Annual Methodological Archive Research Review
http://amresearchreview.com/index.php/Journal/about
Volume 3, Issue 9 (2025)

Online ISSN 3007-3197
Print ISSN 3007-3189

http://amresearchreview.com/index.php/Journal/about

Micronuclei as Early Warning Markers: A Study on Diabetic Patients in Narowal

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ABSTRACT

This study investigated the frequency of micronuclei (MN) in diabetic patients (females) of District Narowal, Pakistan. Participants (aged 40 -60) from the general population and various hospitals were included in this study, who were further divided into a control group (Normal) and an experimental group (Obese and Overweight) for the assessment of micronucleus formation using the Micronucleus Assay. Blood smear was prepared from a diabetic patient's sample, fixed with methanol, and stained with Giemsa stain. The slide was then examined under a microscope using oil immersion to analyze the presence of micronuclei. The study found that MN frequency was significantly higher in diabetic patients compared to

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controls, suggesting cytogenetic toxic effects associated with diabetes mellitus. In the control group, the frequency of mononucleated cells is 1, with a percentage is 0.01. The frequency of binucleated is 0 with 0.00 %. In the experimental group(Overweight), the frequency of mononucleated is 1 with 0.01 %. The frequency of binucleated cells is 2 with 0.02 %.In the experimental group (Obese), the frequency of mononucleated cells is 8 with 0.08 %. The frequency of binucleated is 6 with 0.06 %. The findings of this study demonstrated a clear increase in micronucleus (MN) frequency among diabetic patients compared to healthy controls, with the highest rates observed in obese diabetic individuals. This suggested that diabetes mellitus, especially when associated with higher body mass index (BMI), is linked to greater abnormalities in lymphocytes as evidenced by both mononucleated and binucleated micronucleus counts.

Key Words: Lymphocytes, Diabetes biomarkers, Genetic damage, Chromosomal instability

Introduction

Diabetes Mellitus (DM) is a prolonged, progressive disorder of metabolism defined by continual high blood glucose levels. This situation arises due to failing in insulin secretion, insulin action, or a combination of both (1). The pancreas which regulates blood glucose levels, produces by hormone is insulin. Diabetes disrupts the body's ability to use or produce insulin efficiently, leading to a range of acute and chronic diseases. DM is one of the most prevalent granular (hormone-related) dysfunction globally and signifies a significant public health problem, contributing to significant death rates and economic costs (2). Diabetes Mellitus signifies a considerable global health problem, with its accelerative increasing significantly over the previous several years. According to the International Diabetes Federation (IDF), as of 2021, approximately 537 million adults (20-79 years) were dealing with diabetes worldwide, representing 10.5% of the global adult population. This amount is predicted to reach 643 million by 2030 and 783 million by 2045 if actual directions proceed. (3).

Pakistan, as a populous South Asian nation, is consistent with the trend and is dealing with the rising challenge of non-communicable diseases (NCDs), and DM has appeared as a significant problem of public health over the previous several years (4). Pakistan, as the world's fifth most populous country, deals with many health problems, such as the increasing prevalence of NCDs (5). The WHO estimated that in 2016, NCDs accounted for 58% of all deaths in Pakistan. (6). Diabetes is most commonly diagnosed in children, adolescents, and young adults, although it can occur at any age. Patients with T1DM need lifelong insulin therapy to manage their condition (7).

The most current form of diabetes is T2DM, which is defined by insulin resistance, where the body's cells do not react effectively to insulin. The pancreas may eventually become less able to generate enough insulin to meet the body's requirements.T2DM is typically related to aging, obesity, physical inactivity, and unhealthy lifestyle components, such as poor dietary habits(8). The likelihood of Type 2 diabetes increases with age, particularly after 45 years old. Diets high in processed foods and

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sugary beverages, and low in fiber, are also associated with an elevated risk of diabetes. Certain demographic groups, including African Americans, Hispanics, Native Americans, and Asian Americans, face disproportionately higher chances of developing the disease. Additionally, chronic stress and mental health problems can increase diabetes risk by affecting blood sugar levels and promoting unhealthy lifestyle habits(9).

Adipose tissue is the body's main fuel (10) and the size of the adipose tissue mass determines how long a person will survive hunger. Lean men who lose more than 35% of their body weight perish after about 60 days of hunger(11). While individuals with extreme obesity can endure prolonged fasting, the longest known fasting period was 382 days, during which a man with extreme obesity lost 60% of his body weight while consuming only caloric fluids, vitamins, and minerals(12). whereas people with severe obesity can endure long-term fasting; the furthest known duration of fasting was, according to a man with intense obesity, who fasted for 382 days, consuming only caloric fluids, vitamins (13 ,14).In the early and middle of the 20th century, obesity was an issue of only in high-income countries, such as almost every country of Europe and the USA. High rates of undernutrition, including stunting, wasting, underweight, and infectious illnesses, have plagued low-income nations(15). But in the 21st century, obesity has spread to low- and middle- income countries of every region of the world(16) . Obesity is currently regarded as one of the world's most deadly health issues (17).

A common and accurate anthropometric technique for measuring obesity and evaluating a person's nutritional and health state, the Body Mass Index (BMI) is applicable to both adult men and women(18, 19). Therefore, its unit is kg/m2 or lb/inch 2 (20). A table or chart can be used to determine the BMI. A BMI that falls between 18.5 and 29.9 is considered desirable(21).

The metric formula of BMI is as follows (WHO, 2004) :

BMI = mass kg/height m^2

where unit is kg / m^2 (22,23).

A common test for assessing the cytotoxic and genotoxic effects of various substances is called the MN assay. This test can be performed on tissues that divide often and is quick, inexpensive, and accurate (24). The in vitro micronucleus (MN) assay is used worldwide to evaluate the capability of various chemicals or other factors to stimulate DNA damage in the fields of population biomonitoring and radiation bio dosimetry (25). MN, one of the most constituted biomarkers of chromosome disorder, is completed in cells due to the missegregation of chromosome fragments and complete chromosomes during mitosis(26). Micronuclei are more prevalent in diabetic patients, according to the few studies that have looked at how MN damages DNA in patients with type 2 diabetes(27, 28).

Micronuclei are common in diabetic individuals and can be associated with chromatid fragmentation, lagging acentric chromosomes, and abnormal chromosomal segregation (29). Diabetic people frequently have micronuclei, which are linked to aberrant chromosomal segregation, trailing acentric chromosomes, and chromatid breakage(30). According to Martinez-Perez et al., type 2 diabetes mellitus patients display much greater genetic disorder than non-diabetics (regarding MN frequency). This proposes that a biomarker panel for the risk of diabetes may benefit from

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containing MN as an element(31). However, there is a strong correlation between the occurrence of MN and telomere shortening, a biomarker for diabetes mellitus that results in genetic instability(32). The most often engaged cells for human biomonitoring are lymphocytes acquired from peripheral blood. There is an insufficiency of activity that attempts to investigate the MN ratio with T2DM. Hence, to assess MN frequency in T2DM patients reported to different diagnosis periods of time as a DNA damage biomarker (33).

Previously, a study was done on Mexican patients with type 2 diabetes mellitus (DM2) that exhibited differences in micronuclei (MN) frequency compared to a control group. The control group consisted of ten individuals aged 38–54 without DM2. The frequency of MN in binucleated lymphocytes was analyzed using the Fenech criteria. Since it was not possible to fully control for potential confounding factors, this investigation should be regarded as an exploratory study. The findings showed that MN frequency was significantly twice as high in DM2 patients compared to controls, suggesting that MN could be a useful biomarker for assessing DM2 risk. Additionally, consistent with previous research, this type of cytogenetic damage may indicate an increased risk of cancer(34).

As per our literature survey, no research investigation was done in Punjab, Pakistan, so this study was designed to assess and compare the frequency of micronuclei in peripheral blood smears of diabetic patients and healthy controls.

Materials and Methods

Study Design

This research was conducted using a comparative cross-sectional study design to assess the abnormalities related to micronuclei (MN) among diabetic patients (female) in Narowal, Pakistan. The study took place at the Diagnostic Laboratory of Medical Laboratory Technology, Alshifa Institute of Health Sciences, Narowal, from April 2025 to July 2025, with approval from the institution's Ethical Review Board.

Study Area

The study was conducted in the district of Narowal, located in Punjab, Pakistan's northeastern region. Patients were gathered from two sources

1. Private diabetic care centers and clinics (Umer Surgical Complex, ZafarWal , Mahmooda Complex, Zafarwal, Islam Hospital, Zafar Wal)
2. General Population

Study Population

Patients with Type 2 diabetes who lived in Narowal and a Control group of healthy, non-diabetic people made up the study population.

Inclusion Criteria

This study only included people between the ages of 40 and 60 who had been diagnosed with Type 2 diabetes, had a verified history of the disease for at least a year, and had no other major health conditions. The control group consisted of healthy people without diabetes or any known chronic illnesses

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Exclusion Criteria

Patients with a history of cancer, radiation exposure, or chemotherapy
Smokers or Patients exposed to environmental or occupational genotoxins.
Patients with other chronic inflammatory or infectious diseases.
Pregnant women.

Sample Size

A total of 400 subjects participated and were subsequently divided into two groups: the Control Group and the Experimental Group (comprising Overweight and Obese individuals).

Data Collection and Variables

Clinical and Demographic Information, like Age, weight, Height, gender, type of diabetes, duration of diabetes, blood glucose levels (fasting), and medication history, were gathered using a structured questionnaire and medical records.

Measurement of blood sugar level:

To determine the diabetic status of participants, blood sugar levels were measured using a standard glucometer(on-call Plus-ACON Laboratories , Inc.,USA) . A capillary blood sample was obtained from each participant via finger prick under sterile conditions. The glucometer was calibrated before use to ensure accuracy. Each participant's fasting blood was recorded. This step was essential for confirming diabetes in patients and for comparing results with those of non-diabetic controls(35).

MN assay

Sample collection

Participants render two milliliters of blood via sterile, non-pyrogenic syringes (3cc) , which were then processed for additional analysis within a day in an EDTA tube.

Micronuclei test procedure

The patients ' blood sample was utilized to prepare the blood smear, which was then allowed to air dry for at least half an hour before being fixed at room temperature. Fixation was finished for 10 to 15 minutes using a freshly prepared, ice-cold methanol solution. The slides were fixed and then rinsed twice in phosphate buffer saline (pH 6.8). After that, the slides were instantly stained for five minutes using a 5% Giemsa solution. Slide boxes were used to store the slides until they were examined under a microscope.Unique nucleated cells with clear abnormalities were focused slide. A structure was classified as a micronucleus if it was inside the cytoplasm, had a regular border, and had staining intensity that was lower than or equal to that of the main nucleus. Immersion oil was used to view these slides at 100 objective and 10 eyepiece magnifications. To be eligible for the Micronuclei analysis, each slide needs to contain at least 100 lymphocyte cells. Using a light microscope (100x magnification with oil immersion), micronuclei were identified using the standard protocol (36,37)

Scoring Procedure

The presence of micronuclei was assessed in 100 cells. Cells with ambiguous

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morphology, overlapping nuclei, or fragmented cytoplasm were not included.

Quality Control

To guarantee quality, results were cross-validated and mark twice. 10% of the slides are arbitrarily bank check by a second perceiver(56).

Statistical Analysis

Software known as Minitab (version XX) was used to analyze the data. We computed descriptive statistics (mean± SD by Excel. The MN frequency between diabetics and controls was compared using independent t-tests s and one way ANOVA. P-values less than 0.05 were considered as statistically significant

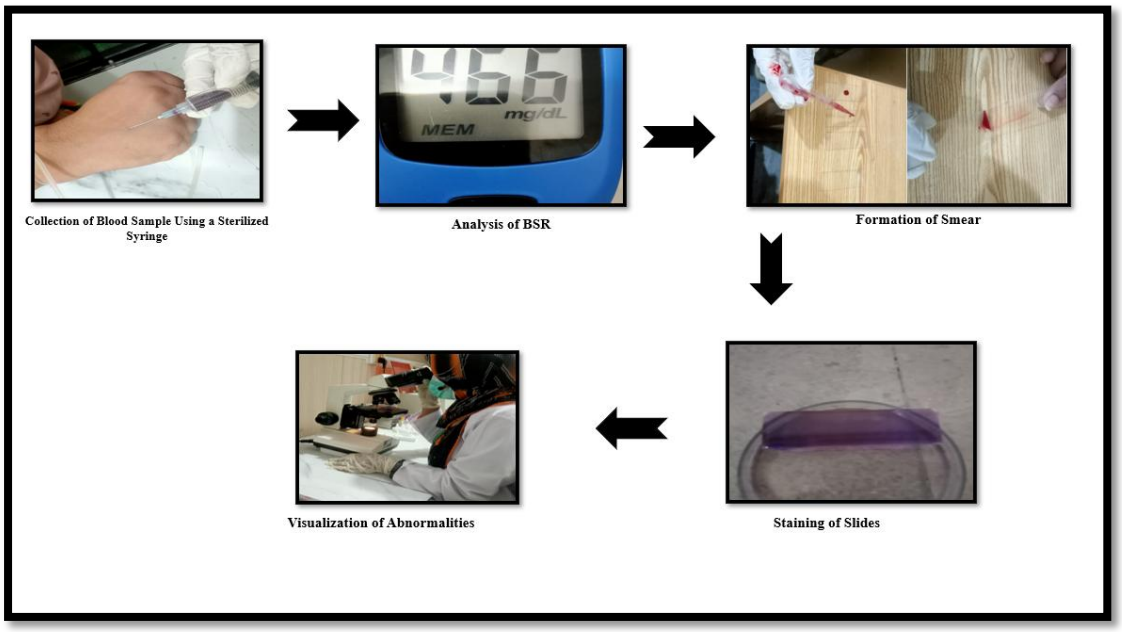


Fig1. Schematic representation of the methodological workflow

Results

This study was conducted on diabetic patients (aged 60 -80) from the general population and various hospitals, who were further divided into a control group (Normal/Healthy) and an experimental group (Obese and Overweight) for the assessment of cytogenetic changes in Diabetic patients by Micronucleus Assay

Mean Value of BMI in Control and Experimental Groups

The mean value of BMI of the control group is (21.33±1.78) .The mean value of BMI of the experimental group(Obese) is (36.28±7.70) . The mean value of BMI of the experimental group (overweight) is (26.93± 1.38) as shown in Table 1 and Fig 2

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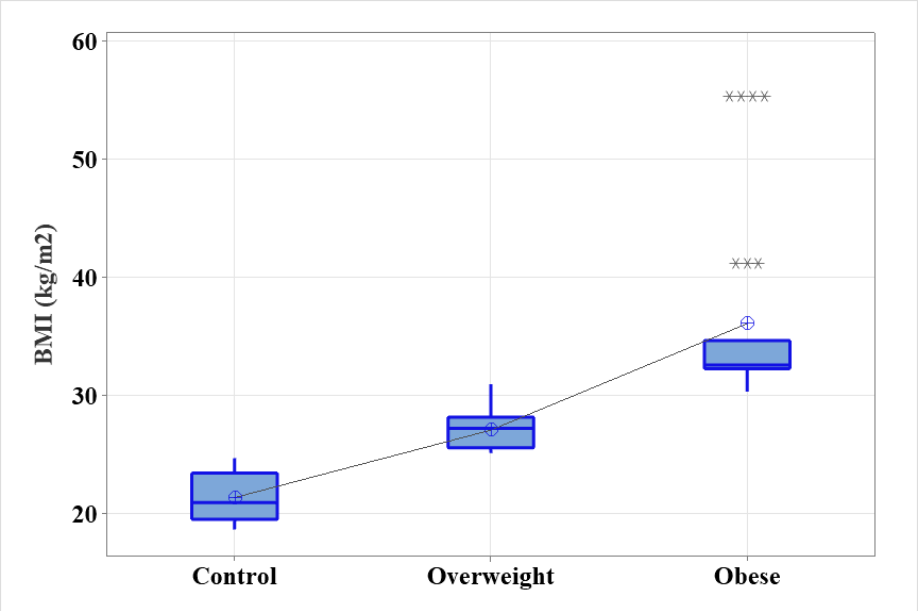


Figure 2 BoxPlot showing BMI of Control and Experimental Groups (Overweight and Obese)

The mean value of blood sugar Random (BSR) of the control group is(134.84 ± 17.22). The mean value of BSR of the experimental group (obese) is (372.56 ±59.56). The mean value of BSR of the experimental group (overweight) is(394.75 ±65.23).

Abnormalities of Lymphocytes

Lymphocytes and variations in blood were also visualized on the blood of a diabetic patient. There are two abnormalities of Lymphocytes: Micronuclei are observed . One is mononucleated other is binucleated. The frequency of mononeucleated is 8 with 0.08 %. The frequency of binucleated is 6 with 0.06 %. Various genotoxic anomalies, such as binucleated (BN), multinucleated (MtN), were observed in the Experimental Group as shown in **Table 2**. Among all the observed Mononucleated (MN), Binucleated (BN) cells were most prevalent.

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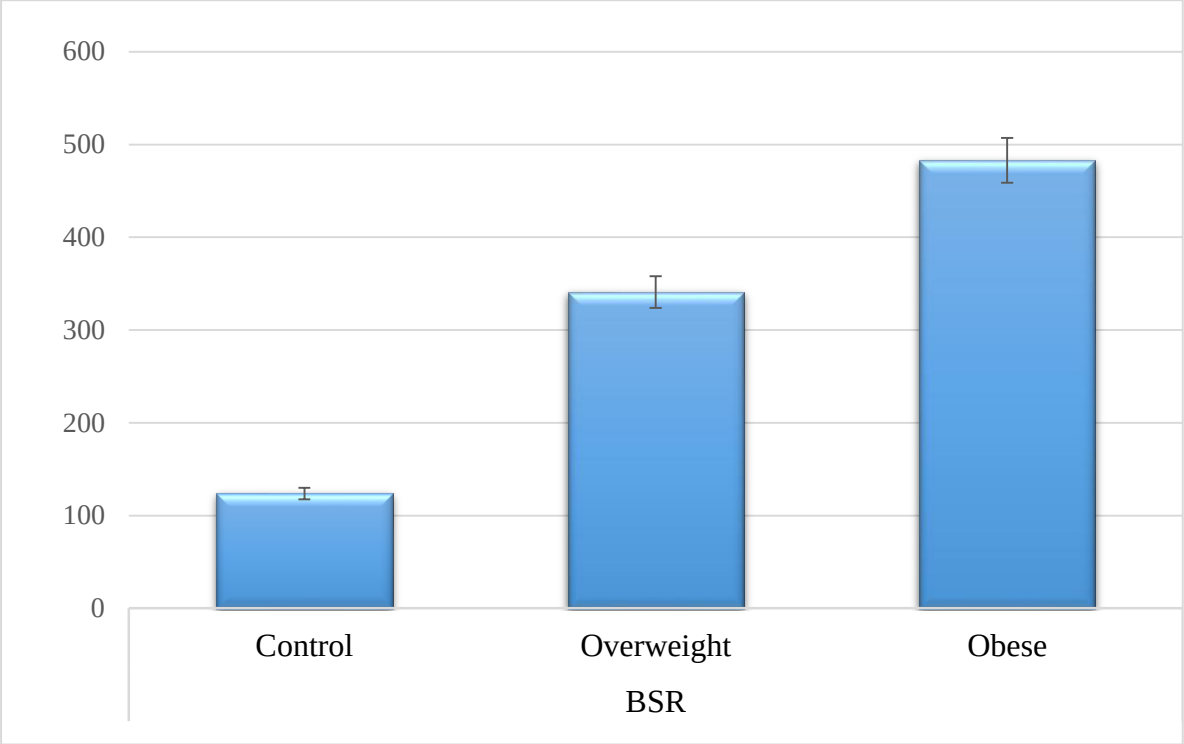


Figure 3 Graph showing BSR of Control and Experimental Groups (Overweight and Obese)

Table 1: Mean value of BMI and BSR of Control and Experimental Groups (Overweight and Obese)

Parameters	Control Group	Experimental Groups	
		Obese	Overweight
	Mean ± SD	Mean Value ± SD	Mean Value
BMI	21.33±1.87	36.28±7.709	26.93±1.389
BSR	123.72±8.4	483±7.8	341±27.58

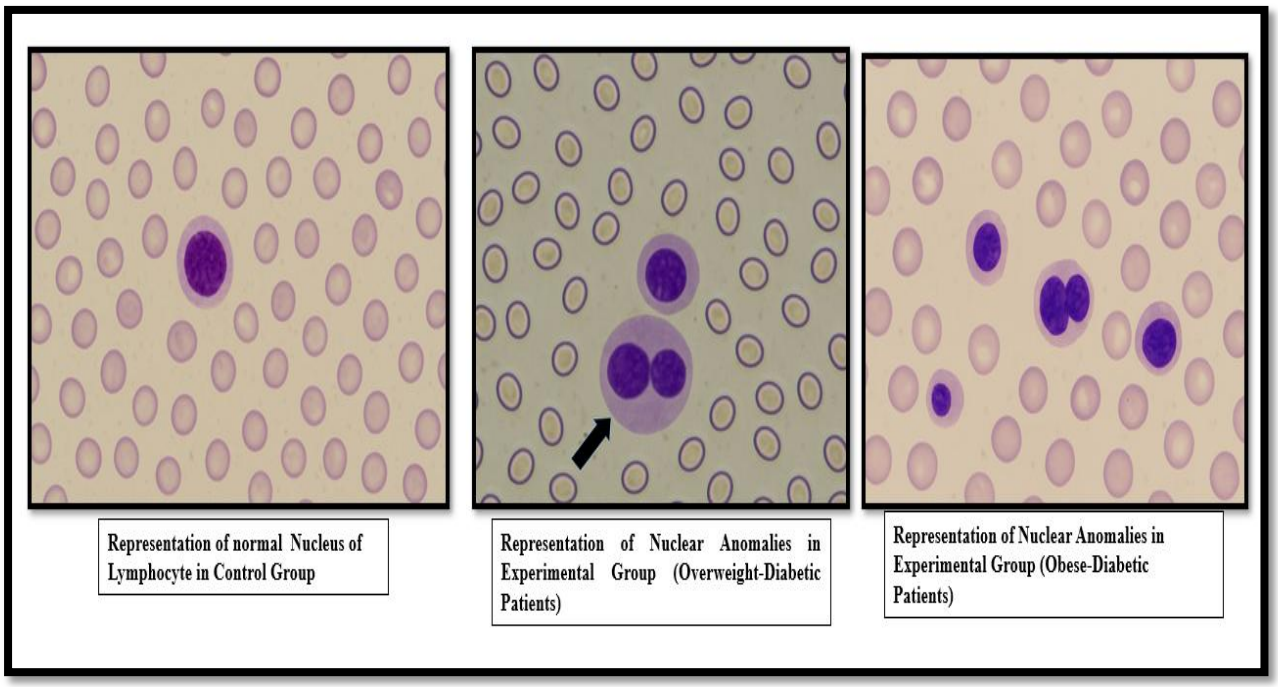
Table 2: Genotoxic Frequency among Control and Experimental Groups (Overweight and Obese)

Abnormalities	Mononeucleated		Binucleated	
	Frequency	Percentage	Frequency	Percentage
control	1	0.01	0	0.00
overweight	1	0.01	2	0.02
obese	8	0.08	6	0.06

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Discussion

This study was conducted on diabetic patients (aged 40-60) from the general population and various hospitals, who were further divided into a control group (Normal) and an experimental group (Obese and Overweight) for the assessment of DNA Damage in Diabetes with varying BMI measured by Micronucleus Assay.

The mean value of BMI of the control group is (21.33±1.78) . The mean value of BMI of the experimental group (Obese) is (36.28±7.70). The mean value of BMI of the experimental group (overweight) is (26.93± 1.38). This study examined the impact of BMI on the time to diagnosis of diabetes mellitus (DM) and its complications in individuals over the age of 40. Our findings indicated that excess weight and obesity are significant contributors to type 2 DM and its associated complications for both men and women. Individuals classified as overweight (BMI 25–29.99) faced an increased cumulative risk of developing DM, 30% higher for men and 10% higher for women. For those with a BMI between 30 and 3.99, both genders had double the risk of developing DM compared to their counterparts with a normal BMI. A study done previously also showed the same results that a BMI of 40 or above raised the likelihood of developing DM by 150% in women and 180% in men. These results suggest a stronger relationship between BMI and the onset of DM than previously reported in similar studies (38).

To prevent diabetes mellitus (DM) complications, maintaining a healthy weight may be more crucial for women than men at lower levels of excess weight, as women face

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increased risk even when slightly overweight (BMI between 25 and 27.49). For men, the risk of DM complications typically rises only when BMI reaches 27.5 or higher. Those categorized as obese (BMI ≥ 30) consistently show a significantly higher risk—up to 168% greater—for all types of DM complications regardless of gender. Additionally, obese men have a higher likelihood of developing cardiovascular, kidney, eye, and lower limb complications compared to women with the same BMI. Our findings suggested that weight loss is a key preventive measure for overweight individuals with pre-diabetes, potentially interrupting the progression to DM. Weight management is also critical in reducing the risk of DM-related complications, as even a BMI slightly above 25 increases relative risk. Various weight loss programs, including those focusing on diet, physical activity, and behavioral changes, have demonstrated success in achieving long-term weight reduction and significantly lowering the incidence of diabetes. One such program targeting older adults, Medical Nutrition Therapy (MNT), offers education, dietary and physical activity counseling, and sometimes weight-loss prescriptions to help reduce the risk of diabetes complications. Currently, MNT is the only program covered by Medicare and other insurers when provided by a dietitian. (39).

Lymphocytes and variations in blood were also visualized in the blood of a diabetic patient. There are two abnormalities of Lymphocytes are observed. One is mononucleated and the other is binucleated. The frequency of mononeucleated is 8 with 0.08 %. The frequency of binucleated is 6 with 0.06 %. Various genotoxic anomalies, such as binucleated (BN), multinucleated (MtN), were observed in the Experimental Groups. Among all the observed Mononeucleated (MN), Binucleated (BN) were most prevalent. Whereas, participants in the control group displayed normal Lymphocytes with centrally placed oval-shaped nuclei. The frequency of nuclear abnormalities was quantitatively assessed and categorized into three main groups: mild (frequency < 50), moderate (frequency ranged from 50 - 100), and severe (frequency > 100). The formation of micronuclei was the most significant alteration observed in the treatment group and exhibited a high frequency (f) of 183 with a prevalence percentage of 17.2%. No distorted nuclei are seen (40)

. No Notched shape nuclei are seen. The average amount of cells with MN per 100 cells in the control group was 3.1, which is accordant with the results of a past study(61), which reported a value of 3.0 in healthy women. Patients with DM2 had a high ratio of 6.5 cells with MN/1000 cells, comparative to the ratio in healthy individuals (3.1), which is according to a past study (41).This shows that our study aligns with previous studies.This may assist to inform the strong correlation between high serum glucose concentrations and DNA damage (42)

Conclusion

The use of the micronucleus assay proved valuable in highlighting this genotoxic stress, reinforcing its potential application as a sensitive biomarker for early detection of DNA damage in diabetic populations.

Competing Interest

No

Online ISSN 3007-3197
Print ISSN 3007-3189

References

Yameny AA. Diabetes Mellitus Overview 2024. Journal of Bioscience and Applied Research. 2024;10(3):641-5.

Vianni DD, Subramanian SS, Vishnuram S, Razali H, Sekar M, Alyahyawi N, et al. Exploring the relationship between glycated hemoglobin levels and geriatric syndromes in elderly patients with diabetes (a cross-sectional study). 2024.

de Paula D, Bracco P, Gregg EW. The Dynamics of Diabetes Prevalence, Morbidity, and Mortality. The Diabetes Textbook: Clinical Principles, Patient Management and Public Health Issues: Springer; 2023. p. 15-23.

Chanarsa S, Semakul N, Jakmunee J, Iamprasertkun P, Aubert P-H, Ounnunkad K. A strategy of forming sandwich electrodes based on graphene and two-dimensional transition metal dichalcogenides as supercapacitors to avoid gas evolution. Journal of Energy Storage. 2024;98:113083.

Hasan SU, Siddiqui MR. Epidemiology of diabetes mellitus in Pakistan: a systematic review protocol. BMJ open. 2024;14(3):e079513.

Muniyappa R, Narayanappa SBK. Disentangling dual threats: premature coronary artery disease and early-onset type 2 diabetes mellitus in South Asians. Journal of the Endocrine Society. 2024;8(1):bvad167.

Chew B-H, Lai PSM, Sivaratnam DAP, Basri NI, Appannah G, Mohd Yusof BN, et al. Efficient and Effective Diabetes Care in the Era of Digitalization and Hypercompetitive Research Culture: A Focused Review in the Western Pacific Region with Malaysia as a Case Study. Health Systems & Reform. 2025;11(1):2417788.

Roe G, Sawczuk T, Owen C, Tooby J, Starling L, Gilthorpe MS, et al. Head Acceleration Events During Tackle, Ball-Carry, and Ruck Events in Professional Southern Hemisphere Men's Rugby Union Matches: A Study Using Instrumented Mouthguards. Scandinavian journal of medicine & science in sports. 2024;34(6):e14676.

Rebelos E, Iozzo P, Guzzardi MA, Brunetto MR, Bonino F. Brain-gut-liver interactions across the spectrum of insulin resistance in metabolic fatty liver disease. World Journal of Gastroenterology. 2021;27(30):4999.

Özyildirim C, Unsal EN, Ayhan NY. Performance of triponderal mass index, body mass index z scores, and body mass index performance in the diagnosis of obesity in children and adolescents. Nutrition. 2023;114:112116.

Saadati HM, Sabour S, Mansournia MA, Mehrabi Y, Nazari SSH. The direct effect of body mass index on cardiovascular outcomes among participants without central obesity by targeted maximum likelihood estimation. Arquivos Brasileiros de Cardiologia. 2021;116:879-86.

Crewe C, Funcke J-B, Li S, Joffin N, Gliniak CM, Ghaben AL, et al. Extracellular vesicle-based interorgan transport of mitochondria from energetically stressed adipocytes. Cell metabolism. 2021;33(9):1853-68. e11.

Mohajan D, Mohajan HK. Body mass index (BMI) is a popular anthropometric tool to measure obesity among adults. Journal of Innovations in Medical Research. 2023;2(4):25-33.

Online ISSN 3007-3197
Print ISSN 3007-3189

Antuña E, Cachán-Vega C, Bermejo-Millo JC, Potes Y, Caballero B, Vega-Naredo I, et al. Inflammaging: implications in sarcopenia. International journal of molecular sciences. 2022;23(23):15039.

Mohajan HK, Mohajan D. Glaserian grounded theory and Straussian grounded theory: Two standard qualitative research approaches in social science. Journal of Economic Development, Environment and People. 2023;12(1):72-81.

Aryal JP, Sapkota TB, Rahut DB, Krupnik TJ, Shahrin S, Jat ML, et al. Major climate risks and adaptation strategies of smallholder farmers in coastal Bangladesh. Environmental Management. 2020;66(1):105-20.

Allan D, Tooby J, Starling L, Tucker R, Falvey É, Salmon D, et al. The incidence and propensity of head acceleration events in a season of men's and women's English elite-level club rugby union matches. Sports Medicine. 2024;54(10):2685-96.

Aarushi B, Shankar H, Swati S. Comparative analysis of haematological parameters in diabetics and non diabetics and their correlation with fasting blood sugar levels and glycated haemoglobin. Indian J Pathol Res Pract. 2020;9(1).

Henriques BM, Yates RM, Fu J, Guo Q, Kauffmann G, Srisawat C, et al. L-GALAXIES 2020: Spatially resolved cold gas phases, star formation, and chemical enrichment in galactic discs. Monthly Notices of the Royal Astronomical Society. 2020;491(4):5795-814.

Nwosu IA, Njemanze VC, Ekpechu JO, Eteng MJ, Ukah JA, Eyisi EC, et al. Prevalence and determinants of use of traditional methods of infertility treatment among women attending infertility clinic in Southeast Nigeria. African Journal of Reproductive Health. 2022;26(3):63-73.

Louis DN, Wesseling P, Ellison DW. Introduction to the WHO classification of tumors of the central nervous system. Oxford Textbook of Neuro-Oncology. 2025:1.

Zúñiga-González GM, Martínez-Sánchez JO, Zamora-Perez AL, Gallegos-Arreola MP, Torres-Mendoza BM, Gutiérrez-Sevilla JE, et al. Micronuclei analysis in mice peripheral blood exposed to polarized polychromatic noncoherent light (Bioptron® Light). Journal of Photochemistry and Photobiology. 2023;13:100164.

Nersesyan A, Proietti S, Knasmueller S, Bonassi S, Fenech M. High Correlation between Micronuclei in Lymphocytes and Buccal Cells in Humans provides further Validation of their use as Biomarkers of DNA Damage and Cancer Risks in vivo. Mutagenesis. 2025:geaf006.

Fenech M, Knasmueller S, Knudsen LE, Kirsch-Volders M, Deo P, Franzke B, et al. "Micronuclei and Disease" special issue: Aims, scope, and synthesis of outcomes. Mutation Research/Reviews in Mutation Research. 2021;788:108384.

Smail HO. Identification of micronuclei in the lymphocytes of the type 2 diabetes mellitus according to the period of diagnosis as a biomarker. Polytechnic Journal. 2023;13(2):4.

Chaphekar S, Jadhav ND, Rajurkar S, Chigure G, Rathod P, Jadhav M. Evaluation of anti-anemic activity of ferrous sulphate and copper sulphate in phenylhydrazine induced anemia in wistar rats. Journal of Ayurvedic and Herbal Medicine. 2024;10(3):81-8.

Online ISSN 3007-3197
Print ISSN 3007-3189

Pappuswamy M, Rajesh N, Philip AM. Analysis of chromosomal aberrations and micronuclei in type 2 diabetes mellitus patients. Asian Pacific Journal of Cancer Biology. 2020;5(1):15-8.

Eremina NV, Zhanataev AK, Lisitsyn AA, Durnev AD. Genotoxic markers in patients with diabetes mellitus (Literature review). Ecological genetics. 2021;19(2):143-68.

Martínez-Pérez-Cejuela H, Gionfriddo E. Evolution of green sample preparation: fostering a sustainable tomorrow in analytical sciences. Analytical chemistry. 2024;96(20):7840-63.

Singh A, Durbha KS, Sinha A, Pasupuleti S. Comparative assessment of fluoride and arsenic mobilization mechanisms among the groundwater of the major affected river basins of India. Water Supply. 2024;24(9):2969-98.

Ladeira C, Møller P, Giovannelli L, Gajski G, Haveric A, Bankoglu EE, et al. The comet assay as a tool in human biomonitoring studies of environmental and occupational exposure to chemicals—a systematic scoping review. Toxics. 2024;12(4):270.

Gojanur S. Assessment of Micronuclei in Oral Buccal Smears Stained with Acridine Orange in Type 2 Diabetes Mellitus Patients Using Oral Hypoglycaemic Drugs: Rajiv Gandhi University of Health Sciences (India); 2018.

Abbas R, Gowhar O, Dar MS, Hamid S. Evaluation & comparison of micronuclei in smokers with & without diabetes. IJAR. 2022;8(12):250-5.

Cinkilic N, Kiyici S, Celikler S, Vatan O, Gul OO, Tuncel E, et al. Evaluation of chromosome aberrations, sister chromatid exchange and micronuclei in patients with type-1 diabetes mellitus. Mutation Research/Genetic Toxicology and Environmental Mutagenesis. 2009;676(1-2):1-4.

Ali H, Hamayun S, Ullah M, Abbas M, Rehman M, Waleed A, et al. A Systematic Review: Clinical Manifestations of Diabetes Mellitus and The Role of Pharmacists in Management of Type II Diabetes. Journal of Women Medical and Dental College. 2023;2(1).

AL-Allaff, R. G. and M. A. Al-Shahery (2017). "Evaluation of T-lymphocytes in Peripheral Blood of Diabetic Patients." Tikrit Journal of Pure Science **22**(9): 30-.

Smail HO. Identification of micronuclei in the lymphocytes of the type 2 diabetes mellitus according to the period of diagnosis as a biomarker. Polytechnic Journal. 2023;13(2):4.

Hu FB, Manson JE, Stampfer MJ, Colditz G, Liu S, Solomon CG, Willett WC. Diet, lifestyle, and the risk of type 2 diabetes mellitus in women. Obstet Gynecol Surv. 2002; 57:162–164. 25.

Norris S, Zhang X, Avenell A, Gregg E, Brown T, Schmid C, Lau J. Long-term nonpharmacological weight loss interventions for adults with type 2 diabetes mellitus. Cochrane Database Syst Rev. 2005:2.

[November 18 2013] Obesity and Weight Loss Coverage [article online]. 2013.

Franz, M. J., J. P. Bantle, et al. (2002). "Evidence-based nutrition principles and recommendations for the treatment and prevention of diabetes and related complications." Diabetes care **25**(1): 148-198.

Online ISSN 3007-3197
Print ISSN 3007-3189

Leal-Garza, C. H., R. M. Cerda-Flores, et al. (2002). "Micronuclei in cervical smears and peripheral blood lymphocytes from women with and without cervical uterine cancer." Mutation Research/Genetic Toxicology and Environmental Mutagenesis **515**(1-2): 57-62.