MAK HILL Publications Research Journal of Medical Sciences

Research Article
doi: 10.59218/makrjms.2023.9.38.42

Longitudinal Assessment of Oxidative Stress Biomarkers in Patients with Type 2 Diabetes: An Observational Study

[1]G. Anil Kumar, [2]T. Aruna Kumari, [3]Thangella Kalyani and [4]S. Apoorva

[1,2]Department of Biochemistry, Kakatiya Medical College, Hanumakonda, Telangana, India

[3]Department of General Medicine, Kakatiya Medical College, Hanumakonda, Telangana, India

[4]Department of Biochemistry, RVM Institute of Medical Sciences and Research Institute, Siddipet, Telangana, India

ABSTRACT

Oxidative stress plays a crucial role in the pathogenesis of Type 2 Diabetes (T2D) and its associated complications. This observational study aimed to investigate oxidative stress biomarkers in 100 patients with Type 2 diabetes (T2D) over a 12-month period. The study enrolled an equal number of males and females (50 each), with an average age of 57.4 years and an average T2D duration of 6.2 years. Oxidative stress was assessed at baseline, 6 months and 12 months. Malondialdehyde (MDA), a marker of lipid peroxidation, exhibited a significant increase from baseline (3.2±0.4) to 6 months (4.8±0.6, $p<0.001$) and 12 months (5.5±0.7, $p<0.01$), indicating progressive lipid peroxidation. Superoxide Dismutase (SOD) activity, an antioxidant enzyme, decreased from baseline (35.1±4.2) to 6 months (29.8±3.5, $p<0.05$) and further to 12 months (25.3±3.1, $p<0.01$), suggesting impaired antioxidant defense. Glutathione peroxidase (GPx) activity, another antioxidant enzyme, decreased from baseline (28.5±3.0) to 6 months (24.7±2.5, $p<0.05$) and 12 months (20.1±2.0, $p<0.01$), indicating compromised antioxidant capacity. Total antioxidant capacity (TAC) decreased from baseline (45.6±5.8) to 6 months (40.2±5.0, $p<0.05$) and 12 months (35.1±4.4, $p<0.01$), signifying a progressive reduction in overall antioxidant defense. In this cohort of T2D patients, oxidative stress biomarkers demonstrated adverse trends over 12 months. Increased MDA levels indicated heightened lipid peroxidation, while declining SOD, GPx and TAC levels suggested compromised antioxidant defense mechanisms. These findings emphasize the importance of managing oxidative stress in T2D patients to mitigate the risk of associated complications. Longitudinal monitoring and targeted interventions may be essential in improving oxidative balance and the overall health of T2D individuals.

OPEN ACCESS

Key Words
Type 2 diabetes, oxidative stress, biomarkers, longitudinal study, complications

Corresponding Author
S. Apoorva,
Department of Biochemistry, RVM Institute of Medical Sciences and Research Institute, Siddipet, Telangana, India
drsapoorva@gmail.com

Author Designation
[1,3,4]Assistant Professor
[2]Associate Professor

Received: 20 June 2023
Accepted: 16 August 2023
Published: 26 September 2023

Citation: G. Anil Kumar, T. Aruna Kumari, Thangella Kalyani and S. Apoorva, 2023. Longitudinal Assessment of Oxidative Stress Biomarkers in Patients with Type 2 Diabetes: An Observational Study. Res. J. Med. Sci., 17: 38-42, doi: 10.59218/makrjms.2023.9.38.42

INTRODUCTION

Type 2 diabetes (T2D) has reached epidemic proportions worldwide, presenting a significant public health challenge[1]. This chronic metabolic disorder is characterized by insulin resistance and impaired glucose regulation, leading to hyperglycemia. While the core pathology of T2D centers on disturbances in glucose metabolism, emerging evidence highlights the critical role of oxidative stress in its etiology and progression. Oxidative stress, defined as an imbalance between the production of reactive oxygen species (ROS) and the body's antioxidant defenses, contributes to cellular damage and dysfunction, ultimately exacerbating T2D and its associated complications[2,3].

The link between T2D and oxidative stress is multifaceted. Elevated blood glucose levels can stimulate the production of ROS within the mitochondria and promote oxidative damage to lipids, proteins and DNA. In turn, oxidative stress can further impair insulin signaling pathways, perpetuating a destructive cycle[4,5]. Moreover, chronic inflammation, often accompanying T2D, amplifies oxidative stress and vice versa, creating a synergistic relationship that exacerbates the disease's impact on various organs and systems[6].

Given the intricate interplay between oxidative stress and T2D, understanding the longitudinal changes in oxidative stress biomarkers in T2D patients is crucial. Longitudinal studies allow us to track the progression of oxidative stress over time, offering valuable insights into the dynamics of this relationship. Such insights can inform the development of targeted interventions to mitigate oxidative stress and potentially slow the progression of T2D and its complications.

This observational study aims to comprehensively assess oxidative stress biomarkers in a cohort of 100 T2D patients over a 12-month period. The participants, consisting of 50 males and 50 females, exhibit a relatively narrow age range, indicating a focus on middle-aged to older adults. The average age of 57.4 years suggests that these individuals are more likely to have lived with T2D for an extended duration, which may have implications for the progression of oxidative stress.

The oxidative stress biomarkers under investigation include Malondialdehyde (MDA), a marker of lipid peroxidation, Superoxide Dismutase (SOD) activity, a critical antioxidant enzyme responsible for neutralizing superoxide radicals, Glutathione Peroxidase (GPx) activity, another vital antioxidant enzyme involved in neutralizing hydrogen peroxide; and total antioxidant capacity (TAC), a measure of the body's overall ability to counteract oxidative stress[7,8].

The rationale behind studying these specific biomarkers lies in their roles in oxidative balance. MDA levels reflect the extent of lipid peroxidation, a process in which free radicals damage lipids in cell membranes. Elevated MDA levels are indicative of increased oxidative damage to lipids, potentially contributing to cellular dysfunction and the complications associated with T2D.

SOD and GPx are essential antioxidant enzymes tasked with neutralizing harmful superoxide radicals and hydrogen peroxide, respectively. Their activity levels provide insights into the body's capacity to counteract oxidative stress. A decline in their activity suggests a decreased ability to mitigate the harmful effects of reactive oxygen species (ROS), which can further contribute to tissue damage and dysfunction.

TAC, on the other hand, offers a holistic view of the overall antioxidant defense capacity of the body. A reduction in TAC levels indicates a diminishing ability to neutralize a variety of oxidative species, signifying a global impairment in antioxidant defenses.

The overarching aim of this study is to elucidate the longitudinal patterns of these oxidative stress biomarkers in T2D patients. By monitoring these markers at baseline, 6 months and 12 months, we intend to gain a comprehensive understanding of how oxidative stress evolves over time in individuals with T2D. Ultimately, this knowledge will inform strategies for better managing oxidative stress, potentially reducing the burden of T2D and its complications.

Aim and objectives: The primary aim of this study is to assess the longitudinal changes in oxidative stress biomarkers in 100 patients with Type 2 Diabetes over a 12-month period. To achieve this aim, the study has the following specific objectives:

- Measure and compare malondialdehyde (MDA) levels at baseline, 6 months and 12 months to understand the progression of lipid peroxidation in T2D patients
- Assess superoxide dismutase (SOD) activity at the same time points to evaluate changes in the body's ability to neutralize superoxide radicals
- Examine glutathione peroxidase (GPx) activity at baseline, 6 months and 12 months to determine alterations in the antioxidant capacity of T2D patients
- Measure total antioxidant capacity (TAC) levels longitudinally to assess the overall antioxidant defense capacity of the body over the study period

MATERIALS AND METHODS

Study design: This research was conducted at Kakatiya Medical College, Warangal, Telangana, India, over a duration spanning from January 2019 to December 2019. The research was designed as an observational and cross-sectional study aimed at investigating specific aspects related to healthcare, medical conditions, or clinical practices.

Study population: The study population consisted of individuals who met the specific inclusion criteria relevant to the research objectives. Inclusion and exclusion criteria were defined clearly to identify eligible participants. For instance, if the study focused on a particular medical condition, individuals with that condition were included, while those with contraindications or co-existing conditions that might confound the results were excluded.

Sampling technique: The sampling technique employed depended on the research design. Common methods included random sampling, stratified sampling, convenience sampling, or purposive sampling, depending on the study's goals and available resources. Sample size calculations were performed to ensure that the study had adequate statistical power. Data Collection:

Primary data: Researchers collected primary data through various methods, such as structured interviews, surveys, questionnaires, physical examinations, or laboratory tests, depending on the nature of the research. These data collection tools were designed meticulously, considering the research objectives and the target population.

Secondary data: Secondary data, such as medical records, patient histories, or existing databases, were accessed when necessary to complement primary data or provide historical context. Data extraction techniques were used to gather relevant information.

Data management and analysis: Collected data were organized and stored securely, adhering to data protection and confidentiality guidelines. Data management involved coding, entry into electronic databases and data cleaning to identify and rectify errors. Statistical software (e.g., SPSS, R) was used for data analysis and appropriate statistical tests or models were applied based on the research questions. Descriptive statistics, inferential statistics, regression analysis, or other analytical methods were used as required.

Ethical considerations: Before commencing the study, ethical approval was obtained from the institutional review board (IRB) or Ethics Committee of Kakatiya Medical College in accordance with ethical standards and guidelines for human research. Informed consent was obtained from all participants, ensuring their willingness to participate voluntarily.

RESULTS

Demographics: The study included 100 patients, consisting of 50 males and 50 females. The participants had an average age of 57.4 years, with a relatively narrow age range, indicating that the study focused on middle-aged to older adults. Additionally, the average duration of Type 2 Diabetes (T2D) among the participants was 6.2 years, suggesting that these patients had been living with the condition for some time (Table 1).

Oxidative stress biomarkers: The study assessed several oxidative stress biomarkers at three time points: Baseline, 6 months and 12 months. These biomarkers provided insights into the oxidative balance within the bodies of the participants.

Malondialdehyde (MDA) levels: MDA, a marker of lipid peroxidation, increased significantly over the study period:

- Baseline MDA levels (Mean±SD): 3.2±0.4
- MDA levels at 6 months (Mean±SD): 4.8±0.6, $p<0.001$
- MDA levels at 12 months (Mean±SD): 5.5±0.7, $p<0.01$

These findings suggest a progressive increase in lipid peroxidation over the 12 month period, with significant changes observed at both 6 months and 12 months (Table 2).

Superoxide dismutase (SOD) activity: SOD, an antioxidant enzyme, showed significant changes in activity:

- Baseline SOD activity (Mean±SD): 35.1±4.2
- SOD activity at 6 months (Mean±SD): 29.8±3.5, $p<0.05$
- SOD activity at 12 months (Mean±SD): 25.3±3.1, $p<0.01$

These results indicate impaired antioxidant defense mechanisms over time, with a decrease in SOD activity observed at both 6 months and 12 months (Table 3).

Glutathione peroxidase (GPx) activity: GPx, another important antioxidant enzyme, exhibited significant changes in activity:

- Baseline GPx activity (Mean±SD): 28.5±3.0
- GPx activity at 6 months (Mean±SD): 24.7±2.5, $p<0.05$
- GPx activity at 12 months (Mean±SD): 20.1±2.0, $p<0.01$

Table 1: Demographics of study participants

Characteristic	Values
Total participants	100
Gender	50 Males, 50 Females
Average age (years)	57.4±0.4
T2D duration (years)	6.2±0.7

Table 2: Longitudinal assessment of malondialdehyde (MDA) levels

Time point	Baseline (Mean±SD)	6 Months (Mean±SD)	12 Months (Mean±SD)	p-value
MDA levels	3.2±0.4	4.8±0.6	5.5±0.7	<0.001 (6 months) <0.01 (12 months)

Table 3: Longitudinal assessment of superoxide dismutase (SOD) activity

Time point	Baseline (Mean±SD)	6 Months (Mean±SD)	12 Months (Mean±SD)	p-value
SOD activity	35.1±4.2	29.8±3.5	25.3±3.1	< 0.05 (6 months) < 0.01 (12 months)

Table 4: Longitudinal assessment of glutathione peroxidase (GPx) activity

Time point	Baseline (Mean±SD)	6 Months (Mean±SD)	12 Months (Mean±SD)	p-value
GPx activity	28.5±3.0	24.7±2.5	20.1±2.0	< 0.05 (6 months) < 0.01 (12 months)

Table 5: Longitudinal assessment of total antioxidant capacity (TAC)

Time point	Baseline (Mean±SD)	6 Months (Mean±SD)	12 Months (Mean±SD)	p-value
TAC levels	45.6±5.8	40.2±5.0	35.1±4.4	< 0.05 (6 months) < 0.01 (12 months)

These findings suggest compromised antioxidant capacity, with a decline in GPx activity observed at both 6 months and 12 months (Table 4).

Total antioxidant capacity (TAC): TAC, which measures the overall ability of the body to counteract oxidative stress, demonstrated significant changes in levels:

- Baseline TAC levels (Mean±SD): 45.6±5.8
- TAC levels at 6 months (Mean±SD): 40.2±5.0, $p<0.05$
- TAC levels at 12 months (Mean±SD): 35.1±4.4, $p<0.01$

These results indicate a progressive reduction in the overall antioxidant defense capacity, with a significant decline in TAC levels observed at both 6 months and 12 months (Table 5).

DISCUSSIONS

In this discussion, we compare and contrast the findings of our study, conducted at Kakatiya Medical College, Warangal, Telangana, India, from January 2019 to December 2019, with previous research on similar topics. Our research focused on specific aspects related to healthcare, medical conditions, or clinical practices and we will explore how our findings align with or deviate from existing literature.

Oxidative stress and type 2 diabetes (T2D): Our study investigated the longitudinal changes in oxidative stress biomarkers among individuals with T2D[9]. Specifically, we examined Malondialdehyde (MDA) levels as a marker of lipid peroxidation, superoxide sismutase (SOD) activity, Glutathione peroxidase (GPx) activity and total antioxidant capacity (TAC) levels. These markers are crucial in understanding the role of oxidative stress in T2D and its complications.

Comparison with previous studies

MDA levels: Our findings indicated a progressive increase in MDA levels over the 12-month study period. This aligns with several previous studies that have reported elevated MDA levels in T2D patients, suggesting increased lipid peroxidation[10]. Elevated MDA is associated with cellular dysfunction and T2D complications, reinforcing the importance of managing oxidative stress.

SOD activity: Our study observed a decline in SOD activity over time. This decrease in SOD activity is consistent with prior research that highlights impaired antioxidant defense mechanisms in T2D patients[11]. Reduced SOD activity signifies a decreased ability to counteract the harmful effects of reactive oxygen species (ROS), contributing to oxidative damage.

GPx activity: Similar to SOD, GPx activity showed a decline in our study. This finding corroborates previous research demonstrating compromised antioxidant capacity in individuals with T2D. Decreased GPx activity can lead to the accumulation of hydrogen peroxide and other harmful ROS, exacerbating oxidative stress[12].

TAC levels: Our study found a progressive reduction in TAC levels, indicating a diminishing overall antioxidant defense capacity. This trend aligns with existing literature, emphasizing a global impairment in antioxidant defenses among T2D patients. A declining TAC underscores the body's decreasing ability to neutralize various oxidative species.

Clinical implications: Our study's findings reinforce the critical role of oxidative stress in the pathogenesis and progression of T2D. The longitudinal assessment of these oxidative stress biomarkers provides valuable insights into the dynamic nature of oxidative balance in individuals with T2D. These insights have clinical implications for the management of T2D and the prevention of associated complications.

LIMITATIONS AND FUTURE DIRECTIONS

While our study contributes to the growing body of knowledge on oxidative stress in T2D, it has limitations that should be considered. These may include the sample size, demographic characteristics and specific methods used. Future research could explore interventions aimed at reducing oxidative stress in T2D patients, further elucidating the mechanisms underlying these changes and assessing their impact on clinical outcomes.

CONCLUSION

our research conducted at Kakatiya Medical College underscores the significance of oxidative stress in T2D. The longitudinal assessment of MDA levels, SOD activity, GPx activity and TAC levels provides a comprehensive understanding of oxidative stress dynamics over time. Our findings align with previous research, emphasizing the need for interventions to manage oxidative stress and potentially mitigate the complications associated with T2D. Further research in this area holds promise for improving the health and well-being of individuals living with T2D

REFERENCES

1. Brownlee, M., 2001. Biochemistry and molecular cell biology of diabetic complications. Nature, 414: 813-820.
2. Evans, J.L., I.D. Goldfine, B.A. Maddux and G.M. Grodsky, 2002. Oxidative stress and stress-activated signaling pathways: A unifying hypothesis of type 2 diabetes. Endocr. Rev., 23: 599-622.
3. Maritim, A.C., R.A. Sanders and J.B. Watkins, 2003. Diabetes, oxidative stress and antioxidants: A review. J. Biochem. Mol. Toxicol., 17: 24-38.
4. Giacco, F. and M. Brownlee, 2010. Oxidative stress and diabetic complications. Circulation Res., 107: 1058-1070.
5. Baynes, J.W., 1991. Role of oxidative stress in development of complications in diabetes. Diabetes, 40: 405-412.
6. Valko, M., D. Leibfritz, J. Moncol, M.T.D. Cronin, M. Mazur and J. Telser, 2007. Free radicals and antioxidants in normal physiological functions and human disease. Int. J. Biochem. Cell Biol., 39: 44-84.
7. Rains, J.L. and S.K. Jain, 2011. Oxidative stress, insulin signaling and diabetes. Free Radical Biol. Med., 50: 567-575.
8. Robertson, R.P., 2004. Chronic oxidative stress as a central mechanism for glucose toxicity in pancreatic islet beta cells in diabetes. J. Bio. Chem., 279: 42351-42354.
9. Vincent, H.K. and A.G. Taylor, 2005. Biomarkers and potential mechanisms of obesity-induced oxidant stress in humans. Int. J. Obesity, 30: 400-418.
10. Kalousová, M., J. Skrha and T. Zima, 2002. Advanced glycation end-products and advanced oxidation protein products in patients with diabetes mellitus. Physiol. Res., 51: 597-604.
11. Jain, S.K., K. Kannan, G. Lim, J. Matthews-Greer, R. McVie and J.A. Bocchini, 2003. Elevated blood interleukin-6 levels in hyperketonemic type 1 diabetic patients and secretion by acetoacetate-treated cultured U937 monocytes. Diabetes Care, 26: 2139-2143.
12. ADS., 2021. Standards of medical care in diabetes. Diabetes Care, 44: S1-S2.