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Dietary Patterns with Healthy and Unhealthy Traits Among Overweight/Obese Hispanic Women with or at High Risk for Type 2 Diabetes

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Abstract
Hispanic women are at high risk for type 2 diabetes (T2D), with obesity and unhealthy eating being important contributing factors. A cross-sectional design was used in this study to identify dietary patterns and their associations with diabetes risk factors. Participants completed a culturally adapted Food Frequency Questionnaire capturing intake over the prior 3 months. Overweight/obese Hispanic women ($n = 191$) with or at risk for T2D were recruited from a community clinic into a weight loss intervention. Only baseline data was used for this analysis. Dietary patterns and their association with diabetes risk factors (age, body mass index, abdominal obesity, elevated fasting blood glucose [FBG], and hemoglobin A1c). An exploratory factor analysis of dietary data adjusted for energy intake was used to identify eating patterns, and Pearson correlation coefficient (r) to assess the association of the eating patterns with the diabetes risk factors. Six meaningful patterns with healthful and unhealthful traits emerged: (1) sugar and fat-laden, (2) plant foods and fish, (3) soups and starchy dishes, (4) meats and snacks, (5) beans and grains, and (6) eggs and dairy. Scores for the "sugar and fat-laden" and "meats and snacks" patterns were negatively associated with age ($r = -0.230$, $p = 0.001$ and $r = -0.298$, $p < 0.001$, respectively). Scores for "plant foods and fish" were positively associated with FBG ($r = 0.152$, $p = 0.037$). Being younger may be an important risk factor for a diet rich in sugar and fat; this highlights the need to assess dietary patterns among younger Hispanic women to identify traits potentially detrimental for their health.

Keywords Dietary patterns · Hispanic women · Type 2 diabetes · Exploratory factor analysis · Eating patterns

Introduction

Hispanic women are disproportionately at higher risk for developing type 2 diabetes (T2D) relative to non-Hispanic white women because of a higher prevalence of cardiometabolic risk factors including abdominal obesity, dyslipidemia, and hyperglycemia [1]. Although obesity prevalence did not increase from 1999 to 2010 in the overall US adult women population, it increased significantly for non-Hispanic black (59%) and Mexican-American (44%) women [2]. This increase is important due to obesity being one of the most important determinants for diabetes incidence [3].

Mexican-Americans are the largest growing minority group in the USA [4]. Concurrent with an increase in diabetes prevalence in the overall US population [5], it is estimated that 11.6% of Hispanic women have diabetes, with prevalence being the highest among Mexican women (12.8%) relative to Puerto Ricans (11.9%), Central/South Americans (7.6%), and Cubans (6.0%) [6]. Unawareness of prediabetes or a late diagnosis appears to be a common problem among Hispanics as well. In 2013–2016, it was estimated that 36.1% of Hispanic adults in the USA had prediabetes but only 11.5% of them were aware of their condition [6]. Moreover, diabetes

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onset is highly influenced by weight gain in childhood and weight status [7–9]. Given the growing pediatric obesity rates observed among Hispanics, with the excessive weight trajectory carrying through adulthood [10], it is not surprising to observe increasing rates of diabetes among Hispanic women at younger ages.

It is well stablished that differences in T2D prevalence across ethnicities exist, and that socioeconomic status may account for some of the reported race/ethnicity disparities in diabetes statistics [11]. These differences are explained in large part by modifiable risk factors such as dietary quality, physical activity, BMI, and waist circumference. However, disparities are evident when published data shows that if Hispanic women had only achieved the same level of education as whites, their risk of diabetes would be 14% lower [3].

A low-quality diet contributes to poor health and is a modifiable risk factor for diseases such as T2D and cardiovascular disease [12]. Given that T2D continues to be among the leading causes of mortality for Hispanic/Latinos in the USA [13], there is a need to better characterize the diet of Hispanic women at risk for T2D. Traditionally, the study of how diet impacts T2D has focused on individual nutrients (e.g., carbohydrates, dietary fiber) [14, 15] or food items consumed (e.g., sugar, sweetened drinks, whole grains, fruits, and vegetables) [14, 16] rather than focusing on the diet as a whole [17]. The influence of the overall diet, instead of single foods and nutrients, on health outcomes (e.g., cardiovascular disease, T2D, cancer) can be studied with dietary pattern analysis [18]. Dietary pattern refers to the different foods and beverages that constitute an individual's whole dietary intake, and may describe a way of eating including proportions, combinations of different foods and beverages, and also the frequency with which they are consumed [19]. Historically, the Mexican diet has been characterized by a mixture of pre-Hispanic and Hispanic foods, consisting of corn-based foods prepared with garlic, onions, chilies and herbs, squash, citrus fruits, rice, meats, beans, and lard. Many traditional Mexican meals are prepared with fruits, vegetables, legumes, and whole grains, and have been associated with healthful outcomes [20]. Higher acculturation among adults of Mexican descent living in the USA has been associated with lower intake of the healthy food characteristic of a traditional Mexican diet, and adhering more to a typical US or Western diet, usually low in fruits and vegetables and high in refined grains and added sugar [21]. For example, in a prior study with Mexican-Americans based on 2001–2002 NHANES data, authors identified four distinct patterns: *poultry and alcohol*, *milk and baked products*, *meat*, and *traditional Mexican*, with no dietary pattern having traits of a "healthful diet" [22]. In contrast, a later study based on 2003–2004 and 2004–2005 NHANES data reported four dietary patterns among Mexican-American adults (18 to 69 years): *western*, *healthy*, *tomato/tortilla*, and *coffee and sugar* [21]. Nevertheless, studies looking at the role of acculturation on the presence or absence of "healthful" dietary patterns have reported mixed findings, potentially due to inconsistencies in how acculturation is assessed [23–27].

Dietary patterns change over time [28] and are likely to differ based on socioeconomic status, sex, ethnic group, culture, and acculturation [21, 24]. Notwithstanding, studying dietary patterns can provide useful information because they reflect the actual practices in the studied population. Assessing dietary patterns among specific ethnic/racial groups such as Hispanics can help to augment our understanding of the role of diet in T2D, and to explain the associations between the overall diet and coexisting risk factors for T2D. To the best of our knowledge, there is scant recent available literature about dietary patterns among Hispanics and focusing on women at high risk for T2D.

The objective of this work was to identify dietary patterns among overweight/obese Hispanic women enrolled in a behavioral intervention for weight loss and diabetes risk reduction, and to explore associations of the dietary patterns with diabetes risk factors including age, body mass index (BMI), abdominal obesity, hyperglycemia, and hemoglobin A1c (HbA1c).

Materials and Methods

This manuscript reports a secondary, cross-sectional analysis of data collected from 191 participants enrolled in a randomized controlled trial assessing the efficacy of a culturally tailored Spanish language diabetes risk reduction program, "De Por Vida." For purposes of the current analysis, only baseline data were used.

Recruitment

Women receiving their primary medical care at the Virginia Garcia Memorial Health Center (VGMHC), Hillsboro, OR, were recruited via posters in clinic exam rooms, by direct physician referral, and through a data pull of their electronic medical records (EMR).

Inclusion criteria were (1) females who self-identified as Hispanic; (2) aged 18 years and older; (3) BMI ≥ 27 kg/m^2; and (4) have a diabetes or prediabetes diagnosis per the International Classification of Diseases (ICD)-9 codes and/or inclusion of the diagnoses on patients' problem lists, or at risk for developing T2D due to metabolic syndrome, high blood pressure, hyperlipidemia, family history of diabetes, or history of gestational diabetes. Exclusion criteria were (1) having received treatment for cancer in the past 2 years with the exclusion of non-melanoma skin cancers; (2) psychiatric hospitalization in the past 2 years; (3) taking weight loss medication currently or within the past 6 months; (4) current or recent pregnancy (≤ 12 months), breastfeeding, or planning to get pregnant in the following 18 months; (5) current participation in other studies; and (6) planning to leave the area within the following 18 months.

Participants and Sample Size

A total of 200 participants were enrolled in the parent trial. One participant did not complete the food frequency questionnaire (FFQ) at baseline and thus was excluded from the analyses. From the remaining 199 participants with complete diet data, 8 participants were excluded because their reported energy intake was considered implausible, due to being ± 2 SD from the sample mean. A final sample of 191 participants was used for the current analysis. All interested women with confirmed eligibility provided written informed consent prior to data collection. All study materials and procedures were approved by the Kaiser Permanente Center for Health Research, Virginia Garcia Memorial Health Center, and Arizona State University Institutional Review Boards.

Data Collection

Participants completed a telephone survey in Spanish that included sociodemographic questions and a food frequency questionnaire. After completing the interview, participants were scheduled for a clinic visit during which height, weight, and 12-h fasting blood glucose (FBG) and HbA1c were collected.

Diabetes Risk Factors

FBG and HbA1c were measured from capillary blood via finger stick using point of care devices. Fasting blood glucose was measured with a OneTouch Ultra glucometer (LifeScan Inc., Milpitas, CA). HbA1c was measured using an A1cNow + device (Bayer HealthCare LLC, Sunnyvale, CA). While the American Diabetes Association does not recommend the use of point of care devices for diagnostic purposes [29], these devices were used for data collection in this pragmatic clinical trial because their results have been strongly correlated with standard laboratory tests ($R^2 = 0.712$, $p < 0.001$).

Height was measured barefoot and recorded to the nearest 0.1 cm using a calibrated wall-mounted stadiometer. Weight was measured following a standard protocol with participants wearing light indoor clothes and barefoot and recorded to the nearest 0.1 kg with a calibrated digital scale. Waist circumference was measured at the midpoint between the lower rib and the iliac crest and recorded to the nearest 0.5 cm with a linen non-stretch tape measure with a tension device.

Dietary Assessment

Baseline dietary data were collected by trained bilingual interviewers from Kaiser Permanente Center for Health Research and Arizona State University. Interviewers administered the Southwestern Food Frequency Questionnaire (SWFFQ) [30] as a telephone interview. The SWFFQ [30] is a semi-quantitative questionnaire that includes frequencies (three or more times a day, one or two times a day, four to six times a week, two to three times a week, one time a week, two to three times a month, less than one time a month, and rarely or never) and portion sizes (small, medium, large) of foods; is bicultural and bilingual (English/Spanish); and is adapted from the Arizona Food Frequency Questionnaire [31]. The SWFFQ includes 158 food items with culturally appropriate elements of the diet for the southwestern Hispanic population in the USA, predominantly of Mexican descent. Relevant and characteristic food items included *nopales* (cactus leaves), corn tortillas, refried beans, *machaca* (dried beef), and *chorizo*. Supplement intake was collected in the SWFFQ; however, this data was not considered for the nutrient intake results reported herein.

Dietary data were captured to reflect the prior 3 months of intake. The questionnaires were analyzed by the Arizona Diet, Behavior, and Quality of Life Assessment Laboratory at the University of Arizona, based on the USDA Nutrient Data Bank databases of food composition [32]. The output provided data for 87 nutrients, in addition to 25 computed variables (e.g., percentage of calories from macronutrients), and 867 potential food items. After the SWFFQ, the food items were aggregated into 23 food groups as follows: (1) milk; (2) cheese; (3) meat; (4) mixed dishes; (5) soups, sauces, and gravies; (6) eggs; (7) beans, nut, and seeds; (8) breads, cereals, and crackers; (9) cakes, cookies, and pastries; (10) salty snacks; (11) fruits; (12) fruit juice; (13) starchy side dishes; (14) vegetables; (15) vegetable juice; (16) condiments; (17) fats; (18) sweets, candy, and syrup; (19) non-alcohol and non-fruit beverages; (20) alcohol; (21) fish; (22) poultry; and (23) soy products. The standard SWFFQ analysis includes diet soft drinks in the beverages group; however, due to diet soft drinks not contributing to total energy, they were removed and considered a separate *diet soft drinks* food group, yielding a total of 24 food groups. Based on the approach of previous published studies [33, 34], food groups that included food items with similar nutrient content or that indicated different ways of eating foods from the same group were further collapsed as follows: (1) fruits and fruit juice were collapsed into the *total fruit* group; (2) vegetables and vegetable juice were collapsed into the *total vegetables* group; (3) soy products and beans, nuts, and seeds were collapsed into the *beans* group; and (4) cheese and milk were collapsed into the *dairy* group.

Food group variables were non-normally distributed. Square root, natural logarithm, or inverse functions were used for transformations, which improved skewness and kurtosis substantially, except for "diet soft drinks." This group was excluded from the analysis due to low reporting and because it was not possible to normalize the variable after transformations. Individual daily frequencies of consumption of the remaining 19 food groups were divided by the total energy consumed (in kilocalories/day) to adjust for energy, resulting in a total of 19 adjusted food group variables for the analysis. Food groups assessed with the SWFFQ and their respective food items are shown in Table 1.

Statistical Analysis

Data were tested for normality visually and with the Kolmogorov-Smirnov normality test. Data were considered outliers based on energy intake levels and removed if they fell in the lowest and upper 2.5 percentile of the distribution ($Z_{.975}$ score) yielding a final sample of $n = 191$ for all analyses. After removal of outliers, most variables remained non-normally distributed. Descriptive data and participants' nutrient intake are reported from non-normal and untransformed data and include the median and interquartile range in addition to mean ± standard deviation (mean ± SD). Intake of carbohydrate, protein, fat, saturated fat, and alcohol was expressed as percentage of total energy/day.

Dietary patterns were derived from the 19 transformed food groups using exploratory factor analysis. The Kaiser-Meyer-Olkin measure of sampling adequacy was 0.731, above the recommended value of 0.60, and Bartlett's test of sphericity was significant (chi-square [190] = 771.325 $p < 0.001$). The principal axis factoring method with Kaiser normalization was used to extract the factors. A scree test suggested six meaningful factors (eigenvalues ≥ 1.0) explaining 56% of variance, which were retained for rotation. To decide the factor rotation, coefficients of factors in the factor correlation matrix (data not shown) created by promax (oblique) were examined. Tabachnick and Fidell [35] propose that correlations among factors that are > 0.32 indicate there is 10% or more overlap in variances among factors, which would warrant oblique rotation. The observed correlations between factors in the matrix surpassed 0.32; therefore, oblique rotation methods (e.g., oblimin and promax) were used to enhance interpretability of the resultant factors and to allow them to correlate. After multiple rotations, the promax solution provided a simpler structure [36], which was used for interpretation of the factors. An item was determined to load on a given factor if the factor loading was ≥ 0.30 for that factor and < 0.30 for the other. Factors with at least three item loadings > 0.30 with no or few cross loadings were retained [37]. Using this criterion, *six distinct dietary patterns emerged* and regression factor scores of each eating pattern were used to test their associations (Pearson correlation coefficients, r) with risk factors including age, BMI, waist circumference, FBG, and HbA1c. Statistical significance was set at the $p < 0.05$ level. All the statistical analyses were performed with IBM SPSS Statistics for Windows, version 21.

Results

Descriptive Characteristics

Age range among women in this study was 18 to 73 years (Table 2), with 86% of participants being classified as obese. Mean waist circumference was above 88 cm among most participants (99.5%). FBG ranged from 80 to 278 mg/dL, and was in the pre-diabetic or diabetic range for 86% of participants ($n = 162$). HbA1c ranged from 5 to 12% and was in the pre-diabetic or diabetic range for 73% of participants ($n = 138$).

Nutrient Intake

Reported mean energy intake was 1603 ± 748 kcal per day, with a macronutrient distribution for carbohydrate, protein, and fat of 54%, 18%, and 31%, respectively (Table 3). Reported total sugar and carbohydrate intake values were high at 82 ± 52 g/day and 213 ± 100 g/day, respectively. Mean fiber intake was 16 ± 4.3 g/1000 kcal and reported mean alcohol intake contributed to 0.3 ± 0.4% of total energy intake (Table 3).

Dietary Patterns

Factor analysis identified six distinct dietary patterns (Table 4). Briefly, factor loadings (or loading scores) are the correlation between the variables (food groups) and factors (dietary patterns). Eigenvalues indicate the amount of variation in food intake explained by each dietary pattern. Thus, higher factor loadings were considered for labeling each dietary pattern. The first pattern was named *sugar and fat-laden* because of the high loadings of foods high in sugar such as candy, and ice cream, and foods rich in fat such as butter and margarine. The second was named *plant foods and fish* because of the high loadings of vegetables, fruit, fish, and beans. The third pattern was labeled *soups and starchy dishes* because of the high loadings of soups and gravies, starchy side dishes, and mixed dishes with meat. The fourth pattern was named *meat and snacks* because of the high loadings of red meat, caloric condiments, and salty snacks (e.g., pork rinds). The fifth pattern was labeled *beans and grains* because of the high loadings of beans, seeds, nuts, whole wheat and refined grain products (e.g., 100% wheat bran and flour tortillas, respectively), fish, and alcohol. The sixth and last pattern was labeled *eggs and dairy* because of the high loadings of eggs, high-fat dairy products, and oils and fats. Poultry was highly

Table 1 Food groupings and food items assessed with the Southwestern Food Frequency Questionnaire used for the analysis of dietary patterns among 191 Hispanic women enrolled in a diabetes risk reduction program

Food group	Food items
Dairy	Milk (whole, 2%, 1%, and skim), evaporated milk, cream (half and half, sour, semi-sweet), yogurt, cheese (cheddar, Swiss, spreads, fresh, and cottage)
Red meat	Beef, pork, hamburgers, dried shredded beef (*machaca*), chorizo, beef steaks (*carne asada*), sausage, ham, liver, hot dogs, bacon
Mixed dishes	Spaghetti or pasta, pizza, dishes with chicken, Chinese dishes, Mexican dishes, crispy taco (*flautas*), tacos w/beef and cheese, soft taco, tamales with and without meat, quesadilla, menudo, pozole, chile relleno, enchiladas, chili, sushi, mole, chimichangas, tostadas, burritos, macaroni and cheese, beef stew, meat with chile (e.g., *birria*)
Soups	Cazuela soup, meatball soup (*caldo de albóndigas*), soup w/cheese and chile (*caldo de queso*), noodle soup, tortilla soup, vegetable soup, vegetable beef (*cocido*), salsa, taco sauce, barbeque sauce, gravies
Eggs	Eggs
Beans	Lentils, beans, refried beans, chickpeas, sunflower seeds, flaxseed, shelled nuts (peanuts, walnuts, almonds, pistachios), peanut butter, almond butter, tofu, soy milk, soy-meat substitutes, soy-based protein powder
Grains	White bread, biscuits, muffins, whole wheat muffins, bagels, rolls, waffles, pancakes, cornbread, oat bran, cooked cereal, cold cereals (e.g., corn flakes), 100% wheat bran cereals (e.g., all bran), sugary cereals (e.g., frosted flakes), granola and breakfast bars, crackers, Mexican bread, corn tortillas, flour tortillas
Pastries	Cookies, cake, doughnuts, molasses turnover (*coyotas*) pastries, sweet bread (*pan dulce*), pumpkin pie
Salty snacks	Pork rinds (*chicharrón*), popcorn, potato chips, corn chips, tortilla chips
Fruits	Bananas, peaches, nectarines, cantaloupe, watermelon, mangoes, grapefruit, oranges, pineapple, strawberries, cherries, blueberries, raspberries, pomegranate, apples, pears, guava, grapes, plums, dried fruit (prunes, raisins, figs), natural fruit juice (grape, cranberry, orange, grapefruit).
Starchy dishes	French fries, mashed potatoes, baked or cooked potato, white rice, Spanish rice, noodles
Vegetables	Green beans, squash, broccoli, cauliflower, carrots, spinach, turnip greens, coleslaw, cabbage, sweet potato, onion, garlic, celery, radish, cucumber, jicama, cactus leaf (*nopales*), cilantro, artichoke, peppers, chile peppers, tomatoes, corn, peas, mixed vegetables with carrots, mushrooms, olives, avocado, guacamole, asparagus, kale, zucchini, lettuce, tomato juice, other vegetable juice (not carrot or tomato)
Condiments	Artificial sweetener, fat-free salad dressing, non-fat mayonnaise, mustard, horseradish, non-dairy creamer
Fats	Butter, lard, margarine (regular and low-calorie), mayonnaise (regular and low-calorie), salad dressing (regular and low-calorie), vegetable oil (olive and canola)
Sweets	Sugar, candy, chocolate candy, milkshake, pudding, custard, flan, jelly, syrup, honey, sherbet (jello), sherbet or sorbet, ice cream, popsicles
Fish	Shellfish, canned fish (tuna or salmon), canned tuna (oil or water), fried fish, baked or broiled fish
Poultry	Fried chicken, chicken or turkey (with or without skin), ground turkey, buffalo wings
Drinks	Coffee, specialty coffees (latte, mocha, cappuccino), lemonade, Jamaica, tea (herbal, black, green caffeinated or decaffeinated) sweetened fruit juice, rice drink (*horchata*), Tang, juice drinks, regular soft drinks
Alcohol	Beer, wine, liquor

reported during dietary data collection; however, this food item did not load on any of the meaningful dietary patterns observed in this study.

Associations of Dietary Patterns with Risk Factors

Results of the cross-sectional associations between dietary pattern factor scores and diabetes risk factors are shown in Table 5. Regression scores for the dietary patterns *sugar and fat-laden* and *meat and snacks* were negatively associated with age ($r = -0.230$, $p = 0.001$; $r = -0.298$, $p < 0.001$). Regression scores for the dietary pattern *plant foods and fish* were positively associated with FBG ($r = 0.152$, $p = 0.037$). No other significant associations with age, BMI, waist circumference, FBG, and HbA1c were observed for the *soups and starchy dishes*, *beans and grains*, and *eggs and dairy* patterns (Table 5).

Table 2 Anthropometric, diabetes risk factors, and risk categories among overweight/obese Hispanic women enrolled in a diabetes risk reduction program

Characteristics	*n*	Mean	SD	Median	Interquartile range
Age (years)	191	44.0	10.0	43.0	14.0
BMI (kg/m^2)	191	36.4	6.4	35.0	8.7
BMI categories					
Overweight (25.0–29.9 kg/m^2)	26	28.6	0.9	28.6	1.4
Obesity class I (30.0–34.9 kg/m^2)	70	32.7	1.5	32.6	2.6
Obesity class II (35.0–39.9 kg/m^2)	47	37.4	1.6	37.7	2.8
Obesity class III (≥ 40 kg/m^2)	48	45.3	5.1	44.4	4.9
Waist circumference (≥ 88 cm)	190	115.4	13.4	113.4	18.0
Fasting blood glucose (mg/dL)	188	135.0	45.4	117.5	41.0
Fasting blood glucose categories based on diabetes diagnosis criteria					
Normoglycemia (< 100 mg/dL)	26	94.0	4.4	96.0	6.0
Prediabetes or impaired fasting glucose (≥ 100–< 126 mg/dL)	88	112.0	7.0	112.0	11.0
Diabetes mellitus (≥ 126 mg/dL)	74	177.0	47.0	156.0	79.0
Hemoglobin A1c (%)	188	6.5	1.4	5.9	1.5
Hemoglobin A1c categories based on diabetes diagnosis criteria					
Normal (< 5.7%)	50	5.4	0.2	5.5	0.3
Prediabetes (5.7–< 6.5%)	82	5.9	0.2	5.9	0.3
Diabetes mellitus (≥ 6.5%)	56	8.4	1.4	8.1	1.9

Values shown as mean ± standard deviation (SD) from non-normal and untransformed data

Discussion

In the current study, the *sugar and fat-laden* and *meats and snacks* patterns were negatively associated with age. The *sugar and fat-laden* pattern was considered the most relevant as it explained the greatest proportion of the variance in food intake (20%) relative to the other patterns. The remaining five eating patterns explained smaller percentages of the variance in food intake (36% of the variance when combining these five patterns). Interestingly, the *plant foods and fish* pattern, which had healthful traits, was associated with FBG.

Table 3 Energy intake and macronutrient distribution among 191 overweight/obese Hispanic women enrolled in a diabetes risk reduction program

Nutrients	Mean	SD	Median	Interquartile range
Total energy (kcal)	1603.0	748.0	1423.0	964.0
Carbohydrates (% energy)	54.0	8.0	53.0	12.0
Carbohydrates (g)	213.0	100.0	191.0	111.0
Total sugars (g)	82.0	52.0	70.0	54.0
Fiber (g)	24.0	11.0	21.0	13.0
Protein (% energy)	18.0	3.0	18.0	4.0
Total fat (% energy)	31.0	5.4	31.0	8.0
Alcohol (% energy)	0.3	0.4	0.1	0.0

Values shown as mean ± standard deviation (SD) from non-normal and untransformed data

The *soups and starchy dishes*, *meats and snacks*, and *eggs and dairy* patterns were characterized by high loadings of red meat, fat, fried snacks high in sodium, and foods containing saturated fat and cholesterol. These three patterns share characteristics with a "Western"-type pattern, which has been associated with increased risk of coronary heart disease, metabolic syndrome, and T2D [38–40]. The *beans and grains* eating pattern was composed of some food items, including legumes, nuts, seeds, soy products, fish, whole grain bread, and 100% wheat bran cereals. However, the *beans and grains* pattern was also characterized by a large number of processed foods high in refined carbohydrates with added sugars and fats, such as biscuits, muffins, rolls, flour tortillas, and sugar-sweetened cereals. Alcohol also loaded as part of this pattern.

The *plant foods and fish* pattern resembled a Mediterranean dietary pattern [41] because of its high loadings of vegetable origin foods, fiber, and marine protein. Mediterranean diets have been consistently associated with reduced risk of total and cardiovascular mortality in adults with diabetes [42, 43]. However, the *plant foods and fish* pattern observed in the current study was not labeled as a Mediterranean pattern because of the lack of information regarding the specific use of olive oil among participants. Fruits and vegetables were the items with the highest loading scores in the *plant foods and fish* pattern. There is increasing evidence pointing to the role of a "vegetable-rich" dietary pattern in the aging process, and associating this type of pattern with longer telomeres in women, which are normally shortened with age [44]. The *plant*

Table 4 Factor loadings for the first six factors from exploratory factor analysis of Food Frequency Questionnaires among 191 overweight/obese Hispanic women enrolled in a diabetes risk reduction program, where input variables are servings/day

Food group[a]	Servings/day		Factors or dietary patterns[b,c] Factor loadings[d]					
			Sugar and fat-laden	Plant foods and fish	Soups and starchy dishes	Meats and snacks	Beans and grains	Eggs and dairy
	Mean	SD	1	2	3	4	5	6
Sweets	0.43	0.53	*0.96*	0.01	− 0.06	− 0.21	0.01	− 0.07
Drinks	1.50	1.20	*0.51*	0.14	− 0.04	− 0.14	− 0.08	0.09
Pastries	0.42	0.46	*0.47*	− 0.20	0.06	0.08	0.19	0.14
Fats	0.21	0.29	*0.37*	− 0.04	− 0.06	0.14	− 0.12	*0.33*
Dairy	1.60	1.40	0.21	0.18	− 0.03	0.01	0.22	*0.34*
Salty snacks	0.10	0.14	0.19	− 0.02	0.12	*0.61*	− 0.09	− 0.17
Beans	0.82	0.76	0.12	*0.32*	− 0.07	0.16	*0.47*	− 0.13
Mixed dishes	0.92	0.78	0.12	− 0.04	*0.34*	0.20	0.01	0.17
Fish	0.21	0.22	0.07	*0.34*	− 0.01	0.21	*0.41*	0.03
Eggs	0.32	0.38	0.06	0.13	0.05	0.03	− 0.02	*0.49*
Grains	3.40	2.30	0.06	− 0.03	0.05	0.06	*0.45*	0.02
Vegetables	4.50	3.10	0.05	*0.88*	0.14	− 0.10	− 0.04	0.09
Starchy dishes	0.45	0.43	− 0.03	− 0.03	*0.63*	− 0.17	− 0.03	0.16
Fruits	2.80	2.50	− 0.05	*0.62*	− 0.08	0.17	0.08	0.10
Soups	1.00	0.75	− 0.09	0.12	*0.70*	0.02	0.08	− 0.14
Poultry	0.17	0.22	− 0.10	0.07	− 0.01	0.11	0.13	0.15
Red meat	0.43	0.41	− 0.10	− 0.08	0.02	*0.61*	0.07	0.27
Alcohol	0.20	0.06	− 0.16	0.02	0.05	− 0.23	*0.39*	0.11
Condiments	0.16	0.29	− 0.25	0.17	− 0.15	*0.49*	− 0.01	0.09
% Variance explained[e]			20.3	8.9	8.3	6.4	6.3	5.4

[a] Transformed food group variables

[b] Extraction method, principal axis factoring; rotation method, promax with Kaiser normalization

[c] Factors with three or more factor loadings ≥ 0.30 were retained (shown in italics)

[d] Factor loadings, correlation between the observed variables and factors

[e] Variance explained (eigenvalues), primary or major sources of dietary variation in the set of variables

Table 5 Associations between dietary patterns and diabetes risk factors among 191 overweight/obese Hispanic women at high risk for type 2 diabetes enrolled in a diabetes risk reduction program

Risk factors	Regression scores of dietary patterns					
	Sugar and fat-laden	Plant foods and fish	Soups and starchy dishes	Meat and snacks	Beans and grains	Eggs and dairy
Age (years)	*− 0.230***	0.082	− 0.114	*− 0.298***	0.002	− 0.051
BMI (kg/m^2)	0.012	− 0.042	0.014	− 0.042	0.067	− 0.055
Waist circumference (cm) (*n* = 190)	0.017	− 0.044	0.064	0.023	− 0.053	0.001
Fasting blood glucose (mg/dL) (*n* = 188)	− 0.044	*0.152**	0.039	0.031	− 0.028	0.075
Hemoglobin A1c (%) (*n* = 188)	− 0.097	0.128	− 0.016	− 0.047	− 0.026	0.016

*Correlation is significant at the $p < 0.05$ level (2-tailed)

**Correlation is significant at the $p < 0.01$ level (2-tailed). $n = 191$ unless otherwise indicated *foods and fish* pattern also included high loadings of fish, an important source of marine protein and omega-3 fatty acids, both associated with a lower risk of metabolic syndrome [45].

Multiple studies have reported dietary patterns aligned to a "prudent" or "healthy" pattern characterized by high intakes of vegetables, fruits, legumes, whole grains, fish, and poultry [25, 40, 44, 46]; this pattern has been consistently associated with lower risk of T2D [47] and coronary heart disease [48]. Findings of a study developed in the Southwestern United States with adult Hispanic and non-Hispanic white women identified five meaningful dietary patterns: (1) *Western*, (2) *native Hispanic*, (3) *prudent*, (4) *Mediterranean*, and (5) *dieter eating* [49]. Interestingly, Hispanic women had a higher calorie intake, and a greater proportion of energy from fat and vegetable protein, less alcohol, and less energy from animal protein compared with non-Hispanic white women. These findings share similarities with patterns observed in the present study, such as the identification of the *sugar and fat-laden* pattern with Western-like traits, as well as the *plant foods and fish* pattern that aligns with a prudent pattern. Another study among Mexican-American population reported four eating patterns: *poultry and alcohol*, *milk and baked products*, *meat*, and *traditional Mexican*. However, the traditional Mexican patter was not considered having healthy traits, on the contrary, was characterized for foods very rich in cholesterol [22]. Similar to the current study, earlier work including Mexicans or Mexican-Americans has reported a wide variety of dietary patterns with healthier and less healthy traits such as *prudent*, *Western*, *high protein/fat*, *traditional Mexican*, *poultry and alcohol*, *milk and baked products*, and *meat* patterns [22, 40, 50]. In these studies, there was high contribution of energy from soft drinks, refined grain products, fast foods, and snacks among the patterns with less healthful traits. Soft drinks have been reported as one of the main contributors to total energy intake among Mexicans (17–20% of total energy intake) [50, 51] regardless of whether data represent consumption in urban or rural areas [50]. In Mexico, soft drinks intake per capita ranks second only to the USA [51]. Thus, it is not surprising that Mexican immigrants in the USA continue to follow this dietary behavior. In the current study, sweets and soft drinks were one of the most important components of the *sugar and fat-laden* pattern observed in the current study. In a previous study among Mexican-Americans, poultry loaded in one of the patterns was observed [22]. Interestingly, although poultry was highly reported during dietary data collection in the present study, it did not load on any of the six meaningful dietary patterns observed. A possible explanation is that reported poultry intake was very homogeneous among all participants.

Although the Hispanic/Latino population has been frequently considered and studied as a homogenous group, there are important differences in the dietary patterns of Hispanic/Latino populations of different backgrounds. Puerto Rican and Mexican traditional diets have differences in their characteristics and food items. For instance, a traditional Puerto Rican diet usually includes rice, beans, and oils [52]. In contrast, a traditional Mexican pattern usually includes corn tortillas, tacos, citrus fruits, vegetables including cactus pads, "aguas frescas" (a combination of water, sugar, and fruits or flowers), and legumes [20]. These differences in diet and food preferences may interact with other factors that influence eating patterns and physical activity, such as disparities in access to nutrient-rich foods and health care [53]. This may be reflected in the variety of dietary patterns observed among Puerto Ricans, Mexicans, and Mexican-Americans. Furthermore, some discrepancies in findings related to dietary patterns may be related to the use of different questionnaires to assess dietary intake, which adds heterogeneity to the number of food groups and items in each food group. It is also possible that among Mexican-Americans, there are differences in diet behaviors depending on some factors such as food insecurity, environment, access to health care, socioeconomic status, beliefs about nutrition [54], lack of knowledge about nutrition [55], and sociocultural norms [56].

Regarding the association of dietary patterns with diabetes risk factors, we identified negative associations between age and the *meat and snacks* and *sugar and fat-laden* patterns. A report from a randomized controlled feeding trial in healthy women of Mexican descent indicated that younger and more acculturated women adhered more to a Western-type pattern at baseline, and therefore, benefited more from the intervention (a healthy traditional Mexican diet, versus a control typical US diet) than those less acculturated overweight/obese women [20], which partially aligns with the observed in our study. It has been previously reported that women at increasing age were less likely to eat according to a *meat* dietary pattern, characterized by processed meats, red meats, fish, and poultry, and more likely to adhere to a *vegetable* pattern, characterized by dark yellow and green leafy vegetable [57]. This is potentially due to increased awareness of health conditions later in life (e.g., high cholesterol). Higher intake of *plant foods and fish* was also associated with a higher FBG in the current study. The reasons are not clear, but it can be argued that even when a diet includes vegetables, fruits, and fish, an excessive amount of overall calories could potentially contribute to insulin resistance [58]. This could also suggest that women with altered glucose are perhaps attempting to adhere to a dietary pattern with healthier traits.

Strengths of our study include the use of trained interviewers, which minimizes data entry errors and missing data. The use of a validated food frequency questionnaire to collect dietary data in the Hispanic population ensured that our instruments captured the characteristics of the studied population. Also, by using exploratory factor analysis to derive dietary patterns, no a priori assumptions were made; thus, the derived dietary patterns are independent of any definitions of a healthy pattern.

In the current study, the lack of significant associations for four dietary patterns with unhealthy traits rich in meat, salty snacks, and foods rich in sugar and/or fat are potentially due to sample size, study design, and the fact that only women at high risk for T2D were included in the study. The possibility that other protective factors may potentially attenuate these associations cannot be ruled out. For instance, the so-called Hispanic health paradox suggests that behaviors related to the original culture might be protective to Hispanic immigrants [24]. However, it would be difficult to discern how participants' specific regional and cultural background may affect associations with risk factors. Other limitations should also be noted. The study sample was homogeneous, comprised low-income overweight/obese Mexican women. Whereas the sample strongly reflects the ethnic makeup of the patient population attending the clinic where the study took place, results may not be generalizable to the Mexican or Mexican-American adult population. The sample may have been underpowered to detect significant associations between risk factors and dietary patterns, given that all participants were at increased risk of T2D. Information about diabetes medication use among participants was not collected. The use of a food frequency questionnaire has the limitation of recall bias, which can lead to under- or overestimation of food and nutrient intake. The analysis was limited to 19 food groups, which could have limited the variety and specificity of the dietary patterns found in the present study [59]. Lastly, exploratory factor analysis relies on multiple subjective decisions (e.g., number of factors to retain, type of rotations used), which could limit the reproducibility of the current study.

Conclusions

The findings of this study revealed six distinct dietary patterns with both healthful and unhealthful traits in a homogeneous sample of overweight/obese Hispanic women with, or at risk for, T2D. Even though the women in our study reported eating a variety of healthy foods, the majority of dietary patterns contained foods rich in sugar, fat, and sodium. This finding is concerning, because the study participants were at high risk of developing frank T2D, and it underscores the continued need to promote a shift to healthier dietary patterns to reduce metabolic risk among this high-risk population. Our analysis found that younger women aligned more with dietary patterns including foods rich in sugar, red meat, and salty snacks. This finding might indicate a need to target younger women in particular with future interventions. Further studies assessing dietary patterns among healthy and at-risk Hispanic women with larger samples are needed to determine how dietary patterns differ among women with and without risk for T2D.

Authors' Contributions MAG, ML, MB, CW, CDA, SH, and SVL conceptualized the study; NL, SG, AT, KV, ES, VS, and SVL were involved in study administration and data collection; MAG, ML, MB, CW, CDA, SH, and SVL analyzed and interpreted the data; MAG and SVL wrote the manuscript. All authors reviewed, edited, and approved the final manuscript.

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Compliance with Ethical Standards

All interested women with confirmed eligibility provided written informed consent prior to data collection. All study materials and procedures were approved by the Kaiser Permanente Center for Health Research, Virginia Garcia Memorial Health Center, and Arizona State University Institutional Review Boards.

Conflict of Interest The authors declare that they have no conflict of interest.

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