# **SERUM LEVELS OF IL-10, TNF-ALPHA AND ALBUMIN IN TYPE 2 DIABETES MELLITUS MALE SUBJECTS IN FEDERAL MEDICAL CENTRE, ASABA**

**ABSTRACT**

Type 2 Diabetes Mellitus (T2DM) is a chronic metabolic disorder characterized by insulin resistance, hyperglycaemia, and systemic inflammation. Pro-inflammatory cytokines like Tumour Necrosis Factor-alpha (TNF-α) and anti-inflammatory cytokines such as Interleukin-10 (IL-10) play crucial roles in modulating immune responses and metabolic processes in T2DM. Additionally, albumin, a key serum protein, reflects nutritional status and systemic inflammation. This study aimed to evaluate and compare serum levels of TNF-α, IL-10, and albumin between male T2DM patients and healthy controls. The case-control study was conducted at the Federal Medical Centre, Asaba, involving 60 male subjects (30 T2DM patients and 30 healthy controls). Serum TNF-α and IL-10 levels were quantified using enzyme-linked immunosorbent assay (ELISA), while albumin was measured via the bromocresol green (BCG) method. Statistical analyses, including t-tests and Pearson correlation analyses, were performed using SPSS and statistical significance was assumed at p<0.05. The results revealed significantly elevated TNF-α (53.97 ± 10.22 Vs 15.11 ± 2.82) and IL-10 (17.07 ± 1.42 Vs 4.12 ± 0.88) levels in the male T2DM patients compared to the control group (p < 0.001), suggesting a concurrent pro-inflammatory state and compensatory anti-inflammatory response. However, no significant difference in the mean serum albumin level was observed between the test and control groups (p = 0.267). IL-10 exhibited a negative correlation with age in controls (p = 0.013). These findings highlight the clinical relevance of TNF-α and IL-10 as biomarkers for inflammation in T2DM, with potential applications in early diagnosis and treatment monitoring. Further research is warranted to explore their combined predictive value and gender-specific variations. Understanding these biomarkers' roles may enhance personalized therapeutic strategies for T2DM management.

**KEY WORDS:** Diabetes mellitus, Inflammation, Biomarkers, TNF-α, IL-10, Serum albumin, male T2DM patients.

**INTRODUCTION**

Type 2 Diabetes Mellitus (T2DM) formerly known as non-insulin-dependent Diabetes Mellitus is the most common form of Diabetes Mellitus characterized by hyperglycemia, insulin resistance and relative insulin deficiency (Agarwal *et al*., 2024; Ogbodo *et al*., 2019). Individuals living with T2DM are more susceptible to various forms of both short- and long-term complications, which often lead to their premature death (Chijioke *et al*., 2010). This tendency of increased morbidity and mortality seen in patients with T2DM especially in resource-poor developing countries like Nigeria has been linked to rapid lifestyle changes, population growth, and increased longevity due to increasing urbanization and industrialization (Flood *et al*., 2021; Hill-Briggs *et al*., 2020). Globally, the prevalence of T2DM has reached alarming proportions, with significant regional variations influenced by socioeconomic factors, healthcare access, and urbanization (Pinchevsky *et al*., 2020). Type 2 Diabetes Mellitus (T2DM) is a chronic metabolic disorder characterized by persistent hyperglycemia and associated with systemic inflammation (Młynarska *et al*., 2025). Elevated levels of pro-inflammatory cytokines, such as Tumor Necrosis Factor-alpha (TNF-α), and altered levels of anti-inflammatory cytokines like Interleukin-10 (IL-10), have been implicated in the pathogenesis of T2DM. Studies have demonstrated that T2DM patients exhibit significantly higher serum TNF-α concentrations compared to healthy individuals, suggesting a state of heightened inflammation (Chen *et al*., 2017; Akash *et al*., 2018). Tumour necrosis factor alpha (TNF-α) is a cytokine that has pleiotropic effects on various cell types. It has been identified as a major regulator of inflammatory responses and is known to be involved in the pathogenesis of some inflammatory and autoimmune diseases (Jang *et al.,* 2021).

Conversely, IL-10, an anti-inflammatory cytokine, plays a crucial role in modulating immune responses and maintaining metabolic homeostasis (Saraiva *et al*., 2020). Dysregulation of IL-10 has been associated with the progression of T2DM and its complications (Islam *et al*., 2025; Novianti and Nur'aeny, 2024; Ayelign *et al*., 2021). According to Iyer & Cheng (2012), interleukin 10 (IL-10) is a cytokine with potent anti-inflammatory properties that plays a central role in limiting host immune response to pathogens, thereby preventing damage to the host and maintaining normal tissue homeostasis. Dysregulation of IL-10 is associated with enhanced immunopathology in response to infection as well as an increased risk for the development of many autoimmune diseases.

Albumin, a major serum protein, is essential for maintaining oncotic pressure and serves as a marker of nutritional and inflammatory status. Alterations in serum albumin levels have been observed in T2DM patients, with studies indicating a negative correlation between albumin levels and the presence of diabetic complications, such as retinopathy (Alhalwani *et al*., 2023; Hui *et al*., 2023; Wang *et al*., 2022; Zhang *et al*., 2022).

The interplay between these biomarkers reflects underlying pathophysiological processes in T2DM, including insulin resistance, beta-cell dysfunction, and systemic inflammation. Elevated TNF-α contributes to insulin resistance by interfering with insulin signaling pathways, while reduced IL-10 levels may exacerbate inflammatory responses, further impairing insulin sensitivity. Changes in albumin levels can indicate systemic inflammation and are associated with the severity of diabetic complications. Despite the global prevalence of T2DM, there is a paucity of data regarding the behavior of these biomarkers in male T2DM patients in Nigeria. This present study aims to unearth the relationship between the serum levels of the cytokines (interleukin-10, TNF-alpha) and albumin in correlation with type 2 diabetes mellitus in male subjects.

This study employed a case and control study design involving male subjects with Type 2 Diabetes Mellitus in Federal Medical Centre, Asaba. Thus, understanding the specific patterns of TNF-α, IL-10, and albumin levels in this population is crucial for early diagnosis, risk stratification, and monitoring of therapeutic responses. This study aims to fill this research gap, providing insights that could lead to personalized treatment strategies, ultimately improving clinical outcomes and informing public health policies in Nigeria.

MATERIALS AND METHODS

## **Study Site**

The research was conducted at the Federal Medical Centre (FMC) Asaba, Delta State, Nigeria, a tertiary healthcare facility with a well-equipped laboratory capable of conducting biomarker assays relevant to Type 2 Diabetes Mellitus (T2DM).

## **Study Design**

This study adopted a case-control design to assess the serum levels of TNF-α, IL-10, and albumin in male T2DM patients. A total of sixty (60) participants were randomly recruited, with 30 individuals diagnosed with T2DM serving as test subjects and 30 healthy individuals serving as controls. Informed consent was obtained from all participants, and each subject completed a structured questionnaire capturing demographic and clinical information.

## **Sample Size Determination**

The sample size for this study was calculated using the documented prevalence of diabetes mellitus in Nigeria which was found to be 1.7% (International Diabetes Federation, 2017). The sample size for this study was calculated using the formula described by Charan and Biswas (2013);

N =

Where:

N = Required sample size when population of the facility is large

Z = The standard normal deviate, set at 1.96 which corresponds to the 95% confidence level

p = Estimated prevalence of diabetes mellitus in Nigeria which was found to be 1.7% (International Diabetes Federation, 2017)

d = Degree of accuracy required which set at 0.05 (margin of error at 5%)

Applying the method,

N = x p x (1-p)/

N =

N =

N = 25.7 ̴ N = 26

N = 26 minimum sample sizes

60 subjects were used for this study; 30 subjects served as control subjects while the other 30 type 2 diabetic male patients served as the test group.

**Inclusion Criteria**

The study included male subjects who were up to the age of 18 and above (those with and without diabetes mellitus). Those with T2DM served as the test group while subjects without diabetes mellitus which served as controls.

**Exclusion Criteria**

1. The study excluded subjects that were below the age of 18, male subjects with or without diabetes mellitus and other forms of diabetes mellitus.
2. Individuals with chronic inflammatory diseases, autoimmune disorders (e.g., rheumatoid arthritis), chronic infections (e.g., HIV, hepatitis), active malignancies, obesity, etc as well as active smokers were excluded from the study.
3. Use of corticosteroids or nonsteroidal anti-inflammatory drugs (NSAIDs) within the past six months was also an exclusion criterion due to their potential immunomodulatory effects.

## **Ethical Considerations**

The study adhered to ethical guidelines outlined in the Declaration of Helsinki (Puri *et al*., 2009). Ethical approval was obtained from the Ethics Committee of the Federal Medical Centre Asaba, Delta State, Nigeria. All participants provided informed consent before enrollment. Confidentiality was strictly maintained, and participants were assigned unique identification numbers to anonymize data. No financial compensation was provided to participants to minimize coercion. Participants had the right to withdraw at any stage without consequences.

## **Informed Consent**

Prior to participation, informed consent was obtained from all subjects. Each participant completed a questionnaire designed to capture relevant demographic and clinical information.

## **Sample Collection and Handling**

Venous blood samples (5 mL) were collected using standard venepuncture techniques and dispensed into plain tubes. Proper sample handling procedures were implemented to prevent biomarker degradation. Samples were immediately placed on ice and centrifuged at 3000 rpm for 10 minutes within one hour of collection to separate serum. Aliquots were stored at −20°C until analysis to preserve biomarker stability and prevent degradation. Quality control measures included the use of positive and negative controls, adherence to manufacturer protocols, and strict compliance with standard operating procedures.

**Determination of Cytokine Levels Tumor necrosis factor-alpha (TNF-α)**

The sandwich enzyme linked immunosorbent assay (sandwich-ELISA) method was used for the determination of tumor necrosis factor-alpha (TNF-α) and interleukin-10 (IL-10) levels in the participants’ sera.

**Estimation of Serum Albumin**

This was determined using the Bromocresol green method (BCG), as described by Doumas and Watson (1971) and cited by Okpogba *et al*. (2021).

**Statistical Analysis**

Data were analyzed using IBM SPSS Statistics (version 25.0) and presented using mean standard deviation. Student t-test and Pearson correlation was used to determine statistical difference and the association between variable. The values was considered statistically significant at P value 0.05.

**RESULTS**

The analysis of the cytokine levels (TNF-α and IL-10) revealed significant differences between the test and control groups. The mean concentration of tumor necrosis factor-alpha (TNF-α) was significantly elevated in the male T2DM patients test group (53.97 ± 10.22 Vs 15.11 ± 2.82; p < 0.001), suggesting a heightened inflammatory response in individuals diagnosed with T2DM. Similarly, the mean serum level of IL-10 was significantly higher in the test group than in the control group (17.07 ± 1.42 Vs 4.12 ± 0.88; p < 0.001), indicating a potential compensatory anti-inflammatory mechanism in the male T2DM patients. Conversely, no significant difference in serum albumin level was observed between the test and control groups (p = 0.267). Furthermore, the test group exhibited no significant differences in the mean age compared to the control group (p = 0.705). (See table 1).

**Table 1: Comparison of TNF-α, IL-10, Albumin, and Mean Age Between Test (male T2DM patients) and Control Groups**

| Variables | Test Group (Mean ± SD) | Control Group (Mean ± SD) | t-test | p-value |
| --- | --- | --- | --- | --- |
| TNF-α (pg/ml) | 53.97 ± 10.22 | 15.11 ± 2.82 | 17.216 | <0.001 |
| IL-10 (pg/ml) | 17.07 ± 1.42 | 4.12 ± 0.88 | 36.662 | <0.001 |
| Albumin (g/L) | 34.52 ± 5.43 | 36.14 ± 4.07 | -1.124 | 0.267 |
| Age (years) | 56.09 ± 4.32 | 54.86 ± 3.25 | 0.968 | 0.705 |

\* *Statistical significance at p < 0.05.*

Correlation analysis among TNF-α, IL-10, albumin, and age in the test group (male T2DM patients) revealed no statistically significant associations among the measured variables (p > 0.05). Specifically, TNF-α did not exhibit a significant correlation with IL-10 (r = -0.124, p = 0.574), albumin (r = -0.130, p = 0.554), or age (r = 0.030, p = 0.890). Similarly, IL-10 was not significantly associated with albumin (r = 0.332, p = 0.122) or age (r = 0.224, p = 0.304). See table 2.

**Table 2: Correlation Analysis in Male T2DM Patients**

| Variables | Statistics | TNF-α | IL-10 | Albumin | Age |
| --- | --- | --- | --- | --- | --- |
| TNF-α | *r* | - | -0.124 | -0.130 | 0.030 |
|  | *p-value* | - | 0.574 | 0.554 | 0.890 |
| IL-10 | *r* | -0.124 | - | 0.332 | 0.224 |
|  | *p-value* | 0.574 | - | 0.122 | 0.304 |
| Albumin | *r* | -0.130 | 0.332 | - | 0.244 |
|  | *p-value* | 0.554 | 0.122 | - | 0.262 |
| Age | *r* | 0.030 | 0.224 | 0.244 | - |
|  | *p-value* | 0.890 | 0.304 | 0.262 | - |

\* *Statistical significance at p < 0.05*

In contrast to the test group, correlation analysis among control subjects revealed a significant negative correlation between IL-10 and age (r = -0.521, p = 0.013), suggesting that IL-10 levels declined with increasing age in healthy individuals. However, no significant correlations were found between TNF-α and IL-10 (r = 0.201, p = 0.370), albumin (r = 0.245, p = 0.273), or age (r = 0.204, p = 0.362). Likewise, albumin did not exhibit a significant correlation with IL-10 (r = -0.259, p = 0.245) or age (r = 0.194, p = 0.387). These findings suggest that, unlike T2DM patients, the regulatory mechanisms influencing inflammatory cytokine levels in healthy individuals may be influenced by age-related physiological changes rather than metabolic dysregulation.

**Table 3: Correlation Analysis in Male Control Subjects**

| Variables | Statistics | TNF-α | IL-10 | Albumin | Age |
| --- | --- | --- | --- | --- | --- |
| TNF-α | *r* | - | 0.201 | 0.245 | 0.204 |
|  | *p-value* | - | 0.370 | 0.273 | 0.362 |
| IL-10 | *r* | 0.201 | - | -0.259 | -0.521\* |
|  | *p-value* | 0.370 | - | 0.245 | 0.013\* |
| Albumin | *r* | 0.245 | -0.259 | - | 0.194 |
|  | *p-value* | 0.273 | 0.245 | - | 0.387 |
| Age | *r* | 0.204 | -0.521\* | 0.194 | - |
|  | *p-value* | 0.362 | 0.013\* | 0.387 | - |

\**Statistically significant at p<0.05.*

## **DISCUSSION**

In the current study, we found significantly elevated levels of tumor necrosis factor-alpha (TNF-α) and interleukin-10 (IL-10) in the male T2DM patients compared to the control group, indicating a dysregulated inflammatory response in individuals with Type 2 Diabetes Mellitus (T2DM). This finding aligns with previous research demonstrating increased pro-inflammatory cytokines in T2DM patients (Bashir *et al*., 2022; Akash *et al*., 2018). The significantly elevated TNF-α levels in male diabetic subjects reinforce the cytokine's role in insulin resistance as TNF-α is known to impair insulin and contribute to chronic low-grade inflammation (Bashir *et al*., 2020). TNF-α has been implicated in the disruption of insulin signaling via serine phosphorylation of insulin receptor substrate-1 (IRS-1), thus exacerbating hyperglycaemia (Lee *et al*., 2022).

Furthermore, the increased IL-10 levels observed in the male test subjects in this study contradict earlier studies suggesting an anti-inflammatory role of IL-10 (Islam *et al*., 2022). However, this paradoxical increase may indicate a compensatory response to heightened inflammatory burden in T2DM (dos Santos Haber *et al*., 2023).

Notably, albumin levels remained comparable between groups (p > 0.05). this is in keeping with the reports of Analike *et al*. (2019) that documented no significant alterations in diabetic patients compared to control subjects. Nevertheless, some other studies showed lower serum albumin levels in diabetic patients than in control group (Ubani *et al*., 2024; Junaid *et al*., 2022; Chang *et al*., 2019). The disparity in the results by these various studies may be due to variations in the durations of diabetes mellitus patients recruited in the different studies as well as the differences in the sample sizes employed.

The lack of significant correlations in this study (T2DM patients) may be attributed to sample size limitations. In male control subjects, a significant negative correlation between IL-10 and age was observed, indicating that IL-10 levels declined with increasing age in healthy individuals. This aligns with studies suggesting that aging is associated with a decrease in anti-inflammatory cytokines, potentially contributing to a pro-inflammatory state (Navarro-González *et al*., 2011). However, no significant correlations were found between TNF-α and IL-10, albumin, or age, suggesting that in the absence of metabolic dysregulation, these biomarkers may not be interrelated. However, the study did not assess correlations in female subjects, limiting the ability to assess sex-based differences in these associations. Previous research has indicated that inflammatory responses and cytokine profiles may differ between sexes, potentially influencing T2DM pathogenesis and progression (Panagi *et al*., 2019). Future studies should include sex-specific analyses to elucidate these potential differences.

Potential limitations included the small sample size, which may limit generalizability. Additionally, only male participants were included, precluding sex-based comparisons. Biomarker levels were assessed at a single time point, limiting insights into temporal changes in inflammation and albumin levels. Future studies should incorporate longitudinal designs with larger, more diverse populations to enhance generalizability and causal inference.

**CONCLUSION**

The study highlights the significant role of inflammatory markers in Type 2 Diabetes Mellitus (T2DM), with elevated TNF-α and IL-10 levels observed in male T2DM patients, indicating a complex interplay between pro- and anti-inflammatory responses. While albumin levels did not differ significantly between groups, the negative correlation between IL-10 and age in male controls suggests age-related declines in anti-inflammatory activity. However, the study's small sample size, male-focused population, and lack of longitudinal data limit its generalizability. Future research should explore gender differences, larger cohorts, and multi-center collaborations to enhance understanding of inflammatory dynamics in T2DM, particularly within Nigeria’s diverse population, and inform personalized treatment strategies.

**REFERENCES**

Agarwal, S., Mishra, A., Katiyar, P., Kumar, C., Kushwaha, S., kumar, H. (2024). Diabetes Mellitus: Understanding the Disease, Its Diagnosis, and Management Strategies in Present Scenario. *African Journal of Biomedical Research*, 27(3), 320-331.

Akash, M.S.H., Rehman, K., & Liaqat, A. (2018). Tumor Necrosis Factor-Alpha: Role in Development of Insulin Resistance and Pathogenesis of Type 2 Diabetes Mellitus. *Journal of Cellular Biochemistry*, *119*(1), 105–110. <https://doi.org/10.1002/jcb.26174>

Alhalwani, A., Khan, M., Bahadur, R., Almalki, H., & Sannan, N. (2023). Assessment of Globulin Levels and Albumin-to-globulin Ratio in Patients with Type 2 Diabetes and Retinopathy: A Retrospective Single-center Study . *Open Ophthalmology Journal*, 2023; *17*, e18743641277168. <http://dx.doi.org/10.2174/0118743641277168231201102545>

Analike, R.A., Ihim, A.C., Iweanya, S.C., Ogbodo, E.C., Onah, C.E., Asomugha, A.L., Amah, A.K., Obi, P.C., Nwobodo, E.I., & Timothy, C.O. (2019). Assessment of glycated haemoglobin, total protein and albumin levels in patients with type 2 diabetes mellitus visiting NAUTH, Nnewi. *Indian Journal of Pathology and Oncology, 6*(4), 700-703. [https://doi.org/ 10.18231/j.ijpo.2019.132](https://doi.org/10.18231/j.ijpo.2019.132)

Ayelign, B., Negash, M., Andualem, H., Wondemagegn, T., Kassa, E., Shibabaw, T., Akalu, Y., & Molla, M. D. (2021). Association of IL-10 (- 1082 A/G) and IL-6 (- 174 G/C) gene polymorphism with type 2 diabetes mellitus in Ethiopia population. *BMC Endocrine Disorders*, *21*(1), 70. https://doi.org/10.1186/s12902-021-00738-1

Bashir, H., Ahmad Bhat, S., Majid, S., Hamid, R., Koul, R. K., Rehman, M. U., Din, I., Ahmad Bhat, J., Qadir, J., & Masood, A. (2020). Role of inflammatory mediators (TNF-α, IL-6, CRP), biochemical and hematological parameters in type 2 diabetes mellitus patients of Kashmir, India. *Medical Journal of the Islamic Republic of Iran*, *34*, 5. https://doi.org/10.34171/mjiri.34.5

Bashir, H., Hayat Bhat, M., & Majid, S. (2022). Molecular Pathogenesis of Inflammatory Cytokines in Insulin Resistance Diabetes Mellitus. IntechOpen. doi: 10.5772/intechopen.100971

Chang, D.C., Xu, X., Ferrante, A.W., Krakoff, J. (2019). Reduced plasma albumin predicts type 2 diabetes and is associated with greater adipose tissue macrophage content and activation. *Diabetology and Metabolic Syndr*ome, *11*, 14. <https://doi.org/10.1186/s13098-019-0409-y>

Charan, J., & Biswas, T. (2013). How to calculate sample size for different study designs in medical research?. *Indian Journal of Psychological Medicine*, *35*(2), 121–126. <https://doi.org/10.4103/0253-7176.116232>

Chen, Y. L., Qiao, Y. C., Xu, Y., Ling, W., Pan, Y. H., Huang, Y. C., Geng, L. J., Zhao, H. L., & Zhang, X. X. (2017). Serum TNF-α concentrations in type 2 diabetes mellitus patients and diabetic nephropathy patients: A systematic review and meta-analysis. *Immunology Letters*, *186*, 52–58. https://doi.org/10.1016/j.imlet.2017.04.003

Chijioke, A., Adamu, A.N, & Makusidi, A.M. (2010). Mortality patterns among type 2 diabetes mellitus patients in Ilorin, Nigeria. Journal of Endocrinology, Metabolism and Diabetes of South Africa (JEMDSA), *15*(2), 79–82.

Dos Santos Haber, J.F., Barbalho, S.M., Sgarbi, J.A., de Argollo Haber, R.S., de Labio, R.W., Laurindo, L.F., Chagas, E.F.B., & Payão, S.L.M. (2023). The Relationship between Type 1 Diabetes Mellitus, TNF-α, and IL-10 Gene Expression. *Biomedicines*, *11*(4), 1120. <https://doi.org/10.3390/biomedicines11041120>

Doumas, B.T., Watson, W.A., & Biggs, H.G. (1971). Albumin standards and the measurement of serum albumin with bromcresol green. *Clinica Chimica Acta; International Journal of Clinical Chemistry*, *31*(1), 87–96. <https://doi.org/10.1016/0009-8981(71)90365-2>

Flood, D., Seiglie, J.A., Dunn, M., Tschida, S., Theilmann, M., Marcus, M.E., Brian, G., Norov, B., Mayige, M.T., Singh Gurung, M., Aryal, K.K., Labadarios, D., Dorobantu, M., Silver, B.K., Bovet, P., Adelin Jorgensen, J.M., Guwatudde, D., Houehanou, C., Andall-Brereton, G., Quesnel-Crooks, S., Manne-Goehler, J. (2021). The state of diabetes treatment coverage in 55 low-income and middle-income countries: a cross-sectional study of nationally representative, individual-level data in 680 102 adults. *The Lancet. Healthy Longevity*, *2*(6), e340–e351. https://doi.org/10.1016/s2666-7568(21)00089-1

He, K.J., Wang, H., Xu, J., Gong, G., Liu, X., & Guan, H. (2024). Global burden of type 2 diabetes mellitus from 1990 to 2021, with projections of prevalence to 2044: a systematic analysis across SDI levels for the global burden of disease study 2021. *Frontiers in Endocrinology*, *15*, 1501690. <https://doi.org/10.3389/fendo.2024.1501690>

Hill-Briggs, F., Adler, N.E., Berkowitz, S.A., Chin, M.H., Gary-Webb, T.L., Navas-Acien, A., Thornton, P.L., & Haire-Joshu, D. (2020). Social Determinants of Health and Diabetes: A Scientific Review. *Diabetes Care*, *44*(1), 258–279. https://doi.org/10.2337/dci20-0053

Hui, D., Zhang, F., Lu, Y., Hao, H., Tian, S., Fan, X., Liu, Y., Zhou, X., & Li, R. (2023). A Multifactorial Risk Score System for the Prediction of Diabetic Kidney Disease in Patients with Type 2 Diabetes Mellitus. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy*, *16*, 385–395. <https://doi.org/10.2147/DMSO.S391781>

International Diabetes Federation. Diabetes atlas. 8th ed. Brussels: International Diabetes Federation; 2017.

Islam, H., Jackson, G.S., Boultbee, J., Tsai, S.H., Moreno-Cabañas, A., Teixeira, A.A.S., Wright, D.C., Mui, A.L., & Little, J.P. (2025). Interleukin-10 resistance in type 2 diabetes is associated with defective STAT3 signaling in human blood leukocytes. *American Journal of Physiology. Cell Physiology*, *328*(4), C1293–C1302. <https://doi.org/10.1152/ajpcell.00124.2025>

Iyer, S. S., & Cheng, G. (2012). Role of interleukin 10 transcriptional regulation in inflammation and autoimmune disease. *Critical Reviews in Immunology*, *32*(1), 23–63. https://doi.org/10.1615/critrevimmunol.v32.i1.30

Jang, D. I., Lee, A. H., Shin, H. Y., Song, H. R., Park, J. H., Kang, T. B., Lee, S. R., & Yang, S. H. (2021). The Role of Tumor Necrosis Factor Alpha (TNF-α) in Autoimmune Disease and Current TNF-α Inhibitors in Therapeutics. *International Journal of Molecular Sciences*, *22*(5), 2719. https://doi.org/10.3390/ijms22052719

Junaid, O.A., Ojo, O.A., Adejumo, O.A., Junaid, F.M., Ajiboye, K.J., Ojo, O.E., Akitikori, T.O., Kolawole, A.B., & Ikem, T.R. (2022). Malnutrition in elderly patients with type 2 diabetes mellitus in a Nigerian tertiary hospital: A cross-sectional study. Dialogues in Health, 1, 100030. <https://doi.org/10.1016/j.dialog.2022.100030>

Lee, S. H., Park, S. Y., Choi, C. S. (2022). Insulin Resistance: From Mechanisms to Therapeutic Strategies. *Diabetes & Metabolism Journal*, *46*(1), 15–37.

Młynarska, E., Czarnik, W., Dzieża, N., Jędraszak, W., Majchrowicz, G., Prusinowski, F., Stabrawa, M., Rysz, J., & Franczyk, B. (2025). Type 2 Diabetes Mellitus: New Pathogenetic Mechanisms, Treatment and the Most Important Complications. International Journal of Molecular Sciences, 26(3), 1094. <https://doi.org/10.3390/ijms26031094>

Navarro-González, J. F., Mora-Fernández, C., Muros de Fuentes, M., & García-Pérez, J. (2011). Inflammatory molecules and pathways in the pathogenesis of diabetic nephropathy. *Nature Reviews. Nephrology*, *7*(6), 327–340. https://doi.org/10.1038/nrneph.2011.51

Novianti, Y., & Nur'aeny, N. (2024). Exploring Interleukin-10 Levels in Diabetes Patients with and without Oral Diseases: A Systematic Review. *Journal of Inflammation Research*, *17*, 541–552. https://doi.org/10.2147/JIR.S449546

Ogbodo, E.C., Okafor, C.C., Ogah, H.G.O., Ezeugwunne, I.P., Igwebuobi, C.F., Okezie, A.O., Agada, U.N., Amah, A.K., & Odumodu, I.O. (2019). Thyroid hormone profiling and enzymatic antioxidant status in diagnosis and management of type-ii-diabetes mellitus: a review of literature. *World Journal of Pharmaceutical and Life Sciences, 5*(12), 6-21.

Okpogba, A.N., Odeghe, O.B., Ogbodo, E.C., Okwara, N.A., Izuchukwu, E.C.O., Ejovi, O., Gbodo, E.A., & Obi-Ezeani, C.N. (2021). Effect of occupational exposure to heavy metals on the liver functions in persons working in cable manufacturing factory in Nnewi. *IP International Journal of Forensic Medicine and* *Toxicological Science, 6*(1), 20-27.

Panagi, L., Poole, L., Hackett, R.A., Steptoe, A. (2019). Sex differences in interleukin-6 stress responses in people with Type 2 diabetes. *Psychophysiology*, *56*, e13334. <https://doi.org/10.1111/psyp.13334>

Pinchevsky, Y., Butkow, N., Raal, F. J., Chirwa, T., & Rothberg, A. (2020). Demographic and Clinical Factors Associated with Development of Type 2 Diabetes: A Review of the Literature. *International Journal of General Medicine*, *13*, 121–129. https://doi.org/10.2147/IJGM.S226010

Puri, K. S., Suresh, K. R., Gogtay, N. J., & Thatte, U. M. (2009). Declaration of Helsinki, 2008: implications for stakeholders in research. *Journal of Postgraduate Medicine*, *55*(2), 131-134..

Saraiva, M., Vieira, P., & O’Garra, A. (2020). Biology and therapeutic potential of interleukin-10. ***Journal of Experimental Medicine***, 217: e20190418. doi:10.1084/jem.20190418.

Ubani, B.C., Umoren, U., Nwafor, N.N., Dike, F.O. (2024). Malnutrition-related diabetes mellitus in a destitute male Nigerian. *Ibom Medical Journal, 17*(3),598-601.

Wang, G. X., Fang, Z. B., Li, J. T., Huang, B. L., Liu, D. L., Chu, S. F., & Li, H. L. (2022). The correlation between serum albumin and diabetic retinopathy among people with type 2 diabetes mellitus: NHANES 2011-2020. *PloS one*, *17*(6), e0270019. https://doi.org/10.1371/journal.pone.0270019

Zhang, J., Deng, Y., Wan, Y., He, S., Cai, W., & Xu, J. (2022). Association Between Serum Albumin Level and Microvascular Complications of Type 2 Diabetes Mellitus. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy*, *15*, 2173–2182. https://doi.org/10.2147/DMSO.S373160