

Correlation between ABO Blood Groups and Blood Sugar Levels as Cross Sectional Study of Healthy Student, In Wasit University

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Annotation: Objective: Our study have been performed in wasit, Iraq to look at association of blood groups and blood sugar level.

Samples and methodology: It was a cross sectional study conducted at University of wasit . The blood samples were collected from student in year 2024 involving 75 samples were taken from both male and female, healthy individual with age ranging from (18-25) years, the samples were tested for ABO blood groups using (ABO_kit) additionally, the samples were submitted to Glucometer machine to evaluate the glucose level.

Result: Chi-square test result showed all blood groups especially B have positive association with blood sugar level which involve 2.82 mg / dl and $p=0.0469$ also statistical analysis appeared the blood groups O is the most dominant No 26 (34.670 %) followed by other blood groups , the statistical data explained a highly significant difference in the distribution of blood types , ($p<0.01$).Our research showed there was no significant difference (NS) achieved between

individuals with blood sugar level Over than 100(mg/dl)that are prediabetes (developing diabetes in the future) and individual with blood sugar level less than 100 (mg /dl)

Conclusion: The research suggests a positive association between ABO blood groups and blood glucose levels. It was found that blood group O is the most prevalent, while group AB is the rarest, with a frequency of 10 (13.33%). Further large-scale studies in different ethnic populations are needed to confirm these findings

Keywords: ABO Blood Groups, Rh+, Rh-, Blood Glucose, Prediabetes.

1- Introduction

The most general and largest classification of blood group, the ABO and Rh system which it's determined by the presence or absence of A and B antigens on red blood cells, and these antigens are also expressed in various body tissues., as shown in table (1) (1,2,3). These genetic factors are significantly different in geographical, ethnic, and socioeconomic groups in several parts of the world (4). Several studies have reported that blood group antigens play a vital role in genetics and creating, preventing, and exacerbating various diseases such as gastric cancer, thyroid disorders, coronary artery disease, and diabetes, especially type 2 diabetes (5-7).

The ABO locus is located on chromosome 9 at position 9q34.1-q34.2, and it includes 7 exons that span over 18 kb of genomic DNA(8). An individual's blood group is genetically determined, which may lead to associations with genetically predisposed diseases. For example, individuals with certain blood groups have been found to have an increased risk of stomach cancer(9), while those with blood group O are more prone to duodenal and gastric ulcers (10). Blood groups and the Rh factor have also been shown to be useful in predicting periodontitis, as observed in other studies(11). Additionally, Rh antigens have been linked to a higher risk of breast cancer (12). Research from various countries has produced diverse and sometimes conflicting results regarding the susceptibility of individuals with specific blood types to diabetes across different populations, the results were controversial.

Table (1): ABO Blood Groups Phenotypes (Dean, 2005)

Blood group	Antigen(s) present on the red blood cells	Antibodies present in the serum	Genotype(s)
A	A antigen	Anti-B	AA or AO
B	B antigen	Anti-A	BB or BO
AB	A antigen and B antigen	None	AB
O	None	Anti-A and Anti-B	OO

According to the American Diabetes Association, a normal fasting blood sugar level (measured in the morning after an 8-hour fast with only water) is below 100 mg/dL, while normal postprandial (after meals) blood glucose levels are typically under 140 mg/dL. A fasting blood sugar level between 100-125 mg/dL indicates prediabetes, and a level above 125 mg/dL indicates diabetes (13).

Blood sugar levels are influenced by a variety of factors, including diet, exercise, genetics, and gut health. Recent research has identified several surprising factors that may contribute to blood sugar dysregulation and the development of Type 2 diabetes, such as genetics, the gut microbiome, sleep disturbances, micro plastics, and even cesarean sections. Some studies have proposed that blood type might be one of these unexpected factors affecting metabolic health. However, while certain research has suggested a weak link between blood type and blood sugar regulation, the overall body of evidence indicates that any such connection, if it exists, is likely to be weak (14).

Therefore, The present study was conducted to investigate whether there is any correlation between ABO and Rh blood groups and normal blood sugar levels in the Wasit population.

2- Methodology

Our present Investigation was cross sectional study that involved : (75) samples were taken from both females (no: 51) and males (no: 24) healthy individuals with ages ranging from (18 to 25) years collected from the College of Science at the University of Wasit. ABO-kit was using to determine blood groups types in addition to that blood glucose levels were measured using a glucose meter. Ultimately, The samples were analyzed statistically using the SPSS software.

- **Place of study:-** The study was conducted in the Department of biology College of Science
- **Study Population:-** (75) samples were taken from both females and males healthy students with ages ranging from (18 to 25) years.
- **Sample design:-** All the subjects were selected by random sampling technique.
- **Study design:-** university of wasit based cross-sectional study.
- **Study Tool:-** For blood grouping- Glass slides, (1) antibodies; Anti A. Anti B. Anti D (2)Blood Mixing Sticks. (3)Glass slid (4) Blood (5) Cotton (5) Surgical spirit (6) Lancet needle (7) Glucometer machine
- **Blood sampling:-** three drops of blood sample was collected from students by using lancet needles. ABO blood group was determined using the ABO kit test and also one drop was taken for detecting blood sugar level by using glucometer machine.



Statistical Analysis

The Statistical Package for the Social Sciences (SPSS) program (2019) was used to assess the impact of different groups on the study parameters. The Least Significant Difference (LSD) and T-test were employed to make significant comparisons between the means. Chi-square test was used to significant compare between percentage (0.05 and 0.01 probability) in this study (15).

3-Results:

A- ABO Blood groups Percentage and Distribution :

In this cross-sectional study of seventy five (75) healthy student, the blood group O+ was the most prevalent (23; 30.70%) followed by group A+ (17; 22.7%), then group B+ (14; 18.7%) while the percentage of other blood groups types is equal and less than 10%. Statistically, the results showed a highly significant difference in the distribution of blood types, with ($P \leq 0.01$), as shown in table (2), figure (1) & chart (1):

Table (2): Distribution of sample study according to Blood groups

Blood groups	No	Rh+ No. (%)	Rh- No. (%)	P-value
A	21 (28.00%)	17 (22.70%)	4 (5.30%)	8.047 ** (0.0046)
B	18 (24.00%)	14 (18.70%)	4 (5.30%)	3.630 * (0.0497)
AB	10 (13.33%)	8 (10.70%)	2 (2.70%)	3.630 * (0.0497)
O	26 (34.67%)	23 (30.70%)	3 (4.00%)	15.384 ** (0.0001)
Total	75	62 (82.67%)	13 (17.33%)	32.013 ** (0.0001)
P-value	7.186 * (0.0476)	7.548 * (0.0458)	0.846 NS (0.838)	---
* ($P \leq 0.05$), ** ($P \leq 0.01$).				

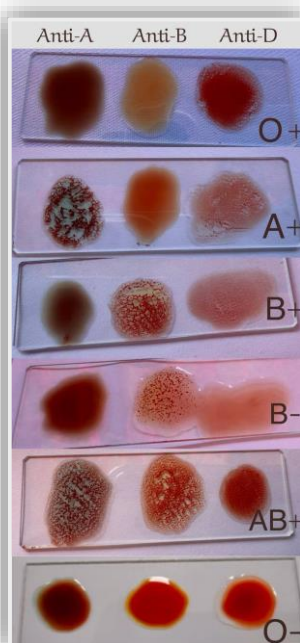


Figure (1): Blood Groups Test Results

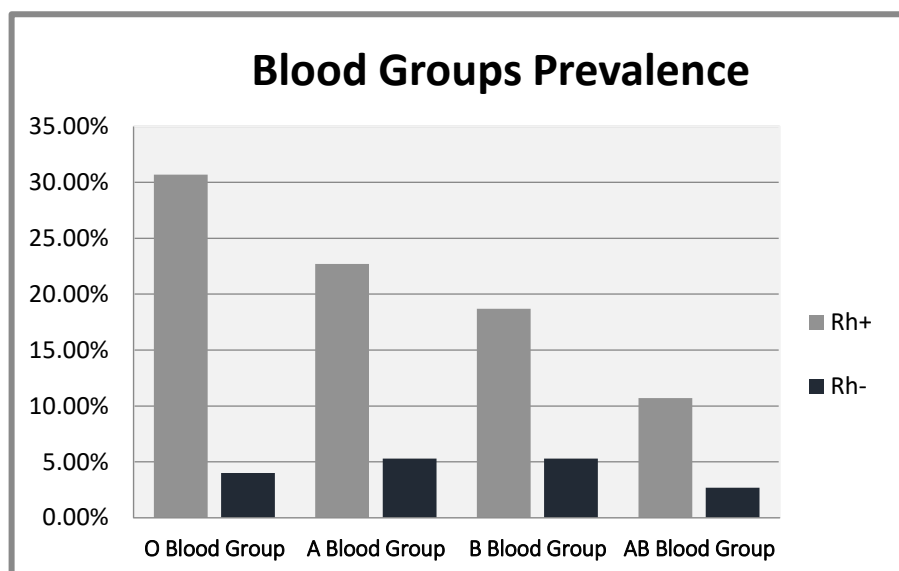


Chart (1): Explain Percentage of Blood Groups

B- Estimation of Blood Sugar Level

In general the results of random blood sugar levels in the current study was divided into two groups; the first groups involved individuals with blood sugar levels over than 100 (mg/dL), that are prediabetes (developing diabetes in the future), while the second groups included individuals with blood sugar levels less than 100 (mg/dL).The frequency of first groups was(31; 41.3%) which consist of (11; 35.5%) males and (20; 64.5%) females, while the frequency of second groups was (44; 58.7%) which included (13; 29.5%) males and (31; 70.5%) females. Statistically, Our research showed there is no significant difference between the two groups (NS), and there is no differences in glucose level according to the sex, as shown in table (3):

Table (3): Distribution of sample study according to Sex and level of Blood sugar

Sex	No	Level of Blood sugar		P-value
		Less Than 100 (mg/dL) No. (%)	Over Than 100 (mg/dL) No. (%)	
Male	24	13 (17.33%)	11 (14.67%)	0.683 NS
Female	51	31 (41.33%)	20 (26.67%)	0.123 NS
Total	75	44 (58.67%)	31 (41.33%)	0.133 NS
P-value	---	0.0067 **	0.106 NS	---
** (P<0.01).				

C- Relationship between Blood groups and Blood sugar

In this present study, the Chi-square test showed a significant correlation between the general blood types (A,B,AB and O) and blood sugar levels, with a significant difference approximately (p=0.0469) also, our detection appeared all blood groups were interrelated with sugar level and had positive association especially(B+) had higher value (a) as well as the strength of significant correlation differs between each blood types. Furthermore, the controversial significant differences among them was noted in table (4):

Table (4): Relationship between Blood groups and Blood sugar

Blood groups	No	Mean \pm SE of Fasting blood sugar- FBS (mg/dl)
A	21	98.24 \pm 2.21 ab
B	18	102.17 \pm 2.82 a
AB	10	93.60 \pm 2.55 b

O	26	102.11 \pm 2.05 a
L.S.D. (P-value)	---	7.334 * (0.0469)
Means having with the different letters in same column differed significantly. 1* ($P \leq 0.05$).		

4- Discussion

The World Population Review provides distribution of blood type across countries, showing the prevalence of blood types O, A, B, and AB in various populations. It emphasizes that blood type O is the most prevalent globally, whereas blood type AB is the rarest. The percentages of each blood type vary by region, with some countries having a significantly higher prevalence of one blood type over others. In Iraq O+ blood type is the most prevalence (32.1%) then A+ (25%), 25.6% B+ , 7.4% AB+, 3% O- , 2.7%A-, 2.7% B- and 0.9%AB- , according to the data of world population review (16), and these data comes agree with our result as showing in table (2).

Previous studies have suggested that blood groups play a role in disease mechanisms at the molecular level, either through blood group antigens or by blood group-reactive antibodies (17). Several systematic reviews and meta-analyses have explored the correlations between ABO and Rh blood groups and various health outcomes (18, 19). However, the relationship between these blood groups and human health outcomes remains a topic of controversy (20, 21, 22).

Therefore, the data on the relationship between the distribution of ABO blood types and blood sugar levels is conflicting, with some studies reporting no association, while others show a positive association (23).

A large prospective study conducted in France found no connection between Rh blood type and the risk of developing type 2 diabetes mellitus (T2DM). However, individuals with blood type O had the lowest risk of T2DM, while those with blood type B had the highest risk, followed by blood types AB and A. However, the risk for individuals with blood type AB was not statistically significant (24, 25). When both Rh and ABO blood types were considered together, individuals with blood type B+ had the highest risk, followed by those with blood types AB+, A-, and A+. No significant differences in risk were observed for other blood types (24, 25).

Other studies have also shown inconsistent results. For example, a study in Yemen found that the highest blood sugar and insulin levels were associated with blood type A, while blood type AB showed a protective effect (26). Our findings align with research conducted in Iraq, which showed higher blood glucose, total cholesterol, and blood pressure levels in individuals with blood type O, followed by lower risk in individuals with blood types A, B, and AB, with the lowest risk observed in blood type AB individuals (24, 25, 27).

In contrast to the findings of the current study, several large studies in Bangladesh (28), Germany (29), and Glasgow (30) concluded that there was no significant association between ABO blood groups and type 2 diabetes mellitus (T2DM). Additionally, a study in Malaysia reported a lower risk of T2DM in individuals with blood types A and O (23). Furthermore, clear genetic evidence has been found in individuals of European descent, linking nonsecretor status (se/se; homozygous for the A/A alleles of the FUT2 gene) to insulin-dependent type 1 diabetes mellitus (T1DM) (24).

In addition, there were reports from Italy (31) and Trinidad (32) showing an increased frequency of blood group B among diabetics. Furthermore, In Pakistan a study by Qureshi and Bhatti found that O and A blood groups appear to be more frequent in healthy controls (39.28 and 25%) compared to patients with DM type 2 (34.28 and 15.71%), but this as well was not statistically significant (33). While in Qatar, a study by Bener and Yousafzai that examined 1631 patients with type 2 DM and 1650 healthy control subjects (34). The researchers reported blood group B being significantly common while blood group O being significantly less usual among diabetic patients. Several other studies have reported the same results (35, 36, 37).

From other hand, Prediabetes in males and females, many studies suggest that prediabetes affects both men and women, but the prevalence rates may differ slightly. In many countries, men tend to have a slightly higher rate of prediabetes compared to women, particularly in middle-aged and older adults. However, the difference is not typically vast (38).

In the United States, for example, the Centers for Disease Control and Prevention (CDC) states that approximately 38% of adults have prediabetes, and the condition affects more men (15%) than women (12%) based on national surveys. This pattern can also be seen in other developed countries with similar lifestyle and health patterns (39).

Also according to a statistical study in the United States, between 2017 and 2020, as well as in 2021, a higher percentage of men (41.0%) compared to women (32.0%) had prediabetes, based on fasting glucose levels or A1C values ranging from 5.7% to 6.4%, while the results of the current study showed the opposite, as it indicated that the prevalence of prediabetes in females is higher than in males, this may be due to the fact that the number of female samples is double the number of male samples. Despite this, it is an insignificant increase, so we suggest conducting other studies with a larger and equal number of samples between males and females to determine the prevalence rate accurately.

Generally men have a slightly higher rate of prediabetes, especially in middle age, the prevalence can depend on age, hormones, lifestyle, and geographical location. Overall, both men and women should be aware of their risk factors and regularly monitor their blood sugar levels to prevent progression to diabetes (40). The risk of prediabetes increases with age, especially after age 45. Both men and women in this age group have a higher chance of developing prediabetes due to increased insulin resistance, but some studies indicate that women may develop prediabetes later in life compared to men, especially after menopause (41).

Therefore, further studies are needed to confirm the results, with a larger number of samples and a wide range of age groups, taking into consideration other influential physiological factors, in order to determine the extent of the relationship between blood groups and the development of diabetes and the prevalence of prediabetes among men and women as a risk factor. Appropriate lifestyle are recommended for people with prediabetes possessing blood group B or O, to prevent progression to diabetes.

Conclusion

We conclude that blood group O are the most prevalence and AB are the rarest, and there was an association between blood groups B with blood sugar levels, which indicates that there is a relationship, even if weak, between sugar levels and blood groups. Large studies in other ethnic groups are needed to confirm these results .

References

1. **Sapanont, K., Sunsaneevithayakul, P., & Boriboonhirunsarn, D. (2019).** Relationship between ABO blood group and gestational diabetes mellitus. *The Journal of Maternal-Fetal & Neonatal Medicine*, 34, 1255 - 1259.
2. **Franchini, M., & Lippi, G. (2015).** The intriguing relationship between the ABO blood group, cardiovascular disease, and cancer. *BMC medicine*, 13, 7. <https://doi.org/10.1186/s12916-014-0250-y>
3. **Dean L. (2005).** Blood Groups and Red Cell Antigens [Internet]. Bethesda (MD): National Center for Biotechnology Information (US). Chapter 5, The ABO blood group. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK2267/>
4. **Legese, B., Abebe, M., & Fasil, A. (2020).** Association of ABO and Rh Blood Group Phenotypes with Type 2 Diabetes Mellitus at Felege Hiwot Comprehensive Referral Hospital Bahir Dar, Northwest Ethiopia. *International journal of chronic diseases*, 2020, 2535843. <https://doi.org/10.1155/2020/2535843>

5. **Edgren, G., Hjalgrim, H., Rostgaard, K., Norda, R., Wikman, A., Melbye, M., & Nyrén, O. (2010).** Risk of gastric cancer and peptic ulcers in relation to ABO blood type: a cohort study. *American journal of epidemiology*, 172(11), 1280–1285. <https://doi.org/10.1093/aje/kwq299>
6. **Zhang, B. L., He, N., Huang, Y. B., Song, F. J., & Chen, K. X. (2014).** ABO blood groups and risk of cancer: a systematic review and meta-analysis. *Asian Pacific journal of cancer prevention : APJCP*, 15(11), 4643–4650. <https://doi.org/10.7314/apjcp.2014.15.11.4643>
7. **Fagherazzi, G., Gusto, G., Clavel-Chapelon, F., Balkau, B., & Bonnet, F. (2015).** ABO and Rhesus blood groups and risk of type 2 diabetes: evidence from the large E3N cohort study. *Diabetologia*, 58(3), 519–522. <https://doi.org/10.1007/s00125-014-3472-9>
8. **Yamamoto, F., Clausen, H., White, T., Marken, J., & Hakomori, S. (1990).** Molecular genetic basis of the histo-blood group ABO system. *Nature*, 345(6272), 229–233. <https://doi.org/10.1038/345229a0>
9. **Wang, Z., Liu, L., Ji, J., Zhang, J., Yan, M., Zhang, J., Liu, B., Zhu, Z., & Yu, Y. (2012).** ABO blood group system and gastric cancer: a case-control study and meta-analysis. *International journal of molecular sciences*, 13(10), 13308–13321. <https://doi.org/10.3390/ijms131013308>
10. **Alkebsi, L., Ideno, Y., Lee, J. S., Suzuki, S., Nakajima-Shimada, J., Ohnishi, H., Sato, Y., & Hayashi, K. (2018).** Gastroduodenal Ulcers and ABO Blood Group: the Japan Nurses' Health Study (JNHS). *Journal of epidemiology*, 28(1), 34–40. <https://doi.org/10.2188/jea.JE20160204>
11. **Vivek, S., Jain, J., Simon, S. P., Battur, H., Supreetha, S., & Haridas, R. (2013).** Association of ABO Blood Group and Rh factor with Periodontal Disease in a Population of Virajpet, Karnataka: A Cross-Sectional Study. *Journal of international oral health : JIOH*, 5(4), 30–34.
12. **Meo, S. A., Suraya, F., Jamil, B., Rouq, F. A., Meo, A. S., Sattar, K., Ansari, M. J., & Alasiri, S. A. (2017).** Association of ABO and Rh blood groups with breast cancer. *Saudi journal of biological sciences*, 24(7), 1609–1613. <https://doi.org/10.1016/j.sjbs.2017.01.058>
13. **American Diabetes Association. (2024).** Diagnosis of diabetes and prediabetes. American Diabetes Association. <https://www.diabetes.org/about-diabetes/diagnosis>
14. **Rentia, U., & Joseph, R. (2024).** Can blood type affect my blood sugar? Probably not. Levels. Retrieved December 12, 2024, from <https://www.levels.com/blog/can-blood-type-affect-my-blood-sugar-probably-not>
15. **SPSS (2019).** Statistical Packages of Social Sciences-SPSS/ IBM Statistics 26 step by step. 16th Edition. <https://doi.org/10.4324/9780429056765>
16. **Blood Type by Country 2024. (2024-12-12).** World Population Review. <https://worldpopulationreview.com/country-rankings/blood-type-by-country>
17. **Bruun-Rasmussen, P., Hanefeld Dziegiel, M., Banasik, K., Johansson, P. I., & Brunak, S. (2023).** Associations of ABO and Rhesus D blood groups with phenome-wide disease incidence: A 41-year retrospective cohort study of 482,914 patients. *eLife*, 12, e83116. <https://doi.org/10.7554/eLife.83116>
18. **Iodice, S., Maisonneuve, P., Botteri, E., Sandri, M. T., & Lowenfels, A. B. (2010).** ABO blood group and cancer. *European journal of cancer (Oxford, England : 1990)*, 46(18), 3345–3350. <https://doi.org/10.1016/j.ejca.2010.08.009>
19. **Getawa, S., Bayleyegn, B., Aynalem, M., Worku, Y. B., & Adane, T. (2022).** Relationships of ABO and Rhesus blood groups with type 2 diabetes mellitus: a systematic

- review and meta-analysis. *The Journal of international medical research*, 50(10), 3000605221129547. <https://doi.org/10.1177/03000605221129547>
20. **Bawazir W. M. (2022).** Systematic Review and Meta-Analysis of the Susceptibility of ABO Blood Groups to Venous Thromboembolism in Individuals with Factor V Leiden. *Diagnostics* (Basel, Switzerland), 12(8), 1936. <https://doi.org/10.3390/diagnostics12081936>
21. **Dentali, F., Sironi, A. P., Ageno, W., Turato, S., Bonfanti, C., Frattini, F., Crestani, S., & Franchini, M. (2012).** Non-O blood type is the commonest genetic risk factor for VTE: results from a meta-analysis of the literature. *Seminars in thrombosis and hemostasis*, 38(5), 535–548. <https://doi.org/10.1055/s-0032-1315758>
22. **Zhang, Q., Peng, H., Hu, L., Ren, R., Peng, X., & Song, J. (2022).** Association Between ABO Blood Group and Venous Thromboembolism Risk in Patients With Peripherally Inserted Central Catheters: A Meta-analysis and Systematic Review. *Frontiers in oncology*, 12, 906427. <https://doi.org/10.3389/fonc.2022.906427>
23. **Kamil, M., Ali Nagi Al-Jamal, H., & Mohd Yusoff, N. (2010).** Association of ABO blood groups with diabetes mellitus. *Libyan Journal of Medicine*, 5(1). <https://doi.org/10.3402/ljm.v5i0.4847>
24. **Ewald, D. R., & Sumner, S. C. (2016).** Blood type biochemistry and human disease. *Wiley interdisciplinary reviews. Systems biology and medicine*, 8(6), 517–535. <https://doi.org/10.1002/wsbm.1355>
25. **Fagherazzi, G., Gusto, G., Clavel-Chapelon, F., Balkau, B., & Bonnet, F. (2015).** ABO and Rhesus blood groups and risk of type 2 diabetes: evidence from the large E3N cohort study. *Diabetologia*, 58(3), 519–522. <https://doi.org/10.1007/s00125-014-3472-9>
26. **El-Sayed, M. I. K., & Amin, H. K. (2015).** ABO blood groups in correlation with hyperlipidemia, diabetes mellitus type II, and essential hypertension. *Asian J Pharm Clin Res*, 8(5), 236–243.
27. **Abegaz, S. B. (2021).** Human ABO blood groups and their associations with different diseases. *BioMed Research International*, 2021, 6629060. <https://doi.org/10.1155/2021/6629060>
28. **Rahman M. (1976).** Non-association of ABO blood groups with diabetes mellitus in Bangladesh. *Bangladesh Medical Research Council bulletin*, 2(2), 144–146.
29. **Maehr G. (1959).** *Wiener klinische Wochenschrift*, 71, 536–538.
30. **Craig, J., & WANG, I. (1955).** Blood groups in diabetes mellitus. *Glasgow medical journal*, 36(8), 261–266.
31. **Macafee A. L. (1964).** BLOOD GROUPS AND DIABETES MELLITUS. *Journal of clinical pathology*, 17(1), 39–41. <https://doi.org/10.1136/jcp.17.1.39>
32. **Henry MU, Poon-King T.(1961).** Blood groups and diabetes. *West Ind Med J.* 1961; 10: 156-60
33. **Qureshi, M. A., & Bhatti, R. (2003).** Frequency of ABO blood groups among the diabetes mellitus type 2 patients. *Journal of the College of Physicians and Surgeons--Pakistan : JCPSP*, 13(8), 453–455.
34. **Bener, A., & Yousafzai, M.T. (2014).** The distribution of the ABO blood groups among the diabetes mellitus patients. *Nigerian Journal of Clinical Practice*, 17, 565–568.

35. **Meo, S. A., Rouq, F. A., Suraya, F., & Zaidi, S. Z. (2016).** Association of ABO and Rh blood groups with type 2 diabetes mellitus. *European review for medical and pharmacological sciences*, 20(2), 237–242.
36. **Fagherazzi, G., Gusto, G., Clavel-Chapelon, F., Balkau, B., & Bonnet, F. (2015).** ABO and Rhesus blood groups and risk of type 2 diabetes: evidence from the large E3N cohort study. *Diabetologia*, 58(3), 519–522. <https://doi.org/10.1007/s00125-014-3472-9>
37. **Ordooei, M., Namiranian, N., Jam-Ashkezari, S., Jalali, H., & Golzar, A. (2022).** Is type 1 diabetes mellitus associated with ABO & Rh blood groups? A cross-sectional study. *Iranian Journal of Pediatric Hematology and Oncology*, 1(1), 49–54. doi:10.18502/ijpho.v1i1.8362
38. **Rooney, M. R., Fang, M., Ogurtsova, K., Ozkan, B., Echouffo-Tcheugui, J. B., Boyko, E. J., Magliano, D. J., & Selvin, E. (2023).** Global Prevalence of Prediabetes. *Diabetes care*, 46(7), 1388–1394. <https://doi.org/10.2337/dc22-2376>
39. **Centers for Disease Control and Prevention. (2024).** National Diabetes Statistics Report Prediabetes prevalence in the United States. Centers for Disease Control and Prevention. <https://www.cdc.gov/diabetes/php/data-research/index.html>
40. **Centers for Disease Control and Prevention. (2024).** Appendix: Diabetes data and research. Centers for Disease Control and Prevention. https://www.cdc.gov/diabetes/php/data-research/appendix.html#cdc_report_pub_study_section_6-table-6
41. **Centers for Disease Control and Prevention. (2024).** The truth about prediabetes. Centers for Disease Control and Prevention. <https://www.cdc.gov/diabetes/prevention-type-2/truth-about-prediabetes.html>