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A new perspective of blood routine test for the prediction and diagnosis of hyperglycemia

Wei Wang[1], Yanjun Zhu[2], Guangchao Zhao[3], Xiaojun Kong[4], Cai Chen[3*] and Binbin Chen[5*]

Abstract

Background and Aims The presence of hyperglycemia induces alterations in the blood cell microenvironment. However, further investigations are warranted to comprehend the regulation of physiological parameter changes within the hyperglycemic cohort and validate their correlation. This study aims to investigate the correlation between hyperglycemia and peripheral blood physiological parameters, providing valuable insights for the screening and treatment of hyperglycemia.

Methods A retrospective study was conducted to analyze the demographic characteristics and blood routine test (blood RT) results of both the normal population and individuals with hyperglycemia. The distribution of abnormal blood RT results was compared between the hyperglycemic groups and the normal group. Univariate and multivariate logistic regression analyses were employed to investigate the correlation between blood RT results and levels of hyperglycemia. In addition, the stored red blood cells (RBCs) were placed in high glucose concentration and low glucose concentration environment, and the changes of physiological parameters of RBCs were observed after 35 days of storage.

Results The study included a total of 413 participants, with 202 individuals representing the normal population. Among these, there were 95 males (47.03%) and 107 females (52.97%). The hyperglycemia group consisted of individuals with impaired glucose tolerance (IGT) and diabetes mellitus (DM). Out of the total sample, 61 participants with IGT, consisting of 45 males (73.77%) and 16 females (26.23%). Additionally, there were 150 participants with DM, including 107 males (71.33%) and 43 females (28.67%). The prevalence of hyperglycemia showed a significant increase among males aged over 45 years ($p < 0.05$). The levels of white blood cell count (WBC), red blood cell count (RBC), hemoglobin (HGB), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin concentration (MCHC) in the hyperglycemia group were significantly higher than those in the normal group ($p < 0.05$). The distribution of abnormal blood RT results revealed that the DM group had the highest proportion of abnormal WBC, while the IGT group exhibited the highest proportions of abnormal RBC, HGB, and HCT ($p < 0.05$). Univariate logistic regression analysis showed that WBC (odds ratio [OR], 1.422; 95% CI, 1.249–1.631), RBC (OR, 2.163;

*Correspondence:
Cai Chen
chencai_sxk@163.com
Binbin Chen
13814086941@163.com

Full list of author information is available at the end of the article

95% CI, 1.449–3.270), HGB (OR, 1.033; 95% CI, 1.020–1.047), HCT (OR, 4.549; 95% CI, 0.569–8.591), MCH (OR, 1.175; 95% CI, 1.057–1.319), MCHC (OR, 1.071; 95% CI, 1.047–1.098) were the predictor indices for hyperglycemia ($p < 0.05$). Multivariate logistic regression analysis showed that WBC (OR, 1.434; 95% CI, 1.193–1.742) and MCHC (OR, 4.448; 95% CI, 0.084–237.9) were predictor indices for hyperglycemia ($p < 0.05$). The results of in vitro experiments demonstrated that the high glucose concentration significantly decreased MCV, while concurrently increasing MCHC and coefficient variation of the distribution width of the red blood cell (RDW-CV) ($p < 0.05$).

Conclusion The present study revealed significant correlations between hyperglycemia and gender, age, as well as certain peripheral blood physiological parameters. Moreover, in vitro experiments provided further support for these associations. Consequently, peripheral blood physiological parameters can serve as valuable predictor indices for DM and IGT prevention, offering essential insights to enhance preventive strategies.

Keywords Blood routine test, Impaired glucose tolerance, Diabetes mellitus, Red blood cells

Introduction

The prevalence of diabetes mellitus (DM) has been gradually increasing since the early 21st century due to a multitude of complex environmental and individual factors, thereby posing significant global health challenge [1]. The International Diabetes Federation (IDF) reported in 2021 that the global prevalence of diabetes stands at 537 million individuals, representing approximately 10.5% of the world's population [2]. Similarly, the prevalence of DM in China has increased from 2.6 to 12.4% over the past two decades, making it the country with the highest number of cases [3]. Among these, adolescents and children have seen the most significant increases in DM diagnoses [4]. In addition, the global prevalence of undiagnosed DM is estimated to be around 240 million individuals, with China alone accounting for nearly 54% of these cases that remain undetected [2, 5]. The presence of hyperglycemia is associated with a spectrum of complications [6], encompassing cardiovascular disease [7], chronic kidney disease [8], immuno-inflammation [9]. To conclude, the current issue of the high prevalence of DM is a pressing concern, particularly among young individuals and potential patients. Consequently, the early detection, prevention, and treatment of DM are crucial strategies for impeding its progression. The primary objectives of this study were to investigate biomarkers associated with diabetes and identify potential predictor indices in order to enhance the efficacy of diabetes prevention strategies.

The blood routine test (blood RT), serving as the fundamental and widely utilized adjunctive tool, has become an indispensable component of almost all patients' pathological examinations [10]. The recent years have witnessed not only the routine utilization of blood tests for quantitative blood count, but also a growing research focus on leveraging these test results to predict the occurrence and progression of various diseases. Moreover, this approach aims to enhance the capacity for evaluating therapeutic efficacy in patients with diverse conditions such as cancer [11], respiratory disease [12], viral infections [13], and mental disorders [14].

Currently, various fundamental research has demonstrated that blood cells, including RBC, WBC, and platelet (PLT), may undergo alterations in their structure, morphology, physiological function and immune status when exposed to hyperglycemic conditions [15–17]. However, our systematic search found that the specificity and differential changes of blood RT results in patients with hyperglycemia are rarely reported. Consequently, the blood RT, although a regular and convenient check, still requires further exploration of its clinical and preventive value of hyperglycemia.

The focus of this study was on the hyperglycemia group in blood RT results. On one hand, this facilitates the exploration of the cytological mechanisms underlying various complications associated with hyperglycemia. On the other hand, as a biomarker, blood RT can effectively screen individuals with hyperglycemia in a timely manner, thereby preventing the onset of diabetes and providing valuable reference data. Furthermore, by comparing changes in blood RT among patients at different stages, it is anticipated that these tests will serve as clinical indicators to assist in evaluating therapeutic efficacy. In summary, the objective of this study was to analyze the correlation between hyperglycemia and abnormal blood routine indexes within the population and provide effective reference data for the prevention and treatment of hyperglycemia.

Methods

General information

From January 2023 to June 2023, a total of 211 patients with hyperglycemia were selected from all the population who underwent physical examination at the Jinling Hospital. Among them, 150 patients met the diagnostic criteria for DM, while 61 patients met the diagnostic criteria for IGT. Simultaneously, a control group comprising 202 individuals with normal glycemic levels was chosen for comparative analysis. Demographic information, blood glucose levels, and blood RT results were collected for all participants in these three groups. This study selected

the blood RT indexes including white blood cell count (WBC), neutrophil percentage (NE.%), lymphocyte percentage (LY.%), eosinophil percentage (EO.%), basophil percentage (BA.%), monocyte percentage (MO.%), red blood cell count (RBC), hemoglobin (HGB), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), coefficient variation of the distribution width of the red blood cell (RDW-CV), platelet count (PLT#), thrombocytopenia (PCT), mean platelet volume (MPV), and platelet distribution width (PDW). The blood RT indexes were determined using an automated haematology analyser (Sysmex XE-5000; Wakinohama-Kaigandori, Japan).

Diagnostic criteria

The diagnostic criteria of the present study adhere to the guidelines set by the international diabetes associations (International Diabetes Federation [IDF], American Diabetes Association [ADA], European Association for the Study of Diabetes [EASD], etc.) and the World Health Organization (WHO). DM was defined as fasting plasma glucose of ≧7.0mmol/l (≧126 mg/dl), and IGT was defined as fasting glucose values of < 5.6–6.9 mmol/l (100–125 mg/dl). Persons with fasting glucose values of < 5.6 mmol/l (100 mg/dl) were included in the normal group [18]. The research subject of this investigation has excluded numerous potential underlying diseases, including cardiovascular disease, chronic respiratory diseases, impaired liver and kidney function, hematological disorders, neurological disorders, neuromuscular damage, metabolic disorders, as well as immunosuppressive states or compromised immune systems.

Research design

This study primarily encompasses two aspects. Firstly, it involves conducting a retrospective case-control study to analyze the correlation between blood glucose levels and results of blood RT. Specifically, the subjects were categorized into three groups based on their blood glucose levels: normal group, IGT group, and DM group. The differences in blood RT results among these three groups were compared. Additionally, the blood RT results were considered abnormal if the results of blood RT fell outside the reference intervals, and the distribution of these abnormal indicators was recorded. Secondly, an in vitro validation experiment was conducted to verify the direct impact of glucose concentration on erythrocyte physiological parameters. The subjects were divided into a high glucose concentration group and a low glucose concentration group, with observations made at 0 and 35 days of storage.

Collection and preparation of stored RBCs

This study was conducted at the Blood Bank Unit of Jinling Hospital. A total of 10 whole blood (400 ml) donated by voluntary donors was collected. The 5 cases in each group were randomly allocated into two groups, namely the high glucose concentration group and low glucose concentration group. In the high glucose concentration group, blood was collected directly from the original blood bag without any additional treatment. In the low glucose concentration group, 200 ml normal saline solution was added to decrease the glucose concentration in the blood bag. The glucose concentrations at the high and low levels were 26.47 ± 1.45 and 18.23 ± 0.87 mmol/L (476.5 ± 26.1 and 328.1 ± 15.7 mg/dl), respectively. Whole blood was collected using disposable leucocyte filter blood bags produced by Fresenius Kabi Medical Supplies Co., Ltd (Guangzhou, China), batch No. 85UG04FC00. The glucose concentrations were measured using an automated biochemical analyser (Hitachi 7600, Tokyo, Japan).

Statistical analysis

All statistical analyses were performed using the GraphPad Prism software 9.4.1 (GraphPad Software, San Diego, CA, USA). Frequency distributions determined the percent of samples. The data were expressed as the mean ± SD. The means and standard error of the means (SEM) between two groups were assessed using Student's t-test. The correlation between the distribution of abnormal blood RT results and blood glucose levels was analysed using the chi-square test. The correlation analysis of the blood RT results and levels of hyperglycemia was performed by univariate and multivariate logistic regression analysis. Variables with a p value of less than 0.05 were considered statistically significant.

Results

Demographics characteristics of study participants

A total of 413 participants were included in the survey, comprising 202 individuals with normal glucose levels, 61 individuals with IGT, and 150 individuals diagnosed with DM. The normal group consisted of 95 males (47.03%) and 107 females (52.97%). In the IGT group, there were 45 males (73.77%) and 16 females (26.23%), while in the DM group, there were 107 males (71.33%) and 43 females (28.67%). The mean ages of the normal group, IGT group, and DM group were 42.70 ± 12.07, 54.88 ± 12.59, and 54.69 ± 12.74 years old, respectively ($p < 0.05$). The prevalence of IGT in individuals aged over 45 was observed in 47 cases (77.05%), while DM was diagnosed in 120 patients (80%) within the same age group. In comparison, the normal group exhibited a lower incidence rate of 82 cases (40.59%). The abnormal blood glucose levels, including IGT and DM prevalence, exhibited significant

variations across different genders and age ($p < 0.05$) (Table 1).

Comparison of blood RT results among individuals with varying levels of blood glucose

The results of WBC, RBC, HGB, HCT, MCH, MCHC and PDW exhibited significant differences among the normal group, IGT group and DM group ($p < 0.05$). The detection values of WBC, RBC, HGB, HCT, MCH, and MCHC in the hyperglycemia group (including IGT group and DM group) exhibited higher levels compared to those in the normal group, however, PDW demonstrated an inverse trend in the Fig. 1.

Comparison of abnormal blood RT parameters distribution

The study examined the distribution of abnormal blood RT parameters among different groups (the normal group, the IGT group, and the DM group). The results revealed significant differences in the proportion of abnormal WBC, RBC, HGB, and HCT parameters among the three groups ($p < 0.05$). Specifically, the DM group exhibited the highest proportion of abnormal WBC levels, while the IGT group had the highest proportion of abnormal RBC, HGB, and HCT levels (Table 2).

Predictive factors associated with blood RT parameters in hyperglycemia

In this study, the relationship between blood RT and the hyperglycemia was analyzed by logistic multiple regression analysis. Univariate logistic regression analysis showed that WBC (OR, 1.422; 95% CI, 1.249–1.631), RBC (OR, 2.163; 95% CI, 1.449–3.270), HGB (OR, 1.033; 95% CI, 1.020–1.047), HCT (OR, 4.549; 95% CI, 0.569–8.591), MCH (OR, 1.175; 95% CI, 1.057–1.319), MCHC (OR, 1.071; 95% CI, 1.047–1.098) were correlated with the occurrence of hyperglycemia ($p < 0.05$). Multivariate logistic regression analysis showed that WBC (OR, 1.434; 95% CI, 1.193–1.742) and MCHC (OR, 4.448; 95% CI, 0.084–237.9) were correlated with the occurrence of hyperglycemia ($p < 0.05$) (Table 3).

The impact of varying glucose concentrations on RBCs in vitro

The study selected RBC suspensions with high glucose concentration group and low glucose concentration group as the experimental subjects to investigate the physiological parameters after 35 days of storage. Results revealed that in the high glucose concentration group, MCV decreased with prolonged storage time, while MCHC and RDW increased significantly in the Fig. 2 ($p < 0.05$). However, these changes were not observed in the low-glucose group ($p > 0.05$).

Discussion

The global prevalence of abnormal glucose metabolism is steadily increasing, with an estimated 537 million individuals affected by DM, of whom approximately 45% remain undiagnosed [2]. The survey revealed an upward trend in the prevalence of diabetes among Chinese adults, with a recorded increase to 12.4% between 2018 and 2019. Projections indicate that this ratio is expected to escalate to 19.8% by the year 2030 [19]. However, due to the complexity of DM treatment, effective preventive measures implemented at this stage can help reduce the incidence of DM, additionally alleviate the health and economic impact caused by elevated blood glucose levels. Currently, the screening methods for DM patients primarily involve inquiry, physical examination, and laboratory serum detection [20]. The prevalence of undiagnosed DM, however, continues to be significantly high, this indicates a need for further enhancement of the screening approach. By incorporating supplementary screening measures, integrating additional risk predictors, implementing interventions targeting multiple risk factors, and integrating effective biomarkers, the overall effectiveness of diabetes screening can be improved. The present study collected and analyzed the fundamental data on epidemic

Table 1 The demographic characteristics distribution for the study cohort

	Normal group	IGT group	DM group	χ^2	*p* value
Number of participants, (*n* = 413)	202	61	150		
Age (year), Mean ± SD	42.70 ± 12.07	54.88 ± 12.59	54.69 ± 12.74	F=48.22	< 0.0001
Age (year), n (%)					
≦18 (*n*=0)	0	0	0	0	0
18～ (*n*=7)	7 (3.47)	0	0	7.438	< 0.05
25～ (*n*=70)	53 (26.24)	4 (6.56)	13 (8.67)	25.42	< 0.0001
35～ (*n*=87)	60 (29.70)	10 (16.39)	17 (11.33)	14.34	< 0.001
45～ (*n*=161)	63 (31.19)	27 (44.26)	71 (47.33)	10.27	< 0.01
≧60 (*n*=88)	19 (9.40)	20 (32.79)	49 (32.67)	33.40	< 0.0001
Gender, n (%)					
Male (*n*=247)	95 (47.03)	45 (73.77)	107 (71.33)	26.96	< 0.0001
Female (*n*=166)	107 (52.97)	16 (26.23)	43 (28.67)		

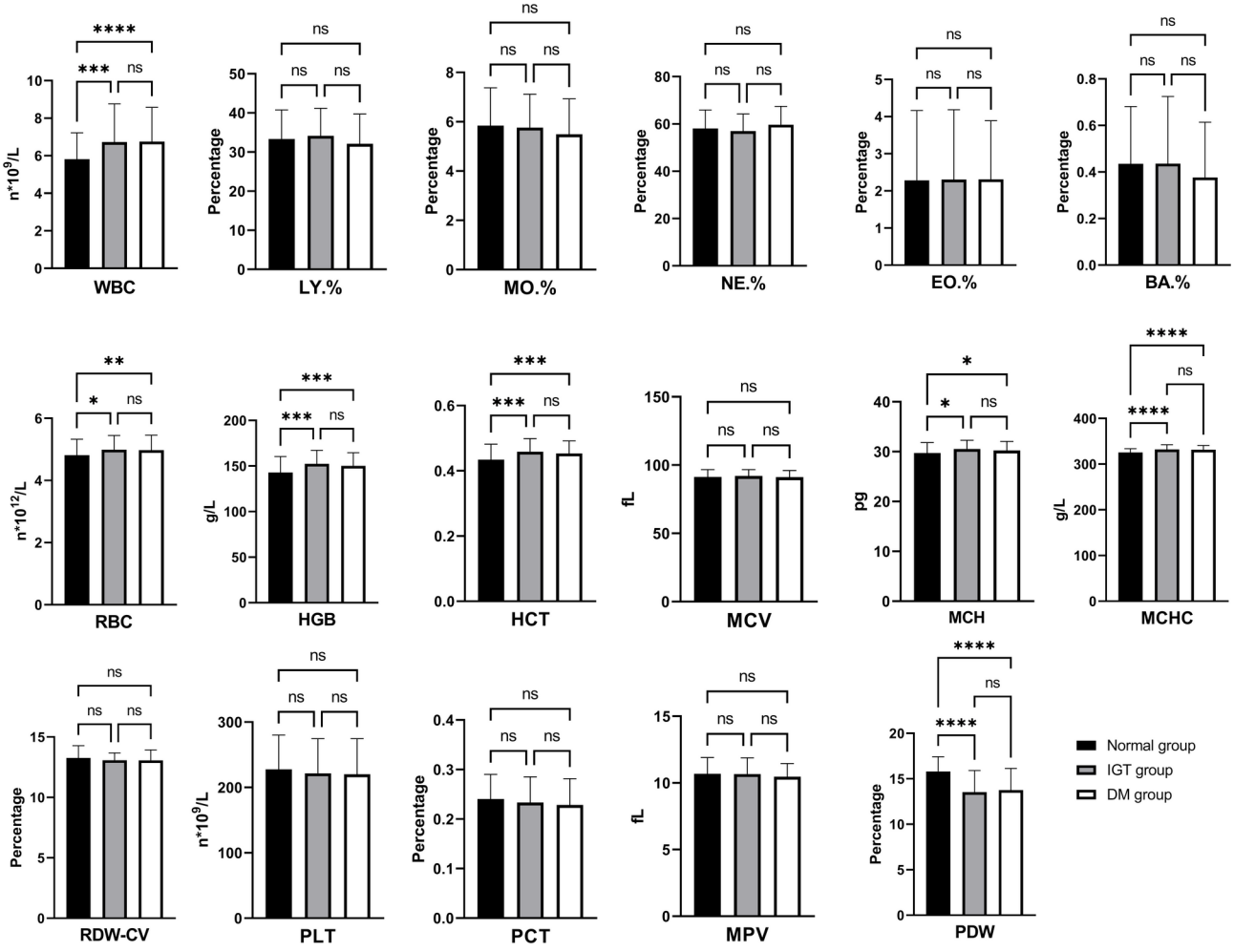

Fig. 1 The blood RT parameter values of the normal group, the IGT group, and the DM group, $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$, $^{****}p<0.0001$, $^{ns}p>0.05$

characteristics of individuals with hyperglycemia, in addition to conducting a statistical analysis of their blood RT results. Our study demonstrated a positive association between age and the severity of hyperglycemia in individuals aged 45 years and above, with a higher prevalence observed among males compared to females. Global and Chinese statistics corroborate this observation, showing a consistently higher prevalence of hyperglycemia in men compared to women, which aligns with our results [21, 22]. Nevertheless, it is crucial to acknowledge the potential presence of selection bias in our dataset. Therefore, additional objective and comprehensive evidence is required to further substantiate these conclusions. The outcomes of this study serve as a valuable reference for investigating gender disparities in hyperglycemia. Additionally, certain blood RT parameters exhibited significant correlations with hyperglycemia. Consequently, age, gender, and blood RT parameters should be considered as predictor indices for diabetes prevention.

Our study found a correlation between hyperglycemia and WBC. The hyperglycemia have higher WBC counts, and the results of univariate analysis also indicate that WBC are one of the predictor indices for hyperglycemia. Hyperglycemia triggers an inflammatory response within the body, thereby contributing to the development of various diseases [23]. The impaired glucose metabolism observed in DM patients is frequently accompanied by elevated levels of chronic inflammatory biomarkers, including interleukin (IL)-1β, IL-6, and tumor necrosis factor (TNF)-α. These hyperactivated proinflammatory cytokines perpetually stimulate immune cell activation and induce proinflammatory responses [24]. In addition, inflammatory mediators, such as IL-6, are closely linked to insulin resistance, thereby initiating a cascade of pathological reactions [25]. The persistent activation of the inflammatory response results in sustained stimulation of white blood cells, leading not only to an elevated white blood cell count but also to suppression of the anti-inflammatory response [26]. The findings of our study indicated a positive correlation between elevated levels of WBC and blood glucose in patients with hyperglycemia, providing theoretical support for the hypothesis that

Table 2 Abnormal blood routine parameters distribution in different population groups

	Normal group (*n*=202)	IGT group (*n*=61)	DM group (*n*=150)	χ^2	*p* value
Percentage of abnormal value, %					
WBC	3.465	6.557	7.333	2.769	0.251
LY.%	5.941	4.918	5.333	0.118	0.943
MO.%	1.980	1.639	1.333	0.218	0.897
NE.%	0.495	4.918	1.333	3.065	0.216
EO.%	3.465	1.639	1.333	1.841	0.398
BA.%	1.485	4.918	2.667	2.397	0.302
RBC	28.71	47.54	40.67	9.614	< 0.01
HGB	41.58	60.66	54.67	9.684	< 0.01
HCT	43.56	59.02	54.67	6.634	< 0.05
MCV	7.921	4.918	4.667	1.775	0.412
MCH	6.436	6.557	4.000	1.104	0.576
MCHC	10.89	8.197	4.667	4.415	0.110
RDW-CV	5.446	1.639	3.333	2.086	0.353
PLT	3.465	3.279	4.000	0.096	0.953
PCT	10.40	8.197	8.000	0.678	0.713
MPV	7.426	1.639	4.667	3.348	0.188
PDW	0.000	0.000	1.333	3.524	0.172

diabetes promotes cellular-level inflammatory responses. Furthermore, it suggests that elevated WBC levels should be considered as one of the predictor indices for DM prevention.

Previous studies found high glucose concentration can impact the energy metabolism, morphology and immune status of RBCs [27]. In the presence of high glucose levels, there is a decrease in the expression of Band 3 protein (B3p) on the surface of RBCs [28]. This leads to a gradual transformation in their morphology from double concave discs to spherical shapes, increased osmotic fragility, and susceptibility to hemolysis. Simultaneously, elevated blood glucose levels also stimulate the release of RBC-derived extracellular vesicles (REVs), which further compromise the integrity of the red cell membrane [29]. The biological influence mechanism of hyperglycemia on peripheral blood cell parameters can be primarily attributed to the following aspects. First, the hyperglycemic environment induces irreversible glycosylation at the N-terminus of the hemoglobin β chain, leading to the formation of haemoglobin A1c (HbA1c) and consequently diminishing the oxygen-carrying capacity of red blood cells [30]. Additionally, glycosylation of erythrocyte membrane proteins and lipids enhances membrane rigidity, reduces deformability, and increases the likelihood of red blood cells being recognized and cleared by macrophages, thereby shortening their lifespan and potentially causing hemolytic anemia [31]. Second, hyperglycemia activates the polyol pathway and mitochondrial respiratory chain, resulting in the production of reactive oxygen species (ROS). This process damages erythrocyte membrane lipids and proteins, induces lipid peroxidation, and increases membrane fragility [16]. Furthermore, osmotic pressure changes due to hyperglycemia may cause red blood cell dehydration, leading to abnormal volume and morphology, and triggering apoptosis mechanisms [32]. However, extensive research has been conducted on the impact of hyperglycemia on RBCs function, while there is relatively less attention given to the retrospective cross-sectional comprehensive analysis of changes in RBCs in patients with hyperglycemia. Our

Table 3 Logistic regression analysis of variables associated with the blood RT parameters in hyperglycemia

	Univariate analysis			Multivariate analysis		
	OR	95% CI	*p* value	*OR*	95% CI	*p* value
WBC	1.422	1.249–1.631	< 0.0001	1.434	1.193–1.742	< 0.001
LY.%	0.984	0.959–1.010	0.221			
MO.%	0.889	0.778–1.013	0.080			
NE.%	1.020	0.995–1.046	0.124			
EO.%	1.015	0.907–1.137	0.796			
BA.%	0.509	0.226–1.118	0.097			
RBC	2.163	1.449–3.270	< 0.001			
HGB	1.033	1.020–1.047	< 0.0001			
HCT	4.549	0.569–8.591	< 0.05			
MCV	1.008	0.970–1.049	0.677			
MCH	1.175	1.057–1.319	< 0.01			
MCHC	1.071	1.047–1.098	< 0.0001	4.448	0.084–237.9	< 0.01
RDW-CV	0.742	0.580–0.929	< 0.05			
PLT	0.997	0.993–1.001	0.122			
PCT	0.021	0.0004–1.014	0.053			
MPV	0.893	0.748–1.064	0.208			
PDW	0.693	0.626–0.763	< 0.0001	0.671	0.590–0.758	< 0.0001

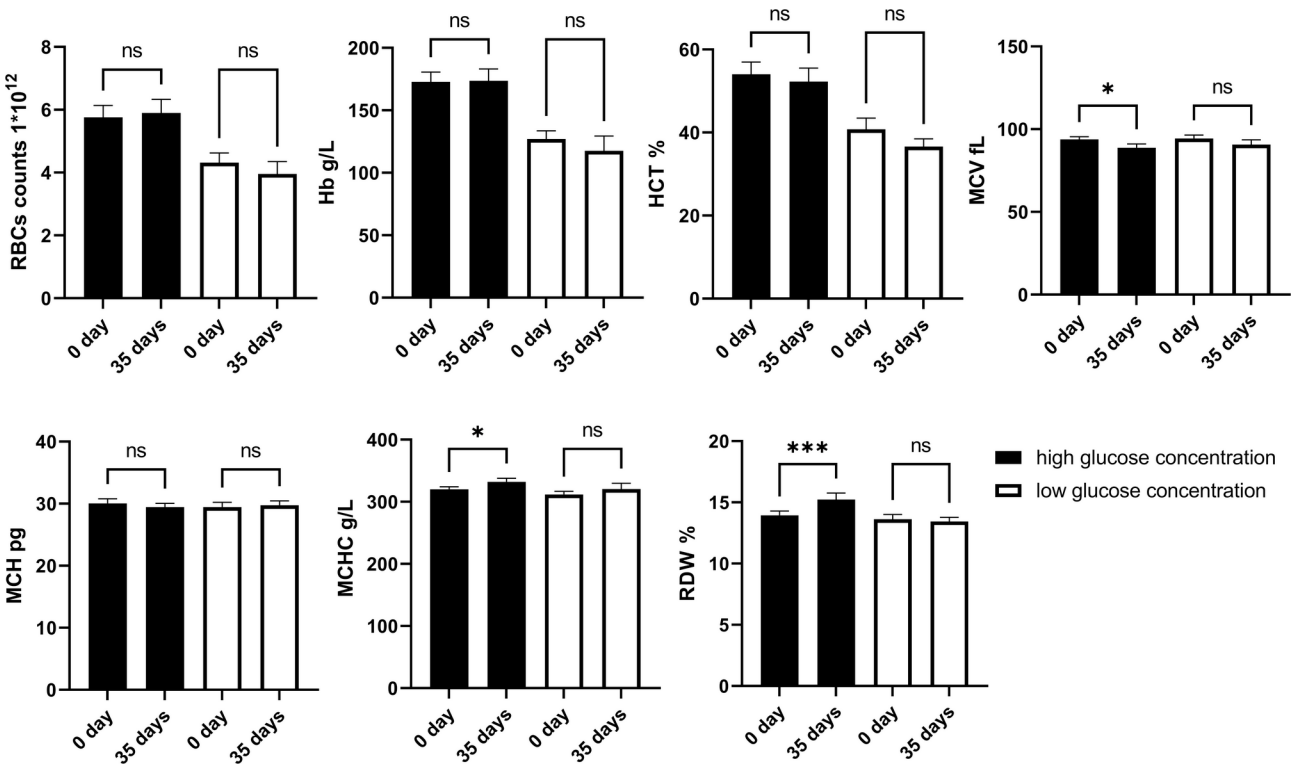

Fig. 2 Effects of different glucose concentrations on physiological parameters of stored RBCs, $^{*}p < 0.05$, $^{***}p < 0.001$, $^{ns}p > 0.05$

survey revealed significant alterations in RBC parameters, such as RBC count, HGB, HCT, MCH and MCHC, among individuals with hyperglycemia. Furthermore, we observed a clear correlation between these RBC parameters and the occurrence of hyperglycemia. However, it is important to highlight that previous studies have demonstrated a significant association between MPV and RDW with the pathogenesis and progression of various diseases, including infections [33], autoimmune disorders [34], tumors [35], and gastrointestinal diseases [36]. Nevertheless, the findings of this study indicate that there are no statistically significant differences in the MPV and RDW indices. This may be attributable to the restricted selection criteria and relatively small sample size of the study population. Consequently, future research endeavors should aim to broaden the categorization of samples and enhance the sample size to derive more precise and reliable conclusions. This study provides compelling evidence and theoretical support for investigating the physiological aspects of RBC in relation to glucose metabolism and immune function. Additionally, it is suggested that these related RBC parameters have potential as supplementary indicators for DM screening and auxiliary diagnosis.

The clinical application of blood RT tests has been expanding, with the existing prediction and assessment of findings being applicable to a variety of diseases. The heterogeneity of blood RT parameters provides valuable references for diagnosing and treating these diseases [11–14]. However, little attention has been given to the correlation between blood RT parameters and hyperglycemia. Changes in blood RT parameters in DM patients identified above in our study, can improve the identification of novel biomarkers for the prevention and management of DM.

Our study has certain limitations. This study employs a retrospective analysis approach, which may be subject to certain selection biases. This study established an association between blood cell parameters and hyperglycemia, however, it is insufficient to draw definitive conclusions regarding causation. To establish causality, a prospective study design along with long-term follow-up data would be necessary. The data for individuals under the age of 18 were not included in this study, which resulted in a lack of comprehensive information and test results. Additionally, the overall population data used in this study were obtained from a single source, potentially introducing bias into our findings. The relatively small number of the IGT group in this study, compared to other groups, may introduce potential bias into the statistical results. Future research endeavors will focus on expanding the sample size to enhance both the representativeness and reliability of the data. The establishment of different glucose concentration groups in vitro experiments is infrequent, and the observed indicators are limited solely to the physiological parameters of RBCs. In addition, in vitro

experiments possess inherent limitations in fully replicating the complexity of the in vivo environment. In future studies, we aim to further investigate the specific effects of a hyperglycemic environment on blood cells and their underlying mechanisms using animal models.

Conclusion

This survey revealed significant correlations between gender, age, WBC, and certain RBCs parameters with elevated glucose levels. These findings serve as a timely reminder for the general population to promptly monitor any abnormal blood glucose occurrences. Moreover, the potential of incorporating blood RT tests as a universal screening tool for predicting blood glucose levels should be explored further.

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Author contributions
WW, CC and GCZ, designed the study and drafted the manuscript. WW and BBC revised the manuscript. YJZ and XJK collected and interpreted the data. All the authors have read and approved the final version of the manuscript.

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Data availability
The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Declarations

Ethics approval and consent to participate
All strategies conducted in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later modifcations or comparable ethical standards. This study was approved by the Medical Ethics Committee of Jinling Hospital, with the approval number: 2022DZGZR-012. We examined the impact of a high-glucose environment on the physiological parameters of red blood cells derived from the voluntary blood donors through in vitro experiments, and written informed consent of the voluntary blood donors was obtained. In addition, in studies involving retrospective data analysis, written informed consent from patients was not obtained because this study is a secondary analysis of the data collected routinely for the purpose of evaluating the association between hyperglycemia and peripheral blood physiological parameters. Our research did not disclose any results related to the patient's personal identification information.

Competing interests
The authors declare no competing interests.

Consent for publication
Not Applicable.

Author details
[1]Department of Laboratory, Suzhou Xiangcheng Centers for Disease Control and Prevention, Suzhou, China
[2]Yan 'an Street Community Health Service, Centers of Longzihu District, Bengbu, China
[3]Department of Blood Transfusion Medicine, School of Medicine, Jinling Hospital, Nanjing University, Nanjing, China
[4]Department of Blood Transfusion, The Affiliated Jiangning Hospital with Nanjing Medical University, Nanjing, China
[5]Department of Laboratory, School of Medicine, Jinling Hospital, Nanjing University, Nanjing, China

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References

1. The Lancet. Diabetes: a defining disease of the 21st century. The Lancet. 2023;401(10394):2087.
2. Magliano D, Boyko EJ. *IDF diabetes atlas*. 10th edition. International Diabetes Federation; 2021. https://diabetesatlas.org/atlas/tenthedition/
3. FuYou T, XinTong G, Lu Z, et al. The prevalence of diabetes distress in Chinese patients with type 2 diabetes: A systematic review and meta-analysis. Diabetes Res Clin Pract. 2023;206:110996.
4. Kandemir N, Vuralli D, Ozon A, et al. Epidemiology of type 1 diabetes mellitus in children and adolescents: A 50-year, single-center experience. J Diabetes. 2024;16(5):e13562.
5. Shishi X, Yuchao W, Juan L, et al. Evaluation of the value of diabetes risk scores in screening for undiagnosed diabetes and prediabetes: a community-based study in Southwestern China. Postgrad Med. 2020;132(8):737–45.
6. Antar SA, Ashour NA, Sharaky M, et al. Diabetes mellitus: classification, mediators, and complications; A gate to identify potential targets for the development of new effective treatments. Biomed Pharmacother. 2023;168:115734.
7. Lei D, Hongda Z, Cong D, et al. The prognostic value of the stress hyperglycemia ratio for all-cause and cardiovascular mortality in patients with diabetes or prediabetes: insights from NHANES 2005–2018. Cardiovasc Diabetol. 2024;23(1):84.
8. Gupta S, Dominguez M, Golestaneh L. Diabetic kidney disease: an update. Med Clin North Am. 2023;107(4):689–705.
9. Chongxiang X, Keyu C, Zezheng G et al. Common mechanisms underlying diabetic vascular complications: focus on the interaction of metabolic disorders, immuno-inflammation, and endothelial dysfunction. Cell communication and signaling:CCS. 2023;21(1):298.
10. Jiayi H, Jiajia L, Min W, et al. The blood routine test holds screening values for influenza A in 2023: a retrospective study. Translational Pediatr. 2024;13(2):236–47.
11. Oh JH, Ahn KM, Chung SJ, et al. Usefulness of routine blood test-driven clusters for predicting acute exacerbation in patients with asthma. Respir Med. 2020;170:106042.
12. Liping L, Yubo T, Shixuan Z, et al. The potential of high-order features of routine blood test in predicting the prognosis of non-small cell lung cancer. BMC Cancer. 2023;23(1):496.
13. Ajuwon BI, Roper K, Richardson A, et al. Routine blood test markers for predicting liver disease post HBV infection: precision pathology and pattern recognition. Diagnosis. 2023;10(4):337–47.
14. Yuling W, Hua G, Sen J, et al. Principal component analysis of routine blood test results with Parkinson's disease: A case-control study. Exp Gerontol. 2021;144:111188.
15. Viskupicova J, Blaskovic D, Galiniak S, et al. Effect of high glucose concentrations on human erythrocytes in vitro. Redox Biol. 2015;5:381–7.
16. Qasim N, Arif A, Mahmood R. Hyperglycemia enhances the generation of ROS and RNS that impair antioxidant power and cause oxidative damage in human erythrocytes. Biochem Cell Biol. 2023;101(1):64–76.
17. Kaur R, Mittal K, Cheema RK, et al. Association of blood donor characteristics with in vitro platelet storage properties. Transfus Apheres Sci. 2023;62(5):103746.
18. Pleus S, Tytko A, Landgraf R, et al. Definition, classification, diagnosis and differential diagnosis of diabetes mellitus: update 2023. Exp Clin Endocrinol Diabetes. 2024;132(3):112–24.
19. Jinli L, Mingwang S, Guihua Z, et al. Investigating the Temporal trends of diabetes disease burden in China during 1990–2019 from a global perspective. Front Endocrinol. 2024;15:1324318.
20. Martinez LC, Sherling D, Holley A. The screening and prevention of diabetes mellitus. Prim Care. 2019;46(1):41–52.
21. Kautzky-Willer A, Leutner M, Harreiter J. Sex differences in type 2 diabetes. Diabetologia. 2023;66(6):986–1002.

22. Xu Y, Lu JL, Li M, et al. Diabetes in China part 1: epidemiology and risk factors. Lancet Public Health. 2024;9(12):e1089–97.
23. Lontchi-Yimagou E, Sobngwi E, Matsha TE, et al. Diabetes mellitus and inflammation. Curr Diab Rep. 2013;13(3):435–44.
24. Dehghan M, Ghorbani F, Najafi S, et al. Progress toward molecular therapy for diabetes mellitus: A focus on targeting inflammatory factors. Diabetes Res Clin Pract. 2022;189:109945.
25. Zhao L, Hu HR, Zhang L et al. Inflammation in diabetes complications: molecular mechanisms and therapeutic interventions. MedComm (2020). 2024;5(4):e516.
26. Weiss G, Ganz T, Goodnough LT. Anemia of inflammation. Blood. 2019;133(1):40–50.
27. Mortaş T, Arıkan Durmaz Ş, Sezen ŞC, et al. Assessment of erythrocyte morphology in patients with type 2 diabetes mellitus: a pilot study of electron microscopy-based analysis in relation to healthy controls. Turk J Med Sci. 2021;51(5):2534–42.
28. Morabito R, Remigante A, Spinelli S, et al. High glucose concentrations affect band 3 protein in human erythrocytes. Antioxid (Basel Switzerland). 2020;9(5). https://doi.org/10.3390/antiox9050365.
29. Ghodsi M, Cloos AS, Mozaheb N, et al. Variability of extracellular vesicle release during storage of red blood cell concentrates is associated with differential membrane alterations, including loss of cholesterol-enriched domains. Front Physiol. 2023;14:1205493.
30. Saudek CD, Derr RL, Kalyani RR. Assessing glycemia in diabetes using self-monitoring blood glucose and hemoglobin A1c. JAMA. 2006;295(14):1688–97.
31. Catan A, Turpin C, Diotel N. Aging and glycation promote erythrocyte phagocytosis by human endothelial cells: potential impact in atherothrombosis under diabetic conditions. Atherosclerosis. 2019;291:87–98.
32. Yang W, Fu J, Yu M, et al. Effects of flaxseed oil on anti-oxidative system and membrane deformation of human peripheral blood erythrocytes in high glucose level. Lipids Health Dis. 2012;11:88.
33. Samson SM, Anandhi C, Sharmila RR. Umbilical cord blood hematological parameters in predicting early onset neonatal sepsis (EOS) - a prospective cohort study. J Perinat Med. 2024;52(1):102–7.
34. Aktas G, Sit M, Dikbas O, et al. Could red cell distribution width be a marker in Hashimoto's thyroiditis? Exp Clin Endocr Diab. 2014;122(10):572–4.
35. Aktas G, Sit M, Karagoz I, et al. Could red cell distribution width be a marker of thyroid cancer?? Jcpsp-J Coll Physici. 2017;27(9):556–8.
36. Li XC, Chen QC, Bi XY, et al. Preoperatively elevated RDW-SD and RDW-CV predict favorable survival in intrahepatic cholangiocarcinoma patients after curative resection. BMC Surg. 2021;21(1):105.

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