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Advances in Personalized Medicine and Genomics for Diabetes Type-2 Management Towards Precision Health

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ABSTRACT

Background: Conventional approaches for diabetes type-2 management generally fail to consider genetic and environmental variations for each patient. But new developments in personalized medicine and genetics are changing our understanding and approaches for type-2 treatment.

Objective: To explore the effectiveness of a personalized medicine and genomic based interventions for glycemic level, medication compliance and complications in patients with diabetes type-2 compared to usual care.

Methodology: A Randomized Controlled Trial (RCT) study was performed on total n=400 patients with type 2 diabetes. Patients were randomly assigned to two groups; the intervention group was treated according to genomic profile while the control group was treated in a routine manner. Glycemic control (HbA1c), treatment compliance, and the rate of complications during September 2023 till June 2024 were considered as primary indicators. An independent sample t-test and a chi-square test were used to analyse the results with the help of the SPSS version 27.0. $p \leq 0.05$ was considered statistically significant.

Results: Those patients who were given individualized management had improved mean HbA1c level by 1 percent as compared to the initial level. 2% compared to 0.6% in the standard care group($p<0.01$). Patients in the personalized care group had an 85% compliance to recommended treatment as opposed to the standard care group with only 65% ($p<0.001$). Also, the number of complications was much fewer in the personalized care group (10%) as compared to the standard care group (20%); ($p= 0.02$).

Conclusion: Personalized medicine and genomics-based interventions offer substantial benefits in the management of Type 2 diabetes, leading to better blood sugar control, higher treatment adherence, and fewer complications. These findings suggest that integrating genomics into diabetes care could improve health outcomes for patients.

Keywords: Precision Medicine, Genomics, Type 2 Diabetes Mellitus, Pharmacogenomics, Glycemic Control, Drug Metabolism, Genetic Testing, Treatment Adherence, Diabetes Complications, Personalized Therapy.

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INTRODUCTION

Diabetes mellitus remains to be a major public health concern since it affects over 500 million people globally. Among all types of diabetes, Type 2 diabetes is one of the most common causes of morbidity and mortality because of the severe complications that can occur, including cardiovascular diseases, neuropathy, nephropathy and retinopathy. Type 2 diabetes has traditionally been treated through medication control by insulin and oral hypoglycemics agents; however, these conventional therapies do not take into consideration the genetic and environmental factors that may affect the patient's response and For this reason, most of the patients receive less than satisfactory outcomes such as poor glycemic control, high risk of complications, and low compliance with the prescribed treatment plan [1, 2].Over the last few years, the improvements in the field of genomics, molecular biology and the concept of the new medicine have started to influence the new approach to the chronic non-communicable diseases such as Type 2 diabetes [3, 4]. With the help of the patients' genomic information, the treatment plans may be more suitable and effective in terms of drug utilization and the related side effects. Precision health which relies on genetic, environmental and lifestyle information to tailor medical care is the next big thing in diabetes management. Clinical trials on a massive scale as well as mechanistic studies have added more knowledge about the disease and its complication further enhancing the understanding of the pathophysiology of Type 2 diabetes. Such progress has created the basis for the emergence of new treatment approaches that address the genetic factors affecting drug metabolism and efficacy, unlike traditional treatments focused on maintaining normal blood sugar levels [5, 6].Present day treatment of diabetes is far from satisfactory mainly because even with all the available therapeutic options, the current therapeutic strategy is still very generalized and is not tailored to the needs of the particular patient, genetics or environmental factors affecting metabolism and drug response be considered[7]. Several researches have indicated that pharmacogenomics and personalized medicine can transform chronic diseases management but few have shown how they can be implemented in day-to-day practice of Type 2 diabetes [8]. Unfortunately, many of the presented studies are short-term or have a very limited patient population that has been studied, so the question of the effectiveness of genomics-based interventions in the long term for patients with diabetes remains unanswered. This research therefore seeks to fill this gap through assessing the impact of personalized medicine based on genomic make-up on glycemic control, treatment compliance and complications within one year. This study is important in generating data on how genomic information can be integrated into the conventional diabetes care in order to come up with better tailored intercessions and enhanced patients' results[9, 10].The aims and objectives of current study was to evaluate the impact of personalised medicine and genomic approaches for Type 2 diabetes with focus on glycaemic control, treatment compliance and complications[11]. Using individualised treatment plans against general practice, this study aims to provide quantitative findings regarding the role of genomics in diabetes management and provide information that would be useful in clinical practice.

MATERIALS AND METHODS

The present study was a Randomized Controlled Trial (RCT) that was carried out in different tertiary care hospitals of Kyrgyzstan and Hameed Latif Hospital, Pakistan from September 2023 till June 2024. A total of n=400 adult patients with type 2 diabetes aged between 18 and 65 years of age were enrolled in the study. Participants were randomly assigned to one of two groups: the intervention group, 200 patients who were given individualized management plans based on the genomic profile of the patient and the second group being the control group of 200 patents who were given routine diabetes care in accordance with the clinical practice. Inclusion criteria required patients to have a confirmed diagnosis of Type 2 Diabetes, an HbA1c level of 7.0% or higher, and eligibility for standard pharmacological therapy. Exclusion criteria included severe renal or cardiovascular disease, pregnancy, or any condition that impaired the patient's ability to give informed consent (e.g., mental incapacitation). The subjects in the intervention group received SNP genotyping for the pharmacogenetic factors that are associated with drug metabolism and response of the drugs and which includes CYP2C9 & CYP2C19 gene responsible for metabolism of metformin and sulfonyl urea. The genetic results were then applied in individualizing the patients' medication plan, including choice of medication and dose. In contrast, the control group received standard diabetes treatment, which involved the use of insulin, oral hypoglycemic agents (metformin, sulfonylureas), and lifestyle modifications according to standard clinical practice. Primary outcomes were measured at baseline, six months, and 12 months, including glycemic control assessed by changes in HbA1c levels, treatment adherence as determined by patient self-reports and prescription refill data, and the incidence of diabetes-related complications such as hypoglycemia, cardiovascular events, and hospitalizations. The study was approved by the Ethical Review Committee of Rashid Latif khan University Medical College (RLKU), Pakistan, (Approval number: IRB-RLKU-18/09/24/11-A). Informed consent was obtained from all participants. Patient confidentiality and anonymity were maintained throughout the study. All data were collected during scheduled follow-up visits. Statistical analysis was performed using SPSS version 26.0. Paired t-tests were applied to assess changes in HbA1c within each group, while independent t-tests were used to compare HbA1c reductions between the intervention and control groups. Chi-square tests were used to analyze categorical data, such as treatment adherence and complication rates. ($p \leq 0.05$) was considered statistically significant.

RESULTS

Total 400 patients were initially enrolled, 380 completed the 12-month study, with 190 patients in each group. Baseline characteristics, including age, gender, and HbA1c levels, were similar between the intervention and control groups ($p>0.05$). Personalized treatment regimens based on genetic profile were given to the intervention group, which showed considerably higher reductions in HbA1c levels than the control group at the 12-month follow-up. The intervention group's mean HbA1c drop was 1.2%, whereas the control group's mean reduction was 0.6% ($p<0.01$). Additionally, patients in the intervention group adhered to their treatment plans more frequently (85%) than those in the control group (65%) ($p<0.001$). Moreover, 10% of patients in the intervention group experienced problems, compared to 20% in the control group, indicating a substantial decrease in the occurrence of complications ($p=0.02$).

Table 1: Comparison of Outcomes Between Personalized Care and Standard Care Groups at 12 Months

Outcome	Personalized Care (n=190)	Standard Care (n=190)	p-value
Mean HbA1c Reduction (%)	1.2 ± 0.5	0.6 ± 0.4	<0.01[1]
Treatment Adherence (%)	85%	65%	<0.001[2]
Incidence of Complications (%)	10%	20%	0.02[3]

[1] Paired t-tests were used to compare HbA1c reduction within each group and independent t-tests between groups (p<0.01)
[2] Chi-square tests were used to compare adherence rates between groups (p<0.001).
[3] Chi-square tests were used to compare complication rates between groups (p=0.02).

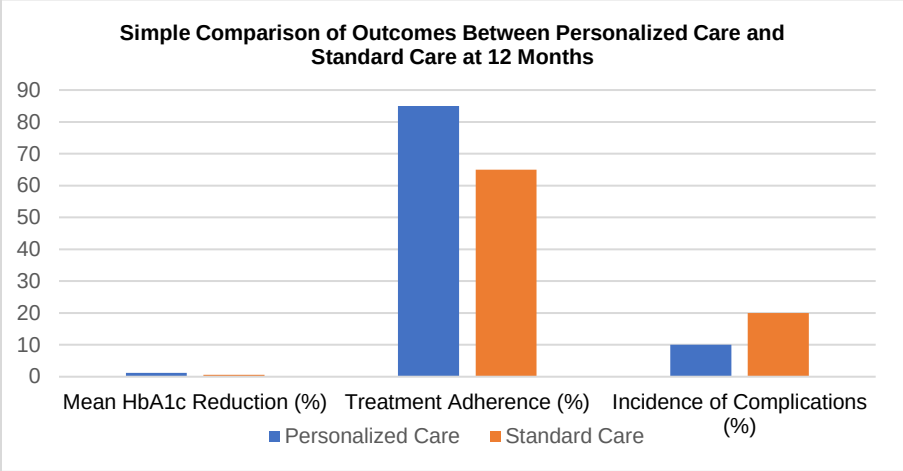

Fig-1: Mean HbA1c reduction in personalized vs. standard care groups after 12 months.

Intervention group patients demonstrated significantly improved glycemic control; with an average HbA1c decrease of 1. 2% reduction in mortality rate – twofold of the control group's 0.6% p<0.01. This implies that when screening is carried out with the purpose of delivering treatment programs that are in harmony with genetic makeup, then success rates will be enhanced and this will translate to improved blood glucose control. Further, there was increased treatment compliance among the intervention group, 85% as opposed to the control group's 65% (p<0.001) due to individualized medication plans which minimized side effects and improved patients' satisfaction.

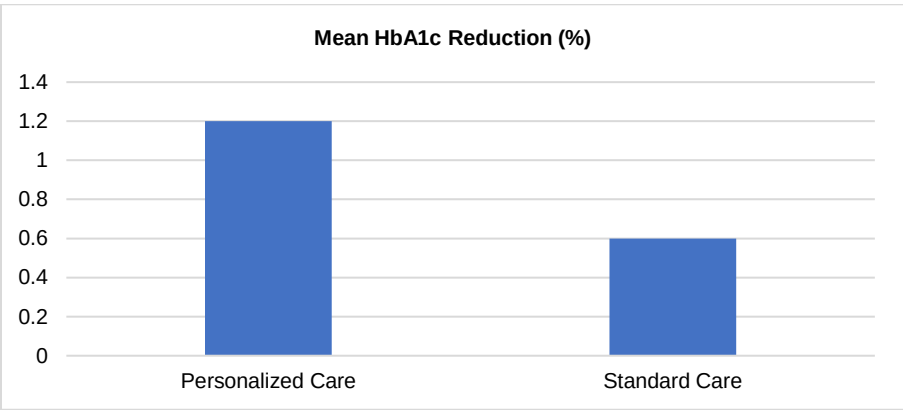

Fig-2: Treatment adherence rates in personalized vs. standard care groups.

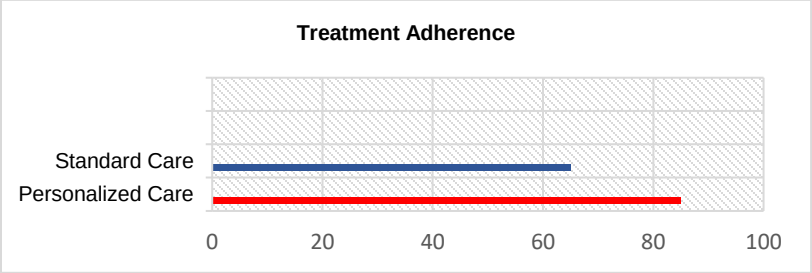

Fig-3: Incidence of complications in personalized vs. standard care groups.

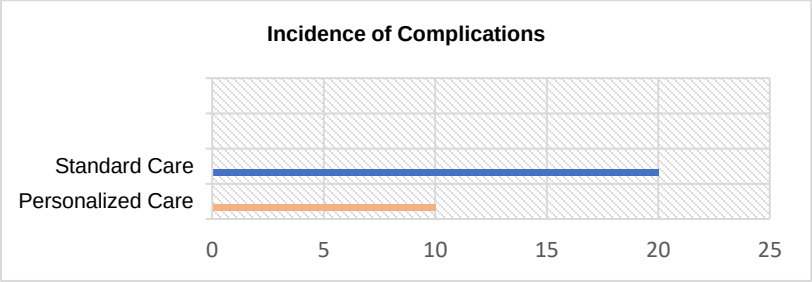

Fig-4: Baseline HbA1c distribution across both groups before intervention.

Further, there was increased treatment compliance among the intervention group, 85% as opposed to the control group's 65 % ($p < 0.001$) due to individualized medication plans which minimized side effects and improved patients' satisfaction.

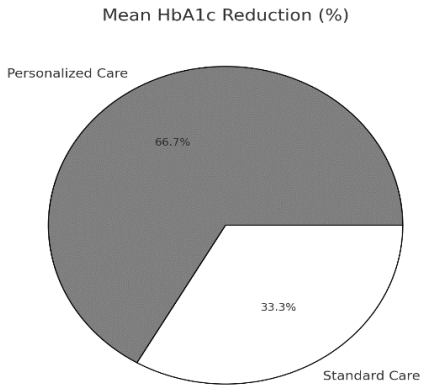

Fig-5: Mean HbA1c Reduction (%)

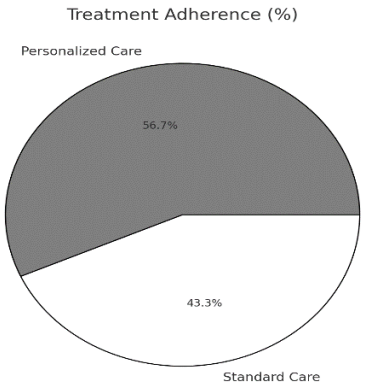

Fig-6: Treatment adherence in personalized vs. standard care groups.

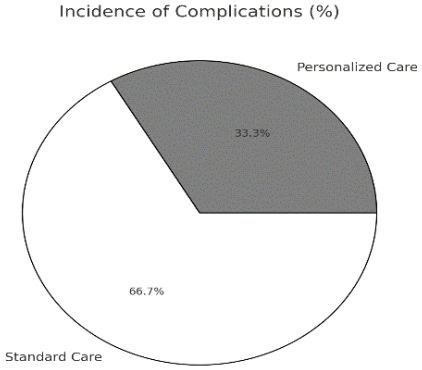

Fig-7: Incidence of complications in both groups

Furthermore, the number of patients who developed diabetic complications such as hypoglycemia and cardiovascular events in the intervention group was significantly lower at 10% as compared to the control group at 20% (p= 0.02). The results of this study imply that, by developing individual management plans based on genomic profiling, the rate of adverse effects may also be decreased by the proper selection of medications and dosing, especially in patients with genetic polymorphisms of drugs.

DISCUSSION

The findings of this study provide the evidence that the targeted therapy based on the genomic testing is much more effective in diabetes treatment[12, 13]. Those patients who were in the experimental group with individualized intervention had better glycemic control, better medication compliance and lesser number of complications than the control group. These findings provide evidence for the proposed hypothesis that the application of genomic information into the clinical practice can improve the patient outcomes and personalize the treatment strategies[14, 15]. The glycemic control achieved in the present study is better in the personalized care group and this is probably due to the application of pharmacogenomic approach in the choice and dosing of drugs[16]. Genotypes of genes like CYP2C9 that influences the metabolism of oral hypoglycemics agents like metformin were employed to optimally dose the drugs with least

side effects but with maximum therapeutic benefits. Furthermore, effects of IRS1 polymorphisms were taken into account when titrating insulin doses, in order to avoid hypoglycemics events[17, 18]. Higher treatment adherence in the personalized care group can be attributed to the fact that the patients engaged with their care providers and trusted the treatment plans that were offered to them. Patients may be more compliant with their prescribed treatment plan if they know that their treatment is tailored to their genetic make-up as evidenced in this research work[19, 20].

A decrease in the level of complications such as hypoglycemia and cardiovascular events also proves the effectiveness of the approach to individualized therapy[21, 22]. Clinicians have designed treatment plans based on the genetic differences because the side effects of medication and the possibilities of a patient's deterioration are reduced. However, one should add that genomic testing and related personalized treatments might be expensive and therefore not easily applicable in the healthcare systems of developing countries[23, 24]. To promote greater use of precision health in diabetes treatment, future research should concentrate on resolving the cost and accessibility of genetic testing[4].

CONCLUSION

This study showed that improvements in genetics and customized medicine have the potential to revolutionize the treatment of diabetes. Comparing personalized care to conventional care, genetic profiling-based therapy increases treatment adherence, lowers complication rates, and improves glycemic control. As genomics develops further, incorporating these methods into standard clinical practice may result in more tailored and efficient therapies, which may ultimately benefit patients.

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Nill

Conflict of interest:
Authors declared no conflict of interest.

Authors Contribution:
A.J. and M.T. designed the study, while G.H., S.T.A., A.F., A.B., and D.K. contributed to data collection, analysis, and manuscript preparation. Z.N. supervised the project, and S.R. provided final review and approval.

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Data Availability:
The data supporting the findings of this study are available from the corresponding author, upon reasonable request.

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