Prev. Nutr. Food Sci. 2019;24(4):373-380
https://doi.org/10.3746/pnf.2019.24.4.373
pISSN 2287-1098 · eISSN 2287-8602

Dietary Intake and Physical Activity in Relation to Insulin Resistance in Young Overweight Saudi Females: An Exploratory Pilot Study

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ABSTRACT: Insulin resistance is a major contributor to the development of several chronic metabolic diseases, including type 2 diabetes mellitus, and is an increasing health concern in Saudi Arabia. Diet and physical activity have been postulated to affect insulin resistance; however, their effects on development of insulin resistance in young overweight Saudi females have not been explored. Therefore, the aim of the study is to investigate whether diet and physical inactivity increases the risk of insulin resistance in young overweight Saudi females. In a cross-sectional study, 42 overweight female Saudi students, aged between 20 and 30 years, were recruited from King Abdul-Aziz University. A questionnaire was used to collect demographics, anthropometric measurements, physical activity, and food frequency data. Blood biomarkers (lipid profile, fasting glucose, and fasting insulin) were measured. Insulin resistance was assessed using homeostasis model assessment 2 (HOMA2)-insulin resistance (IR) scores. A significant difference in median body mass index (BMI) was observed between the HOMA2-IR normal and HOMA2-IR raised index groups (P=0.04). In terms of dietary habits, the insulin resistant group had a higher intake of canned beverages compared with the normal group (P=0.03). No significant differences were found between the groups in terms of waist circumference, hip circumference, waist-to-hip ratio, or body fat percentage. The lipid profile also did not significantly differ between the two groups. This study demonstrates significant differences in HOMA2-IR-defined insulin resistance according to subjects' BMI and canned beverage intake. A larger study is needed to confirm these associations.

Keywords: insulin resistant, HOMA-IR, dietary patterns, overweight, physical activity

INTRODUCTION

Insulin resistance is the central feature of several metabolic syndrome abnormalities, including glucose intolerance, dyslipidaemia, and hypertension (Grundy, 2016).

In Saudi Arabia, there is an increasing prevalence of insulin resistance-related disorders such as type II diabetes mellitus (Mira et al., 2002; Bahijri et al., 2010). According to the IDF Diabetes Atlas (2017), Saudi Arabia has one of the highest prevalence of diabetes mellitus in the world. Given the rapid rise in the rate of diabetes, early identification of insulin resistance could be utilized as a primary preventative strategy to reduce progression to clinical disease (Green et al., 2012).

Risk factors of insulin resistance include genetics and lifestyle factors, such as diet and physical inactivity (Roberts et al., 2013; Satija et al., 2016; Hu et al., 2001; Hanson et al., 2001). Consumption of fruit and vegetables (Spence et al., 2010), certain types of fish (Ikeda et al., 2018) and low-fat dairy products (Tremblay and Gilbert, 2009) has been inversely associated with insulin resistance, while intake of sugar-sweetened beverages and energy-dense foods, such as fast foods (Ma et al., 2016; Pereira et al., 2005) and saturated fatty acids (Koska et al., 2016), has been positively associated with insulin resistance. Moreover, it was reported that a sedentary lifestyle increases the chance of developing insulin resistance while physical activity helps decrease the risk of diabetes (Balkau et al., 2008). Although insulin resistance may be demonstrated in individuals without an increase in intra-abdominal fat or circulating markers of inflammation (Petersen et al., 2007), excess visceral adipose tissue

Received 8 July 2019; Accepted 30 September 2019; Published online 31 December 2019

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is strongly correlated with insulin resistance (Bacha et al., 2006).

In laboratory and clinical studies, several methods are used to assess insulin resistance. The euglycemic hyperinsulinemic clamp (IS clamp) is considered the gold standard. However, use of the IS clamp is time-consuming, invasive and expensive, and requires an experienced clinician. The most common method to assess insulin resistance, especially among health care workers in Saudi Arabia, is the homeostasis model assessment (HOMA)-insulin resistance (IR) (Bahijri et al., 2010). The main advantages of the HOMA-IR model are that it is cheap to carry out and only requires one blood draw from a fasting participant, which can be taken with minimal technical expertise. Although the HOMA-IR is widely used, its cut-off for insulin resistance has not been conclusively determined and may vary between people of different ethnicities (Hedblad et al., 2000; Añez et al., 2015; Esteghamati et al., 2010; Ghasemi et al., 2015; Tang et al., 2015; Timóteo et al., 2014; Tohidi et al., 2018; Yin et al., 2013).

In Saudi Arabia, few studies have used the HOMA as an indicator for insulin resistance; these studies have used cut-off thresholds derived from other study populations, such as Spain (Bahijri et al., 2010; Bahijri et al., 2018; Abdelkarem et al., 2016). In the current study, we categorized participants by HOMA index using the Iranian cut-off (Ghasemi et al., 2015) since, of the available population studies, Iranian dietary patterns are most similar to those of Saudi Arabia.

Factors that contribute to the development of insulin resistance and type 2 diabetes include being overweight or obese (Memish et al., 2014), poor dietary habits (Moradi-Lakeh et al., 2017), and low physical activity (Al-Hazzaa, 2018) are increasing among Saudi women. However, only a limited number of studies examine the dietary habits and physical activity levels in relation to the insulin resistance among Saudi women. Therefore, in this study we aimed to investigate whether diet and physical inactivity increase the risk of insulin resistance in young overweight Saudi women using the HOMA index as an indicator for insulin resistance. Prediction of insulin resistance risk in women of childbearing age is essential to prevent health issues including diabetes/gestational diabetes and to plan for early preventive strategies. We hypothesized that anthropometrics, dietary intake, and physical activity differ between normal and insulin resistance women.

MATERIALS AND METHODS

Study design and subjects

Utilizing a cross-sectional study design, 42 female participants aged 20 to 30 years old were recruited from the female campus (including both medical and non-medical students) at King Abdulaziz University, Jeddah, Saudi Arabia using direct advertising through the distribution of pamphlets. Participants with chronic conditions such as hypertension, endocrine disorders, diabetes, liver diseases, kidney diseases, respiratory disorders, and any type of cancer were excluded. Inclusion criteria included overweight Saudi adult females aged 20～30 years old. The aim and objectives of the study were explained to each participant and all gave informed written consent. Participants were asked to fill out a questionnaire consisting of five parts: demographics, anthropometrics, food intake frequency, laboratory measurements, and physical activity. Demographic information including name, date of birth, gender, and nationality were collected through a face-to-face interview. Ethical approvals were obtained from the Unit of the Biomedical Ethics Research Committee at King Abdulaziz University (Reference No. 400-19).

Anthropometric measurements

Anthropometric measurements, including height, weight, waist circumference (WC), hip circumference (HC), waist-hip ratio (WHR), body mass index (BMI), and fat percentage were performed. Height, weight, WC, HC, and WHR was measured according to standard procedures (Lohman et al., 1988). Participants were weighed in light clothing and without shoes, and weight was recorded in kilograms (kg) using a calibrated digital scale to the nearest 0.1 kg. Height was measured to the nearest 0.1 cm according to the Frankfurt plane position. BMI was computed as a fraction of weight to height squared; the BMI cut-off for adults was considered. WC was measured at the narrowest point between the lowest costal border and the iliac crest and HC was measured at the widest part of the hip. WHR was calculated WC divided by HC. Fat percentage was measured via Bioelectrical Impedance Analysis. In this study, we considered the ethnicity-specific cut-off for Arabs and Europids: normal (BMI 18.5～24.9 kg/m^2); overweight (BMI 25.0～29.9 kg/m^2), and obese (BMI greater than 30 kg/m^2) (World Health Organization, 2000). In addition, we considered the optimal BMI, WC, and WHR cut-off values for predicting metabolic syndrome in Saudi women (28 kg/m^2, 87 cm, and 0.81, respectively) (Al-Rubean et al., 2017).

Dietary intake assessment

A self-administered food-frequency questionnaire (FFQ) to assess dietary intake was used (Alissa and Alama, 2015). For each food item or food group, subjects were asked the frequency of consumption (daily/weekly/monthly) and the number of different portion sizes they had consumed over the past year. The estimation of macronutrients content (energy, carbohydrate, fat, protein, dietary fiber, cholesterol, saturated fatty acids, monoun-

saturated fatty acids, and polyunsaturated fatty acids) was performed by Prof. Alissa according to the analysis described (Alissa and Alama, 2015). Analysis of food group intake was performed according to Alkhaldy using Microsoft Excel (Alkhaldy, 2014). Food intake was grouped into food groups (cereals, breads, fruits, vegetables, legumes, nuts and seeds, meat and meat products, poultry, fish, egg, dairy products, fats and oils, canned beverages, and sweet).

Laboratory measurements

Blood samples were collected in the morning after an overnight fast of at least 8～12 h. All blood samples were processed within 2 h. Serum and plasma extracted from samples were stored at −80°C for analysis of lipid profiles, fasting blood glucose, and fasting insulin level. Fasting glucose was assessed by an automated enzymatic method (Dade Behring Ltd., Milton Keynes, UK). Plasma insulin was measured via an electro-chemi-luminescence immunoassay. Insulin resistance was calculated using the HOMA models (HOMA-2) using fasting glucose and fasting insulin [fasting glucose: 3～25 mmol/L and fasting insulin: 2.88～43.16 LU/mL (20～300 pmol/L)] by the HOMA calculator available from http://www.dtu.ox.ac.uk/homacalculator. Moreover, HOMA of b-cell function (HOMA-B) and HOMA of insulin sensitivity were also considered as they are reported to provide useful insights into glucose metabolism (Song et al., 2007; Caumo et al., 2006). Blood lipid profiles, including high-density lipoprotein (HDL), low-density lipoprotein (LDL), total cholesterol, and triglycerides, were analysed using automated enzymatic methods (Dade Behring Ltd.). All measurements were performed at the Biochemistry Laboratory of the King Abdulaziz University Hospital.

Physical activity assessment

A self-reported physical activity questionnaire that included nine questions about weekly activities such as transport, household, fitness, and sports was used based on that previously reported by Al-Hazzaa and Al-Ahmidi (2003). The questionnaire had 4 categories depending on the participants' answers. The total score was measured as follows: very active (≥40 point), active (39～30 point), moderately active (29～20 point), and inactive (<20 point) (Al-Hazzaa and Al-Ahmidi, 2003).

Statistical analysis

Statistical analysis of all data was performed using Statistical Package for Social Sciences (SPSS) software, version 21.0 for Windows (SPSS Inc., Chicago, IL, USA). A normality test was run for all data to determine if data sets can be modelled by a normal distribution. Descriptive statistics were presented as medians with inter-quartile range (IQR). Comparisons between groups were performed using the Mann-Whitney test for non-normally distributed data and by paired two-sample *t*-tests for normally distributed data. Statistical significance was set a level of $P<0.05$.

RESULTS

Subjects characteristics

Forty-two female participants aged 20～30 years old were recruited. The subjects' characteristics are presented in Table 1. Median BMI was 27.0 kg/m^2, which is within the cut-off range for being classified as overweight. The median WC, HC, and WHR were within the normal female range.

Participants were subdivided into normal and insulin resistance groups based on HOMA index measurements (HOMA2-IR) per the optimal insulin resistance cut off level determined in Iranian populations of 1.41 (Ghasemi et al., 2015). Using the HOMA2-IR index, 78.5% (n=33) of participants were within the optimal insulin resistance level (<1.41) and classified as normal, while 21% (n=9) had a high level of insulin resistance (>1.41) and were classified as insulin resistance. Table 2 presents differences in subject characteristics between the normal

Table 1. Characteristics of study participants (n=42)

Parameter	Median	IQR (Q1～Q3)
Demographic		
Age (yrs)	21	20～22
Marital status		
Single	39 (93%)	–
Married	3 (7%)	–
Arthrometric		
Height (cm)	158.0	152.7～162.3
Weight (kg)	67.6	64.1～74.4
BMI (kg/m^2)	27.0	25.6～29.0
WC (cm)	78.0	76.0～81.6
HC (cm)	107.5	104.1～114.5
WHR	0.7	0.7～0.8
Fat (%)	29.9	26.7～34.2
Blood profile		
FG (mmol/L)	4.5	4.1～4.8
FSI (pmol/L)	51.5	41.1～73.6
HOMA2-IR	0.9	0.7～1.4
HOMA2-B	120.7	101.8～161.8
HOMA2-S (%)	108.2	73.0～136.4
Total cholesterol (mmol/L)	4.1	3.7～4.9
TG (mmol/L)	0.7	0.5～0.9
LDL-C (mmol/L)	2.3	2.0～2.9
HDL-C (mmol/L)	1.4	1.2～1.6

IQR, inter-quartile range; BMI, body mass index; WC, waist circumference; HC, hip circumference; WHR, waist-hip ratio; Fat %, fat percentage; FG, fasting glucose; FSI, fasting serum insulin; HOMA2-IR, homeostasis model assessment 2-insulin resistance; TG, triglycerides; LDL-C, low-density lipoprotein-cholesterol; HDL-C, high-density lipoprotein-cholesterol.

Table 2. Characteristics of study participants according to homeostasis model assessment 2 (HOMA2)-insulin resistance (IR) cut-off in the normal and insulin resistance groups

Parameter	Normal group (cut-off <1.41, n=33)		Insulin resistance group (cut-off >1.41, n=9)		*P*-value
	Median	IQR (Q1~Q3)	Median	IQR (Q1~Q3)	
Age (yrs)[1]	21.0	20.0~22.0	20.0	20.0~21.0	0.09
Arthrometric					
Height (cm)[1]	159.0	152.6~163.0	155.5	154.0~159.0	0.4
Weight (kg)[1]	67.0	64.3~74.0	72.0	64.0~75.0	0.4
BMI (kg/m^2)[1]	26.9	25.5~28.1	29.5	26.6~30.0	0.049
WC (cm)[1]	77.0	76.0~80.0	80.5	78.5~86.0	0.09
HC (cm)[1]	107.0	104.0~111.5	115.0	107~116.5	0.15
WHR[1]	0.7	0.7~0.8	0.8	0.7~0.8	0.29
Fat %[2]	29.1	26.5~32.6	34.2	29.7~36.0	0.10
Blood profile					
FG (mmol/L)[1]	4.5	4.1~4.8	4.3	4.2~4.5	0.61
FSI (pmol/L)[1]	48.6	38.8~59.1	132.5	122.5~142.2	<0.001
HOMA2-IR[1]	0.8	0.7~1.1	2.2	2.1~2.5	<0.001
HOMA2-B[1]	112.7	95.2~130.6	222.5	205.5~247.6	<0.001
HOMA2-S (%)[1]	120.6	93.8~144.6	44.9	40.7~46.6	<0.001
Total cholesterol (mmol/L)[2]	4.2	3.7~5.0	4.1	3.5~4.2	0.36
TG (mmol/L)[1]	0.6	0.5~0.8	0.8	0.7~0.9	0.09
LDL-C (mmol/L)[2]	2.4	2.0~2.9	2.2	1.5~2.3	0.12
HDL-C (mmol/L)[1]	1.4	1.2~1.6	1.4	1.3~1.5	0.79

Data are presented as median (Q1~Q3).
[1]*t*-tests.
[2]Mann-Whitney test.
IQR, inter-quartile range; BMI, body mass index; WC, waist circumference; HC, hip circumference; WHR, waist-hip ratio; Fat %, fat percentage; FG, fasting glucose; FSI, fasting serum insulin; HOMA2-IR, homeostasis model assessment 2-insulin resistance; TG, triglycerides; LDL-C, low-density lipoprotein-cholesterol; HDL-C, high-density lipoprotein-cholesterol.

and insulin resistance groups. HOMA2-IR, HOMA-B, and HOMA-S significantly differed between groups ($P<$ 0.001). In terms of the anthropometric measurements, the median BMI for the normal group (26.9 kg/m^2) was less than the proposed values (28.0 kg/m^2) for identifying risk of metabolic syndrome in Saudi women; the median value for the insulin resistance group (29.5 kg/m^2) was above this proposed cut-off value, and significantly differed from that of the normal group (P=0.04). No significant differences were found between the groups in terms of WC, HC, WHR, or body fat percentage. In addition, no correlation with the HOMA index was found for WHR (R^2=0.0006) or the fat percentage (R^2=0.02853) (data not shown).

Dietary intake assessment

No differences in median estimated energy, carbohydrate, fat, protein, dietary fiber, cholesterol, saturated fatty ac-

Table 3. Estimated energy and macronutrient intake from food-frequency questionnaire in the normal and insulin resistance groups

Nutrients	Overall (n=42)		Normal group (cut-off <1.41, n=33)		Insulin resistance group (cut-off >1.41, n=9)		*P*-value
	Median	IQR (Q1~Q3)	Median	IQR (Q1~Q3)	Median	IQR (Q1~Q3)	
Energy (kcal/d)[1]	2,270.4	1,884.9~2,568.9	2,304.4	1,890.6~2,538.6	2,236.4	1,883.0~2,584.2	0.83
Carbohydrate (g/d)[1]	286.9	227.2~324.5	277.8	226.6~322.6	296.0	238.9~339.7	0.84
Fat (g/d)[1]	96.5	76.7~107.5	97.8	68.5~110.6	84.7	78.3~97.3	0.51
Protein (g/d)[1]	82.6	62.2~94.6	85.7	63.6~94.8	81.4	61.7~94.1	0.94
Dietary fibre (g/d)[2]	18.3	16.1~22.1	18.5	16.2~22.5	18.3	15.5~19.5	0.41
Cholesterol (mg/d)[1]	285.8	218.8~359.2	288.2	217.3~359.6	283.3	264.1~311.0	0.87
SFA (g/d)[2]	31.8	26.1~36.9	34.2	25.1~37.3	30.6	27.6~34.2	0.43
MUFA (g/)d[2]	32.8	26.0~37.4	33.6	22.5~37.5	29.1	27.7~37.3	0.81
PUFA (g/d)[2]	17.3	14.4~21.5	17.5	14.4~24.4	17.1	15.1~21.2	0.76

[1]*t*-tests.
[2]Mann-Whitney test.
IQR, inter-quartile range; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

ids, monounsaturated fatty acids, or polyunsaturated fatty acids intake were reported between the normal and insulin resistance groups (Table 3).

Further, there was no difference in median food intake between the normal and insulin resistance groups, with the exception of consumption of canned beverages, which was higher in the insulin resistance group (14.0 serving/week, IQR 2.3～14.0) than the normal group (2.3 seving/week, IQR 0.3～4.0) (P=0.03) (Table 4).

Physical activity assessment

The data from the physical activity questionnaire classified 79% of the participants as inactive, 19% as moderately active, and 2% as active; no subjects (0%) were classed as very active. There were no significant differences in physical activity levels between the two groups (Table 5).

DISCUSSION

This study was conducted to test the hypothesis that dietary intake and physical inactivity may increase the risk of insulin resistance in overweight Saudi adult females. Although numerous factors have been associated with insulin resistance, our study only reported an association with BMI and consumption of canned beverages.

Based on the anthropometric data measured in this study, we found participants in the insulin resistance group had a significantly higher BMI than those in the normal group (P=0.04). Although the median BMI for both groups was within the overweight range, the median BMI for the HOMA-IR "normal" group was in the bottom half of the range (26.9 kg/m^2) and the median BMI for the insulin resistance group was close to the overweight-obese boundary (29.5 kg/m^2). In addition, the median BMI for the HOMA-IR normal group was less than the proposed value for identifying the risk of metabolic syndrome (28.0 kg/m^2), whereas the median BMI of the insulin resistance group was above the proposed value. The results of our study support the work by Geloneze et al. (2009), who reported a parallel increase in HOMA indexes and BMI. The mechanism behind this

Table 4. Estimation of dietary habits (serving/week) in the normal (n=33) and insulin resistant (n=9) groups, as assessed by food-frequency questionnaire

Food items	Overall (n=42)		Normal group (cut-off <1.41, n=33)		Insulin resistance group (cut-off >1.41, n=9)		P-value
	Median	IQR (Q1～Q3)	Median	IQR (Q1～Q3)	Median	IQR (Q1～Q3)	
Cereals	4.8	2.9 (10.9～8.0)	4.9	8.4 (3.2～11.6)	3.2	5.4 (2.6～8.0)	0.20
Breads	11.3	6.375 (21.5～15.1)	11.3	15 (6.6～21.6)	9.6	8.6 (6.3～14.9)	0.66
Fruits	12.0	6.7 (26.6～19.9)	13.5	20.2 (6.6～26.8)	10.3	7.2 (9.8～17.0)	0.45
Vegetables	21.3	11.55 (36.6～25.1)	22.2	26.1 (10.7～36.8)	18.5	11.1 (15.3～26.4)	0.79
Legumes	2.0	0.9 (4.3～3.4)	2.3	3.4 (1.2～4.6)	1.2	1.4 (0.6～2.0)	0.19
Nuts and seeds	1.2	0.6 (4.5～3.9)	1.2	4.0 (0.6～4.6)	2.9	3.1 (0.9～4.0)	0.34
Meat and meat products	2.3	0.9 (4.8～3.9)	2.3	3.4 (0.9～4.3)	2.3	2.9 (2.0～4.9)	0.53
Poultry	2.0	2.0 (7.0～5.0)	2.0	5.0 (2.0～7.0)	2.0	5.0 (2.0～7.0)	0.72
Fish	0.6	0.6 (2.3～1.7)	0.6	1.7 (0.6～2.3)	0.6	1.7 (0.6～2.3)	0.94
Egg	2.3	2.075 (6.5～4.4)	2.3	5.3 (2.0～7.3)	2.3	1.7 (2.3～4.0)	0.96
Dairy products	26.8	16.075 (39.2～23.2)	28.9	24.7 (16.3～41)	24.6	20.7 (10.5～31.2)	0.40
Fats and oils	12.3	6.7 (21.2～14.5)	13.0	14.7 (6.6～21.3)	11.3	8.1 (7.9～16)	0.97
Fresh juices	0.3	0.3 (2.0～1.7)	0.3	1.7 (0.3～2.0)	2.0	1.7 (0.3～2.0)	0.24
Canned beverages[1)]	2.3	0.375 (7.3～6.9)	2.3	3.7 (0.3～4.0)	14.0	11.7 (2.3～14.0)	0.03
Sweet[2)]	5.8	2.375 (9.8～7.4)	4.9	7 (2.3～9.3)	7.0	18.7 (4.6～23.3)	0.22

[1)]Canned juices and soda.
[2)]Cream caramel, custard, chocolate, and toffee.
IQR, inter-quartile range.

Table 5. Physical activity in the homeostasis model assessment 2-insulin resistance in the normal and insulin resistance groups

Physical activity	Overall (n=42)		Normal group (cut-off <1.41, n=33)		Insulin resistance group (Cut-off >1.41, n=9)		P-value
	n	%	n	%	n	%	
Very active (>40 score)	0	0	0	0	0	0	
Active (30～39 score)	1	2	1	3	0	0	0.083
Moderate active (20～29 score)	8	19	8	24	0	0	
Inactive (<20 score)	33	79	24	72	9	100	

could be relate to an increased amount of non-esterified fatty acids present in circulation (Heptulla et al., 2001) and inflammatory mediators triggered by adipose tissues (Hajer et al., 2008). The remaining anthropometric indicators of being overweight, such as WC, HC, WHR, and body fat percentage, were not significantly correlated with the HOMA2-IR index. Several studies have reported a positive relationship between WHR, WC, and fat percentage with insulin resistance (Wahrenberg et al., 2005; Patel and Abate, 2013; Keswell et al., 2016); however, we could not detect any difference in our study, which could be influenced by the indirect measurements we used. Carey et al. (1996) suggested the relationship between insulin resistance and central abdominal fat in non-obese women cannot be found using indirect traditional anthropometry measurements and that these measurements may be no better than estimates of total fat for predicting insulin sensitivity and central obesity. However, results from direct measurements of regional fat and insulin sensitivity [such as by dual-energy X-ray absorptiometry (DEXA) and an euglycemic clamp or oral glucose tolerance tests, respectively] are significantly correlated with insulin resistance in overweight and normal women (Carey et al., 1996). Furthermore, although the median fat percentage of the insulin resistance group was higher than that of the normal group (29.1% vs. 34.2%), it should be noted that fat percentage reflects whole-body fat and does not specifically measure central obesity, which is linked to insulin resistance and risk of metabolic syndrome.

The HOMA2-IR cut-off used in our study was determined based on an Iranian prospective study which included nine years of follow-up of reporting incidences of diabetes; this study classified 1.41 and 1.7 HOMA2-IR cut-off values as optimal and having insulin resistance, respectively. However, there is a need to determine the cut-off points for diagnosing insulin resistance in the Saudi population according BMI.

The second significant factor identified in our study was related to dietary intake. Participants in the insulin resistance group consumed significantly more canned beverages than those in the normal group. Longitudinal studies have reported that consumption of sugar-sweetened fruit juice, but not 100% fruit juice, is linked with diabetes incidence. The reason 100% fruit juice is not linked to diabetes incidence could be due to its other beneficial components, such as dietary fiber, vitamins, and phytochemicals, which could offset any harm (Imamura et al., 2015).

The FFQ used in this study was not exhaustive and thus not all food items that may be commonly consumed by younger adults could be included (such as fast food meals). During a cross-sectional study, Hsieh et al. (2014) observed that higher insulin resistance was associated with greater access to fast food restaurants. As the FFQ used in this study did not include fast food restaurant meals, we cannot comment on this correlation.

In the current study, we reported that physical activity levels were low in both groups, and that most normal participants (72%) and all insulin resistance participants were scored as inactive according to the Physical Activity Questionnaire, validated by King Saud University. This may be contributed to by a lack of public walking areas for females, and weather in the Jeddah region. Previous studies have reported an inverse association between risk of insulin resistance as measured by HOMA2-index and physical activity levels (Jiménez-Pavón et al., 2013; Byrkjeland et al., 2014). In addition, a study conducted on overweight adolescents reported a significant increase in the risk of insulin resistance in relation to sedentary behaviors (i.e., watching television for at least three hours daily) and increased visceral fats (which are linked to WC) (Velásquez-Rodríguez et al., 2014). The results of our study did not detect a significant association between physical activity and HOMA2-IR; however, it is noted that all individuals in the insulin resistance group had a score in the lowest category for physical activity (score of <20; inactive); therefore, a larger sample size may be required to gain the statistical power needed to examine this factor in more detail. Studies in Saudi Arabia have reported that females are much more inactive than males, which could be due to social and cultural factors. For example, females have fewer opportunities than males to be involved in outdoor leisure activities. Additionally, there are fewer fitness centers available for females and those that are available are often more expensive (Al-Eisa and Al-Sobayel, 2012). Furthermore, in Saudi Arabia may people rely of cars rather than walking for short-distance and trips (Al-Hazzaa, 2004).

In this study, we did not detect any significant differences in lipid profiles between the two groups, which could be due to the small number of participants limiting the statistical power. Studies have reported that plasma triglyceride, high density lipoprotein cholesterol, and total cholesterol are independently associated with insulin resistance and are predictors of cardiovascular diseases (McLaughlin et al., 2003; Jeppesen et al., 1998). This is the first pilot study specifically investigating young overweight Saudi females that assesses the relationship of nutritional status and physical activity with insulin resistance. Furthermore, the combination of nutritional assessments and blood biomarkers makes this study unique. Although this study had a limited sample size, the data generated could inform the design and sample size calculation of larger follow-up studies. Further studies need to consider using direct measurement (such as DEXA) in combination with the indirect anthropometric measurements to measure the visceral and subcutaneous fat.

Although these techniques are more time-consuming and technically difficult, they should be considered for the benefits the results will provide for establishing the data for people in Saudi Arabia. In addition, elevated plasma free fatty acids have been previously associated with insulin resistance (Kashyap et al., 2003), therefore measurement of the plasma free fatty acid concentration as well as inflammatory biomarkers should be considered for future studies.

This study showed that BMI and a high intake of canned beverages are associated with HOMA2-IR in young overweight Saudi females. These factors could contribute to the increase in prevalence of insulin resistance and chronic diseases in the Saudi population. Further prospective studies of larger sample sizes, focusing on Saudi lifestyle factors, are needed to establish a HOMA2-IR cut-off specific to the Saudi population. Such knowledge and awareness could help reduce the prevalence of insulin resistance.

ACKNOWLEDGEMENTS

We would like to thank Prof. Eman Alissa (Department of Clinical and Biochemistry, Faculty of Medicine, King Abdulaziz University) for her permission to use the FFQ and the analysis of the macronutrients content. Moreover, we would like to thank all our participants for their time and contribution in this study.

AUTHOR DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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