

# Dietary patterns are associated with dietary recommendations but have limited relationship to BMI in the Communities Advancing the Studies of Tribal Nations Across the Lifespan (CoASTAL) cohort

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## Abstract

**Objective:** Traditional food systems in indigenous groups have historically had health-promoting benefits. The objectives of the present study were to determine if a traditional dietary pattern of Pacific Northwest Tribal Nations (PNwT) could be derived using reduced rank regression and if the pattern would be associated with lower BMI and current Dietary Reference Intakes.

**Design:** The baseline data from the Communities Advancing the Studies of Tribal Nations Across the Lifespan (CoASTAL) cohort were used to derive dietary patterns for the total sample and those with plausibly reported energy intakes.

**Setting:** Pacific Northwest Coast of Washington State, USA.

**Subjects:** Adult PNwT members of the CoASTAL cohort with laboratory-measured weight and height and up to 4 d of dietary records ( $n$  418).

**Results:** A traditional dietary pattern did not evolve from the analysis. Moderate consumption of a sweet drinks dietary pattern was associated with lower BMI while higher consumption of a vegetarian-based dietary pattern was associated with higher BMI. The highest consumers of the vegetarian-based dietary pattern were almost six times more likely to meet the recommendations for dietary fibre.

**Conclusions:** Distinct dietary patterns were found. Further exploration is needed to confirm whether the lack of finding a traditional pattern is due to methodology or the loss of a traditional dietary pattern among this population. Longitudinal assessment of the CoASTAL cohort's dietary patterns needs to continue.

**Keywords**  
Dietary patterns  
Reduced rank regression  
Native American adults  
BMI

Obesity prevalence rates in Native Americans and Alaska Natives, a geographically and culturally diverse population, have reached alarming rates. In comparison to other populations, such as non-Hispanic whites and Asians, Native Americans/Alaska Natives are more likely to be obese ( $\text{BMI} \geq 30 \text{ kg/m}^2$ )<sup>(1,2)</sup>. Obesity contributes to morbidity and mortality within a population<sup>(3)</sup>. With Native Americans/Alaska Natives displaying a disproportionate burden for chronic diseases such as CVD, cancer and diabetes<sup>(1)</sup>, the high prevalence rates of obesity will affect the health status of these unique populations.

The high prevalence of obesity found within the Native American/Alaska Native population today may be related to the transition away from a traditional food system (TFS). A TFS includes all food within a particular culture available from local, natural resources that is culturally accepted and provides all of the essential nutrients necessary for optimal health<sup>(4)</sup>. A TFS incorporates socio-cultural meanings, acquisition and processing techniques, use, composition and the nutritional consequences of consumption<sup>(5)</sup>. Many of the diets of TFS were dependent on geographic location and season, such as a dominance

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of meat in the Arctic Circle and a large proportion of carbohydrates from corn in the Southwest USA<sup>(6)</sup>. A transition away from traditional foods occurs for various reasons including restricted traditional food resource use and harvesting areas, decreases in species density, concern about exposure to contaminants and the availability of market foods<sup>(5,7,8)</sup>.

The transition away from TFS is disconcerting given the evidence that TFS have health-promoting benefits<sup>(9–12)</sup>. For example, the Mediterranean diet and Asian diets have attracted considerable attention as healthier alternatives to the Western diet<sup>(13–16)</sup>. With the presence of unique cultural and geographic eating patterns, indigenous populations may benefit from promoting their respective TFS. Such a change might improve health, reduce risk for disease, and positively influence cultural and traditional factors important to these populations.

In the present study we sought to determine the dietary patterns present within a unique group of Native Americans from the Pacific Northwest participating in the Communities Advancing the Studies of Tribal Nations Across the Lifespan (CoASTAL) cohort. The CoASTAL cohort represents a novel population and is of particular interest because of the high rates of obesity<sup>(17)</sup>. Our primary hypothesis was that traditional foods of the Pacific Northwest Tribal Nations (PNwT), such as shellfish, salmon, venison and berries, would have significant variance in consumption in comparison to other food groups. Our secondary hypothesis was that higher consumption of the traditional food pattern derived from the CoASTAL cohort would be associated with lower BMI and greater adherence to selected Dietary Reference Intakes (DRI)<sup>(18)</sup>. Our final hypothesis was that limiting the sample to those considered to report energy intake plausibly within the CoASTAL cohort would further elucidate the presence of a traditional dietary pattern and its association with lower BMI and current dietary recommendations.

## Materials and methods

### *Study design and participant recruitment*

The CoASTAL cohort originated from an official invitation of one of the Tribal Nations of the Pacific Northwest Coast of Washington State. The investigators and members of three neighbouring Tribal Nations worked towards establishing trust, creating communication channels and resolving study design issues prior to initiating the study. Enrolment for the 5-year prospective study began in June 2005.

The sample for the present cross-sectional analysis was selected from the 520 non-pregnant adults (18+ years) participating in the CoASTAL cohort. Dietary patterns were estimated for participants who completed up to four dietary records and had weight and height information collected during the first year (418/520; 80%). At the

enrolment visit, participants provided information about educational attainment, occupation and specific healthful behaviours (e.g. smoking). The Institutional Review Boards from the University of Maryland and Purdue University approved the study protocol. Details of the study rationale and methods have been published elsewhere<sup>(19)</sup>, but are summarized briefly here.

### *Dietary assessment*

Field coordinators, who were registered tribal members, participated in day-long training sessions with study dietitians initially and annually. Training included distribution of the dietary records, evaluating completeness of food entries, probing, portion size estimation, food preparation methods and accuracy of data recording. These field coordinators were then able to train the participants in record-keeping techniques using various measuring aids. Participants were provided a tool kit of measuring devices (e.g. measuring cups and spoons) and recording materials. Dietary records were completed every 4 months as two 1 d dietary records and one set of 2 d of dietary records for a total of four dietary records over 1 year. Respondents' recording days were assigned based on the day of their first visit and at least one day included a weekend day. Data coding and entry were performed by staff trained in the use of the Nutrition Data System for Research (NDS-R) Database version 4.07 (© Regents of the University of Minnesota). Food group servings from the dietary records were calculated as the mean of the number of days reported. At least 2 d were reported by 362 individuals (362/418; 87%) and the mean number of days recorded was 3.

### *Food groupings*

We used reduced rank regression (RRR) to consolidate the 166 NDS-R food groupings from the dietary record data into forty-two groups according to macronutrient composition, culinary usage, cultural specificity and prior classifications found in the literature<sup>(20–24)</sup>. Unit designation for the food groupings was servings/d. Some foods (e.g. eggs) comprised their own group. Multiple combinations of food groupings were tested including classifying all of the traditional foods into one food group. The end result did not differ between these combinations and therefore the food groupings ultimately used are described here. Table 1 shows the final food groupings.

### *Anthropometric measures*

Participants were measured for height and weight by the trained field coordinators. Prior to measures, participants were instructed to remove heavy outer clothing to a single layer of clothing, remove shoes and empty pockets. Height was measured to the nearest inch (2.54 cm) using a portable stadiometer (Shorr Infant/Child/Adult Portable Height-Length Measuring Board, Olney, MD, USA). Weight was measured on a calibrated electronic scale and

**Table 1** The forty-two food groups derived from the dietary records used in reduced rank regression analysis

Food group	Food
Fish	Fresh, smoked, fried and canned; halibut, tuna, cod, other fish
Shellfish	Fresh, fried and canned; crabs, scallops, shrimp
Clams	Razor, steamers, manila, butter, other types of clams
Salmon	Salmon
Red meat	All preparations; beef, pork, veal, lamb, organ meats
Game meat	Elk and venison
Poultry	All preparations; chicken, duck, turkey
Processed meats	Luncheon meats, bacon, ham, hot dog, sausage
Legumes	Legumes, beans, soyabeans, soyabean products
Eggs	Eggs
Nuts and seeds	All types of nuts, seeds, peanut butter
Low-fat dairy	Skimmed or reduced fat; milk, yoghurt, cheese, cream
High-fat dairy	Whole; milk, yoghurt, cheese, cream
Meal replacement	SlimFast shakes, Ensure, all types of meal replacements
Dairy dessert	Pudding and frozen dairy
Margarine	Margarine; full and reduced fat
Butter	Butter; full and reduced fat
Miscellaneous fats	Gravy and lard
Vegetable oils	Vegetable oils
Alcohol	Alcohol
Coffee	Coffee
Tea	Tea
Fruit juices	Orange, apple, cranberry, grape
Fruit	Apple, banana, oranges, apple sauce, pears, strawberries, cantaloupe, watermelon, grapes, raisins, peaches, pineapple, blueberries
Other vegetables	Lettuce, green beans, onions, carrots, celery, broccoli, mixed vegetables, green pepper, cucumber, mushrooms, cauliflower
Tomato	Tomatoes, tomato juice
White potatoes	White potatoes
Fried potatoes	Fried potatoes, vegetable savoury snack
Starchy vegetables	Corn, peas
Snack foods	Popcorn, chips, crackers, pretzels
Sweets	Sugar, syrup, honey, jams, sauces, non-chocolate candy, frosting, glazes
Refined grains	Flours, breads, corn muffins, tortillas, buckskin bread
Whole grains	Flours, breads, corn muffins, tortillas
Pasta	Pasta
Desserts	Cakes, cookies, pies, pastries, doughnuts, snack bars, chocolate, fry bread
Condiments	Regular fat
Lite condiments	Reduced fat and reduced calorie
Miscellaneous foods	Pickled foods, soup broth
Sweetened drinks	Soft drinks, water, fruit drinks
Unsweetened drinks	Soft drinks, water, fruit drinks
Cereals	Sweetened
Cereals	Unsweetened

recorded to the nearest pound (0.454 kg; SECA Digital Floor Scale, Hanover, MD, USA). BMI was calculated using the formula  $[\text{weight (kg)}]/[\text{height (m)}]^2$ . Obesity was defined as  $\text{BMI} \geq 30 \text{ kg/m}^2$ <sup>(25)</sup>.

### Plausibility determination

Individuals with plausible reported energy intake (rEI) were classified using previously developed and described methods<sup>(26,27)</sup>. Briefly, DRI equations were used to calculate predicted energy requirements<sup>(28)</sup>. rEI was evaluated as plausible or implausible after applying the 1.4 SD cut-off method to the population sample<sup>(27)</sup>. Individuals within 1.4 SD were considered to have plausible rEI, those with rEI above or below 1.4 SD were considered to implausibly report energy intake. There were no significant differences in characteristics between those considered to plausibly and implausibly report energy intake.

### Statistical analysis

The statistical method RRR, otherwise known as the maximum redundancy analysis, using the PLS procedure in Statistical Analysis Software (SAS), was used to derive dietary pattern scores. The use of this method to derive dietary patterns has been described in detail elsewhere<sup>(29)</sup>. In brief, RRR allows for the calculation of dietary pattern scores similarly to those extracted by factor analysis. However, where factor analysis determines dietary pattern scores by maximizing the explained variation of a set of predictor variables (e.g. food groups), RRR derives dietary pattern scores of predictor variables by accounting for as much of the variation in response variables (e.g. nutrients related to weight) as possible<sup>(29,30)</sup>. The RRR approach has been reported to be preferred to factor analysis for determining dietary patterns that are predictive of risk for chronic disease<sup>(31)</sup> and therefore

was selected as the method used to relate BMI to dietary patterns derived from the CoASTAL cohort.

In the present study, the nutrient densities of total fat, total carbohydrates and fibre (g total fat/4184 kJ (1000 kcal), g carbohydrates/4184 kJ (1000 kcal) and g fibre/4184 kJ (1000 kcal)) were chosen as the response variables because these variables have consistently been found to be associated with weight status (e.g. BMI)<sup>(32–39)</sup>. Intake data from the food groups (e.g. red meat, fruit, eggs, fish, pasta, etc.) determined by the dietary records served as predictors. These food groups (i.e. predictor variables) are summarized into distinct dietary patterns that capture the variation in the nutrient densities of total fat, total carbohydrates and fibre (i.e. response variables). In RRR, the number of extracted dietary patterns cannot be higher than the number of selected response variables (i.e. total fat, total carbohydrates and fibre); therefore, three dietary patterns were obtained for both the total group and the plausible rEI group<sup>(32)</sup>.

Factor loadings, which reflect the correlation of individual food groups within each of the derived dietary patterns, were obtained from the RRR. To focus on food groups that significantly contributed to the dietary pattern, we only considered those food groups with an absolute factor loading  $>0.2$ <sup>(29,32,40–44)</sup>. The food groups above the cut-off were used to label the dietary patterns. For each participant, a dietary pattern score was calculated by summing the product of the contributing food group intakes and scoring coefficients. Those food groupings with an absolute factor loading  $<0.2$  did not contribute to the dietary pattern score. The scores for each dietary pattern were then converted into quartiles for use in further analysis. Thus, for each dietary pattern quartile 4 would be composed of those who conform most (e.g. consume the most) to that particular pattern, while quartile 1 would be the lowest conformers (e.g. consume the least).

In order to assess the relationship between BMI and quartile of dietary pattern intake from the dietary records, multiple linear regression models were used. BMI classification does not differ by gender so men and women were analysed both together and separately. These findings were confirmed with binary logistic regression models using obesity as the dependent variable. For evaluating attainment of nutrient recommendations, the Institute of Medicine specifies using the information from 24 h dietary recalls, observation or dietary records<sup>(18)</sup>. Therefore, binary logistic regression models were used to evaluate how the dietary patterns derived from the dietary records related to the DRI for total fat, saturated fat and dietary fibre. All models were adjusted for age (ages were calculated from date of birth and date of first visit), education, employment and smoking status. Interaction terms were examined but none were significant. For those patterns found to be significantly associated with BMI, the general linear model was used to determine the mean BMI of participants

within each quartile after adjustment for age, education, employment and smoking. All RRR analyses were performed using the SAS statistical software package version 9.1 (SAS Institute, Cary, NC, USA). All other analyses were completed using the SPSS statistical software package version 16.0 (SPSS Inc., Chicago, IL, USA). Results were considered significant at  $P < 0.05$ , using two-sided tests.

## Results

Men and women included in the present analysis were similar in age and BMI (Table 2). A majority of the individuals in the sample were between the ages of 31 and 50 years and had attended at least some college. Foods with a factor loading  $>|0.2|$ , which indicates the level of correlation to the derived dietary patterns, are shown in Table 3. A traditional food pattern did not emerge in either the total group or the group with plausible rEI. A dietary pattern that loaded positively high in only fruit and sweet drinks explained most of the variation between the response variables and predictors in the total sample. The dietary pattern that explained the most variation for the plausible sample was a vegetarian and grains pattern. Legumes, tomato, pasta, sweetened drinks and unsweetened cereals had high positive loadings on this pattern.

Only those dietary patterns that were significantly associated with BMI and/or obesity are shown in Tables 4 and 5, as well as the adjusted mean BMI for each dietary pattern quartile. When examining the total group, significant associations were noted only when evaluating by gender. In men only, moderate consumption of the vegetables, fruit and whole grains pattern was significantly associated with a lower BMI and a lower risk for being obese (see Table 4). For the plausible reporters of energy intake (Table 5), the highest quartile of healthy pattern consumers was associated with a significantly higher BMI than the lowest consumers. When plausible reporters were evaluated by gender, only women demonstrated a significant association between body size and the healthy pattern. The highest quartile of healthy pattern consumers had a BMI significantly higher than the lowest quartile of consumers (see Table 5). Furthermore, the sweet drinks pattern was associated significantly with body weight in women (Table 5), with moderately high consumption significantly associated with a lower BMI.

The likelihood of meeting the Acceptable Macronutrient Distribution Range (AMDR) for percentage of energy consumed from total fat and saturated fat, as well as the Adequate Intake (AI) for dietary fibre, was evaluated for the dietary patterns (see Table 6). Adjusted models only are shown. The likelihood of meeting the AMDR for total fat and saturated fat was significantly higher among the highest consumers of the fruit and sweet drinks pattern. The highest consumers of the vegetables, fruit and whole grains pattern were about six

**Table 2** Characteristics of adults participating in the CoASTAL cohort with complete weight, height and diet information

Characteristic	Total group (n 418)		Plausible rEI group (n 236)	
	Mean	SD	Mean	SD
Age (years)	42	14	42	14
Height (cm)	166	10	166	10
Weight (kg)	87	20	85	20
BMI (kg/m <sup>2</sup> )	31	7	31	7
	<i>n</i>	%†	<i>n</i>	%†
Female	243	58	147	62
Age category (years)				
18–30	102	24	58	25
31–50	205	49	120	51
51–70+	111	27	58	25
Employed	213	51	130	55
Education level				
Less than high school	94	23	46	20
High school	153	37	87	37
Some college	143	34	86	36
Bachelor's degree or higher	28	7	17	7
Current smoker	199	48	115	49
Weight status				
Overweight/obese (BMI ≥ 25 kg/m <sup>2</sup> )	353	84	196	83
Obese (BMI ≥ 30 kg/m <sup>2</sup> )	214	51	117	50

CoASTAL, Communities Advancing the Studies of Tribal Nations Across the Lifespan; rEI, reported energy intake.

†Percentages may not add up to 100 due to rounding.

times more likely to meet the AI for dietary fibre. The highest consumers of the high fat and sugar pattern were almost 70% less likely to meet the AMDR for saturated fat. When limiting the sample only to those with plausible rEI, the third and fourth quartiles of the vegetarian and grains pattern were much more likely to meet the AMDR for total fat and saturated fat. The highest consumers of the sweet drinks pattern were less likely to meet the AMDR for saturated fat and the AI for dietary fibre.

## Discussion

Among the present sample of PNwT adults, a traditional food pattern predominant in foods such as shellfish, fish, game, berries and tea did not emerge using dietary records. Traditional foods were modelled in two different configurations and did not load positively high in any of the extracted dietary patterns examined. This would suggest that the variance was not great enough for traditional foods to emerge as an influential pattern. RRR seeks to capture the variation in intake with regard to certain response variables<sup>(29)</sup>. In the present study, the nutrient densities of total fat, carbohydrates and dietary fibre were used as the response variables to maximize the explained variation among the dietary patterns<sup>(32–39)</sup>. Although not detected by RRR, we know that in this CoASTAL cohort population, traditional foods are being consumed at some level<sup>(19)</sup>. Previously, we reported that over 50% of participants who completed a dietary record were identified as a seafood consumer in comparison to

98% of those completing the FFQ<sup>(19)</sup>. However, their consumption of seafood, which would be considered a traditional food, did not describe the variance in intake based on the selected response variables. To capture the contributions of traditional foods to the health and nutrient intakes of this population, methods other than dietary patterns may need to be used<sup>(12,45)</sup>. For example, the propensity method<sup>(45)</sup> takes advantage of the information from an FFQ as well as dietary records simultaneously.

The patterns derived in this population reflected two different types of eating habits. The pattern contributing the most variance to fat, carbohydrates and fibre density was dominated by food items considered high in energy, such as sweetened beverages, similar to results found in other Native populations<sup>(8)</sup>. In contrast, the dietary pattern contributing the second highest variance to those nutrient densities was heavily influenced by foods considered healthful such as whole grains and vegetables. The presence of a healthy pattern within this population is consistent with dietary pattern studies done in other populations<sup>(32,43,46–49)</sup>. However, in contrast to most of the other studies<sup>(20,32,50,51)</sup>, high intake of the healthy pattern from the present study was associated with a higher BMI. Only one study found a similar association in women<sup>(52)</sup>. Women from the NIH-AARP Diet and Health study with a dietary pattern dominated by foods low in energy were associated with poorer health characteristics<sup>(52)</sup>. Interestingly, similarly to the NIH-AARP Diet and Health study<sup>(52)</sup>, we also found this association to differ by gender. Men tended to be 'health conscious' with

**Table 3** Factor loading matrix and percentage of variance explained for adults (18+ years) participating in the CoASTAL cohort who completed dietary records†

Food group	Total group (n 418)				Plausible rEI group (n 236)			
	Fruit & sweet drinks	Vegetables, fruit & whole grains	High fat & sugar	% of variance explained	Vegetarian & grains	Healthy	Sweet drinks	% of variance explained
Fish			-0.23	6.8			-0.21	5.4
Game meat			-0.22	6.8				–
Alcohol			-0.60	47.5			-0.66	56.8
Salmon			-0.22	7.2			-0.28	9.8
Sweetened drinks	0.37	-0.43	0.22	47.4	0.30	-0.41	0.23	44.0
Unsweetened drinks		0.23		7.6		0.21		7.1
Butter	-0.25		0.21	11.5	-0.21			8.5
Fried potatoes			0.23	8.4				–
Desserts			0.23	8.4				–
Fruit juices (citrus and non-citrus)				–		-0.21		7.7
Fruit (citrus and non-citrus)	0.20	0.36		23.8		0.35		23.5
Legumes, beans, soyabeans		0.37		23.6	0.24	0.34		28.7
Tomato (including juice)				–	0.24			9.1
Nuts, seeds, peanut butter		0.23		13.9		0.29		18.1
Vegetables		0.35		18.5		0.29		14.1
Whole grains		0.26		11.4				–
Unsweetened cereals				–	0.29			15.4
Refined grains				–		-0.23		9.6
Pasta				–	0.29			11.6
Red meat	-0.37			17.3	-0.38		-0.23	24.0
Processed meats	-0.29			9.8	-0.21			6.8
Eggs	-0.34			12.3	-0.33			13.8
High-fat dairy	-0.20			6.1				–
% of variance explained	43.7	22.2	4.3	Σ = 70.3	52.4	24.1	5.9	Σ = 82.3

CoASTAL, Communities Advancing the Studies of Tribal Nations Across the Lifespan; rEI, reported energy intake.

†Factor loadings &lt;|0.20| are not shown.



**Table 4** The relationship of dietary patterns as quartiles and BMI or obesity among men (18+ years) participating in the CoASTAL cohort††

Vegetables, fruit & whole grains pattern	Men (n 175)			
	Quartile 1§	Quartile 2	Quartile 3	Quartile 4
BMI ( $\beta$ )¶	Ref.	-1.64	-4.30***	0.99
BMI (kg/m <sup>2</sup> )				
Mean	31.5 <sup>a</sup>	29.9 <sup>a,b</sup>	27.2 <sup>c</sup>	32.5 <sup>a,d</sup>
SD	5.5	6.3	4.9	6.1
Obesity (OR)††	Ref.	0.53	0.27**	0.96

CoASTAL, Communities Advancing the Studies of Tribal Nations Across the Lifespan; Ref., referent category.

<sup>a,b,c,d</sup>Mean values within a row with unlike superscript letters were significantly different ( $P < 0.05$ ).

\*\* $P < 0.01$ , \*\*\* $P < 0.001$ .

†No significant relationship was apparent in the total sample or women; therefore data are not shown.

‡All models adjusted for age, education, employment and smoking.

§Quartile 1 corresponds to the lowest dietary pattern intake.

||Quartile 4 corresponds to the highest dietary pattern intake.

¶ $\beta$  Coefficient represents the mean difference from quartile 1.

††Obesity defined as BMI  $\geq 30$  kg/m<sup>2</sup>.

**Table 5** The relationship of dietary patterns as quartiles and BMI or obesity among non-pregnant adults (18+ years) participating in the CoASTAL cohort who plausibly reported their energy intake††

Healthy pattern	All (n 236)			
	Quartile 1§	Quartile 2	Quartile 3	Quartile 4
BMI ( $\beta$ )¶	Ref.	0.69	-0.31	2.81*
BMI (kg/m <sup>2</sup> )				
Mean	30.1 <sup>a</sup>	30.9 <sup>a</sup>	29.9 <sup>a,b</sup>	33.0 <sup>c</sup>
SD	5.7	6.7	7.5	7.6
Obesity (OR)††	Ref.	0.89	0.69	0.99
Sweet drinks pattern	Women (n 147)			
	Quartile 1§	Quartile 2	Quartile 3	Quartile 4
BMI ( $\beta$ )¶	ref.	2.09	0.60	5.07**
BMI (kg/m <sup>2</sup> )				
Mean	29.4 <sup>a</sup>	31.8 <sup>a</sup>	30.1 <sup>a,b</sup>	34.2 <sup>c</sup>
SD	6.0	6.4	7.3	8.4
Obesity (OR)††	Ref.	1.21	0.78	1.32

CoASTAL, Communities Advancing the Studies of Tribal Nations Across the Lifespan; Ref., referent category.

<sup>a,b,c</sup>Mean values within a row with unlike superscript letters were significantly different ( $P < 0.05$ ).

\* $P < 0.05$ , \*\* $P < 0.01$ .

†No significant relationship was apparent in men; therefore data are not shown.

‡All models adjusted for age, education, employment and smoking.

§Quartile 1 corresponds to the lowest dietary pattern intake.

||Quartile 4 corresponds to the highest dietary pattern intake.

¶ $\beta$  Coefficient represents the mean difference from quartile 1.

††Obesity defined as BMI  $\geq 30$  kg/m<sup>2</sup>.

moderately high consumption of a pattern dominated by foods considered to be healthy, associated with a lower BMI and risk for being obese. However, this relationship did not remain once plausibly reporting energy intake was accounted for. Also consistent with findings in other populations was the presence of an 'empty calorie' (e.g. fruit juice and sweet beverage) dietary pattern<sup>(53–55)</sup>. Although a previous study did report this pattern to be

associated with a higher BMI<sup>(55)</sup>, we did not find this association in the CoASTAL cohort.

The differences noted between the present population and findings in other populations may be methodological. The use of RRR to determine dietary patterns is a relatively new approach to determining dietary patterns in population-based studies<sup>(29)</sup>. RRR has not been used within Native American populations and applying this

**Table 6** Adjusted odds ratios of dietary patterns derived from dietary records meeting the Dietary Reference Intakes among non-pregnant adults (18+ years) participating in the CoASTAL cohort

Model‡	Total group (n 418)			Plausible rEI group (n 236)		
	Fruit & sweet drinks	Vegetables, fruit & whole grains	High fat & sugar	Vegetarian & grains	Healthy	Sweet drinks
Meeting total fat AMDR§ (OR)						
Quartile 2	3.1**	0.6	1.3	3.0	0.4*	0.5
Quartile 3	9.1***	0.9	0.9	16.0***	0.6	0.3*
Quartile 4	18.3***	0.8	0.7	59.8***	0.4*	0.5
Meeting saturated fat AMDR   (OR)						
Quartile 2	4.8**	0.9	0.8	1.7	0.6	0.5
Quartile 3	14.5***	1.4	0.6	11.2***	0.7	0.3**
Quartile 4	22.8***	1.6	0.3***	12.8***	0.7	0.3**
Meeting fibre AI¶ (OR)						
Quartile 2	0.4	0.5	1.7	1.6	0.0	0.6
Quartile 3	0.8	0.0	1.9	1.6	0.0	0.3
Quartile 4	0.9	6.1**	2.2	2.7	0.0	0.1*

CoASTAL, Communities Advancing the Studies of Tribal Nations Across the Lifespan; rEI, reported energy intake; AMDR, Acceptable Macronutrient Distribution Range; AI, Adequate Intake.

\* $P < 0.05$ , \*\* $P < 0.01$ , \*\*\* $P < 0.001$ .

‡All models adjusted for age, education, employment and smoking.

‡Quartile 1 = referent category.

§20–35% of energy intake.

|| <10% of energy intake.

¶21–38 g/d.

method to the CoASTAL cohort data set may further establish its effectiveness in deriving dietary patterns related to risk factors for chronic disease (e.g. obesity). Previously, dietary patterns have been derived using methods such as principal component analysis<sup>(54,56)</sup>. RRR and principal component analysis are both dimension reduction techniques that result in uncorrelated summary variables (e.g. dietary patterns). However, RRR has become the recommended method to use when evaluating how certain predictors (e.g. food groups) relate to a risk factor for disease (e.g. body weight) because dietary patterns are derived from predictor variables (e.g. food groups) by maximizing the amount of variation in response variables (e.g. body weight). RRR was successfully used to extract dietary patterns that predicted weight change among the cohort of the European Prospective Investigation into Cancer and Nutrition<sup>(32)</sup>. To our knowledge, most studies have used data from an FFQ or 24 h dietary recall(s) to derive dietary patterns and limited studies have used dietary records.

The noted differences from previous literature in reported associations between dietary patterns and BMI may be reflected by the cross-sectional nature of the present study. For example, the high consumers of the healthier patterns may be trying to adopt a healthier eating pattern to lose weight or prevent further weight gain<sup>(52)</sup>. These individuals may also be adopting healthier foods but not adopting recommended eating portions. Further study will need to occur to determine whether these dietary patterns are consistent and maintain the same relationship with body weight over time.

In comparison to the guidelines set for total fat, saturated fat and dietary fibre, high consumption of some of the extracted dietary patterns can be promoted for increasing

the likelihood of meeting these recommendations. For example, higher consumption of (i) the fruit and sweet drink pattern, (ii) the vegetables, fruit and whole grains pattern and (iii) the vegetarian and grains pattern were associated with a significantly higher likelihood for meeting the above recommendations. Other dietary patterns, such as the high fat and sugar pattern, were consistent with expectations. High consumption of the high fat and sugar pattern reduced the likelihood for meeting the AMDR for saturated fat.

The present study is different from other dietary pattern studies in that we accounted for plausible rEI. Dietary assessment methods will likely always have some level of error and adults' ability to accurately self-report their dietary intake may pose challenges<sup>(57,58)</sup>. In a previous study, when accounting for plausible rEI the results of the CoASTAL cohort's energy intake correlated significantly with objective measures, such as body weight and BMI<sup>(17,19)</sup>. In the present study, the amount of variation that was explained increased by 12% when limiting the sample to plausible reporters of energy intake. However, in the present study we found that the dietary patterns extracted from the CoASTAL cohort were robust and not strongly influenced by under-reporting, suggesting that dietary patterns may reduce some of the error associated with dietary assessment. The dietary patterns extracted from the total sample were similar to those patterns extracted in the plausible group. This consistency may validate the presence of these dietary patterns.

In the present study, the extracted dietary patterns are limited by the response variables that were chosen (e.g. total fat, carbohydrates, dietary fibre). These theoretically derived response variables based primarily on non-Hispanic white population groups<sup>(32–39)</sup> could be



different from Native American populations. RRR has never been used to assess the diet of a Native American population; therefore, the response variables chosen may not fully explain the variance in intake of the predictor variables (e.g. food groups) with regard to body weight. Also, we did not determine how these dietary patterns associate with current dietary recommendations for other nutrients. Meeting the recommendations for total and saturated fat and dietary fibre was evaluated because of these nutrients commonly being over- or underconsumed, respectively, in other Native populations<sup>(59–68)</sup>. The proportion meeting the dietary recommendations for other nutrients will need to be explored. Finally, many of the defined food groups are composed of foods not commonly misreported; therefore, there is less of an opportunity for under-reporting to affect our results<sup>(69)</sup>.

## Conclusions

We were not able to document a traditional food pattern in the CoASTAL cohort using RRR. This finding may mean that alternative response variables or methods are needed to describe traditional food patterns consumed today. In the present study, dietary patterns that were high in healthier foods such as vegetables or in less healthful foods such as sweetened beverages were consistently derived. These dietary patterns were also found to be significantly associated with the likelihood of meeting or not meeting the dietary recommendations for total fat, saturated fat and dietary fibre. However, with regard to meeting recommendations for body weight, further longitudinal assessment will be needed to confirm these results.

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