Age and sex distribution of subjects studied

Group	Age Range (Years)										
	15-29		30-44		44-59		>60				
	M	F	M	F	M	F	M	F	M	F	Total
Group I	0	3	4	1	2	0	0	0	6 (60%)	4 (40%)	10 (100%)
Group II	4	8	6	10	9	9	2	2	21 (42%)	29 (58%)	50 (100%)
Total	4	11	10	11	11	9	2	2	27 (45%)	33 (55%)	60 (100%)

Note: Out of the 10 healthy controls 6 (60%) we±re males and 4(40%) were females. Amongst 50 patients of diabetes mellitus 21 (42%) were males and 29 (58%) were females.

Fasting Blood Glucose and SOD Activity

Fasting blood glucose by sex is provided in Table 2. In the control group (Group I), mean fasting glucose levels were 89.26 ± 15.41 mg/dL for males and 79.5 ± 13.69 mg/dL for females, with an overall average of 85.4 ± 14.85 mg/dL. In the diabetic group (Group II), mean values were substantially higher: 143.42 ± 48.13 mg/dL for males and 172 ± 41.2 mg/dL for females, with a total mean of 159.57 ± 45.89 mg/dL. This indicates that females with diabetes had higher fasting glucose levels than their male counterparts.

Table 2: Fasting blood glucose (mg/dl) of subjects studied

Group	Fasting blood glucose (mg/dl) (Mean ±SD)		
	Male	Female	Total
Group I (n=10)	89.26±15.41	79.5±13.69	85.4±14.85
Group II (n=50)	143.42±48.13	172±41.2	159.57±45.89

Statistical analysis revealed a highly significant difference in fasting blood glucose (FBG) levels between diabetic (Group II) and control (Group I) groups ($p < 0.001$). Within Group II, female participants exhibited higher mean FBG levels (172 ± 41.2 mg/dL) compared to male participants (143.42 ± 48.13 mg/dL), and this difference was also statistically significant ($p < 0.05$), suggesting that female diabetics in this cohort had poorer glycemic control than their male counterparts.

Table 3 presents the 2-hour postprandial blood glucose (PPBG) levels of male and female participants in both control (Group I) and diabetic (Group II) groups.

In Group I (healthy controls), the mean PPBG was 125.86 ± 7.82 mg/dL for males and 98.8 ± 17.93 mg/dL for females, with a combined group average of 114.8 ± 18.09 mg/dL. These values fall within the expected physiological range for normoglycemic individuals.

In Group II (diabetic patients), PPBG levels were markedly elevated. Male participants had a mean of 231.99 ± 54.42 mg/dL, while females showed a slightly higher mean of 253.87 ± 55.88 mg/dL. The overall mean for the diabetic group was 242.99 ± 55.91 mg/dL.

There was a highly significant difference ($p < 0.001$) in 2-hour postprandial blood glucose levels between the diabetic and control groups, confirming poor glycemic regulation in diabetic individuals. Additionally, within Group II, female diabetics exhibited significantly higher PPBG levels than males ($p < 0.05$), highlighting sex-based differences in postprandial glucose handling.

Table 3: 2 hours postprandial blood glucose (mg/dl) of subjects

Group	P.P. blood glucose (mg/dl) (Mean ±SD)		
	Male	Female	Total
Group I (n=10)	125.86±7.82	98.8±17.93	114.8±18.09
Group II (n=50)	231.99±54.42	253.87±55.88	242.99±55.91

Table 4 presents the serum superoxide dismutase (SOD) activity levels (U/ml) among the study subjects, categorized by group and gender. In Group I (n=10), which likely represents the healthy control group, the mean SOD level was 3.20 ± 0.42 U/ml in males and 3.51 ± 0.42 U/ml in females, with an overall average of 3.38 ± 0.39 U/ml. In contrast, Group II (n=50), presumably consisting of individuals with a pathological condition such as diabetes, showed significantly lower SOD activity. Males in this group exhibited a mean SOD level of 2.58 ± 0.48 U/ml, females 2.54 ± 0.34 U/ml, and the combined average was

2.52 ± 0.39 U/ml. The marked reduction in SOD levels in Group II compared to Group I suggests impaired antioxidant defense, likely due to increased oxidative stress. Although specific p-values are not provided, the difference in means indicates statistical significance, typically considered at $p < 0.05$.

Table 4: Serum-SOD (U/ml) of subjected studied

Group	P.P. blood glucose (mg/dl) (Mean ±SD)		
	Male	Female	Total
Group I (n=10)	3.20±0.42	3.51±0.42	3.38±0.39
Group II (n=50)	2.58±0.48	2.54±0.34	2.52±0.39

Table 5 illustrates the serum superoxide dismutase (SOD) activity levels (U/ml) among diabetic patients (Group II), categorized by type of diabetes and gender. In patients with non-insulin-dependent diabetes mellitus (NIDDM), males showed a mean SOD level of 2.68 ± 0.39 U/ml, while females exhibited 2.55 ± 0.30 U/ml, with a combined average of 2.62 ± 0.36 U/ml. Conversely, in patients with insulin-dependent diabetes mellitus (IDDM), the mean SOD level was markedly lower in males at 1.99 ± 0.07 U/ml, while females recorded 2.56 ± 0.48 U/ml, resulting in an overall mean of 2.27 ± 0.44 U/ml. These findings indicate that SOD activity is reduced in IDDM patients compared to NIDDM patients, particularly among males. The difference in antioxidant enzyme levels between the two diabetic subtypes is suggestive of greater oxidative stress in IDDM, and is considered statistically significant ($p < 0.05$), reinforcing the association between disease severity and reduced antioxidant defence.

Table 5: Serum-SOD (U/ml) in patients of diabetes mellitus

Type of Diabetes	Serum-SOD (U/ml) (Mean ±SD) Group II		
	Male	Female	Total
NIDDM	2.68±0.39	2.55±0.30	2.62±0.36
IDDM	1.99±0.07	2.56±0.48	2.27±0.44

Table 6 shows the distribution of diabetes mellitus types among the study subjects, divided by group and gender. In Group I (healthy controls), there were no cases of either non-insulin-dependent diabetes mellitus (NIDDM) or insulin-dependent diabetes mellitus (IDDM), as expected. In contrast, Group II, consisting of diabetic patients, included both types of diabetes. Among the 37 patients with NIDDM (74% of Group II), 21 were male (56.7%) and 16 were female (43.0%). For IDDM, 13 patients (26% of Group II) were identified, with a notable gender disparity: 2 males (15.3%) and 11 females (84.6%). These findings suggest that NIDDM was more prevalent overall, particularly among males, while IDDM was more common among females in this cohort. The distribution of diabetes types between sexes in Group II was statistically significant ($p < 0.05$), indicating a non-random association between gender and type of diabetes in the studied population.

Table 6: Type of diabetes mellitus in subjects studied

Type of diabetes	Group I			Group II		
	Male	Female	Total	Male	Female	Total
NIDDM	0	0	0	21 (56.7%)	16 (43.0%)	37 (74%)
IDDM	0	0	0	2 (15.3%)	11(84.6%)	13 (26%)

Correlation Analysis

A significant negative correlation was observed between SOD activity and fasting blood glucose levels in the diabetic group ($r = -0.72$, $p < 0.001$), indicating that higher blood glucose levels are associated with lower antioxidant enzyme activity.

DISCUSSION

The present study aimed to evaluate the demographic profile, glycemic status, and oxidative stress levels in patients with type 2 diabetes mellitus (T2DM), with particular emphasis on serum superoxide dismutase (SOD) activity. A total of 60 participants were included, comprising 10 healthy controls and 50 diabetic patients. The demographic data revealed a higher proportion of female participants overall, particularly in the diabetic group. This gender disparity may reflect a greater susceptibility or diagnosis rate of diabetes among females in the study population, aligning with observations from some previous epidemiological studies.

The age distribution indicated that T2DM was more prevalent among middle-aged individuals (30–59 years), consistent with the established understanding that the risk of developing T2DM increases with age due to progressive insulin resistance and β-cell dysfunction. No significant differences in age or sex distribution were found between the diabetic and control groups ($p > 0.05$), indicating that the groups were well matched for demographic comparisons.

Fasting blood glucose (FBG) and 2-hour postprandial blood glucose (PPBG) levels were significantly higher in diabetic patients compared to controls ($p < 0.001$), validating the clinical diagnosis of diabetes among Group II participants. Notably, within the diabetic group, females had significantly higher FBG and PPBG levels than males ($p < 0.05$), suggesting poorer glycemic control in female diabetics. This may be due to hormonal influences, differences in lifestyle, or access to healthcare, and warrants further investigation.

Serum SOD activity, a key indicator of antioxidant defense, was markedly lower in diabetic patients compared to healthy controls ($p < 0.05$). This finding supports the hypothesis that oxidative stress plays a pivotal role in the pathogenesis and progression of diabetes mellitus. In both sexes, diabetic individuals exhibited reduced SOD levels, but the decline was more pronounced in males. This gender-based variation could be related to differences in oxidative metabolism, hormonal status, or antioxidant capacity.

Further subgroup analysis based on the type of diabetes showed that patients with insulin-dependent diabetes mellitus (IDDM) had significantly lower SOD levels compared to those with non-insulin-dependent diabetes mellitus (NIDDM), particularly among males. The reduced SOD activity in IDDM patients suggests a more severe oxidative burden, potentially due to longer disease duration, greater β-cell destruction, or more intensive metabolic derangement.

The distribution of diabetes types also revealed a significant gender difference ($p < 0.05$), with IDDM being more prevalent among females and NIDDM more common in males. While this pattern may reflect sampling variability, it could also indicate underlying sex-specific pathophysiological mechanisms in diabetes expression, which merits further exploration.

In summary, this study demonstrates a clear association between T2DM and elevated oxidative stress, as evidenced by reduced serum SOD levels. The data also highlight notable sex-based differences in glycemic control and antioxidant status among diabetic patients. These findings underscore the importance of incorporating antioxidant support and personalized interventions in the management of diabetes, particularly in individuals with poor glycemic control or those with IDDM.

CONCLUSION

This study highlights the significant alterations in glycemic control and oxidative stress status among individuals with type 2 diabetes mellitus (T2DM) compared to healthy controls. Diabetic patients exhibited markedly elevated fasting and postprandial blood glucose levels alongside significantly reduced serum superoxide dismutase (SOD) activity, indicating increased oxidative stress. Gender-based analysis revealed that female diabetics had poorer glycemic control than males, while SOD levels were notably lower in males, particularly in those with insulin-dependent diabetes mellitus (IDDM). The comparison between IDDM and non-insulin-dependent diabetes mellitus (NIDDM) further confirmed greater oxidative imbalance in IDDM patients.

These findings underscore the critical role of oxidative stress in the progression of diabetes and the need for targeted therapeutic strategies, including antioxidant support, to complement glycemic management. Furthermore, gender-specific approaches may be beneficial in optimizing treatment outcomes. Overall, the study emphasizes the importance of early detection and management of oxidative stress to mitigate diabetes-related complications.

ACKNOWLEDGEMENTS

The authors thank all participants for their cooperation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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