Food intake patterns and gallbladder disease in Mexican Americans

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Abstract

Objective: Results of previous studies on diet and gallbladder disease (GBD), defined as having gallstones or having had surgery for gallstones, have been inconsistent. This research examined patterns of food intake in Mexican Americans and their associations with GBD.

Design: Cross-sectional.

Subjects: The study population included 4641 Mexican Americans aged 20–74 years who participated in the 1988–94 third National Health and Nutrition Examination Survey (NHANES III). GBD was diagnosed by ultrasound. Food intake patterns were identified by principal components analysis based on food frequency questionnaire responses. Component scores representing the level of intake of each pattern were categorized into quartiles, and prevalence odds ratios (POR) were estimated relative to the lowest quartile along with 95% confidence intervals (CI).

Results: There were four distinct patterns in women (vegetable, high calorie, traditional, fruit) and three in men (vegetable, high calorie, traditional). After age adjustment, none were associated with GBD in women. However, men in the third (POR = 0.42, 95%CI 0.21–0.85) and fourth (POR = 0.53, 95%CI 0.28–1.01) quartiles of the traditional intake pattern were half as likely to have GBD as those in the lowest quartile.

Conclusions: These findings add to a growing literature suggesting dietary intake patterns can provide potentially useful and relevant information on diet–disease associations. Nevertheless, methods to do so require further development and validation.

Keywords
Cholelithiasis
Mexican Americans
Diet
Factor analysis
NHANES III

Gallstones or gall bladder disease (GBD) is an exceptionally common source of morbidity worldwide, particularly among women. Prevalence of the disease varies substantially across geographic and ethnic groups, and crude prevalence is as high as 20% in some European[1–3] and native and Mexican American[4–6] female populations. Diet has long been of interest as a risk factor for gallstones. Numerous mechanisms have been proposed by which various dietary factors may influence the formation of gallstones, including effects on cholesterol metabolism, bile lithogenicity and nucleation time[7].

Ecological studies have noted a rise in the prevalence of gallstones with more western diets, characterized by a higher intake of fat and refined carbohydrate but a lower intake of fibre[8–10]. Overall, findings from other observational nutritional epidemiological studies do not provide strong evidence for an association with caloric intake or intake of fatty acids or cholesterol[11–19], but they offer evidence of a positive association with simple sugars[12,14,15,19] and inverse associations with fibre[12,14,17–21] and alcohol[5,12,14,16,19,20,22–31]. While epidemiological and aetiological studies suggest a role for specific nutrients, however, it is unclear how these findings relate to actual dietary practice, since nutrients are consumed in complex combinations. While perhaps useful for aetiological understanding, such findings do not directly address the issue of whether or not certain characteristic combinations of foods or food intake patterns are associated with disease risk.

The objective of this research was to determine if certain food intake patterns are associated with disease. Our goal was not to elucidate aetiology, but to quantify the

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aggregate risk associated with particular combinations of foods[32]. We used data from NHANES III[33,34] to examine the association between food intake patterns and GBD in Mexican Americans. We chose to focus on Mexican Americans because prevalence of the disease is high, particularly in Mexican American women; based on data from NHANES III, age-adjusted prevalence in this population is 8.9% in men and 26.7% in women, compared to 8.6% and 16.6% in non-Hispanic white and 5.3% and 13.9% in African American men and women, respectively[35]. We used NHANES III data to: (i) identify food patterns in Mexican American women and men using principal components analysis; and (ii) examine the associations of these patterns of intake with GBD.

Materials and methods

Study population

NHANES III, a cross-sectional survey conducted from 1988 to 1994, followed a complex four-stage probability sampling scheme designed to represent the entire United States civilian non-institutionalized population over the age of 2 months[36]. Mexican Americans were oversampled to comprise nearly a third of the survey population, and Mexican American ethnicity was self-reported. Participation in the survey included interviews conducted at the subjects' homes in either English or Spanish, followed by a physical examination, a diet and health interview, and diagnostic tests conducted at a mobile examination centre (MEC).

Disease status

Individuals between the ages of 20 and 74 years were invited to receive a gallbladder ultrasound examination at the MEC using real-time ultrasonography administered by a certified abdominal ultrasound technician. Cases were defined as subjects with gallstones if opacity was viewed in the gallbladder producing a distal shadow in both the supine and the left decubitus positions, according to commonly used criteria[34]. If the gallbladder was not seen by ultrasonography and a right upper quadrant or epigastric scar was observed, it was concluded that a cholecystectomy, or surgical removal of the gallbladder, had been performed. GBD was defined as either having gallstones or having undergone cholecystectomy. Videotapes of all ultrasound examinations were independently reviewed by radiologists specializing in abdominal ultrasonography. The Kappa statistic[37] was used to evaluate agreement between technicians' and radiologists' diagnoses and was found to be 0.94.

Dietary intake and other covariates

Household interviews included a food frequency questionnaire in which respondents estimated the number of times per day, week or month that they ate each of 60 food items during the previous month. Individuals were also asked about the type of milk they usually drank; with the replacement of one generic milk item with four more specific milk items, there was a total of 63 food items from the food frequency questionnaire. A list of these foods is provided in the Appendix. The food list used for the questionnaire is similar to those used in previous NHANES, with several food items added to capture the intake of important sources of nutrients related to cancer, cardiovascular disease and osteoporosis. The food list was additionally modified to include important foods consumed by non-Hispanic whites, African Americans and Mexican Americans, who made up the three major subgroups of the NHANES III study population. Information on foods consumed by these subgroups was based on data from NHANES II and the Hispanic Health and Nutrition Examination Survey (HHANES). Food frequency responses were used to identify patterns of food intake, which were then related to GBD status.

Other interview information was obtained prior to ultrasound examination. Regular breakfast consumption was used as a proxy for length of overnight fast, and attempted weight loss during the past 12 months was used as a proxy for history of dieting. Subjects were classified as ever-smokers if they reported smoking at least 100 cigarettes during their entire lifetime. Body mass index (BMI) was calculated using measurements made at the MEC. Information on reproductive factors for women was obtained in a separate questionnaire administered at the MEC and included current pregnancy, total number of live born children, birth control pill use and oral oestrogen or female hormone use.

Identification of food intake patterns

We used principal components analysis[38] to identify eating patterns underlying the intake of foods in Mexican American women and men (SAS version 6.11, SAS Institute, Cary, NC). We conducted analyses in women and men separately. Individuals were randomly placed into one of two equally sized groups, or split samples, and analyses were conducted in the two split samples for each sex in order to confirm the reliability of results. For each of the four groups, we constructed a matrix of correlations among the frequency of consumption per month for the 63 food items, and the correlation matrix was entered in the principal components analysis.

The number of meaningful components to retain from the total number extracted depended chiefly on the examination of scree plots and on interpretability of the components[39]. Four components consistently emerged in both split samples of women, and three consistently emerged in men; thus, four components in women and three in men were retained for rotation. Since orthogonal and oblique rotations produced similar results, we present the results from the orthogonal rotation only.

Although in general the same major patterns emerged in both samples in women and men, slightly different sets of foods loaded highly on each component across split

samples. To reconcile results from the split samples for each sex, we identified sets of 'definite' and 'possible' foods to attach to each pattern. 'Definite' food items were those with loadings of at least 0.30 in both split samples, but whose loadings on other components were substantially less. 'Possible' foods were those whose loadings were above 0.20 for the given component in both split samples but less for other components. The decision to include or exclude these 'possible' foods from the set of foods describing each pattern was based on their effects on the component's coefficient alpha[40], used to evaluate internal consistency for each component retained. To finalize the set of foods to attach to each pattern, we first calculated a coefficient alpha based on both 'definite' and 'possible' foods together. If removal of a 'possible' food from the set resulted in a higher coefficient alpha for one or both split samples, then we excluded that food from the pattern description.

We calculated factor scores for each pattern by taking the unweighted sum of standardized frequencies of intake for each food associated with the pattern. A factor score was calculated for each dietary pattern for each individual and was taken to represent the individual's level of intake for the pattern.

Over 95% of the study participants responded to all 63 items in the food frequency questionnaire. Three individuals who missed at least 54 items were excluded from these analyses. If individuals were missing responses on individual foods in any given pattern of food intake identified by principal components analysis, we imputed a value for the missing food by taking the average standardized frequency of all other non-missing foods in that pattern. This was necessary in 40 instances in 38 women, and in 90 instances in 80 men. One man was excluded from analyses on the traditional food intake pattern because there were not enough non-missing responses for other food items in that pattern to impute values for missing foods.

Data analysis

We categorized factor scores into quartiles and calculated prevalence odds ratios PORs as measures of association between each food intake pattern and GBD[41]. PORs and their 95%CI were estimated using unconditional logistic regression modelling[41] and were weighted using SUDAAN software (SUDAAN version 7.0, Research Triangle Institute, Research Triangle Park, NC) to take into account the complex sampling design.

PORs were adjusted for age by including age in the model as a continuous variable. They were further adjusted for other potential confounders, including regular breakfast consumption, attempted weight loss last year and smoking history. In women, additional variables evaluated as potential confounders were number of live births, ever use of birth control pills, ever use of oral oestrogen or female hormones, and current pregnancy status.

We also investigated the effect of controlling for BMI as a possible intermediate in the pathway between some dietary patterns and GBD. Because the log odds ratio for GBD did not increase in a linear fashion with increasing BMI in men, BMI was entered into logistic regression models as a nominal variable, with BMI categorized as < 25, >25–29.9, and $\geqslant 30\,\mathrm{kg\,m^{-2}}$, corresponding with categories of normal range BMI, grade 1 overweight, and grades 2 and 3 overweight, respectively, as suggested by a World Health Organization (WHO) Expert Committee[42]. We also left BMI as a continuous variable in models for women since the log odds ratio for GBD increased linearly with increasing BMI in women. However, because results were similar regardless of how BMI was coded, results are presented only for the WHO method of categorization for both sexes.

We estimated PORs for selected individual foods from the food frequency questionnaire that have been associated with GBD previously. We estimated intake of simple sugars from sweetened beverages and from desserts. Monthly frequency of intake of sweetened beverages was estimated by summing together responses for regular sodas and Kool-Aid-type drinks, such as Hi-C, Tang and Hawaiian Punch. Because including coffee and tea did not materially affect results, we present findings without these two beverages. Desserts included summed responses for chocolate and pastries, and alcohol included summed responses for beer, wine and liquor. We created categories of frequency of intake per month that were equivalent to the following categories: never, less than once a week, 1–2 times per week, 2–6 times per week, every day and more than once a day. Categories were subsequently collapsed depending on the frequency distribution for each food item to ensure an adequate number of subjects within each group.

We conducted tests for linear trend in the log odds ratio of categories of intake for each food pattern by fitting a logistic model with age and an ordinal variable representing the median factor score for each pattern quartile.

We performed additional analyses using more limited case definitions by: (i) excluding cholecystectomy cases, assuming that cases with gallstones at ultrasound were less likely to alter their diets as a result of disease diagnosis or symptoms; and (ii) additionally excluding gallstone cases who had been told by a doctor that they had gallstones. These exclusions served to limit cases to those least likely to be aware of their disease status and, hence, least likely to alter their dietary habits as a result of disease.

Results

Of 5551 Mexican Americans aged 20–74 years selected to take part in NHANES III, 4641 (83.6%) – 2306 women and 2335 men – were interviewed at home and invited to receive a gallbladder ultrasound. Characteristics of the study population are shown in Table 1, and associations between various risk factors and GBD in the population are shown in Table 2.

Table 1 Characteristics of the Mexican American study population by sex in the third National Health and Nutrition Examination Survey, 1988–94

	Women (n=2306)*†	Men (n=2335)*†
Mean age (years)	37.5	35.8
GBD (%)	22.1	5.4
Gallstones	11.3	3.9
Cholecystectomy	10.8	1.5
Country of birth (%)		
Mexico	50.8	58.5
USA	48.9	40.9
Other	0.4	0.6
Highest grade completed < 12 (%)	56.5	59.1
Poverty–income ratio < 1 (%)	37.9	32.1

*Numbers may differ because of missing responses for each characteristic. The number missing information for each of the following variables were: GBD, 216 women, 251 men; country of birth, 6 women, 4 men; grade completion, 24 women, 31 men; poverty–income ratio, 286 women, 291 men.
†Means and proportions are weighted to reflect population distribution.

We identified four meaningful intake patterns in women and three similar patterns in men (Table 3). The components retained could explain only a small amount of the variation in food intake in our population; together, the four patterns in women accounted for 19–20% of the total variance, while the three in men accounted for about 15%. Coefficient alphas for the retained components are also shown in Table 3.

To give an idea of the differences in food intake across quartiles for each pattern, median monthly frequencies of intake of selected foods for each pattern are shown in Fig. 1 for women and Fig. 2 for men. Median frequencies of intake for these foods ranged from zero or once a month in the first quartile, to as high as once every day in the fourth quartile. Mean BMI did not vary substantially by quartile for any of the patterns (data not shown).

There were 2090 women and 2084 men with information on disease status. Because adjustment for other risk factors and for BMI did not appreciably change odds ratio estimates or alter our conclusions, only age-adjusted PORs are presented. None of the patterns of intake appeared to be associated with prevalence of GBD in women (Table 4). In men, the traditional pattern was inversely associated with GBD prevalence: men in the third and fourth quartiles of intake of this pattern were roughly half as likely to have GBD as those in the lowest quartile. Age-adjusted PORs were generally similar when we used the more limited case definitions that excluded cholecystectomy and diagnosed gallstones.

In analyses on individual foods (Table 5), alcohol was inversely related to GBD in both women and men; individuals who drank alcohol more than twice a week during the previous month were about half as likely to have GBD as non-drinkers. There was an inverse association between beans and GBD in men only, and a weak inverse association with desserts in women only.

Table 2 Age-adjusted prevalence odds ratios (POR) and 95%CI for gallbladder disease by levels of covariates in Mexican Americans, by sex: third National Health and Nutrition Examination Survey, 1988–94

	Women	Men
BMI (kg m^{-2})		
< 25	1.00	1.00
25–29.9	1.31 (0.89–1.94)	0.82 (0.44–1.56)
⩾ 30	2.76 (2.09–3.64)	1.24 (0.77–1.98)
Ever smoked > 100 cigarettes*	1.23 (0.84–1.82)	0.80 (0.46–1.40)
Eat breakfast every day*	0.82 (0.62–1.07)	1.15 (0.82–1.63)
Tried to lose weight last year*	1.58 (1.15–2.19)	0.97 (0.54–1.74)
Number of live births		
0	1.00	
1–2	2.77 (1.46–5.27)	
3–4	3.38 (1.77–6.45)	
> 4	2.91 (1.53–5.54)	
Currently pregnant*	0.56 (0.27–1.13)	
Ever used birth control pills*	1.30 (0.93–1.83)	
Ever used oestrogens or female hormones*	1.03 (0.49–2.15)	

*POR for yes vs. no.

However, no trend could be discerned in men for lower GBD risk with increasing bean consumption. We found no evidence of an association of GBD with intake of sweetened beverages or fish (results not shown). When we limited our case definition to gallstone cases unaware of disease status, results were generally the same, but a positive association emerged between beans and gallstones in women; PORs relative to those eating beans less than once a week were 1.22 (0.73, 2.03), 1.24 (0.75, 2.06) and 1.58 (1.02, 2.46) for those eating beans 1–2 times a

Table 3 Food intake patterns identified in Mexican Americans, by sex: third National Health and Nutrition Examination Survey, 1988–94

		Women		Men	
Pattern	Food item	Sample 1 (n=1178)	Sample 2 (n=1126)	Sample 1 (n=1192)	Sample 2 (n=1142)
High calorie	Processed meats	0.58	0.54	0.46	0.56
	Salty snacks	0.51	0.49	0.55	0.56
	Chocolate	0.48	0.25	0.47	0.44
	White bread	0.45	0.40	0.50	0.45
	Pork, ham	0.44	0.48	0.25	0.38
	Pastries	0.41	0.37	0.50	0.43
	Beef	0.40	0.50	0.42	0.46
	Cheese dishes	0.36	0.38	0.34	0.28
	Soda	0.34	0.41	0.35	0.40
	Fruit drinks	0.29	0.32	0.36	0.37
	Flour tortillas	0.42	0.39	–	–
	Potato	–	–	0.44	0.41
	Cheese	–	–	0.41	0.40
	Ice cream	–	–	0.36	0.28
	Dressing	–	–	0.30	0.46
	Pizza	–	–	0.30	0.33
	Butter	–	–	0.25	0.27
Variance explained (%)		7.3	7.0	4.7	4.9
Coefficient alpha		0.64	0.64	0.67	0.69
Vegetable	Carrots	0.54	0.60	0.62	0.53
	Salad	0.51	0.55	0.52	0.45
	Broccoli	0.48	0.53	0.55	0.51
	Greens	0.45	0.42	0.38	0.34
	Other vegetables	0.43	0.49	0.35	0.48
	Cauliflower	0.38	0.41	0.49	0.51
	Other fruits	–	–	0.48	0.24
	Melon	–	–	0.46	0.29
	Citrus fruit	–	–	0.46	0.41
	Yellow fruit	–	–	0.44	0.29
	Soups, stews	–	–	0.43	0.49
	Cabbage	–	–	0.42	0.38
	Other juice	–	–	0.38	0.34
	Citrus juice	–	–	0.35	0.36
	Fish	–	–	0.33	0.35
	Chicken	–	–	0.31	0.27
	Rice	–	–	0.29	0.30
	Shellfish	–	–	0.28	0.34
Variance explained (%)		4.1	5.5	7.3	6.9
Coefficient alpha		0.65	0.67	0.75	0.72
Traditional	Beans	0.68	0.55	0.60	0.56
	Corn tortillas	0.52	0.57	0.55	0.57
	Chilli peppers	0.38	0.36	0.45	0.35
	Whole milk	0.28	0.38	0.26	0.28
	Organ meats	0.23	0.30	0.34	0.30
	Low-fat milk	–0.23	–0.25	–0.45	–0.22
	Diet drinks	–	–	–0.39	–0.37
	Dark bread	–	–	–0.44	–0.48
Variance explained (%)		2.9	4.0	4.2	4.1
Coefficient alpha		0.43	0.51	0.54	0.48
Fruit	Yellow fruits	0.52	0.54	–	–
	Citrus juice	0.49	0.34	–	–
	Other juices	0.48	0.41	–	–
	Ice cream	0.44	0.40	–	–
	Melon	0.44	0.47	–	–
Variance explained (%)		5.2	2.9	–	–
Coefficient alpha		0.53	0.46	–	–

Table 4 Age-adjusted prevalence odds ratios and 95%CI for gallbladder disease by quartile of food intake pattern in Mexican Americans, by sex: third National Health and Nutrition Examination Survey, 1988–94

Quartile of food intake pattern	Vegetable	High calorie	Traditional	Fruit
Women				
1 (low)	1.00	1.00	1.00	1.00
2	1.32 (0.95–1.82)	1.10 (0.83–1.44)	1.14 (0.84–1.55)	1.54 (1.16–2.03)
3	1.04 (0.81–1.35)	1.10 (0.75–1.60)	1.01 (0.74–1.37)	1.10 (0.82–1.48)
4 (high)	0.91 (0.63–1.29)	0.87 (0.60–1.24)	0.81 (0.57–1.15)	1.20 (0.89–1.61)
P for trend*	0.06	0.98	0.17	0.97
Men				
1 (low)	1.00	1.00	1.00	
2	1.04 (0.55–1.99)	0.85 (0.47–1.56)	0.78 (0.44–1.40)	
3	1.61 (0.86–3.04)	1.47 (0.68–3.21)	0.42 (0.21–0.85)	
4 (high)	1.28 (0.83–1.95)	1.19 (0.59–2.41)	0.53 (0.28–1.01)	
P for trend*	0.12	0.48	0.01	

**P* value for trend was obtained for each food intake pattern by including an ordinal variable representing the median factor score for each quartile into the logistic model.

week, 2–6 times a week and at least once a day, respectively. In men, the associations of the traditional intake pattern and alcohol with GBD persisted when both were included in the same model (results not shown).

Discussion

We identified four distinct dietary patterns in women and three in men. None appeared to be associated with GBD

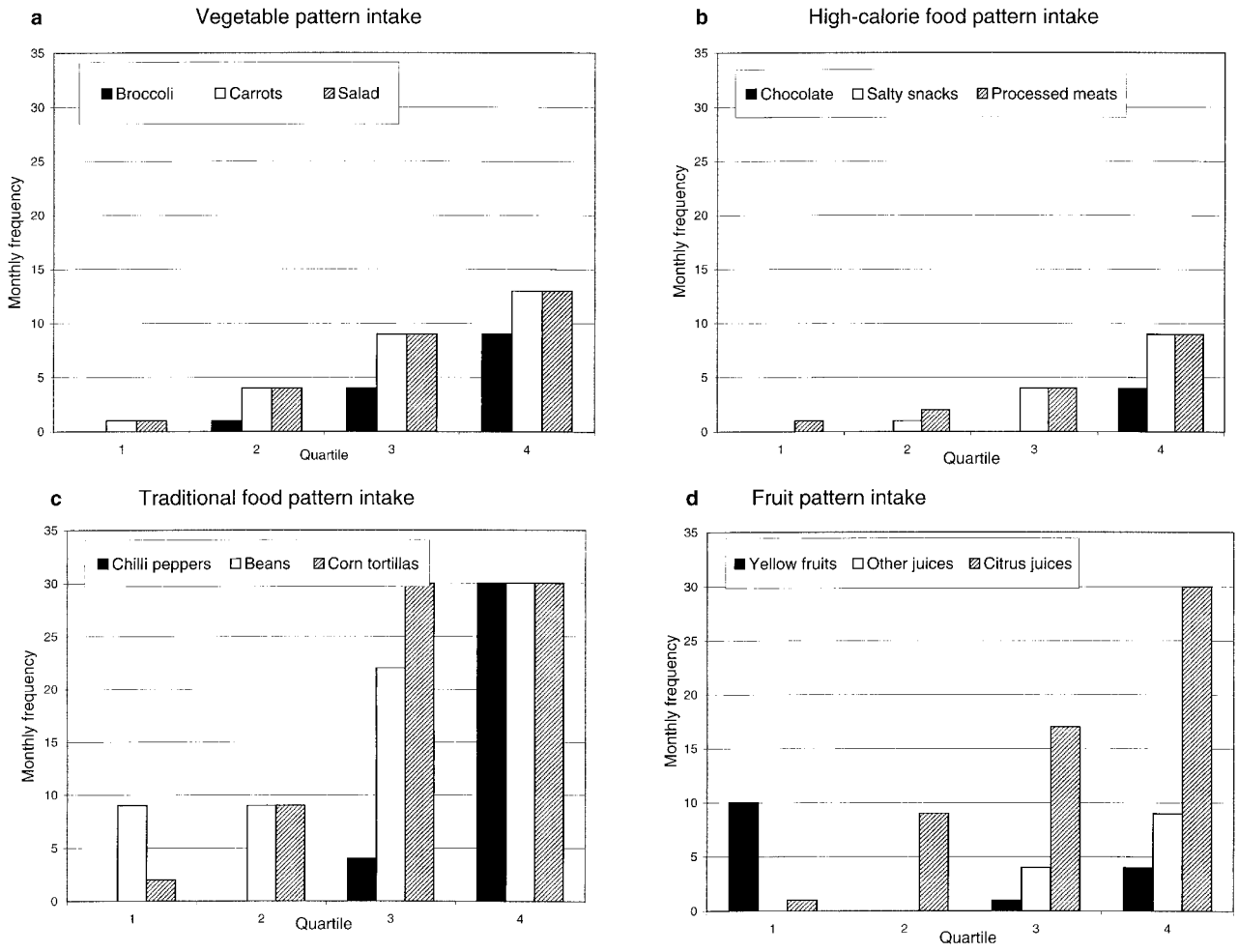

Fig. 1 Median monthly frequency of intake of selected foods by quartile for each food intake pattern in Mexican American women: third National Health and Nutrition Examination Survey, 1988–94

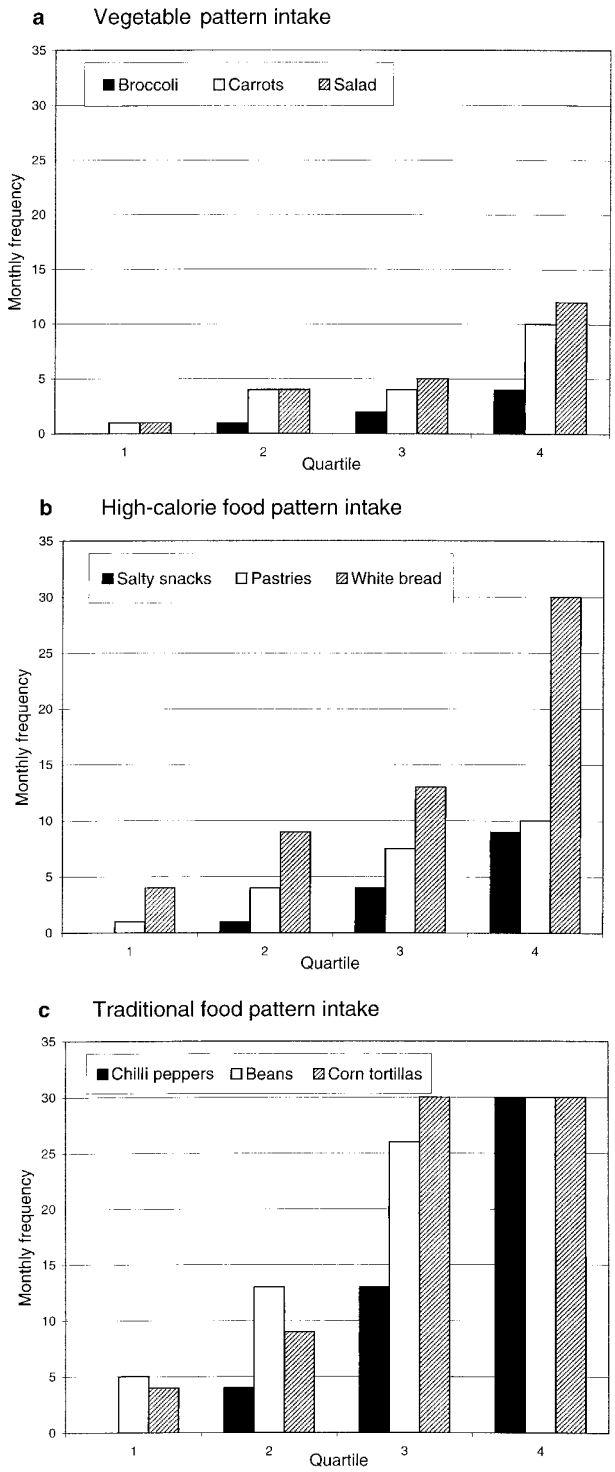

Fig. 2 Median monthly frequency of intake of selected foods by quartile for each food intake pattern in Mexican American men: third National Health and Nutrition Examination Survey, 1988–94

prevalence except the traditional intake pattern in men, which was associated with decreased prevalence of GBD. Among the individual food items that we investigated, intake of beans was inversely associated with GBD in men, and alcohol was inversely associated in both women and men.

Table 5 Age-adjusted prevalence odds ratios and 95%CI for gallbladder disease by levels of intake for specific foods in Mexican Americans, by sex: third National Health and Nutrition Examination Survey, 1988–94

	Women	Men
Alcohol		
Never	1.00	1.00
< 1/week	0.99 (0.59–1.65)	1.24 (0.54–2.82)
1–2/week	0.77 (0.41–1.43)	0.71 (0.42–1.21)
> 2/week	0.51 (0.29–0.89)	0.59 (0.34–1.03)
P for trend*	0.02	0.04
Beans		
< 1/week	1.00	1.00
1–2/week	0.95 (0.60–1.49)	0.65 (0.33–1.29)
2–6/week	1.13 (0.78–1.64)	0.54 (0.25–1.16)
⩾ 1/day	1.05 (0.74–1.51)	0.59 (0.24–1.44)
P for trend*	0.49	0.45
Desserts		
< 1/week	1.00	1.00
1–2/week	1.04 (0.76–1.42)	1.15 (0.63–2.12)
> 2/week	0.75 (0.50–1.12)	1.07 (0.56–2.06)
P for trend*	0.08	0.93

**P* value for trend was obtained for each food intake pattern by including an ordinal variable representing the median frequency for each quartile into the logistic model.

Several studies have attempted to identify food intake patterns in different populations using a variety of methods[43–54]. We chose to use principal components analysis to examine food intake patterns, first identifying foods that are correlated with each other or occur together in the diets of our study participants, and then categorizing people according to their level of intake of each set of foods identified. Although principal components analysis has been criticized for defining patterns that may not be reproducible across populations[55], two patterns identified in the present study, the high-calorie and fruit/vegetable patterns, resembled the 'western' and 'prudent' patterns identified in two recent studies conducted in two separate US populations[48,56]. Hu *et al.*[56] found the two patterns to be reasonably reproducible and valid based on dietary data from the Health Professionals Follow-up Study.

Another study looked at dietary patterns defined by principal components analysis in Mexican American women specifically, using data from HHANES[46]. Again, there were similarities among patterns identified in that and the present study. The 'nutrient dense' and 'traditional' patterns identified in the HHANES analysis corresponded with the vegetable and traditional patterns identified in the present study. Our 'high-calorie' pattern appeared to be a composite of the 'transitional' and 'nutrient dilute' patterns identified in that study. Other patterns identified were 'protein-rich', 'high-fat dairy' and 'mixed dishes'. The seven factors extracted in the HHANES analysis explained 59% of the total variance in frequency of consumption of the food groups. In contrast, the three to four factors extracted in our analyses could explain only 15–20%. The difference in proportion of variance explained arose in part because we extracted fewer factors. More important, however, in the HHANES analysis, 47 foods were

collapsed into 18 food groups, and there is potentially less unique variance among 18 food groups than among 63 food items, as in our analysis. We chose not to collapse food categories because different individual food items – although it may seem to make biological or intuitive sense to group them together – are consumed in different contexts and in different combinations of which we may not be aware a priori. Thus, rather than create groups of potentially dissimilar foods, we chose to use principal components analysis to establish relationships among individual food items empirically.

We are unaware of other studies that have systematically described food intake patterns to evaluate GBD risk, although two studies have found that vegetarians are less likely to have gallstones than non-vegetarians[57,58]. Other studies have looked at the association of GBD with specific foods. Some have observed a positive association with sweet foods[19,59–61], and inverse associations with fish[30,60–62] and with beans and pulses[17,30,61,63]. Observed associations for foods may be attributed to specific factors in these foods, or they may represent the effect of other foods with which they are consumed in the diet.

In our study, there was no clear association of GBD with sweetened beverages and desserts or with fish. We found an inverse association with beans in men but no trend, while beans appeared to be associated with higher prevalence in women when we used a more limited case definition. An experimental study in Chilean men suggested that legume intake may increase biliary cholesterol saturation, thereby contributing to gallstone occurrence[64]. Reasons for the discrepant findings regarding legumes are unknown.

Consistent with most previous research, we found an inverse association between alcohol intake and GBD[5,12,14,16,19,20,22–31]. Moderate alcohol intake may protect against gallstone development through its association with reduced biliary cholesterol saturation and higher serum HDL[7,23].

It is possible that diet is a more important contributor to GBD in men than in women. While no strong risk factors for GBD have emerged for men, several have been identified in women, including BMI, oral contraceptive and oestrogen use, and parity. In the women in our study population, BMI and number of live births were strongly associated with GBD; these, rather than diet, may be more important determinants of disease in this group.

Importantly, in men, a strong association with traditional intake pattern and GBD was found, while only a limited, non-dose-related association was seen with beans, which is a component of the traditional pattern. Furthermore, it is unclear if the association between the traditional pattern and GBD can be attributed to a single specific component of the diet, such as fibre. In this study population, the traditional food pattern was associated with a lower per cent of kilocalories from total fat, but a higher intake of cholesterol and fibre (data not shown). It is notable, however, that one recent clinical trial found no reduction in gallstone recurrence in individuals given a high-fibre, low-refined-carbohydrate diet[65]. In additional analyses in our study population, we found no major differences in intake between those with and without disease for any single nutrients of a priori interest, including total fat, cholesterol and fibre (data not shown).

Selection bias and selective over- or underreporting are unlikely to have produced the observed inverse association between the traditional intake pattern and GBD. The extent to which the association might be confounded by other potentially confounding factors such as physical activity[28,66,67] requires further evaluation.

Various features of NHANES III made it more difficult to find an association between intake patterns and disease. The dietary questionnaire used in NHANES III was not designed specifically to measure dietary patterns. Also, aspects of the food frequency questionnaire – for example, random error arising from difficulty in estimating frequency of intake – may have attenuated correlations among foods, leading to imprecise estimation of factor scores. The grouping of dissimilar food items in the NHANES III food frequency questionnaire may also have attenuated correlations among foods, weakening the factor structure of the food items, and contributing to the relatively low coefficient alphas we observed for some of the components. A stronger factor structure might have produced more internally consistent and precisely quantifiable intake patterns.

Furthermore, dietary data were collected at the time of disease ascertainment and may not reflect past intake or intake during the relevant period of disease development. Differential change in consumption patterns over time may explain the failure to find an association for some dietary patterns. However, limiting cases to those presumably unaware of their gallstones did not alter our conclusions. Also, the proportion of non-cholecystectomy gallstone cases reporting abdominal pain during the previous year was similar to that in the non-case population (data not shown), suggesting that most of them were indeed asymptomatic. Although it is possible that such an approach may limit findings to asymptomatic or less severe cases, we find no reason to expect differences in risk factors for the development of asymptomatic as opposed to symptom-associated gallstones.

We found a traditional intake pattern to be inversely associated with GBD prevalence, but only among Mexican American men. This pattern proved at least as, if not more, strongly associated with GBD as did examination of individual foods. That none of the food intake patterns identified in women were associated with GBD may suggest that other lifestyle factors are more important determinants of GBD, such as BMI and reproductive factors. The purpose of this research was not to uncover aetiology but to determine if food intake patterns as a means of characterizing dietary intake are associated with disease. Our findings add to a growing literature showing

that dietary intake does not have to be characterized in terms of its individual (single nutrient) components to be informative on diet–disease associations. Indeed, if findings are to be used for preventive rather than aetiological purposes, complete understanding of the specific actions and contributions of individual components may not be necessary – an idea recognized in recent clinical trials[68,69]. Measurement of dietary intake patterns in observational studies can provide potentially useful and relevant information on dietary influences on disease risk, but methods to do so require further development and validation.

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Appendix

The 63 foods included in the principal components analysis were as follows.

Milk and milk products

1. Chocolate milk or hot cocoa.
2. Whole/regular milk.
3. Low-fat or 1% milk.
4. Skimmed/non-fat milk.
5. Buttermilk, evaporated milk or other milk.
6. Yogurt or frozen yogurt.
7. Ice cream, ice milk or milkshakes.
8. Cheese, all types.
9. Pizza, calzone or lasagna.
10. Cheese dishes (such as macaroni and cheese or cheese quesadillas).

Main dishes, meat, fish, chicken and eggs

11. Vegetable-containing stew or soup.
12. Spaghetti and pasta with tomato sauce.
13. Bacon, sausage or luncheon meats.
14. Liver and other organ meats.

15. Beef.
16. Pork and ham.
17. Shrimp, clams, oysters, crab or lobster.
18. Fish, including fillets, fish sticks, fish sandwiches and tuna fish.
19. Chicken.
20. Eggs.

Fruit and fruit juices

21. Orange, grapefruit or tangerine juice.
22. Other fruit juices (such as grape or apple juice or fruit nectars).
23. Citrus fruits.
24. Melons.
25. Peaches, nectarines, apricots, guava, mango or papaya.
26. Other fruits (such as apples, bananas or pears).

Vegetables

27. Carrots or vegetable mixtures with carrots.
28. Broccoli.
29. Brussels sprouts or cauliflower.
30. White potatoes.
31. Sweet potatoes, yams or orange squash.
32. Tomatoes, including fresh and stewed tomatoes, tomato juice and salsa.
33. Spinach, greens, collards or kale.
34. Tossed salad.
35. Cabbage, coleslaw or sauerkraut.
36. Hot red chilli peppers.
37. Peppers including green, red and yellow peppers.
38. Other vegetables (such as green beans, corn or peas).

Beans, nuts, cereals and grain products

39. Beans, lentils or chickpeas/garbanzos.
40. Peanuts, peanut butter and other types of nuts or seeds.
41. All-Bran, All-Bran Extra Fiber, 100% Bran or Fiber One.
42. Total, Product 19, Most or Just Right.
43. All other cold cereals (such as corn flakes, Cheerios or presweetened cereals).
44. Cooked and hot cereals.
45. White bread, rolls, bagels, biscuits, English muffins or crackers.
46. Dark breads and rolls.
47. Corn bread, corn muffins or corn tortillas.
48. Flour tortillas.
49. Rice.
50. Salted snacks (such as potato chips, taco chips or salted pretzels).

Desserts, sweets and beverages

51. Cakes, cookies, brownies, pies, doughnuts or pastries.
52. Chocolate candy and fudge.
53. Hi-C, Tang, Hawaiian Punch, Kool-Aid and other drinks with added vitamin C.
54. Diet colas, diet sodas and diet drinks such as Crystal Light.
55. Regular colas and sodas, not diet.
56. Regular coffee with caffeine.
57. Regular tea with caffeine
58. Beer and lite beer.
59. Wine, wine coolers, sangria and champagne.
60. Hard liquor (such as tequila, gin, whiskey and liqueurs), either alone or mixed.

Fats

61. Margarine.
62. Butter.
63. Oil and vinegar, mayonnaise and salad dressings.