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The association between hypertension and glucose tolerance among adults with prediabetes in Hail City, Saudi Arabia

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Abstract. – OBJECTIVE: As a worldwide epidemic, the frequency of prediabetes is rapidly increasing. As a result, the present study investigated pre-diabetes synergistic factors in the Saudi population.

PATIENTS AND METHODS: This descriptive study used samples from 31 Hail-area primary health clinics (PHCs). Participants were chosen at random from December 2021 to June 2022.

RESULTS: There were 164 participants in this study, of which 86 males (52.4%) and 78 females (47.6%). The GTT revealed that none of the study participants had diabetes, but an A1C test revealed that all of them had A1C levels above 6.5%. Approximately 16/86 (18.6%) of the 86 men were overweight, whereas 53/86 (61.6%) were obese.

CONCLUSIONS: Saudi Arabia's prediabetes rate has increased due to obesity/overweight, family history of diabetes, heart rate variability, and poor sleep quality. HbA1c screening should replace GTT to prevent progression to T2DM.

Key Words:
Prediabetes, T2DM, HbA1c, GTT, Obesity.

Introduction

Prediabetes is hyperglycemia between the normal range and the glycemic index thresholds for type 2 diabetes[1]. Prediabetes is a condition in which an individual has impaired glucose metabolism but not high enough glucose or HbA1c levels, impaired fasting glucose, or impaired glucose tolerance to be diagnosed with diabetes. Diagnostic criteria for prediabetes include impaired fasting glucose (IFG), impaired glucose tolerance (IGT), and a HbA1c between 5.7% and 6.4%[2]. Prediabetes is linked to "diabetes-related" chronic complications[3,4].

Prediabetes, a global epidemic, is rising rapidly. Some patients struggle to choose or maintain effective prediabetes treatments, even though lifestyle changes should be the foundation. While a variety of medicinal therapies have been demonstrated to be effective in curing prediabetes, it is still recommended that lifestyle changes must be the major focus[5].

Intercellular communication promotes systemic insulin resistance in prediabetes. Finally, hyperinsulinemia or insulin resistance-induced cell dysfunction and reduced cell mass can cause abnormal insulin secretion and type 2 diabetes mellitus (T2DM). Overnutrition can cause multiple prediabetes phenotypes and T2DM progression *via* multiple pathways. Thus, to reduce T2DM, prediabetes diagnosis and treatment should consider phenotype and disease stage[6].

Hyperglycemia can cause irreversible damage to the eyes, kidneys, nerves, heart, and peripheral vessels if left untreated. Thus, managing hyperglycemia properly prevents disease complications and improves patient outcomes[7]. Hypertension modifies the risk of total and ischemic stroke in prediabetics. In non-hypertensives, prediabetes increases the risk of total and ischemic stroke[8]. For the elderly population, the

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possibility of prediabetes progressing to full-blown diabetes is a serious concern. Prediabetes increases microvascular risk but does not cause cardiovascular consequences or death. Prediabetes must be actively screened to avoid microvascular complications[9]. Prediabetic people are more likely to get diabetes, have dyslipidemic lipid profiles, and get atherosclerotic cardiovascular disease[2].

Prediabetes is prevalent in Saudi Arabia and linked to lifestyle-related disorders[10,11]. As a result, the present study investigated prediabetes synergistic factors in the Saudi community.

Patients and Methods

For this descriptive study, samples were taken from 31 primary health clinics (PHCs) that serve people in the Hail region of northern Saudi Arabia. From December 2021 to June 2022, participants were chosen at random using a simple random method. All male and female adult Saudi with prediabetes between the ages of 20 and 60 who went to PHCs during the study time met the criteria for inclusion.

Pregnant women, people with diabetes, cardiovascular disease, cancer, endocrine disease, sickle cell anemia, or a genetic disorder were excluded from the study.

Blood Sample

For the HbA1c test and the glucose tolerance test (GTT), vein blood was taken from each participant. Below 5.7% are normal, 5.7% to 6.4% are prediabetes, and 6.5% or higher are diabetes A1C levels. For GTT, fasting blood glucose should be below 95 mg/dL (5.3 mmol/L). Normal blood glucose levels are below 180 mg/dL (10 mmol/L) one hour after drinking glucose. Two hours after drinking glucose solution, normal blood glucose levels are less than 155 mg/dL (8.6 mmol/L). We determined that each individual had prediabetes because they were all GTT-diagnosed as non-diabetic and A1c-diagnosed as diabetic.

Statistical Analysis

The analysis was done with SPSS for Windows, Version 16.0. (SPSS Inc., Chicago, IL, USA), and it led to the creation of frequencies, cross-tabulations, and statistically significant values. A confidence interval of 95% was applied to the results of the Chi-square test. To be considered statistically significant, the *p*-value needed to be lower than 0.05. z statistic (a measurement that describes a value's relationship to the mean of a group of values) was also calculated.

Results

This study included 164 individuals, with 86 (52.4%) males and 78 (47.5%) females. The GTT revealed that none of the research participants had diabetes, but an A1C examination revealed that all of them had A1C values greater than 6.5%. About 16/86 (18.6%) of the 86 men were fat, while 53/86 (61.6%) were overweight. Obesity/overweight were significantly prevalent among the Saudi male population ($p<0.0001$). Around 68/78 (87.2%) of the females were fat, while 5/78 (6.4%) were overweight. Obesity/overweight were significantly more prevalent in the female population ($p<0.0001$). Females had a considerably higher risk of obesity than males, with a relative risk (RR) and 95% confidence interval (CI) of 4.6859 (2.9873 to 7.3504), $p<0.0001$, and a z statistic of 6.725 (Table I, Figure 1).

The distribution of participants by prediabetes status and blood pressure is shown in Table II and Figure 2. Most patients had blood pressures ranging from 125/60 to 125/62 mmHg, with A1c readings between 6.8% and 6.7%. Only 5 participants (148/91 and 177/87) developed prehypertension, with a mean A1c of 6.8% in nearly 80%. The majority of participants had heart rates greater than 100 beats per minute, with 91-100, 81-90, and 71-80 representing 67/164 (41%), 52 (32%), 25 (15%), and 20 (12%), respectively. The risk of tachycardia in prediabetics, the relative risk (RR), and the 95% confidence interval (95% CI): RR (95% CI) = 2.6542 (0.6381 to 4.3006), $p=0.0001$, as shown in Table II, Figure 3.

Based on whether a person has prediabetes or not, Table III and Figure 4 show how the level of education, monthly income, and number of days missed from work each month are spread out. The vast majority of participants in this study (157 out of 164 or 95.7%) had a university education. About 88/157 (56%) of the 157 subjects had an A1c score of 6.8%. Approximately 156/164 (95%) participants had a monthly income of 10,000-

Table I. Distribution of the study population by diabetes status and associated factors.

Variable	Males	Females	Total
Diabetic status (HbA1c) levels			
6.7%	32	36	68
6.8%	52	42	94
6.9%	1	0	1
7.0%	1	0	1
GTT levels			
6.7 mmol/L	38	31	69
6.8 mmol/L	46	46	92
7.0 mmol/L	1	0	1
7.4 mmol/L	1	0	1
7.6 mmol/L	0	1	1
Obesity levels			
Normal	17	5	22
Overweight	53	5	58
Obese	16	68	84
Total	86	78	164

12,000 SAR. 88/156 (56.4%) of the 156 people had an A1c level of 6.8%.

Forty-two percent, or 69 out of 164, didn't show up to work at least once last month. In terms of lost productivity, the economic cost of prediabetes is estimated to be RR (95% CI) = 1.2623 (0.9824 to 1.6218), p=0.0685.

Table IV shows the study participants' distribution based on several diabetes-related characteristics. Only two people were diagnosed with hypertension (both with A1c values of 6.8%), and only one had previously taken hypertension medication.

Three participants had previously been diagnosed with hyperlipidemia (A1c=6.8%). Only one had a prior history of hyperlipidemia medication.

Only two people had ever checked their blood sugar and found that it was high, so they took medicine.

Approximately 97% of participants visited a doctor more than four times per year, and 58.5% had an A1c of 6.8%.

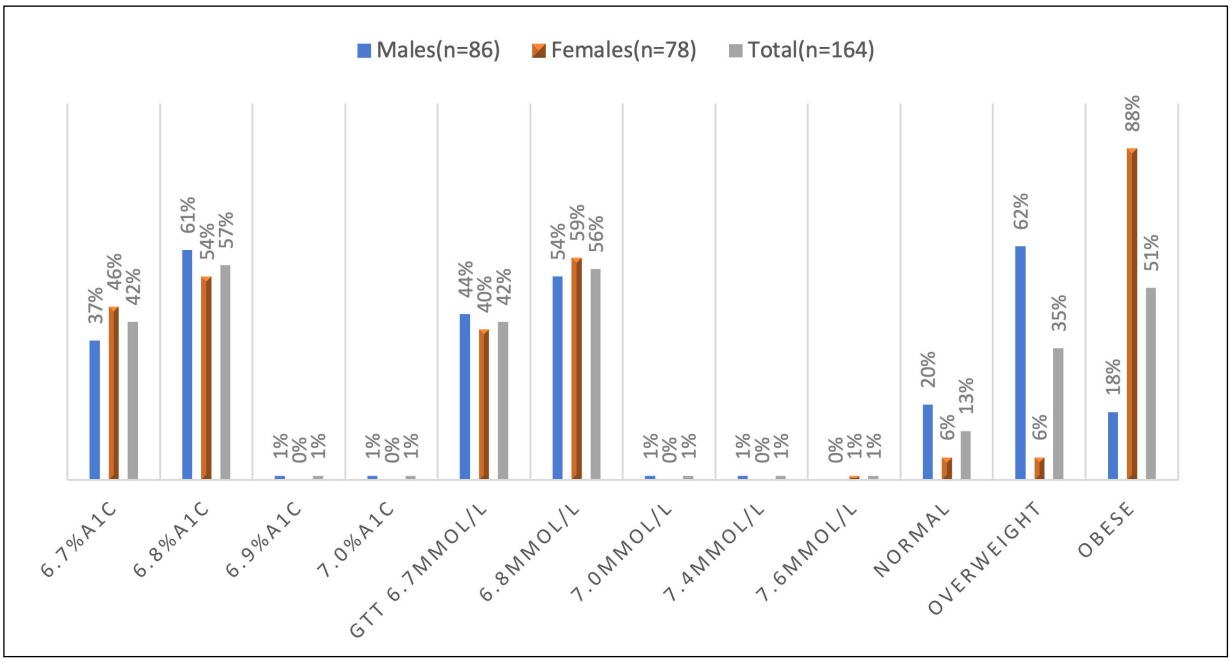

Figure 1. Description of the study population by diabetes status and associated factors.

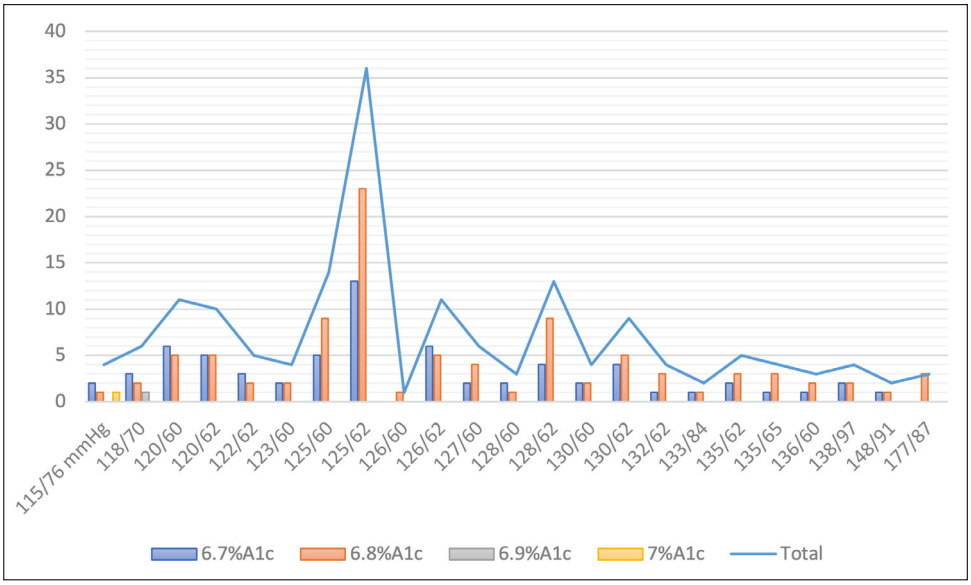

Figure 2. Study subjects by prediabetes and blood pressure.

Table II. Distribution of blood pressure and heart rate based on prediabetes status.

Blood pressure	HbA1c				
	6.7%	6.8%	6.9%	7%	Total
115/76 mmHg	2	1	0	1	4
118/70	3	2	1	0	6
120/60	6	5	0	0	11
120/62	5	5	0	0	10
122/62	3	2	0	0	5
123/60	2	2	0	0	4
125/60	5	9	0	0	14
125/62	13	23	0	0	36
126/60	0	1	0	0	1
126/62	6	5	0	0	11
127/60	2	4	0	0	6
128/60	2	1	0	0	3
128/62	4	9	0	0	13
130/60	2	2	0	0	4
130/62	4	5	0	0	9
132/62	1	3	0	0	4
133/84	1	1	0	0	2
135/62	2	3	0	0	5
135/65	1	3	0	0	4
136/60	1	2	0	0	3
138/97	2	2	0	0	4
148/91	1	1	0	0	2
177/87	0	3	0	0	3
Total	68	94	1	1	164
Heartbeats					
71-80	8	12	0	0	20
81-90	9	16	0	0	25
91-100	18	34	0	0	52
>100	32	33	1	1	67
Total	67	95	1	1	164

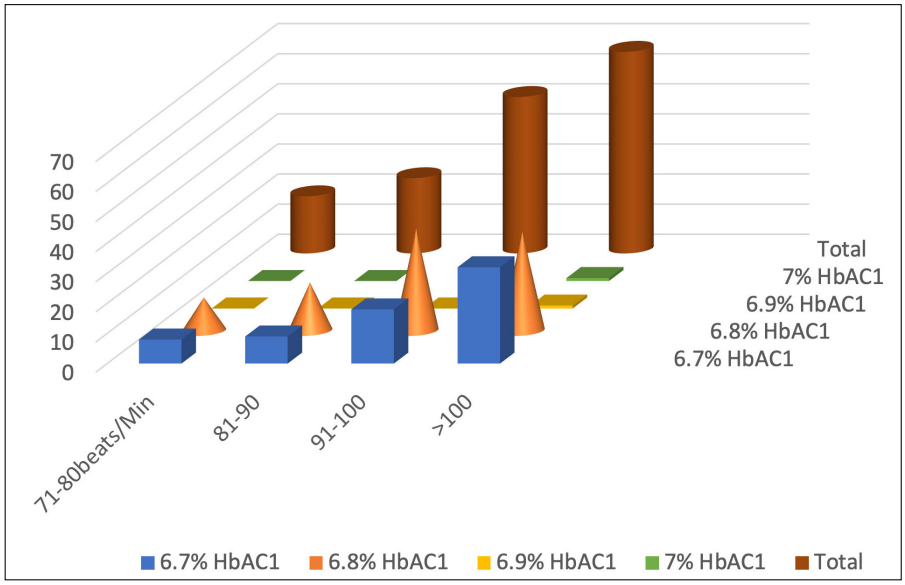

Figure 3. Study subjects by prediabetes status and heartbeat rates.

Table III. Education, income, and work absence by prediabetic status.

Variable	HbA1c				
	6.7%	6.8%	6.9%	7%	Total
Education					
read and write	0	4	0	0	4
intermediate	0	1	0	0	1
secondary	0	1	1	0	2
university	67	88	1	1	157
Total	67	94	2	1	164
Monthly Income					
12,000-14,000 SAR	0	1	0	0	1
10,000-12,000	67	88	1	0	156
7,000-10,000	1	2	0	1	4
<7,000	0	3	0	1	4
Total	68	93	1	1	164
Absence from work per month					
No	44	49	1	1	95
Yes	23	45	1	0	69
Total	67	94	1	1	164

A family history of diabetes was present in approximately 98% of the participants. The father was the person most frequently associated with family history, followed by the mother and grandfather, constituting 92 (56%), 45 (27.3%), and 24 (14.6%), respectively. In 98.7% of cases, a family member with high fat or cholesterol was identified.

Table V and Figure 5 summarize the distribution of study subjects by level of physical activity and smoking habits in relation to prediabetes. When asked if their daily jobs required physical activity, 98.7% said yes. Wanderley: 71.3% reported sitting for more than 4 hours per day. When asked, "What time do you usually go to sleep?" 117 people (71.3%) said "12 pm to 2 am". Only seven participants (4.3%) were current smokers, while five (3% were former smokers).

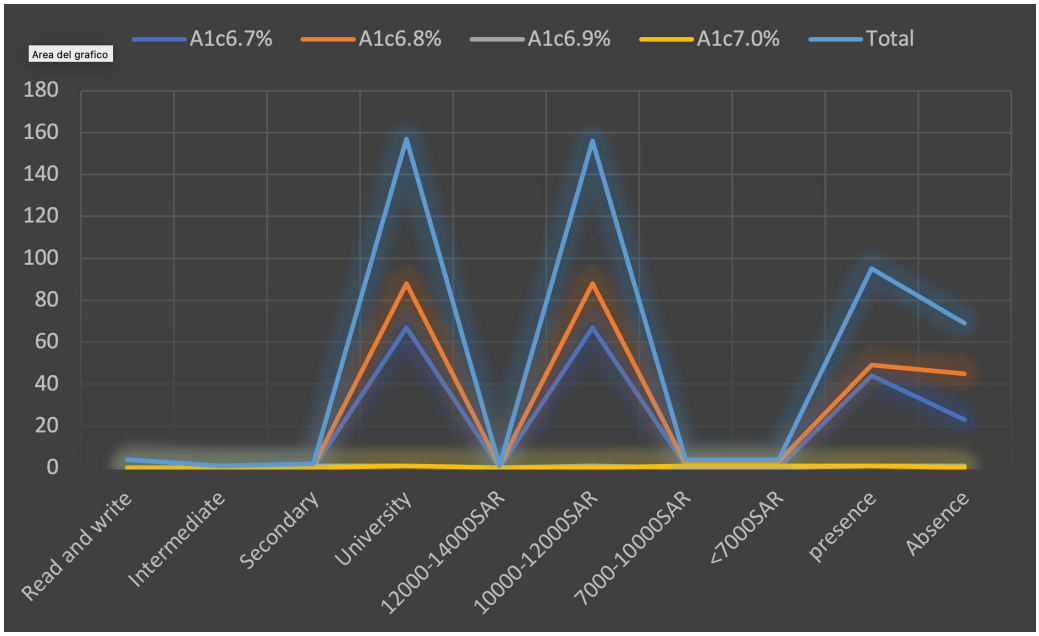

Figure 4. Education, income, and work absence by prediabetic status.

Discussion

The increasing prevalence of prediabetes in Saudi Arabia has been attributed to a number of lifestyle factors, including bad eating habits and a lack of physical activity, both of which result in obesity or being overweight. The results of the present investigation indicate that obesity and overweight are highly prevalent among patients with prediabetes. Previously, several Saudi studies[12-14] revealed such findings. Insulin resistance occurs when cells stop responding to insulin, preventing glucose from entering the cells. This can lead to an increase in weight as well as visceral and ectopic (abdominal) fat[15].

In this study, both men and women had higher prediabetic limits, but women had higher obesity rates. Gender impacts diagnosis, treatment, complications, and death. Steroid and sex hormones have an impact on body fat distribution, insulin resistance, hypertension, dyslipidemia, glucose and lipid metabolism, and energy balance. Males develop diabetes earlier and have a lower BMI. Diabetes-related cardiovascular diseases increase after menopause. Inflammation, poor coagulation, and high blood pressure are associated with prediabetes and diabetes in females. Strokes, heart attacks, and amputations are more common in diabetic and prediabetic women. Due to higher obesity and inactivity rates, women may benefit more from regular exercise than men[16].

Even though the blood pressure of most of the prediabetic people in this study was normal, many of them had tachycardia. It is not clear whether prediabetes alone or prediabetes plus high blood pressure is a bigger risk factor for CVD. The increased risk of myocardial infarction (MI) associated with prediabetes is primarily due to concomitant hypertension rather than prediabetes itself[17]. In prediabetics, hypertension reduced the risk of total and ischemic strokes. In non-hypertensives, prediabetes increases the risk of total and ischemic stroke[8]. Current guidelines recommend prediabetes screening for overweight or obese patients with at least one cardiovascular risk factor. It's important to know if hypertensive individuals should be examined regardless of other cardiovascular risk factors. Hypertension and prediabetes increase the risk of cardiovascular and overall death, especially in young people[18].

Reduced heart rate variability (HRV) increases prediabetes and T2DM risk. Independent, continuous connections between hyperglycemia measures and reduced HRV support this. These findings show that in prediabetes, autonomic cardiac dysfunction precedes diabetes[19].

In this group of cases, a rising heart rate may be caused by both gaining weight and not being active enough. HRV measures autonomic nervous system activity, equilibrium, and response to internal and external stimuli. Lifestyle and health outcomes affect health-related quality of life.

Table IV. The study subjects were distributed based on various diabetes-related factors.

Variable	HbA1c				
	6.7%	6.8%	6.9%	7%	Total
Have you been diagnosed with hypertension?					
No	67	92	1	1	161
Yes	0	2	0	0	2
Do you take medication for blood pressure?					
No	67	93	1	1	162
Previously	0	1	0	0	1
Have you ever been diagnosed with hyperlipidemia by your doctor?					
No	67	91	1	1	160
Yes	0	3	0	0	3
Do you take cholesterol medication?					
No	67	93	1	1	162
Previously	0	1	0	0	1
Have you ever been diagnosed with a thyroid issue by your doctor?					
No	67	93	1	1	162
More active	0	1	0	0	1
Do you take any thyroid medications?					
No	67	94	1	1	163
Have you ever done a blood sugar test?)					
No	67	93	1	1	162
Yes	0	1	0	0	1
Was the sugar previously measured found to be high?					
No	67	92	1	1	161
Yes	0	2	0	0	2
Have you ever been diagnosed with diabetes by your doctor?					
No	67	92	1	1	161
Yes	0	2	0	0	2
Do you take diabetes medication?					
No	67	92	1	1	161
previously	0	2	0	0	2
Has your doctor ever diagnosed you with gestational diabetes, married women?					
No	67	94	1	1	163
How often do you go to the doctor on average per year?					
Zero	2	0	0	0	2
1-3times	0	1	1	0	2
>4times	65	93	0	1	159
Family member with DM					
No	3	0	0	0	3
Father	25	66	0	1	92
Mother	19	25	1	0	45
Grandfather	21	3	0	0	24
Family member with High fat or cholesterol					
No	2	0	0	0	2
Yes	66	94	1	1	162

Smart watches and self-monitoring make heart rate monitoring easy and popular. Obesity, weight loss, exercise, and diet were studied on HRV. Time and frequency domain HRV parameters can track weight loss, exercise, and diet. Weight loss programs will soon require HRV monitoring to assess how weight affects health and homeostasis. An electrocardiogram (ECG) every two to four weeks can track HRV parameters during weight loss. The standard deviation of normal-to-normal beat intervals (SDNN), heart rate, premature ventricular complexes, and others may improve[20].

Table V. The study subjects were distributed based on various diabetes-related factors.

Variable	HbA1c				
	6.7%	6.8%	6.9%	7%	Total
Does your job involve physical exertion on a daily basis?					
No	1	0	0	1	2
Yes	66	94	1	1	162
The number of sitting hours per day					
<4 hours	23	23	0	0	46
>4 hours	44	71	1	1	117
What time do you naturally go to bed?					
Before 12	42	4	0	0	46
12-2 am	25	90	1	1	117
The amount of sleep each night					
<8 hrs	64	7	0	0	71
>8 hrs	3	87	1	1	92
Smoking habits					
Nonsmoker	60	89	1	1	151
Smoker	4	3	0	0	7
Ex-smoker	3	2	0	0	5

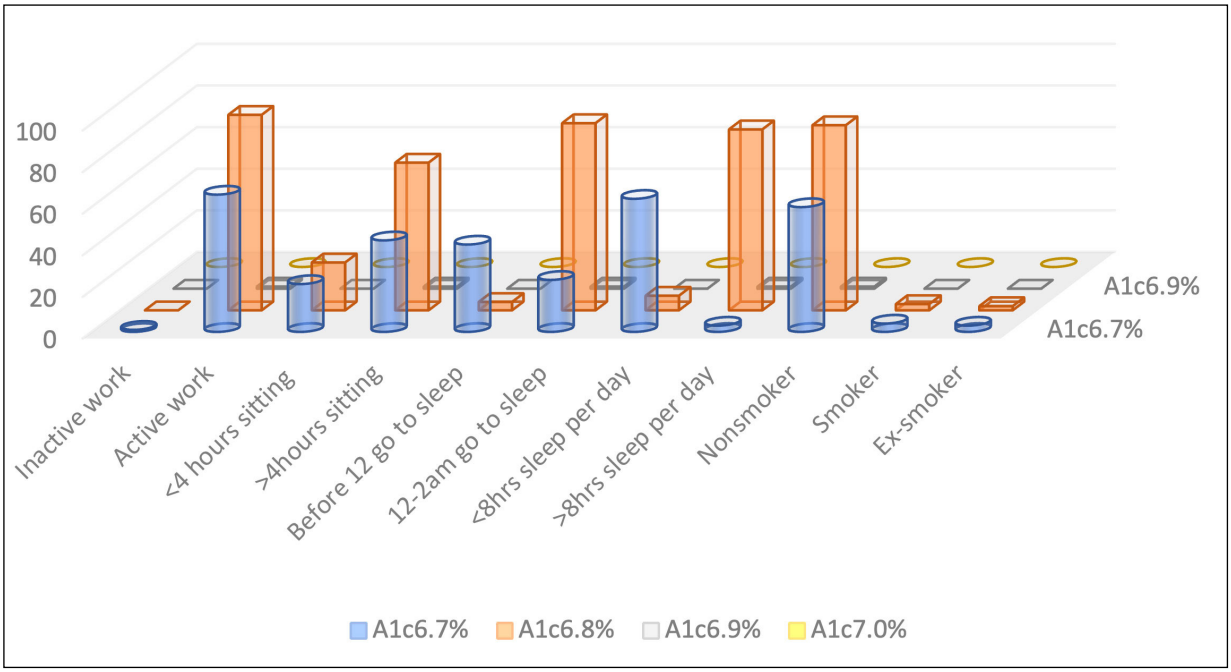

Figure 5. Level of physical activity and smoking habits in relation to prediabetes level.

Most people in this study had college degrees and made more monthly money than average. Even though these are meant to make people live healthier, they increase the risk of prediabetes. People with prediabetes were more likely to not know enough about health and make bad choices about their lifestyle. By helping people with prediabetes learn about, talk about, and take charge of their health through interventions, the risk of developing T2DM can be lowered[21].

The results of this study show that there is a strong link between prediabetes and a history of diabetes in the family. Increased susceptibility to developing T2D is linked to the presence of a positive FHD. When it comes to prediabetes, FHD is a major risk factor, especially for combined IGT

and IFG. Obese people don't appear to see its importance as much as leaner people do[22].

Even though most of the people in this study said they worked in a physically active way, most of them also said they sat for more than 4 hours a day. The risk of T2DM goes down as the amount of daily physical activity (PA) goes up. It is not clear, though, how much different parts of PA can protect against prediabetes in different ways[23]. Increasing physical activity can help minimize diabetes risk. However, the long-term therapeutic efficacy and cost-effectiveness of physical activity programs for individuals at high risk for T2DM are uncertain[24].

Many of the participants in this study do not get enough sleep. The risk of developing prediabetes increases when sleep quality is poor. More research into the link between prediabetes and sleep deprivation is needed, and it is possible that elevated C-reactive protein levels are a key underlying mechanism. Clinical practitioners should consider assessing patients' sleep quality as a means of preventing the development of diabetes in the future[25].

According to the findings of this study, there is a small number of tobacco smokers. Smokers are more likely to develop prediabetes and T2DM. Smoking increases the risk of all-cause death and chronic diabetic complications and worsens glycemic control in diabetics[26]. Smoking causes micro- and macrovascular problems with metabolic dysregulation, including prediabetes. Current global diabetes prevention strategies, which seem glucocentric, do not fully account for cardiorenal risk factors in smokers and ex-smokers. Vascular problems in prediabetes and diabetes require a more comprehensive approach before and after treatment[27].

Conclusions

An increase in the number of people with prediabetes in Saudi Arabia has been linked to being overweight or obese, having a family history of diabetes, having an irregular heart rate, and not getting enough sleep. To stop the condition from getting worse and turning into T2DM, population screening should be done with HbA1c instead of GTT.

Acknowledgments
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Informed Consent
We made sure everyone agreed on the study's ethics, both verbally and in writing, before collecting any samples.

Ethics Approval
Approved by the General Directorate of Health Affairs, Hail Region, Kingdom of Saudi Arabia (KSA). IBR registration with CACS, KSA: H-08-L-074. IRB number: 2021-40.

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Conflict of Interest
The authors declare that there are no conflicts of interest.

Data Availability
Data available upon request from the corresponding author.

Authors' Contributions
FSA: Study conception, design, and revising it critically for intellectual content. AOA: Analysis and interpretation of the data, conception. BA: Analysis and interpretation of the data, conception. MHA: Analysis and interpretation of the data, conception. NMA: Analysis and interpretation of the data, conception. TZA: Design, analysis, and interpretation of the data, conception. RSA: Design, analysis, and interpretation of the data, conception. KHOA: Design, analysis and interpretation of the data, the drafting of the paper. MSA: Design, analysis, and interpretation of the data, conception. NFA: Design, analysis, and interpretation of the data, conception. HGA: Analysis and interpretation of the data and the drafting of the paper, revising it critically for intel-lectual content.

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