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ABSTRACT

OBJECTIVE: Study the association of dietary habits and other indicators of lifestyle with dysglycemia in Saudi adults.

METHODS: In a cross-sectional design, data were obtained from 1403 Saudi adults (≥ 20 years), not previously diagnosed with diabetes. Demographics, lifestyle variables and dietary habits were obtained using a predesigned questionnaire. Fasting plasma glucose, glycated hemoglobin and 1-hour oral glucose tolerance test were used to identify dysglycemia. Regression analysis was performed to determine the associations of dietary factors and other indicators of lifestyle with dysglycemia.

RESULTS: A total 1075 adults (596 men, and 479 women) had normoglycemia, and 328 (195 men, and 133 women) had dysglycemia. Following adjustment for age, BMI and waist circumference, in men the weekly intake of 5 portions or more of red meat and Turkish coffee were associated with decreased odds of having dysglycemia odds ratio (OR) 0.444 (95% CI: 0.223, 0.881; $P = .02$) and 0.387 (95% CI: 0.202, 0.74; $P = .004$), respectively. In women, the intake of fresh juice 1 to 4 portions per week and 5 portions or more were associated with OR 0.603 (95% CI: 0.369, 0.985; $P = .043$) and OR 0.511 (95% CI: 0.279, 0.935; $P = .029$) decreased odds of having dysglycemia, respectively compared with women who did not drink fresh juice. The intake of 5 times or more per week of hibiscus drink was associated with increased odds of having dysglycemia, OR 5.551 (95% CI: 1.576, 19.55, $P = .008$) compared with women not using such a drink. Other lifestyle factors were not associated with dysglycemia.

CONCLUSION: Dietary practices by studied Saudis have some impact on risk of dysglycemia, with obvious sex differences.

KEYWORDS: Dysglycemia, Saudi population, lifestyle, dietary habits

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Introduction

Dysglycemia, which include impaired glucose regulation (LDL-C), and diabetes mellitus (DM), is one of the major factors contributing to high risk for developing cardiovascular disease (CVD),¹⁻³ the number one cause of death globally.⁴ Both IGT and type 2 DM (T2DM) are highly prevalent in Saudi Arabia.^{5,6} Age as well as genetics were reported to be major non-modifiable risk factors for dysglycemia in various populations.⁷ However, there are a number modifiable risk factors, mainly dietary habits and other lifestyle factors with a varying degree of importance depending on studied population.⁸ Modifying lifestyle and

dietary practices has been reported to prevent or even reverse dysglycemia in various clinical trials on populations of different ethnicities.⁹⁻¹⁵ The association between lifestyle, dietary habits and dysglycemia has not been well studied in people living in the Kingdom of Saudi Arabia. Recently our group investigated these factors in a population sample who had not been previously diagnosed with diabetes in Jeddah to formulate a risk score to identify people at risk of dysglycemia.¹⁶ In the present study we aimed at studying the association of dietary habits and other lifestyle indicators with dysglycemia in Saudi adults with a hope of finding information for developing a T2DM prevention program.



Materials and Methods

Study design and data collection

Samples were collected from Saudi adults (≥ 20 years), not previously diagnosed with diabetes, between July 2016 and February 2017, following a detailed protocol outlined earlier.¹⁶ The “Committee on Ethics of Human Research” at Faculty of Medicine, King Abdulaziz University (KAU), and the “Committee on Research Ethics” at Ministry of Health, Kingdom of Saudi Arabia approved the study.

In summary, a cross-sectional design was used aiming to recruit 1500 (750 men and 750 women) participants from selected public healthcare centers by employing stratified, 2-stage cluster sampling method.¹⁷ A consent form was signed by recruited participants. Demographics, lifestyle variables, dietary habits, and personal medical and family history were obtained using a predesigned questionnaire based on factors associated with dysglycemia found in other populations.^{9–15,18–22} Participants were instructed to fast overnight for 8 to 14 hours, and fasting blood sample was collected to estimate fasting plasma glucose (FPG) and glycated hemoglobin (HbA1c). Another sample was collected 1 hour after ingestion of 50-g glucose solution (CASCO NERL Diagnostics, East Providence, RI, USA) for estimating plasma glucose (1-hour oral glucose tolerance test; 1h-OGTT).^{23,24} Results were used to identify dysglycemia. Anthropometric measurements, (height, weight, waist, and neck circumference) and blood pressure (BP) were measured using standardized equipment and techniques as outlined earlier.¹⁶ Weight and height measurements were used to calculate body mass index (BMI) in kg/m^2 , and categorize participants into underweight (< 18.5), healthy weight (18.5 – < 25), overweight (25 – < 30), and obese (> 30). Abdominal adiposity, based on waist circumference (WC), was defined as level 1 > 94 cm for men, and > 80 cm for women, and level 2 as > 102 cm for men and > 88 cm for women.^{25,26}

Biochemical assays

All samples (whole blood or plasma) were analyzed at the Clinical Chemistry Laboratory at National Guard Hospital in Jeddah. HbA1c was measured with HbA1c analyzer G8 (TOSOH Corporation, Japan). Plasma glucose was measured by spectrophotometric methods using Architect c8000 auto-analyzer (ABBOTT, USA).

Definition of dysglycemia

Dysglycemia was defined as an abnormality in blood sugar including prediabetes, and diabetes.^{1,2} Diabetes was diagnosed using cutoff point HbA1c $\geq 6.5\%$, and/or FPG ≥ 7 mmol/L and/or 1h-OGTT ≥ 11.1 mmol/L, while prediabetes was defined when FPG was 6.1 to 6.9 mmol/L (impaired fasting glucose, IFG), and/ or HbA1c 5.7% to 6.4% (39–46 mmol/mol) and/or 1-hour plasma glucose (1-hPG) 8.6 to 11.0 mmol/L (impaired glucose tolerance, IGT).^{1,2,24,27}

Statistical analysis

Data analysis was done using IBM SPSS statistics version 20.0 for Windows. Baseline characteristics were expressed as, frequencies, and mean \pm standard deviations (SD). Demographic, clinical, dietary, and lifestyle variables of people with dysglycemia were analyzed by comparing to those with normoglycemia. Independent *t*-test was used to compare factors with continuous variables between the 2 groups, while chi-square test or Fisher's exact test, as appropriate, was used to compare categorical variables. Unadjusted and adjusted logistic regression models were used for assessing association between demographic, lifestyle, and dietary variables, and outcome variables namely dysglycemia. Stepwise regression analysis was performed to determine the dietary factors that had an influence on dysglycemia. Only related independent variables, where $P < .15$ after an initial logistic regression between the dependent and independent variable were used in the corresponding stepwise regression model. A $P < .05$ value (2-sided test) was accepted as statistically significant.

Results

A total of 1477 adults were recruited for the study by the end of August 2016. Complete data were obtained for 1403 people. Following biochemical measurements, a total of 1075 people (596 men and 479 women) were found to have normoglycemia, and 328 (195 men and 133 women) had dysglycemia. Hence, dysglycemia prevalence was 23% in the studied population.

Association between dysglycemia with anthropometric measurements, lifestyle, clinical, and biochemical characteristics

Lifestyle, demographic, and anthropometric characteristics of the 2 study groups are presented in Table 1. There were significant differences in the means of demographic and anthropometric measurements between the normoglycemic and dysglycemic groups; the dysglycemic group had significantly higher means of age, BMI, weight, fat percentage, and neck, waist, and hip circumferences, and waist to hip and waist to height ratios (all $P < .001$, Table 1). Men and women dysglycemia groups also had significantly higher means of systolic and diastolic blood pressure compared with people with normoglycemia ($P < .05$ at least), and significantly higher means of total cholesterol (TC), triglycerides (TG), LDL-C, HbA1C and both fasting and 1 hour plasma glucose and lower high density lipoprotein cholesterol (HDL-C) compared with normoglycemic people ($P < .01$ at least, Table 1).

Comparison of the distribution of various characteristics between the normoglycemia and the dysglycemia groups is presented in Table 2. Of the participants 77.7% with dysglycemia were over 30 years of age, 34.5% of were overweight and 47.3% obese. Additionally, 62.8% of them did not have a regular daily physical activity for at least 30 minutes. Only age, BMI, waist circumference, and physical inactivity were found to be significantly and directly associated with dysglycemia

Table 1. Demographic, anthropometric, clinical, and biochemical characteristics of studied groups.

	MEN		WOMEN	
	NORMOGLYCEMIA N=596	DYSGLYCEMIA N=195	NORMOGLYCEMIA N=479	DYSGLYCEMIA N=133
	MEAN ± SD	MEAN ± SD	MEAN ± SD	MEAN ± SD
Anthropometric measurements				
Age (years)	29 ± 8.8	38 ± 12.6***	31 ± 10.9	41.9 ± 13.4***
Weight (kg)	79.7 ± 17.9	87.21 ± 20.1***	66.7 ± 15.9	75.9 ± 16.3***
BMI	27.0 ± 5.7	29.90 ± 6.4***	26.7 ± 6.3	30.8 ± 6.0***
Fat (%)	26.1 ± 9.0	30.66 ± 9.6***	38.7 ± 11.3	43.9 ± 10.3***
Neck circ. (cm)	39.3 ± 5.4	40.68 ± 4.1**	33.3 ± 3.9	35.1 ± 4.8***
Waist circ. (cm)	94.7 ± 14.8	103.73 ± 15.9***	86.3 ± 15.5	96.5 ± 15.4***
Hip circ. (cm)	105.9 ± 13.2	111.03 ± 14.3***	103.8 ± 13.3	111.1 ± 13.8***
Waist to hip ratio	0.89 ± 0.08	0.93 ± 0.07***	0.83 ± 0.09	0.87 ± 0.10***
Waist to height ratio	0.55 ± 0.09	0.61 ± 0.09***	0.55 ± 0.10	0.62 ± 0.10***
Clinical measurements				
BP-Systolic	120 ± 12.1	125 ± 17.4***	112 ± 14.6	118 ± 17.6***
BP-Diastolic	74 ± 11.2	78 ± 11.5***	70 ± 11.3	73 ± 12.6*
Biochemical measurements				
Serum TC (mmol/L)	4.7 ± 0.9	5.0 ± 0.1***	4.76 ± 0.9	5.16 ± 1.1***
Serum HDL-C (mmol/L)	1.3 ± 0.3	1.2 ± 0.3**	1.49 ± 0.3	1.44 ± 0.3
Serum TG (mmol/L)	1.4 ± 1.0	1.7 ± 1.1***	0.98 ± 0.5	1.34 ± 0.8***
Serum LDL-C (mmol/L)	3.2 ± 0.9	3.5 ± 0.9***	3.09 ± 0.8	3.40 ± 0.9***
HbA1c %	5.0 ± 1.0	5.8 ± 1.2***	5.01 ± 0.9	5.81 ± 1.1***
Plasma glucose (0 hour)	4.0 ± 1.0	5.3 ± 2.4***	4.15 ± 0.6	5.16 ± 1.8***
Plasma glucose (1 hour)	5.7 ± 1.8	9.3 ± 3.5***	5.97 ± 1.4	8.98 ± 3.1***

Data are presented as mean ± SD. Differences in measurements between individuals with and without dysglycemia was analyzed using Student's *t*-test. Abbreviations: Circ., circumference; BP, blood pressure; TC, total cholesterol; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol, TG, triglycerides, HbA1c, glycated hemoglobin. *Denotes significantly different between dysglycemia groups ($P \leq .05$). **Denotes significantly different between dysglycemia groups ($P \leq .01$). ***Denotes significantly different between dysglycemia groups ($P \leq .001$).

($P < .01$ at least, Table 2). Sex, sleeping duration, sitting duration, and smoking habits were not associated with dysglycemia.

Sex-differences in dietary habits

The difference in the recorded pattern of dietary habits between men and women is shown in Table 3. Women reported eating more fresh and cooked vegetables compared to men, whereas men had a higher intake of red meat ($P < .001$). In addition, men reported drinking more fresh and non-fresh juice, soft

drinks, energy drinks, red tea, cappuccino and hibiscus drinks compared with women ($P < .01$ at least), whereas women reported drinking more Arabic and Turkish coffee than men ($P < .05$ at least). There were no sex-difference in the consumption of fruits, whole grain products, American coffee or cinnamon drink (Table 3).

Association between dietary habits and dysglycemia

Association between dietary habits, physical activity, and dysglycemia in men. Comparing the dietary habits in men between the

Table 2. Demographic, anthropometric, and lifestyle characteristics of normoglycemia and dysglycemia study groups presented as number of participants and (% of group).

VARIABLE	NORMOGLYCEMIA (N= 1075)		DYSGLYCEMIA (N=328)		TOTAL (N= 1403)		χ^2
	N	N%	N	N%	N	N%	P VALUE
Age							
<30	632	58.8	73	22.3	705	50.2	134.185
30+	443	41.2	255	77.7	698	49.8	P<.001
Sex							
Men	596	55.4	195	59.5	791	56.4	1.643
Women	479	44.6	133	40.5	612	43.6	P=.2
BMI							
Underweight	47	4.4	2	0.6	49	3.5	
Healthy	387	36.1	58	17.7	445	31.8	81.955
Overweight	379	35.3	113	34.5	492	35.1	P<.001
Obese	260	24.2	155	47.3	415	29.6	
Waist circumference							
Normal	649	61.6	109	33.9	758	55.1	83.269
Level 1	197	18.7	83	25.8	280	20.3	P<.001
Level 2	208	19.7	130	40.4	338	24.6	
Physical activity (30 minutes/day to 5 days/week)							
No	584	54.3	206	62.8	790	56.3	7.345
Yes	491	45.7	122	37.2	613	43.7	P=.007
Sleeping duration							
<6 hours	408	38	145	44.2	553	39.4	4.321
6-8 hours	567	52.7	153	46.6	720	51.3	P=.115
>8 hours	100	9.3	30	9.1	130	9.3	
Sitting hours/day							
Less than 4	192	17.9	71	21.6	263	18.7	
4-5	326	30.3	100	30.5	426	30.4	2.87
6-8	344	32.0	94	28.7	438	31.2	P=.412
More than 8	213	19.8	63	19.2	276	19.7	
Smoking habits							
Non smoker	817	76	237	72.3	1054	75.1	3.148
Smoker	227	21.1	76	23.2	303	21.6	P=.207
Previous smoker	31	2.9	15	4.6	46	3.3	

Data is shown as frequency and percentages. Participants were classified according to their BMI as underweight (<18.5 kg/m²), normal 18.5->25 kg/m², overweight 25-<30 kg/m² and obese ≥30 kg/m². Participants were classified according to their waist circumference as normal adiposity (≤94 cm for men, ≤80 cm for women), level 1 (>94 cm for men, >80 cm for women) and level 2 (>102 cm for men, >88 cm for women). Association between measures and dysglycemia was analyzed using chi-square test.

χ^2 is the chi-square test value followed by its P-value. Significant differences between groups are shown in bold font.

Table 3. Dietary habits patterns by sex.

	MEN (N=791)	WOMEN (N=612)	TOTAL (N=1403)	χ^2
	N (N%)	N (N%)	N (N%)	P-VALUE
Fruit (portion)				
No intake	111 (14.0)	72 (11.8)	183 (13)	1.727 P=.422
1-4/week	399 (50.4)	323 (52.8)	722 (51.5)	
5 or more/week	281 (35.5)	217 (35.5)	498 (35.5)	
Fresh vegetable (portion)				
No intake	115 (14.5)	53 (8.7)	168 (12)	15.259 P<.001
1-4/week	310 (39.2)	225 (36.8)	535 (38.1)	
5 or more/week	366 (46.3)	334 (54.6)	700 (49.9)	
Cooked vegetable (portion)				
No intake	164 (20.7)	67 (10.9)	231 (16.5)	27.975 P<.001
1-4/week	356 (45.0)	278 (45.4)	634 (45.2)	
5 or more/week	271 (34.3)	267 (43.6)	538 (38.3)	
Whole grains (portion)				
No intake	113 (14.3)	93 (15.2)	206 (14.7)	3.187 P=.203
1-4/week	146 (18.5)	91 (14.9)	237 (16.9)	
5 or more/week	532 (67.3)	428 (69.9)	960 (68.4)	
Red meat (portion)				
No intake	58 (7.3)	139 (22.7)	197 (14)	77.64 P<.001
1-4/week	453 (57.3)	335 (54.7)	788 (56.2)	
5 or more/week	280 (35.4)	138 (22.5)	418 (29.8)	
Fresh juice (portion)				
No intake	182 (23.0)	186 (30.4)	368 (26.2)	10.039 P=.007
1-4/week	412 (52.1)	281 (45.9)	693 (49.4)	
5 or more/week	197 (24.9)	145 (23.7)	342 (24.4)	
Non fresh juice (portion)				
No intake	252 (31.9)	259 (42.3)	511 (36.4)	20.572 P<.001
1-4/week	253 (32.0)	191 (31.2)	444 (31.6)	
5 or more/week	286 (36.2)	162 (26.5)	448 (31.9)	
Soft drinks (portion)				
No intake	247 (31.2)	298 (48.7)	545 (38.8)	56.848 P<.001
1-4/week	233 (29.5)	175 (28.6)	408 (29.1)	
5 or more/week	311 (39.3)	139 (22.7)	450 (32.1)	
Red tea (portion)				
No intake	166 (21.0)	182 (29.7)	348 (24.8)	14.346 P=.001
1-4/week	201 (25.4)	133 (21.7)	334 (23.8)	
5 or more/week	424 (53.6)	297 (48.5)	721 (51.4)	

(Continued)

Table 3. (Continued)

	MEN (N = 791)	WOMEN (N = 612)	TOTAL (N = 1403)	χ^2
	N (N%)	N (N%)	N (N%)	P-VALUE
Green tea (portion)				
No intake	464 (58.7)	323 (52.8)	787 (56.1)	7.39 P = .025
1-4/week	168 (21.2)	130 (21.2)	298 (21.2)	
5 or more/week	159 (20.1)	159 (26)	318 (22.7)	
Arabic coffee (portion)				
No intake	464 (58.7)	323 (52.8)	579 (41.3)	7.39 P = .025
1-4/week	168 (21.2)	130 (21.2)	367 (26.2)	
5 or more/week	159 (20.1)	159 (26.0)	457 (32.6)	
Turkish coffee (portion)				
No intake	347 (43.9)	232 (37.9)	1005 (71.6)	10.33 P = .006
1-4/week	214 (27.1)	153 (25.0)	216 (15.4)	
5 or more/week	230 (29.1)	227 (37.1)	182 (13)	
American coffee (portion)				
No intake	565 (71.4)	440 (71.9)	1157 (82.5)	0.112 <i>P = .946</i>
1-4/week	124 (15.7)	92 (15.0)	124 (8.8)	
5 or more/week	102 (12.9)	80 (13.1)	122 (8.7)	
Cappuccino (portion)				
No intake	626 (79.1)	531 (86.8)	904 (64.4)	14.183 P = .001
1-4/week	81 (10.2)	43 (7.0)	296 (21.1)	
5 or more/week	84 (10.6)	38 (6.2)	203 (14.5)	
Energy drinks (portion)				
No intake	536 (67.8)	368 (60.1)	1168 (83.3)	9.881 P = .007
1-4/week	157 (19.8)	139 (22.7)	160 (11.4)	
5 or more/week	98 (12.4)	105 (17.2)	75 (5.3)	
Hibiscus drinks (portion)				
No intake	623 (78.8)	545 (89.1)	1275 (90.9)	26.237 P < .001
1-4/week	115 (14.5)	45 (7.4)	100 (7.1)	
5 or more/week	53 (6.7)	22 (3.6)	28 (2)	
Cinnamon drink (portion)				
No intake	719 (90.9)	556 (90.8)	1185 (84.5)	0.57 <i>P = .752</i>
1-4/week	58 (7.3)	42 (6.9)	152 (10.8)	
5 or more/week	14 (1.8)	14 (2.3)	66 (4.7)	

Data is shown as frequency and percentages of total participants in the sex group. χ^2 is the chi-square test value followed by its *P*-value. Significant difference between groups is shown in bold font.

normoglycemic and dysglycemic groups, the lower intake of red meat, Turkish coffee, American coffee, and energy drinks were significantly associated with dysglycemia ($P < .01$ at least;

Table 4), whereas the higher intake of cappuccino and cinnamon drink was found to be significantly associated with dysglycemia ($P = .002$ at least; Table 4). Of normoglycemic men,

Table 4. Dietary habits in men with normoglycemia and dysglycemia.

	NORMOGLYCEMIA (N=596)		DYSGLYCEMIA (N=195)		χ^2
	N	N%	N	N%	P VALUE
Fruit (portion)					
No intake	83	13.9	28	14.4	0.055
1-4 times/week	302	50.7	97	49.7	<i>P</i> = .973
5 or more/week	211	35.4	70	35.9	
Fresh vegetable (portion)					
No intake	88	14.8	27	13.8	0.915
1-4 times/week	238	39.9	72	36.9	<i>P</i> = .633
5 or more/week	270	45.3	96	49.2	
Cooked vegetable (portion)					
No intake	134	22.5	30	15.4	4.89
1-4 times/week	259	43.5	97	49.7	<i>P</i> = .087
5 or more/week	203	34.1	68	34.9	
Whole grains (portion)					
No intake	82	13.8	31	15.9	0.682
1-4 times/week	109	18.3	37	19.0	<i>P</i> = .711
5 or more/week	405	68.0	127	65.1	
Red meat (portion)					
No intake	37	6.2	21	10.8	15.108
1-4 times/week	327	54.9	126	64.6	<i>P</i> = .001
5 or more/week	232	38.9	48	24.6	
Fresh juice (portion)					
No intake	136	22.8	46	23.6	2.765
1-4 times/week	303	50.8	109	55.9	<i>P</i> = .251
5 or more/week	157	26.3	40	20.5	
Non fresh juice (portion)					
No intake	179	30.0	73	37.4	3.773
1-4 times/week	197	33.1	56	28.7	<i>P</i> = .152
5 or more/week	220	36.9	66	33.8	
Soft drinks (portion)					
No intake	178	29.9	69	35.4	2.127
1-4 times/week	178	29.9	55	28.2	<i>P</i> = .345
5 or more/week	240	40.3	71	36.4	
Red tea (portion)					
No intake	132	22.1	34	17.4	4.355
1-4 times/week	157	26.3	44	22.6	<i>P</i> = .113
5 or more/week	307	51.5	117	60.0	

(Continued)

Table 4. (Continued)

	NORMOGLYCEMIA (N=596)		DYSGLYCEMIA (N=195)		χ^2
	N	N%	N	N%	P VALUE
Green tea (portion)					
No intake	354	59.4	110	56.4	3.472
1-4 times/week	131	22.0	37	19.0	<i>P</i> = .176
5 or more/week	111	18.6	48	24.6	
Arabic coffee (portion)					
No intake	256	43.0	91	46.7	1.65
1-4 times/week	168	28.2	46	23.6	<i>P</i> = .438
5 or more/week	172	28.9	58	29.7	
Turkish coffee (portion)					
No intake	408	68.5	157	80.5	11.42
1-4 times/week	100	16.8	24	12.3	<i>P</i> = .003
5 or more/week	88	14.8	14	7.2	
American coffee (portion)					
No intake	454	76.2	172	88.2	12.893
1-4 times/week	70	11.7	11	5.6	<i>P</i> = .002
5 or more/week	72	12.1	12	6.2	
Cappuccino (portion)					
No intake	391	65.6	145	74.4	5.593
1-4 times/week	124	20.8	33	16.9	<i>P</i> = .061
5 or more/week	81	13.6	17	8.7	
Energy drinks (portion)					
No intake	453	76.0	170	87.2	12.201
1-4 times/week	95	15.9	20	10.3	<i>P</i> = .002
5 or more/week	48	8.1	5	2.6	
Hibiscus drinks (portion)					
No intake	547	91.8	172	88.2	3.302
1-4 times/week	38	6.4	20	10.3	<i>P</i> = .192
5 or more/week	11	1.8	3	1.5	
Cinnamon drink (portion)					
No intake	545	91.4	162	83.1	12.631
1-4 times/week	29	4.9	23	11.8	<i>P</i> = .002
5 or more/week	22	3.7	10	5.1	

Data is shown as frequency and percentages.

χ^2 is the chi-square test value followed by its *P*-value. Significant difference between groups is shown in bold font

38.9% had an intake of 5 portions or more per week of red meat compared with 24.6% of men with dysglycemia (*P* = .001; Table 4). The consumption over 5 cups of other types of coffee

(except Arabic coffee that is not roasted) showed a tendency to be higher in normoglycemic people in unadjusted analyses. The intake of Turkish and American coffee 5 portions or more

Table 5. Unadjusted and adjusted odds ratio (OR) with its 95% confidence interval (CI) for dietary predictors of dysglycemia in men.

	UNADJUSTED OR (95% CI) <i>P</i>	ADJUSTED FOR AGE, BMI AND WC OR (95% CI) <i>P</i>
Red meat		
<i>P</i> for trend	<i>P</i> = .009	<i>P</i> = .029
No intake (reference)		
1-4/week	0.748 (0.415, 1.347) <i>P</i> = .333	0.692 (0.366, 1.308) <i>P</i> = .257
5 or more/week	0.448 (0.237, 0.846) <i>P</i> = .013	0.444 (0.223, 0.881) <i>P</i> = .02
Turkish coffee		
<i>P</i> for trend	NS	<i>P</i> = .005
No intake (reference)		
1-4/week		0.663 (0.392, 1.123) <i>P</i> = .126
5 or more/week		0.387 (0.202, 0.74) <i>P</i> = .004
American coffee		
<i>P</i> for trend	<i>P</i> = .006	NS
No intake (reference)		
1-4/week	0.427 (0.215, 0.848) <i>P</i> = .15	
5 or more/week	0.505 (0.26, 0.981) <i>P</i> = .044	
Energy drinks		
<i>P</i> for trend	<i>P</i> = .011	NS
No intake (reference)		
1-4/week	0.564 (0.332, 0.96) <i>P</i> = .035	
5 or more/week	0.374 (0.143, 0.975) <i>P</i> = .044	
Cinnamon drink		
<i>P</i> for trend	<i>P</i> = .001	NS
No intake (reference)		
1-4/week	2.867 (1.572, 5.23) <i>P</i> = .001	
5 or more/week	2.109 (0.926, 4.801) <i>P</i> = .075	

NS, variable was not included in the model as it was not significant after an initial logistic regression between the dependent and independent variable were used in the corresponding stepwise regression model.

Significant differences between groups are shown in bold font.

per week was 14.8% and 12.1% of normoglycemic men respectively, compared with 12.3% and 6.2% in men with dysglycemia (*P* = .003 and *P* = .002, respectively; Table 4). In addition, 8.1% of normoglycemic men drank 5 portions or more of energy drinks per week compared with 2.6% of men with dysglycemia (*P* = .002; Table 4).

In logistic regression with adjustment for age, BMI and waist circumference as additional confounders in men, the low intake of red meat and Turkish coffee were the strongest factors associated with dysglycemia (*P* = .029 and *P* = .005; Table 5). The weekly intake of 5 portions or more of red meat and Turkish coffee were associated with decreased odds of having

dysglycemia (OR = 0.444 (95% CI: 0.223, 0.881) *P* = .02 and OR = 0.387 (95% CI: 0.202, 0.74) *P* = .004, respectively, Table 5). In multivariable regression analysis, no associations between other dietary factors and dysglycemia were observed in men.

Among other lifestyle variables, physical activity was the only predictor for dysglycemia in men when analyzed without adjustment, but the significance disappeared after adjusting for age, BMI and waist circumference (Table 6).

Association between dietary habits, other lifestyle factors and dysglycemia in women. Comparing the dietary habits in women

Table 6. Unadjusted and adjusted odds ratio (OR) with its 95% confidence interval (CI) for physical activity as a predictor of dysglycemia in men.

	UNADJUSTED OR (95% CI) <i>P</i>	ADJUSTED FOR AGE, BMI AND WC OR (95% CI) <i>P</i>
Physical activity		
<i>P</i> for trend	<i>P</i> = .009	<i>P</i> = .093
30minutes/day to 5days/week (reference)		
No physical activity	1.555 (1.115, 2.168) <i>P</i> = .009	1.369 (0.949, 1.973) <i>P</i> = .093

Significant differences between groups are shown in bold font.

between the normo- and dysglycemic groups, a low intake of fresh juice ($P=.027$) and high intake of hibiscus drinks ($P=.005$) and cinnamon drinks ($P=.001$) were significantly associated with dysglycemia (Table 7). There was a non-significant trend towards for the association between the high intake of green tea and dysglycemia ($P=.056$, Table 7). Of normoglycemic women had an intake of 1 to 4 portions per week of fresh juice and 24.4% of them had an intake of 5 or more portions per week compared with 39.1% and 21.1% of women with dysglycemia respectively ($P=.027$, Table 7). On the other hand, 6% and 12.8% of women with dysglycemia had an intake of hibiscus drink 5 times per or more compared with only 1.3% and 3.5%, respectively of normoglycemic women ($P=.005$ and $P=.001$ respectively, Table 7).

In logistic regression with adjustment for age, BMI, and WC as additional confounders in women, the low fresh juice and high hibiscus drink intake were the strongest factors associated with dysglycemia in women ($P=.047$ and $P=.023$, respectively; Table 8). The weekly intake of 1 to 4 portions per week and 5 portions or more of fresh juice was associated with 0.603 and 0.511 decreased odds of having dysglycemia in women respectively compared with women who did not drink fresh juice (OR=0.603, 95% CI: (0.369, 0.985), $P=.043$ and OR=0.511, 95% CI: (0.279, 0.935), $P=.029$, respectively). The intake of 5 times or more per week of hibiscus drink was associated with 5.551 increased odds of having dysglycemia in women compared to no intake (OR=5.551, 95% CI: (1.576, 19.55), $P=.008$; Table 8). There were no associations between other dietary factors and dysglycemia in women. No other lifestyle variables were predicting dysglycemia in women (data not shown).

Discussion

Successes of programmes focusing on modifications of lifestyle and dietary practices in preventing or reversing type 2 diabetes mellitus and prediabetes (ie, dysglycemia) has been reported in different populations.⁹⁻¹⁵ In view of the high prevalence of dysglycemia in Saudi Arabia,^{5,6} investigating factors associated with the condition is urgently needed in order to develop a local, evidence-based, dysglycemia prevention programme. Therefore, in this study we aimed at investigating the

association between dietary habits and other lifestyle factors with dysglycemia in Saudi adults not previously diagnosed with diabetes.

Our study was conducted in Jeddah, the largest city in the Western region of the country, with a population of mixed ethnicities, reflecting a good representation of the multi-ethnic nature of the country as noted in earlier survey,⁶ and a myriad of dietary and other lifestyle habits and practices. Excluding people with previously diagnosed with diabetes helped to ensure that the reported lifestyle and dietary habits were the actually practiced without knowledge of person's diabetes and not modified following diagnosis.

Most available risk scores to identify individuals at increased risk of developing dysglycemia have included high age, BMI and abdominal obesity, decreased physical activity, smoking status, and low vegetable intake as risk predictors.^{19-22,28,29} A high intake of red meat, low intake of whole-grain bread, and low coffee consumption have also been identified as a risk predictors by some studies.^{30,31} We included all of these factors in our study and also other factors reported to be associated with dysglycemia such as sleeping duration, sitting hours/day, and the intake of various beverages including herbal teas which have been found to have an implication on dysglycemia.^{32,33}

In our recently developed dysglycemia risk score to identify people at high future risk of developing T2M in Saudi Arabia,¹⁶ men sex, age, abdominal obesity, past history of dysglycemia, and family history of T2DM were the only factors included in the final model. Therefore, we adjusted for these factors while analyzing our data.

The current study found that the prevalence of dysglycemia is 23% in this Saudi population sample and that age, obesity and dyslipidemia were significant determinants of dysglycemia, agreeing with what was previously reported.³⁴

Among other studied lifestyle variables, only low physical activity (defined as <150 minutes per week) was associated with dysglycemia in the current study. It was a predictor for dysglycemia in men only when analyzed without adjustment, and its significance disappeared although a trend toward significance remained after adjusting for age, BMI and waist circumference. This suggests that some obese people probably have started physical activity in an effort to control their

Table 7. Dietary habits in women with normoglycemia and dysglycemia.

	NORMOGLYCEMIA (N=479)		DYSGLYCEMIA (N=133)		χ^2
	N	N%	N	N%	P VALUE
Fruit (portion)					
No intake	54	11.3	18	13.5	0.864
1-4 times/week	257	53.7	66	49.6	<i>P</i> = .649
5 or more/week	168	35.1	49	36.8	
Fresh vegetable (portion)					
No intake	46	9.6	7	5.3	2.608
1-4 times/week	176	36.7	49	36.8	<i>P</i> = .271
5 or more/week	257	53.7	77	57.9	
Cooked vegetable (portion)					
No intake	54	11.3	13	9.8	1.412
1-4 times/week	222	46.3	56	42.1	<i>P</i> = .494
5 or more/week	203	42.4	64	48.1	
Whole grains (portion)					
No intake	79	16.5	14	10.5	2.934
1-4 times/week	71	14.8	20	15.0	<i>P</i> = .231
5 or more/week	329	68.7	99	74.4	
Red meat (portion)					
No intake	106	22.1	33	24.8	0.51
1-4 times/week	263	54.9	72	54.1	<i>P</i> = .775
5 or more/week	110	23.0	28	21.1	
Fresh juice (portion)					
No intake	133	27.8	53	39.8	7.221
1-4 times/week	229	47.8	52	39.1	<i>P</i> = .027
5 or more/week	117	24.4	28	21.1	
Non fresh juice (portion)					
No intake	198	41.3	61	45.9	1.495
1-4 times/week	149	31.1	42	31.6	<i>P</i> = .473
5 or more/week	132	27.6	30	22.6	
Soft drinks (portion)					
No intake	222	46.3	76	57.1	5.438
1-4 times/week	146	30.5	29	21.8	<i>P</i> = .066
5 or more/week	111	23.2	28	21.1	
Red tea (portion)					
No intake	148	30.9	34	25.6	2.784
1-4 times/week	107	22.3	26	19.5	<i>P</i> = .249
5 or more/week	224	46.8	73	54.9	

(Continued)

Table 7. (Continued)

	NORMOGLYCEMIA (N=479)		DYSGLYCEMIA (N=133)		χ^2
	N	N%	N	N%	P VALUE
Green tea (portion)					
No intake	258	53.9	65	48.9	5.773
1-4 times/week	107	22.3	23	17.3	<i>P</i> = .056
5 or more/week	114	13.8	45	33.8	
Arabic coffee (portion)					
No intake	181	37.8	51	38.3	0.599
1-4 times/week	123	25.7	30	22.6	<i>P</i> = .741
5 or more/week	175	36.5	52	39.1	
Turkish coffee (portion)					
No intake	342	71.4	98	73.7	0.983
1-4 times/week	71	14.8	21	15.8	<i>P</i> = .612
5 or more/week	66	13.8	14	10.5	
American coffee (portion)					
No intake	415	86.6	116	87.2	1.168
1-4 times/week	32	6.7	11	8.3	<i>P</i> = .558
5 or more/week	32	6.7	6	4.5	
Cappuccino (portion)					
No intake	284	59.3	84	63.2	0.765
1-4 times/week	110	23.0	29	21.8	<i>P</i> = .682
5 or more/week	85	17.7	20	15.0	
Energy drinks (portion)					
No intake	425	88.7	120	90.2	0.88
1-4 times/week	35	7.3	10	7.5	<i>P</i> = .644
5 or more/week	19	4.0	3	2.3	
Hibiscus drinks (portion)					
No intake	441	92.1	115	86.5	10.787
1-4 times/week	32	6.7	10	7.5	<i>P</i> = .005
5 or more/week	6	1.3	8	6.0	
Cinnamon drink (portion)					
No intake	388	81	90	67.7	19.413
1-4 times/week	74	15.4	26	19.5	<i>P</i> = .001
5 or more/week	17	3.5	17	12.8	

Data is shown as frequency and percentages.
Significant association with dysglycemia is shown in bold font.
 χ^2 is the chi-square test value followed by its *P*-value.

weight gain. The upper limit of the 95% CI, 1.973, also suggests that high physical activity could be a significant protective factor for dysglycemia when studied on a larger sample.

This association may relate to the effect of exercise on increasing insulin sensitivity.³⁵ It is reported that a single session of moderate exercise increased the glucose uptake by 40% at

Table 8. Unadjusted and adjusted odds ratio (OR) with its 95% confidence interval (CI) for the predictors of dysglycemia in women.

	UNADJUSTED	ADJUSTED FOR AGE, BMI AND WC
	OR (95% CI) <i>P</i>	OR (95% CI) <i>P</i>
Fresh juice		
<i>P</i> for trend	<i>P</i> = .009	<i>P</i> = .047
No intake (reference)		
1-4/week	0.539 (0.344, 0.844) <i>P</i> = .007	0.603 (0.369, 0.985) <i>P</i> = .043
5 or more/week	0.48 (0.274, 0.84) <i>P</i> = .01	0.511 (0.279, 0.935) <i>P</i> = .029
Hibiscus drink		
<i>P</i> for trend	<i>P</i> = .032	<i>P</i> = .023
No intake (reference)		
1-4/week	1.205 (0.558, 2.603) <i>P</i> = .636	0.815 (0.353, 1.882) <i>P</i> = .631
5 or more/week	4.801 (1.498, 15.381) <i>P</i> = .001	5.551 (1.576, 19.55) <i>P</i> = .008
Cinnamon drink		
<i>P</i> for trend	<i>P</i> = .002	NS
No intake (reference)		
1-4/week	1.514 (0.905, 2.535) <i>P</i> = .114	
5 or more/week	3.722 (1.772, 7.816) <i>P</i> = .001	

NS, variable was not included in the model as it was not significant after an initial logistic regression between the dependent and independent variable were used in the corresponding stepwise regression model.

Significant differences between groups are shown in bold font.

least, and this occurred through an increase in insulin-stimulated glucose transport-phosphorylation which allowed a 2-fold increase in insulin-stimulated glycogen synthesis in muscle, and hence, higher uptake of glucose.³⁶ In addition, this inverse relationship between exercise and dysglycemia could be explained by its effect on reducing general inflammation.³⁷ A previous intervention study reported that reducing body weight in obese women through reducing the caloric intake and increasing physical activity resulted in a significant reduction in the levels of IL-6 and IL-18 pro-inflammatory cytokines and CRP (C-reactive protein) which play a significant role in the pathogenesis of diabetes mellitus, and an increase in adiponectin levels which has anti-inflammatory properties³⁷ and insulin-sensitizing effects.³⁸

Sleep duration was reported to have a U-shaped relationship in a previous meta-analysis with the risk of T2DM with sleeping 7 to 8 hours per day carrying the lowest risk.³² Similar U-shaped relationship was observed in this study, but the sample size was not enough to reach statistical significance. Similarly, we noted that dysglycemia was higher in smokers and previous smokers agreeing with previous findings,³⁹ but the sample size was not enough to reach statistical significance.

Fruit and vegetable consumption was not associated with decreased dysglycemia in the current study. However, the higher intake of fresh fruit juice was associated with decreased dysglycemia in women only even after adjustment for age, BMI

and waist circumference. This suggests that individuals who are following a healthier lifestyle might be replacing some sugar sweetened beverages with fruit juices in an effort to have healthier options.

However, our findings disagree with findings from a previous large prospective study on a cohort of middle-aged American women with an over 18 years of follow up which reported a positive association between fruit juice consumption and diabetes risk.⁴⁰ This disagreement could be explained by the fact that there is a far less consumption of fruit juice by the Saudi population than the American population. A previous study reported that only 2.6% of Saudis aged 15 years or older met both the Saudi and the Center of Disease Control and Prevention (CDC) guidelines for daily consumption of fruits and vegetables as measured by the average daily consumption of fruits, 100% fruit juices, and vegetables suggesting that the intake of 100% fruit juices is too low in the Saudi population.⁴¹ In addition, a huge variety of fruit juices exist and they may also vary among countries for the simple sugar concentration and fiber.

Red meat consumption was inversely associated with dysglycemia in men only in the current study. This disagrees with the findings from previous multiethnic cohort studies in USA and meta-analysis that both unprocessed and processed meat intake was associated with type 2 diabetes.^{42,43} This variability in the association between red meat consumption and risk

of dysglycemia between our study and previous international studies^{42,43} could be due to the difference in the animal source of consumed red meat. Lamb meat is the most consumed red meat in Saudi Arabia. Camel meat is also commonly consumed. Moreover, processed meat is not widely consumed among Saudis, but meat is often directly used in stews and casseroles. Apart from a cohort study of individuals from 30 communities from different parts of Finland reported that unprocessed red meat consumption was not a risk factor for diabetes,⁴⁴ there are no studies that investigated the effect of each meat type separately on dysglycemia. Also there are no studies that investigated this association in populations where lamb meat is common such as in Arab populations. In addition, the difference in the nutritional value and health effects of lamb, beef and camel meat is poorly studied. It has been previously mentioned that lamb meat contains higher concentrations of n-3 polyunsaturated fatty acids compared with beef meat.⁴⁵ A recent meta-analysis reported that the increased intake of n-3 polyunsaturated fatty acids is related to a decreased risk of metabolic syndrome,⁴⁶ which might explain the inverse association between red meat intake and dysglycemia observed in the studied Saudi population where the most consumed meat is lamb. Men had a higher consumption of meat than women in the current study which might explain the absence of the inverse association between red meat intake and dysglycemia in women.

The higher intake of Turkish coffee was associated with decreased dysglycemia in men in the current study. Also the consumption over 5 cups of other types of coffee (except Arabic coffee that is not roasted) showed a tendency to be higher in normoglycemic people in unadjusted analyses. A meta-analysis suggests that an increase in coffee consumption reduces the risk of T2DM by 6% for each cup-per-day.⁴⁷ A cup of Turkish coffee contains 6 to 12 mg of diterpenes, mainly Cafestol and kahweol as it does not undergo filtration process.⁴⁸ In vitro studies suggested that cafestol in coffee may aid in protection of coffee drinkers from T2DM as small concentrations of cafestol (10^{-10} - 10^{-6} M) showed a significant increase in insulin secretion by insulinoma cells and also in glucose uptake by skeletal muscle cells.⁴⁹ A systematic review suggested that the possible mechanisms behind this association is the high concentration of polyphenol, chlorogenic acid, and that coffee components induce modulation of adenosine receptor signaling; and microbiome content and diversity, in addition to their thermogenic, antioxidant, and anti-inflammatory properties.⁴⁷ The intake of Turkish coffee was reported to be higher in women in our study but the its inverse associated with dysglycemia was observed only in men suggesting that there might be variations in the metabolic response to it between sex groups, or that other components in the diet of women mitigate this effect.

High intake of hibiscus tea was associated with dysglycemia in women in the current study. Despite the fact that hibiscus tea was previously established to slow the rate of rise in blood glucose following consumption of high glycemic index food and have hypoglycemic properties,³³ it is commonly consumed with high

amount of sugar due to its high acidity explaining its association with dysglycemia in the studied Saudi population. Future studies investigating diet-disease associations should modify the used FFQs to include information about sugar sweetening of drinks.

Our study has limitations as well as points of strength. Our study is the first in our region to include detailed dietary and other lifestyle practices, and to investigate sex differences in association between these practices and dysglycemia. In addition, since sample selection to avoid bias is most important, we have avoided bias by random selection of PHC and included volunteers. Furthermore, data collections was carried out by well-trained data collectors using standardized methods.

Our main limitation lies in the cross-sectional design, which can only suggest associations, but does not allow inferences about cause and effect. Secondly, since our data relied on self-reported dietary and lifestyle practices, errors in reporting are expected. This is common in all similar papers relying on questionnaires to collect information. However, we tried to minimize errors by conducting face to face interviews by trained data collectors. Finally, our sample size was relatively small, but it was enough to detect several associations.

Conclusion

In conclusion, dietary practices among the sample of adult Saudis studied have some impact on risk of dysglycemia, with obvious sex differences. A study of the impact of lifestyle habits in a larger sample, preferably using a prospective study design, needs to be carried out. Such more detailed studies are needed before reaching firm recommendations for the construction of dysglycemia prevention programmes in Saudi populations.

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Authors' Contributions

Conception and design: all authors. Administrative support: SB, HJ, RA, GA, JA. Provision of study materials or patients: SB, HJ, RA, GA, JA. Collection and assembly of data: SB, HJ, RA, GA, JA. Data analysis and interpretation: SE, SB, HJ. Manuscript writing: all authors. Final approval of manuscript: all authors.

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