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Research article

Evaluation of diagnostic parameters in detecting prediabetes in a cohort of Syrian healthcare providers and staff: correlations with risk factors

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ABSTRACT

Diabetes is spreading more rapidly in lower-middle-income countries like Syria. Early prevention programs are crucial and achievable through identification, treatment, and revision of prediabetes.

Evaluation of hyperglycemia diagnostic parameters (FPG, OGTT, HbA1c) in detecting prediabetes was executed through three phases of screening asymptomatic adults and applying the parameters sequentially. Relationships with risk factors from the American Diabetes Association (ADA) were assessed. Correlations amongst lipid profile (total cholesterol, LDL, HDL, and TG) and hyperglycemic parameters were additionally explored.

Participants (212) were mainly males (60.4%), married (61.5%), healthcare providers (28.8%), and had first-degree relatives with diabetes (32%). 10.6% had hypertension, 6.8% had dyslipidemia, and 10.7% of the female participants had PCO. Following the ADA criteria, 18% and 1.9% of the participants were diagnosed with prediabetes and diabetes, respectively. The cohort of participants with prediabetes and diabetes had higher percentage of first-degree relative with diabetes (70%), obesity (55%), hypertension (25%), dyslipidemia (15%), and PCO in females (20%). They were mainly professors (40%) and healthcare providers (25%). Interrelations amongst the hyperglycemic parameters were revealed, also with lipids and risk factors mainly age, BMI, familial diabetes, dyslipidemia, and hypertension.

Reports on prediabetes are scarce in Syria. This study, one of a few on the topic, investigated the hyperglycemic parameters in detecting prediabetes and revealed the prevalence and the correlation with risk factors and lipids. It adds substantial information to our understanding of the intertwined associations of the studied variables.

1. Introduction

Type 2 diabetes (accounts for >95% of the cases of diabetes) stems from insulin resistance leading to a relative insulin deficiency. Physical inactivity and excess body weight are the main leading foundations of type 2 diabetes. Therefore, it can be delayed or even prevented with maintaining healthy diet, leading an active lifestyle, and undergoing screening whenever suitable to identify people at risk [1, 2]. In the United States, it is estimated that 11.3% of the population have diabetes, 38.0% of the adult population have prediabetes, and 23% of adults have undiagnosed diabetes [3]. Prediabetes is an intermediate condition that manifests by higher than normal blood glucose (100 mg/dl) but below the threshold for diagnosing diabetes (126 mg/dl). It may result from defects in insulin action, insulin secretion, or both without major clinical symptoms [2].

Recently, the health burden of diabetes has been increasing worldwide. Diabetes was the ninth leading cause of death in 2019 [1]. Patients with diabetes are at higher risk for developing chronic microvascular and macrovascular degenerative complications [1, 2]. Additionally, they may suffer major complications such as kidney failure, stroke, blindness, and amputation. Diabetes is a major risk factor for developing CVD, retinal vein occlusion, and a strong contributor to the metabolic syndrome (diabetes, hypertension, and obesity). The latter is an essential pathogenetic factor for non-alcoholic fatty liver disease (NAFLD), the most frequent liver disease worldwide. Furthermore, diabetes alone is an independent risk factor for liver-related mortality and hepatocellular carcinoma development [4, 5, 6].

Therefore, searching for affected individuals before diabetes turns into a major health problem is indispensable. Screening for prediabetes and investigating the occurrence of diabetes whenever possible is critical. Diagnostic tests should be conducted when suitable especially where we expect diabetes the least, such as amongst healthcare providers. According to the American Diabetes Association (ADA), criteria for screening for prediabetes or diabetes in asymptomatic adults are overweight or obesity (BMI $\geq$ 25 kg/m^2) with one or more of the following risk factors: high risk ethnicity, history of CVD, hypertension, first-degree

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relative with diabetes, dyslipidemia, physical inactivity, or women with polycystic ovary syndrome (PCO). For all other cases, screening is performed at the age ≥35 years. Criteria for rescreening asymptomatic adults at intervals are women with gestational diabetes mellitus (GDM) and patients with prediabetes (IFG, IGT, or HbA1C ≥ 5.7%) [2].

Diabetes is spreading more rapidly in lower-middle-income countries, like Syria [1]. Yet, data on prediabetes and diabetes are scarce and occasionally controversial in the Syrian population known to harbor many of the associated risk factors. One report indicated 13.6% of the adult population in Syria have diabetes [7]. Another research conducted on Syrian refugees estimated prevalence of diabetes in adults to be much less (5.3%) [8]. No definite estimation on the number of prediabetes has been reported. This calls for more studies on the topic, particularly that many of the predisposing factors are controllable making identifying and managing prediabetes of substantial value.

The objectives of this study were to 1) Evaluate diagnostic parameters (FPG, OGTT, and HbA1c) in detecting prediabetes in asymptomatic individuals and report prevalence; 2) Explore associations with risk factors; and 3) Investigate correlations with lipid profile.

2. Methods

2.1. Subjects and ethical considerations

The Ethics Committee of the University of Kalamoon (UOK) approved the study. Announcement for the study was placed at the entrance of "the medical city" hospital in Deir Attiah, where the study was conducted. Participants of different background, age, professions responded from the hospital staff and the businesses around. Candidates were briefly interviewed and asked if they had diabetes, or any associated symptoms (polyuria, polydipsia), symptoms of neuropathy (pain, numbness, burning) or vascular diseases (claudication, leg fatigue). Asymptomatic diabetes-free adults were requested to fill in hyperglycemia screening assessment (Supplement A). Every participant's height and body weight (using a digital scale to the nearest 0.1 kg) were measured and BMI (kg/m^2, weight in kilograms divided by height in meters squared) was calculated and registered. Candidates who met the ADA criteria were asked to join the study and those who agreed were requested to sign consents. Additionally, their rights to withdraw at any time was discussed. 212 participants (128 males and 84 females) 19–68 years old were enrolled in the study. Blood pressure (BP) was measured and recorded for each participant. BP measures were repeated in the following visits for participants with previously undiagnosed hypertension. Data were collected, revised and organized into numbered cases, and entered anonymously into the study database.

2.2. Hyperglycemia screening assessment

The questionnaire collected demographic information (DOB, gender, marital status, and work), habits [smoking and physical activity (PA)], risk factors (familial diabetes, hypertension, dyslipidemia, and CVD), and medications. Participants were requested to write previous glucose and lipid tests if applicable. Furthermore, female participants were queried on PCO, and GDM (Supplement A).

2.3. Definition of variables

In the current study and following the ADA guidelines, overweight, obesity, and morbid obesity for both genders were defined as BMI =25–29.9 kg/m^2, =30–39.9 kg/m^2, and ≥40 kg/m^2, respectively. Hypertension was defined as systolic blood pressure ≥140 mmHg and diastolic blood pressure ≥90 mmHg or already on an anti-hypertensive medication [2]. Dyslipidemia was defined as high TG >250 mg/dl and/or low HDL <35 mg/dl [2]. Parameters for prediabetes were (FPG after at least 8h fast =100–125 mg/dl, or OGTT =140–199 mg/dl, or HbA1c =5.7–6.4%) and for diabetes (FPG ≥126 mg/dl, OGTT ≥200 mg/dl, HbA1c ≥6.5%). Diabetes diagnosis mandated two abnormal test values from the same sample or from two separate test samples [2].

2.4. Study phases

The study was divided into three phases. For the first phase, all enrolled participants were asked to come to the hospital laboratory after at least 8 h overnight fast. A sample of venous blood (10 mL) was collected for fasting plasma glucose (FPG) and processed immediately. Participants with predisposing ADA risk factors and borderline FPG results/or abnormal FPG were enrolled in a second phase. Participants in the second phase underwent another FPG and a standard oral glucose tolerance test (OGTT) following the WHO guidelines. Plasma glucose was measured 2 h (PG2h) after giving the participant a glucose load containing the equivalent of 75 g anhydrous glucose dissolved in water. Predisposing ADA risk factors along with values of FPG and OGTT were weighed together for enrolling participants in a third phase in which a sample of venous blood (10 mL) was collected for testing glycated hemoglobin (HbA1c). The HbA1c test was performed at a central reference laboratory in Damascus. Additionally, a full lipid profile (total cholesterol, LDL, HDL, and TG) after at least 12 h fast was examined and correlations with hyperglycemic parameters were explored (Figure 1). Cutoff values for high total cholesterol and high LDL were >200 mg/dl, and >100 mg/dl, respectively.

2.5. Statistical analyses

The statistical analyses were performed using SPSS (v.25). To check for statistically significant differences and correlations, the following tests were utilized where appropriate: Pearson's Spearman's, Kruskal-Wallis, One Way ANOVA, T-test, Mann-Whitney, and Odd ratio.

2.6. Role of the funding source

The funding source had no involvement in the study design; in the collection, analysis, and interpretation of data; in the writing of the report; or in the decision to submit the paper for publication.

3. Results

3.1. General description of the cohort

The majority of the participants were males (60.4%), married (61.5%), nonsmokers (62.1%), and healthcare providers (28.8%). Almost one third of the cohort (32%) had first-degree relatives with diabetes. Based on their answers to the corresponding questions in the hyperglycemia screening assessment, only 10.6% had hypertension, treated with antihypertensive medications in 72.7% of cases. Dyslipidemia was reported by 6.8% of the participants and in most cases (64.3%) it was untreated. Minority (2.8%) of the participants had CVD. Over one-third (37.9%) of the participants were current smokers of either cigarette (28.4%) or Hookah (7.6%), while 1.9% were previous smokers. Over one-half (58%) of the cohort were engaged in some kind of PA (walking in 65% of the cases and on a weekly basis in 54.4%). Around one-third of the cohort (31.1%) was taking medications at the time of the study. These medications were anti-hypertensive drugs, NSAIDs, vitamins, antacids and PPIs, antibiotics, levothyroxine, anti-allergy, anti-hypercholesterol, anti-coagulant, and cardio-augmentor drugs. Furthermore, over one-third of the cohort (36.8%) had undergone hyperglycemia diagnostic tests (FPG) prior to the study. 10.7% of the female participants had PCO, and none had GDM (Supplement B).

3.2. Phases of the study

All participants (212) underwent FPG test and 50 (35 males and 15 females) were asked to join the second phase. The FPG values were in 31

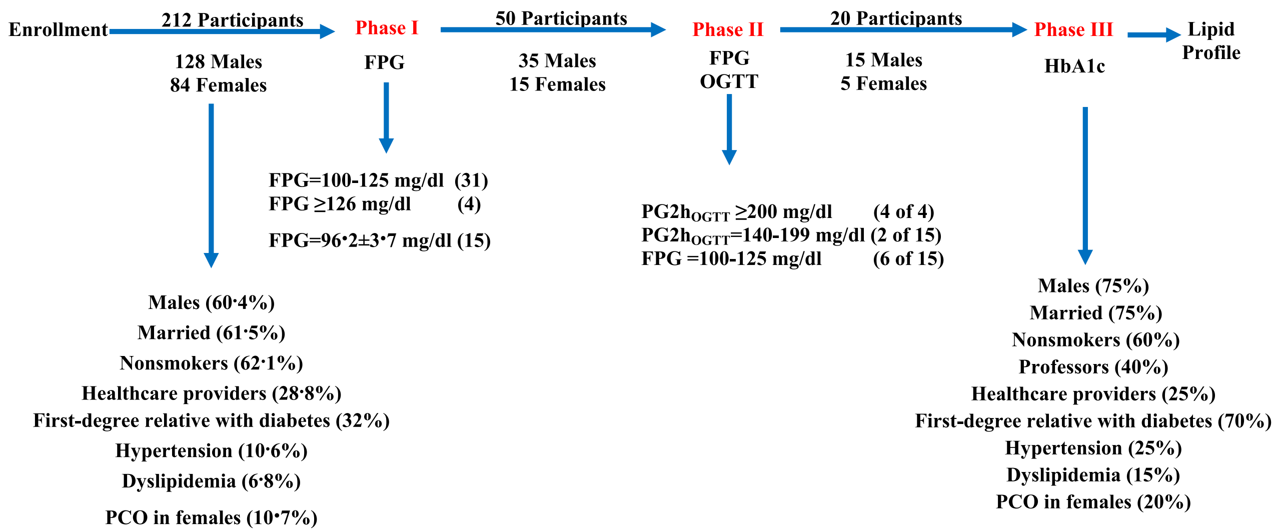

Figure 1. The flow of work conducted on the cohort of participants. The study was completed through three phases performed successively. In the first phase FPG was tested in 212 participants, in the second phase $PG2h_{OGTT}$ was examined in 50 participants, and in the third phase HbA1c was measured in 20 participants. Additionally, lipid profile was investigated.

participants 100–125 mg/dl, in four participants ≥126 mg/dl, and in 15 participants 96.2 ± 3.7 mg/dl (called borderline cases here). The borderline cases were chosen from participants with predisposing risk factors (BMI, first-degree relative with diabetes, PCO, physical inactivity, and age) and FPG values close to the predefined prediabetes values (Figure 1, Table 1). In the second phase, in six of 15 borderline cases FPG reached 100–125 mg/dl, and in two borderline cases $PG2h_{OGTT}$ = 140–199 mg/dl. Additionally, in the four participants with FPG ≥ 126 mg/dl from the first phase, $PG2h_{OGTT}$ values were ≥200 mg/dl which confirmed the diabetes diagnosis for them. In the third phase, four cases had normal values of HbA1c (<5.7%), and 12 cases had prediabetes values (5.7–6.4%), four of which were borderline cases. Four cases had diabetes values of HbA1c (≥6.5%), two had prediabetes FPG or $PG2h_{OGTT}$ values in the earlier phases and one was borderline case (Table 2). In Summary, of the 20 participants enrolled in the third phase concordance in the final diagnosis (prediabetes or diabetes) was revealed between FPG and HbA1c in 14 cases, between $PG2h_{OGTT}$ and HbA1c in ten cases, between FPG and $PG2h_{OGTT}$ in nine cases, and amongst FPG, $PG2h_{OGTT}$, and HbA1c in eight cases.

3.3. Correlations amongst study variables

Real positive relationships with 95% confidence and statistical significance ($P < 0.05$) were detected in the studied cohort amongst the following (Figure 2):

1) BMI (0.305), age (0.381) with FPG meaning that an increase in age and BMI coincided with the increase in the level of FPG (Table 3). A positive correlation was also detected between higher levels of FPG and gender or marital status. These differences were significant and in favor of males (Mann Whitney $p = 0.000$), and married status (Kruskal-Wallis $p = 0.040$).
2) FPG (0.49), age (0.527), with $PG2h_{OGTT}$, meaning that an increase in FPG or age each accorded with higher levels of $PG2h_{OGTT}$ in the studied cohort (Table 3). A positive correlation was detected between $PG2h_{OGTT}$ and each of: work (0.281, $p = 0.048$), marital status (0.361), hypertension (0.363), and taking medications (0.363). Additionally, the average level of $PG2h_{OGTT}$ was higher in married participants (Kruskal Wallis $p = 0.009$), and in participants who were taking antihypertensive medications (Kruskal Wallis $p = 0.025$).

Table 1. Description of the quantitative variables in the study cohort: All participants (212) underwent FPG test. OGTT was performed on 50 participants and 20 participants underwent HbA1c test.

	N	Min	Max	Median	Mean	Std. Deviation
Age (years)	212	19	68	32.5	35.5802	10.94961
Weight (kg)	212	36.6	134	74.4	74.5829	16.66963
Height (m)	212	1.4	1.89	1.68	1.6676	0.1006
BMI (kg/m^2)	212	16.49	40.81	26.3	26.6893	4.98649
FPG (mg/dl)	212	63.8	174.5	89.7	90.6426	13.69913
$PG2h_{OGTT}$ (mg/dl)	50	5..3	310.7	106.685	119.6174	55.22978
HbA1c (%)	20	5.39	7.36	6.025	6.154	0.54476

Table 2. Description of the quantitative variables of the participants in the third phase according to the result of the glycated hemoglobin (HbA1c): Four participants had normal values of HbA1c, 12 participants had prediabetes values of HbA1c and four had diabetes values of HbA1c.

HbA1c	Variable	Min	Max	Mean	Std. Deviation
Normal Value	Age (years)	21	38	31.25	7.23
	Weight (kg)	44	94.5	74.85	22.16
	Height (m)	1.5	1.8	1.68	0.14
	BMI (kg/m^2)	20	33.5	26.1	5.83
	FPG (mg/dl)	97	109	103.2	4.95
	$PG2h_{OGTT}$ (mg/dl)	88	109	101.5	9.71
	HbA1c (%)	5.4	5.6	5.51	0.09
Prediabetes Value	Age (years)	**22**	**60**	**44.67**	**12.59**
	Weight (kg)	54	101	88.27	12.27
	Height (m)	1.5	1.84	1.69	0.1
	BMI (kg/m^2)	23	34.8	31	3.47
	FPG (mg/dl)	94	127	104.3	9.52
	$PG2h_{OGTT}$ (mg/dl)	96	183	132.5	24.62
	HbA1c (%)	5.8	6.44	6.09	0.26
Diabetes Value	Age (years)	**46**	**52**	**49.5**	**2.52**
	Weight (kg)	69	92.1	82.2	11.6
	Height (m)	1.5	1.76	1.67	0.12
	BMI (kg/m^2)	26	31.9	29.63	2.49
	FPG (mg/dl)	97	175	134.9	34.43
	$PG2h_{OGTT}$ (mg/dl)	151	311	213.7	71.5
	HbA1c (%)	6.7	7.36	6.99	0.32

Table 3. Correlation relationships amongst the quantitative variables investigated in the study.

		BMI (kg/m^2)	FPG (mg/dl)	PG2h $_{OGTT}$ (mg/dl)	TG (mg/dl)	Total Cholesterol (mg/dl)	HDL (mg/dl)	LDL (mg/dl)	HbA1c (%)
Age (Years)	r	0.36[b]	0.381[b]	0.527[b]	0.338[b]	0.594[a]	0.159[a]	0.718[a]	0.406[a]
	P	0.00*	0.00*	0.00*	0.145	0.006*	0.503	0.00*	0.076
	N	212	212	50	20	20	20	20	20
BMI (kg/m^2)	r	1	0.305[b]	-0.024[b]	0.338[b]	0.505[a]	0.32[a]	0.543[a]	0.228[a]
	P	.	0.00*	0.868	0.145	0.023*	0.168	0.013*	0.334
	N	212	212	50	20	20	20	20	20
FPG (mg/dl)	r		1	0.491[b]	0.2[b]	-0.146[b]	0.012[b]	0[b]	0.249[b]
	P		.	0.00*	0.398	0.539	0.96	1	0.29
	N		212	50	20	20	20	20	20
$PG2h_{OGTT}$ (mg/dl)	r			1	0.344[b]	0.565[b]	0.236[b]	0.453[b]	0.67[b]
	P			.	0.137	0.009*	0.316	0.045*	0.001*
	N			50	20	20	20	20	20
TG (mg/dl)	r				1	0.455[b]	-0.029[b]	0.23[b]	0.286[b]
	P				.	0.044*	0.905	0.329	0.222
	N				20	20	20	20	20
Total Cholesterol (mg/dl)	r					1	0.515[a]	0.848[a]	0.303[a]
	P					.	0.02*	0.00*	0.194
	N					20	20	20	20
HDL (mg/dl)	r						1	0.448[a]	0.073[a]
	P						.	0.047*	0.759
	N						20	20	20
LDL (mg/dl)	r							1	289[a]
	P							.	217
	N							20	20

* Correlation is significant at the 0.05 level (2-tailed).
[a] Pearson Correlation.
[b] Spearman's rho, r = Correlation Coefficient, P=P-value, N = # of participants.

3) $PG2h_{OGTT}$ and HbA1c (0.670, $p = 0.001$) meaning that an increase in the level of $PG2h_{OGTT}$ agreed with the increase in HbA1c value (Table 3).
4) Over one third of the sample (36.8%) mentioned undergoing glucose tests prior to the current study. There was a significant difference ($P < 0.05$) between the participants who underwent glucose test prior to the study and who did not regarding having first-degree relatives with diabetes. It was revealed that 60.3% of the participants who underwent the test had first-degree relatives with diabetes. Additionally, analyses showed that the probability of choosing to undergo glucose test with familial diabetes was (OR = 1.987) higher than participants with no familial diabetes.

3.4. Description of the cohort that went through the third phase

The enrolled participants in the third phase were diagnosed with prediabetes or diabetes according to the ADA criteria at the end of study. The majority of this cohort were males (75%), married (75%), nonsmoker (60%) and had first-degree relative with diabetes (70%). They worked mainly as professors (40%) and healthcare providers (25%). They were largely obese (55%) judged by their BMI even though the majority stated practicing some kind of PA (55%). Moreover, 25% had hypertension, 15% had dyslipidemia, and 20% of the female participants had PCO. 45% were taking medications at the time of the study, mainly (15%) antihypertensives (Figure 1).

Examining the relationships amongst the investigated variables in the third phase cohort revealed additional important correlations. Significant positive relationships ($p < 0.05$) were uncovered amongst the following (Figure 2):

1) $PG2h_{OGTT}$ with LDL (0.453), and total cholesterol (0.565). An increase in $PG2h_{OGTT}$ coincided with increases in the levels of total cholesterol and LDL (Table 3). 2) Familial diabetes with total cholesterol (T-test, $p = 0.016$). Total cholesterol was higher in participants with first-degree relatives with diabetes in comparison to the cohort that did not. 3) HDL with gender: The average value of HDL was higher in females in comparison to males (T-test, $p = 0.004$). 4) TG with BMI (Kruskal Wallis, $p = 0.034$): The average levels of TG were higher in overweight and obese participants in comparison to participants with normal BMI (Mann Whitney $P = 0.020$, $P = 0.024$, respectively). 5) LDL with BMI (Kruskal Wallis, $p = 0.039$) The average level of LDL was higher in obese participants in comparison to overweight participants (Mann Whitney $p = 0.035$). 6). Total cholesterol and HbA1c (One Way ANOVA $p = 0.022$): The average level of total cholesterol was higher in the participants identified by HbA1c levels as prediabetes (LSD, $p = 0.033$) and diabetes (LSD, $p = 0.007$) in comparison to the participants with normal levels of HbA1c. However, no significant differences were detected between prediabetes and diabetes (LSD, $p = 0.170$). 7) The association between some variables in the study became more intense. This was noted for age with BMI (0.507, $p = 0.022$ versus 0.36, $p = 0.00$) and age with higher level of $PG2h_{OGTT}$ (0.720, $p = 0.000$ versus 0.527, $p = 0.00$) reflecting more homogeneity in the cohort of the third phase compared to the beginning cohort of 212 participants.

4. Discussion

Prediabetes can intensify the absolute risk to diabetes. Yet, prediabetes might be a golden chance to prevent diabetes and to avoid future complications particularly CVD [2]. By uncovering prediabetes, an early prevention program can be implemented to decrease the diabetes prevalence and complications [9]. Screening should be completed with an assessment of risk factors (informal or validated calculator) in asymptomatic adults [2]. Screening tests for prediabetes and diabetes comprise of measurements of the levels of FPG, $PG2h_{OGTT}$, and HbA1c [2,4].

In the current study, the ADA risk factors and hyperglycemia diagnostic parameters were evaluated through implementing them in detecting prediabetes in a cohort of asymptomatic participants. The study

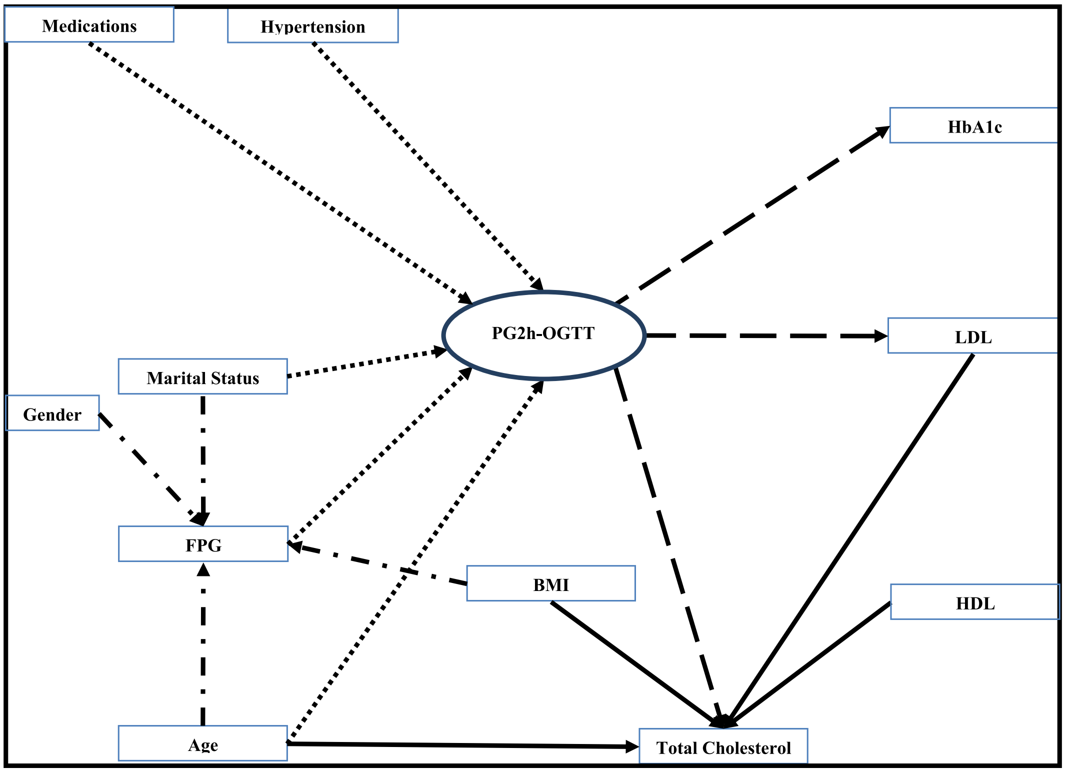

Figure 2. Correlations amongst study variables. As dotted arrows indicate, an increase in blood pressure, age, and FPG in addition to taking medications (including antihypertensive drugs) and marital status (in favor of married) correlated with higher levels of $PG2h_{OGTT}$. The elevated levels of $PG2h_{OGTT}$ coincided with increases in the levels of HbA1c, LDL, and total cholesterol (shown in dashed arrows). Age, BMI, gender (in favor of males), and marital status (in married) each correlated with an increased level of FPG (shown in mixed arrows). Age, BMI, $PG2h_{OGTT}$, were associated with higher levels of total cholesterol, which in turn correlated with augmented levels of LDL and HDL (shown in thick arrows).

included a hyperglycemic screening assessment and sequentially performed tests. The same universal well-established standards for diagnosing prediabetes and diabetes were applied. In the current study, diagnosing diabetes necessitated two abnormal values of diagnosing tests due to absence of unequivocal hyperglycemia [2].

Announcement for the study was placed at the entrance of "the medical city" hospital in Deir Attiah. In the late 1990s, Deir Attiah was a small village that got transferred gradually into a college town after the UOK (the first private university in Syria) was established in 2004 on the outskirt of the village. Around 17,000 people live permanently in town while others visit during summer. Participants from different background, age, and profession responded to the study announcement. 18% of the cohort were identified to have prediabetes diagnosed by one parameter or more. 1.9% were identified to have diabetes diagnosed by two parameters at least.

A discordance amongst hyperglycemia screening parameters was reported and emphasized in different studies [2]. In the current study, an overall concordance was detected amongst the three parameters. An increase in the level of one parameter coincided with the increase of another (Figure 2). This may be due to the fact that the cohort is not only of the same ethnic group, but also from the same local community of Deir Attiah known for high intra-village marriage rate. However, this concordance was not in every participant's case and was less than perfect. Diagnosing prediabetes involves testing one parameter only, which might make diagnosing prediabetes challenging. In Syria, FPG is the most commonly employed parameter in exploring glucose level. Nevertheless, FPG might not be as sensitive as required and may miss cases of prediabetes, as it occurred in the current study (borderline cases). $PG2h_{OGTT}$ might be a better parameter to investigate. $PG2h_{OGTT}$ was more responsive to changes in many important variables examined in the study but poor patient compliance in Syria is an inconvenience. According to the ADA, when results are within normal ranges, testing should be repeated at a minimum of three years intervals. Nevertheless, ADA recommends making the testing more frequent depending on the initial result and risk status [2]. The latter point cannot be emphasized enough. Each case of prediabetes might be different and for hidden reasons a particular parameter might fail to detect prediabetes. Alternatively, a group of two parameters such as FPG and HbA1c might be a better assessing tool [10]. This can be very valuable particularly in candidates with high risk assessment and FPG within normal levels.

Meticulous examination of the associations identified in the study reveals interesting correlation of gender (in favor of male) with higher level of FPG and of gender (in favor of female) with higher level of HDL. These data accord with other studies in which FPG was higher in male participants [11, 12] and HDL was higher in female participants [13, 14]. The queries invite further investigations to set diverse cutoff points of FPG and HDL according to gender for better evaluation of diagnosis. Additionally, the effect of medications, hypertension, and antihypertensive drugs on elevating $PG2h_{OGTT}$ value specifically with no effect on FPG and HbA1c is interesting (Figure 2). This might necessitate adjusting the cutoff normal level of $PG2h_{OGTT}$ in corresponding cases.

Twenty participants (15 males and 5 females) were enrolled in the third phase. This group was representative of the original cohort. Interesting deviations from the main cohort were noted (Figure 1), specifically higher incidence of obesity, first-degree relative with diabetes, hypertension, dyslipidemia, and PCO (in female participants). Additionally, the associations between age and BMI or between age and higher levels of $PG2h_{OGTT}$ became more intense. Remarkably, professor became the leading profession in the participants diagnosed with prediabetes and diabetes, followed by healthcare providers in the second place. This is very alarming as these professions are the elite that leads the community towards awareness of personal health and society welfare.

Interestingly, data revealed higher TG, FPG and $PG2h_{OGTT}$ values in married participants compared to singles, which may indicate changes in eating habits after marriage that reflected on the noted elevation of multiple parameters. Marriage could be considered a predisposing factor to hyperglycemia and/or dyslipidemia in the studied cohort. Whether this could be generalized to the rest of the population needs more in-depth exploration.

In the present study, many positive correlations with lipids were revealed (Figure 2) such as $PG2h_{OGTT}$ with both LDL and total cholesterol, and familial diabetes with total cholesterol. Yet future studies may find interest in deciding the influencers and the influenced parameters. Current data revealed that the average level of total cholesterol was higher in the prediabetes and diabetes participants. This agrees with previous studies that demonstrated significant relationships between total cholesterol and the incidences of prediabetes and diabetes [9]. An abnormal lipid profile has been previously reported in prediabetes and diabetes [15], which was noted in the present study. Furthermore, the average levels of TG and LDL were higher in obese participants. It has been previously shown that LDL increased in the serum of patients with insulin resistance and diabetes might be explained by enhancing cholesterol absorption and reducing clearance [16].

In some ethnic groups such as Asian Americans BMI lower than 25 was found appropriate cut point as a risk factor for diabetes [4]. In the current study, BMI as low as 19.91 was associated with prediabetes in a female participant. Additionally, BMI $= 26.16$ was the lowest BMI associated with diabetes in a male participant. Further investigation on BMI in prediabetes/diabetes to determine the best cut points for future implementation of guidelines tailored to the Syrian society may turn very valuable.

4.1. Strengths and limitations

This research is one of a few studies that add data to a limited literature on prediabetes and diabetes in Syria. The study demonstrated that professionals, including healthcare providers, who are in direct contact with patients and counsel them on diabetes and on the importance of controlling prediabetes, are in equal danger. Another group that seems to be at higher risk is college professors.

Remarkably, higher percentages of diabetes and prediabetes in the study were associated with familial diabetes. Additionally, the study revealed significant correlations amongst familial diabetes, hyperglycemic parameters, and lipids. Of particular interest was the higher level of total cholesterol. Moreover, the study detected intriguing positive behavior in participants with familial diabetes. They had their glucose levels checked more frequently than participants with no familial diabetes.

The current study was able to help the community of Deir Attiah by locating individuals at risk and may further contribute to reversing prediabetes and avoiding the complications of diabetes. The uncovered cases were advised to see the hospital endocrinologists so clinicians could offer patients with prediabetes effective preventive programs and treat diabetes patients before complications occur.

However, the study had many limitations, more in depth investigation of the correlations amongst hyperglycemic parameters, lipids, and risk factors is needed and on larger cohorts that truly represent the Syrian population and do not bind the investigation to particular groups. Additionally, a study on a larger number of female participants with female specific risk factors for diabetes is recommended.

Declarations

Author contribution statement

Lina Albitar: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Part of the data has been submitted in the article. Other parts of the data are being under further investigation for future manuscripts.

Declaration of interest's statement

The authors declare no competing interests.

Additional information

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