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Characterizing the Reproducibility and Reliability of Dietary Patterns among Yup'ik Alaska Native People

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Abstract

Food frequency questionnaire (FFQ) data can be used to characterize dietary patterns for diet-disease association studies. Among a sample of Yup'ik people from Southwest Alaska, we evaluated three previously defined dietary patterns: "subsistence foods" and market-based "processed foods" and "fruits and vegetables". We tested the reproducibility and reliability of the dietary patterns and tested associations of the patterns with dietary biomarkers and participant characteristics. We analyzed data from adult study participants who completed at least one FFQ with the Center for Alaska Native Health Research 9/2009–5/2013. To test reproducibility we conducted a confirmatory factor analysis (CFA) of a hypothesized model using 18 foods to measure the dietary patterns (n=272). To test the reliability of the dietary patterns, we used CFA to measure the composite reliability (n=272) and intraclass correlation coefficients for test-retest reliability (n=113). Finally, to test associations we used linear regression (n=637). All CFA factor loadings, except one, indicated acceptable correlations between foods and dietary patterns (r > 0.40) and model fit criteria were greater than 0.90. Composite and test-retest reliability of dietary patterns were respectively 0.56 and 0.34 for subsistence foods, 0.73 and 0.66 for processed foods, and 0.72 and 0.54 for fruits and vegetables. In the multi-predictor analysis, dietary patterns were significantly associated with dietary biomarkers, community location, age, sex, and self-reported lifestyle. This analysis confirmed the reproducibility and reliability of the dietary patterns in this study population. These dietary patterns can be used for future research and development of dietary interventions in this underserved population.

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Keywords

factor analysis; reproducibility; reliability; food frequency questionnaire; FFQ; Yupik; Alaska Native; diet; traditional foods

Introduction

The Yup'ik people of the Yukon-Kuskokwim Delta of Southwest Alaska are undergoing a transition affecting many aspects of their traditional lifestyle, including diet, which may influence health.[1–3] The traditional Yup'ik diet includes fish, marine mammals, wild birds, land mammals, and wild berries. The significant marine-based component to the diet includes high levels of eicosapentaenoic and docosahexaenoic acid (n-3 polyunsaturated fatty acids). These n-3 polyunsaturated fatty acids potentially have beneficial effects including reducing cardiovascular disease risk by lowering circulating triglycerides and inflammatory cytokines, and by increasing high-density lipoprotein cholesterol.[4,5] The current Yup'ik diet consists of a mix of traditional foods and market-based foods, with approximately a quarter of the energy intake coming from traditional foods.[6] Ongoing transition from the cardio-protective marine-based foods to more market-based foods may increase cardio-metabolic disease in this population. Research to improve understanding of associations between diet and obesity, diabetes, and cardiovascular disease will require reliable methods to measure diet in Yup'ik people.

To better understand the diet of Yup'ik people, the Center for Alaska Native Health Research (CANHR) designed a semi-quantitative food frequency questionnaire (FFQ) specifically for Yup'ik people, based on the most frequently eaten foods.[7] A single FFQ captures data on the frequency of foods usually eaten over the previous 12 months, including foods consumed only seasonally. Because many traditional foods are only eaten when they are in season, seasonal consumption is needed to capture the complete diet.

There has been increasing interest in the use of FFQ data to describe dietary patterns for studies of diet and disease associations.[8,9] Dietary patterns are created from FFQ data by combining individual foods into measures that describe groupings of foods eaten by people, and thus may better measure overall diet of individuals because specific foods are not eaten in isolation.[9] However dietary patterns can be population specific,[9] such that it is important to identify dietary patterns in a specific study population of interest, such as the Yup'ik people.

We previously used exploratory factor analysis (FA) to identify three dietary patterns among a sample of 358 Yup'ik people living in the Yukon-Kuskokwim Delta.[7] The dietary patterns described a subsistence diet as well as two distinct market-based dietary patterns, that we named processed foods and fruits and vegetables.[7] These dietary patterns were associated with participant characteristics and also validated objectively measured biomarkers of diet, as well as aligning with findings from previous research.[6,10–12] Exploratory FA uses the underlying structure of the observed data from the sample of study participants to determine the dietary patterns, and thus could vary in different samples of study participants. As such, to facilitate use of the FFQ in future studies we sought to confirm the reproducibility of the dietary patterns using confirmatory FA, an approach that builds on the exploratory FA results.[9] Additionally, we sought to test the reliability of measurement of dietary patterns over a two to three year period. Reliability over this time period should not be significantly impacted by the ongoing nutritional transition since this transition involves population-level changes over multiple years.[1,13] Biomarkers of traditional and market food intake in the Yup'ik population[11] did not change significantly over a 10 year period. Other studies have found dietary patterns to be reliable,[14–17] however evaluation of the reproducibility of dietary patterns using confirmatory FA is less common.[16,18–21] To our knowledge neither reproducibility nor reliability of dietary patterns have been reported for an Alaska Native population.

The purpose of this study was to test the reproducibility of the previously described dietary patterns in an independent sample of Yup'ik people using confirmatory FA methods and evaluate the reliability of the identified dietary patterns and specific foods collected with the FFQ. In addition, we sought to demonstrate the utility of the FFQ to determine dietary patterns by assessing associations of the dietary patterns with validated dietary biomarkers and study participant characteristics.

Methods

Study sample

This dietary study was conducted among a Yup'ik study population living in Southwest Alaska, as previously described.[7] All data were collected as part of the University of Alaska Fairbanks CANHR studies, and detailed study recruitment methods are published elsewhere.[22,23] Briefly, CANHR conducts recurring research visits to 11 communities of the Yukon-Kuskokwim Delta. Within these communities, study participants are recruited using convenience sampling methods in which all individuals who self-identify as Alaska Native or who are married to an Alaska Native descendent, are greater than 14 years of age, and are non-pregnant, are eligible to participate.

For this analysis we restricted our sample to individuals that participated in CANHR studies between September 2009 and May 2013 and self-reported their ethnicity as either Yup'ik or Cup'ik. Due to the longitudinal nature of the study, participants could have completed more than one FFQ. We started with a sample of 770 individuals who completed 916 FFQs (Figure 1). We excluded FFQs that were completed when the study participant was <18 years of age, the FFQ was determined and recorded by the interviewer to be of poor quality, when the FFQ was missing data for analyzed foods, and when the FFQ values were considered unrealistic by study staff. After applying these exclusion criteria, 750 FFQs from 637 participants were available for analysis. In a previous analysis we evaluated FFQs from 358 study participants that completed their first eligible FFQ between September 2009 and August 2011 using exploratory FA.[7] The study participants that completed their first eligible FFQ between September 2011 and May 2013 comprise our "confirmatory FA" sub-sample of participants (n=272) (Figure 1). Our "test-retest" sub-sample of participants completed more than one eligible FFQ between September 2009 and May 2013 (n=113) (Figure 1). Finally our "association study" sample includes all CANHR study participants

September 2009 to May 2013 with complete data on participant characteristics, utilizing the most recent FFQ for participants with >1 FFQ (n=637) (Figure 1).

This study was conducted according to the guidelines of the Declaration of Helsinki and all procedures involving study participants were approved by the University of Alaska Fairbanks Institutional Review Board and the Yukon-Kuskokwim Health Corporation Human Studies Committee. Written informed consent was obtained from participants prior to data collection.

Data collection

Each study participant completed an in-person interview in English or Yup'ik during which the FFQ was administered, a fasting blood sample was collected, and demographic data were obtained. Red blood cells were isolated and samples prepared to obtain the δ^{15}N and δ^{13}C stable isotope ratios at the Alaska Stable Isotope Facility as previously described.[11,12] Among Yup'ik people, δ^{15}N is strongly correlated with traditional marine intake and δ^{13}C is strongly associated with corn-based market foods.[11] Collected demographic data included location of residence (i.e., coastal or inland community), age, sex, and cultural identification (i.e., self-reported adherence to "Kass'aq" [white] and Yup'ik lifestyle). The cultural identification questions were not mutually exclusive; for example, a participant could report "a lot" for adherence to both the Yup'ik and Kass'aq lifestyle.

Dietary data were collected using the CANHR FFQ designed specifically for Yup'ik people and included the 163 mostly commonly eaten foods based on nearly 2000 24-hour food recalls from Yup'ik people. The current version of the FFQ has been used since September 2009. Participants reported how frequently they typically consumed each food during the previous 12 months, and for traditional subsistence foods it was further elicited if they ate the food seasonally or year-round. Frequency of consumption was measured on two 9-point scale groupings of frequency, one for foods and one for beverages. For both scales, the least frequent group was "never or less than once per month"; for foods the greatest frequency group was "2+ times per day" and for beverages the greatest frequency group was "6+ times per day". Serving size was not collected in order to minimize study participant burden.

We converted frequency of consumption from the 9-point scale groups to a continuous scale of annual consumption by multiplying the reported frequency of consumption to a 365 day scale. For foods potentially eaten seasonally (i.e., seal and walrus soup, non-oily fish, wild greens, and bird soup), if the participant reported eating the food seasonally, the annual consumption was calculated as the product of the annual frequency and the proportion of the year that food was typically available (as determined by cultural experts from communities). Annual frequency for each food was then transformed to the natural log scale to improve normality. Foods eaten "never or less than once per month" were changed from an annual frequency of 0.0 to 0.01 for the natural log transformation.

Statistical analysis

We used confirmatory FA to test the reproducibility of the dietary patterns (Analysis A); confirmatory FA and intraclass correlation coefficients (ICC) to test the reliability of dietary patterns (Analysis B); and Pearson correlations and linear regression to test associations of the dietary patterns with dietary biomarkers and participant characteristics (Analysis C). All analyses were conducted using SAS 9.3. Two-sided p-values <0.05 were considered statistically significant.

Reproducibility of dietary patterns (Analysis A)—FA is a data reduction method, using the correlations between observed variables (foods) to derive a smaller number of unobserved variables called factors or underlying constructs, and which we will refer to as the dietary patterns. Broadly, FA can either be categorized as exploratory or confirmatory. We previously used exploratory FA, which requires no *a priori* hypotheses about how the foods are correlated or the number of dietary patterns. In contrast, confirmatory FA requires an *a priori* hypothesis and tests a hypothesized model of directional relationships between foods and dietary patterns. We used the exploratory FA results as a basis for designing the hypothesized model to be tested using confirmatory FA. When conducting the exploratory FA we selected 22 foods from the FFQ, using a two-stage process described in detail elsewhere.[7] A list of foods used in the exploratory FA is provided in Supplemental Table 1.

We tested a confirmatory FA model with same three underlying constructs as the exploratory FA: processed foods; fruits and vegetables; and subsistence foods.[7] For this analysis, we evaluated a "confirmatory FA" sub-sample (Figure 1). We hypothesized a model in which each dietary pattern was computed from the foods with highest exploratory FA standardized loadings for that construct. However, in our exploratory FA, seven of the 22 foods did not have high standardized loadings (>0.35) for any of the three constructs. Four of these seven foods with a standardized loading <0.35 loaded most highly on the fruits and vegetables dietary pattern, even though they were inconsistent with this dietary pattern (i.e., pudding and jello, dried salmon, wild game soup, and pancakes). As such, we *a priori* elected to exclude these foods from the confirmatory FA (Supplemental Table 1). The three other foods with standardized loadings <0.35 each loaded most highly on the food group most consistent with the food item (i.e., canned tuna with processed foods, market berries in akutaq with fruits and vegetables, and bird soup with subsistence foods) and thus we *a priori* decided to include these foods in our confirmatory analysis (Supplemental Table 1).

Thus, for the confirmatory FA, a total of 18 food items were included in the hypothesized model. Specifically we hypothesized that the following foods measured each of the following dietary patterns: 1) Processed foods included: salty snacks, sweetened cereals, pizza, sweetened drinks, hot dogs and lunch meat, fried chicken, and canned tuna; 2) Fruits and vegetables included: fresh citrus, potato salad, citrus juice, corn, green beans, green salad, and market berries in akutaq; and 3) Subsistence foods included: seal or walrus soup, non-oily fish, wild greens, and bird soup. In the model specifications the three dietary patterns were allowed to be correlated. Model fit was assessed based on goodness of fit criteria (relative amount of observed variance predicted); Bentler Comparative Fit Index and Bentler-Bonett Non-normed Fit Index (relative improvements in fit of the model compared to a null model corrected for number of parameters); and the Root Mean Squared Error Approximation (degree of discrepancy per degree of freedom).[24]

Reliability of dietary patterns (Analysis B)—We evaluated the reliability of the 18 individual foods included in the confirmatory FA and the dietary patterns using two complementary approaches, confirmatory FA[25] and test-retest.[26] The confirmatory FA approach measured internal consistency from a single FFQ for each participant, whereas the test-retest approach used two FFQs administered two to three years apart from the same participant. Both measures of reliability are reported on a scale of 0 to 1, with greater values indicating better reliability than lower values.

Using confirmatory FA we calculated the indicator reliability for the individual foods and composite reliability for the dietary patterns in the “confirmatory FA” sub-sample of 272 participants (Figure 1). Factor composite reliability measures the correlation between the dietary pattern and each food hypothesized to measure the dietary pattern, and it is based on the squared standardized loadings and sum of the error variances.[27] Indicator reliability describes the percent of the variance in the food that is explained by the dietary pattern it measures and is calculated by squaring the standardized factor loadings for each food.[25]

We evaluated test-retest reliability among the 113 participants with >1 FFQ (i.e., “test-retest” sub-sample, Figure 1) using ICC,[26,28] which described the proportion of variance for each food between participants as compared to within a participant. As such, the higher the ICC, the less variation observed within the same participant. Using the test-retest sub-sample we also measured the reliability of a participant’s report of eating each of the seasonal foods year-round as compared to only in season. For this we measured reliability using the kappa statistic because seasonal consumption was characterized as yes or no.[26]

Association analyses (Analysis C)—In order to determine if the identified dietary patterns were associated with previously validated dietary biomarkers (i.e., stable isotope ratios) and demographic characteristics (e.g., age, sex) that have been reported to be associated with diet in this[6,10,11] and other indigenous arctic study populations,[29–31] we measured associations of dietary patterns with dietary biomarkers and participant characteristics. For this analysis, we used all 637 participants in our study, referred to as the “association sample” (Figure 1). Estimated dietary pattern scores indicate a participant’s frequency of consumption of foods included in that dietary pattern relative to other study participants. The greater the dietary pattern score, the greater the frequency of consumption of the foods used to measure that dietary pattern. Scores were calculated as the average of the natural log transformed frequency of consumption for each food measuring the dietary pattern (formula provided in Supplemental Table 2). Each food measuring the dietary pattern was equally weighted.[32] Although this differs from the method we used in our previous exploratory FA (scores were weighted by the factor loading of each food), we elected to use this method because the factors scores can be applied to new study participants without the need to calculate new factor loadings.[33] Dietary patterns scores were standardized with a mean of zero and standard deviation of one.

We measured Pearson correlations between each dietary pattern (based on the scores) and the dietary biomarkers $\delta^{15}N$ and $\delta^{13}C$. We also tested associations between the dietary patterns and participant characteristics (i.e., community location, age, sex, and self-reported lifestyle) using simple linear regression. Age was modeled in years as a linear term and community location and sex as binary terms. We consolidated cultural identification measures (i.e., Kass’aq [white] and Yup’ik lifestyle) into those participants reporting “not at all" or "some" in one group and "a lot" in a second group because of a small number of participants in the "not at all" group. Finally, to test for independent associations we regressed the dietary pattern score against the participant characteristics (i.e., inland community, age, male sex, and a lot for Kass'aq and Yup'ik lifestyle) using a multi-predictor linear regression model for each dietary pattern.

Results

Sample characteristics

Participants were from six coastal and four inland communities. Overall the three different sub-samples used for this analysis were similar, with the test-retest sub-sample comprising slightly older participants and a greater proportion of women (Table 1).

Natural log transformation of food frequencies improved the normality (Table 2). However, after transformation, not all foods were normally distributed, with 22% and 56% of foods with skewness and kurtosis values >1 respectively.

Reproducibility (Analysis A)

All confirmatory FA standardized factor loadings were >0.40, with the exception of sweetened cereals with a factor loading of 0.26 (Table 3). The dietary patterns were not necessarily mutually exclusive. We evaluated a number of model fit criteria to assess our measurement model. Goodness of fit, adjusted goodness of fit, Bentler Comparative Fit Index, and Bentler-Bonett Non-normed Index values were 0.93, 0.91, 0.92, and 0.91, respectively, all above the recommended threshold of 0.90.[24,25] Additionally, the Root Mean Squared Error Approximation of 0.04 was less than the recommended threshold of ≤ 0.05.[24] The confirmatory FA t-tests for all foods were >3.29 allowing us to reject the null hypothesis of factor loadings equal to zero (P<0.01).

Reliability (Analysis B)

Composite reliability, a measure of internal consistency, of dietary patterns was 0.73 for processed foods, 0.72 for fruits and vegetables, and 0.56 for subsistence foods (Table 4). In comparison, test-retest reliability, a measure of intra-individual variability, of dietary patterns was 0.66 for processed foods, 0.54 for fruits and vegetables, and 0.34 for subsistence foods (Table 4). For individual foods, indicator reliability, also a measure of internal consistency, ranged from 0.07 for sweetened cereals to 0.46 for pizza, and test-retest reliability from 0.11 for market berries in akutaq to 0.50 for sweetened drinks, with better reliability for market-based foods (Table 4). For seasonal foods, the reliability of reported consumption in season only, as compared to year-round, was 0.21 for seal or walrus soup, 0.19 for non-oily fish, 0.22 for wild greens, and 0.17 for bird soup.

Associations (Analysis C)

Calculated dietary pattern factor scores, a relative ranking across study participants of frequency of intake for foods, were approximately normally distributed (Supplemental Figure 2). The market-based factors, processed food and fruits and vegetables were correlated (r=0.57, P<0.01). The subsistence foods factor scores were weakly correlated with factor scores for processed foods (r=0.10, P=0.01) and fruits and vegetables (r=0.19, P<0.01).

Among the 628 participants with biomarker data, $\delta^{15}N$, a biomarker of marine-food intake, was significantly negatively correlated with the processed foods dietary pattern (r=−0.43, P<0.01) and fruits and vegetables (r=−0.18, P<0.01), and positively correlated with the subsistence food dietary pattern (r=0.29, P<0.01). Conversely, $\delta^{13}C$, a biomarker of corn-based foods, was positively correlated with the processed foods dietary pattern (r=0.29, P<0.01) and fruits and vegetables (r=0.13, P<0.01), but was not correlated with subsistence foods.

In single-predictor linear regression analyses, greater relative frequency of processed foods was significantly associated with living in an inland community, being of younger age, male sex, reporting "a lot" for Kass'aq (white) lifestyle and "not at all/some" for Yup'ik lifestyle (Table 5). All associations remained independently significant in the multi-predictor linear regression analysis except male sex and "not at all/some" for Yup'ik lifestyle. Similar associations were observed for the other market-based dietary pattern; greater relative frequency of fruit and vegetable consumption was significantly associated with living in an inland community and being of younger age (Table 5). In the multi-predictor linear regression analysis, community location and age remained independently associated with fruits and vegetables and sex became significant (significance was borderline based on single-predictor model). In contrast, greater relative frequency for the subsistence dietary pattern was associated with living in a coastal community, being of older age, reporting "not at all/some" for Kass'aq lifestyle, and "a lot" for Yup'ik lifestyle (Table 5). In the multi-predictor analysis, community location, and lifestyle characteristics remained independently associated.

Discussion

We confirmed both the reproducibility and reliability of the processed foods, fruits and vegetables, and subsistence foods dietary patterns identified from FFQs in this Yup'ik study population. Moreover, the observed associations between dietary patterns and participant characteristics and dietary biomarkers aligned with findings from our previous exploratory FA[7] and other studies in indigenous arctic populations using other measures of diet.[6,10,11,29–31] Taken together, these results demonstrate the utility of the FFQ to measure these dietary patterns in Yup'ik people for use in future research.

Measures of the confirmatory FA model fit were acceptable and the hypothesized relationships based on the exploratory FA were significant, suggesting that our model of the three dietary patterns identified from our previous exploratory FA analysis is consistent with the data in the new sample.

The foods measuring the market-based dietary patterns had higher factor loadings than the foods measuring the subsistence foods dietary pattern, an indication that we are better able to measure the market-based dietary patterns. However, only one of the 18 foods (sweetened cereals) did not appear to be a good measure of the dietary pattern it was hypothesized to measure based on the exploratory factor analysis. Finally, the dietary patterns we identified align well with other studies of dietary patterns in Alaska Native people and relatively well with an American Indian population and other global populations. Four dietary patterns were identified among Inupiat Eskimos, the “traditional” dietary pattern with similar foods to our subsistence foods pattern, a “purchased healthy” dietary pattern which was similar to our fruits and vegetables dietary pattern, and the “western” and “beverages and sweets” dietary patterns which together were similar to our processed foods dietary pattern.[34] Similarly a study of American Indians identified four dietary patterns, “western”, “traditional”, “healthy”, and “unhealthy”.[35] The “western” and “unhealthy” dietary pattern foods were similar to those included in our processed foods dietary pattern; the “healthy” pattern included foods in our fruits and vegetables dietary pattern but also included fish which was included in our subsistence foods pattern; and finally the “traditional” dietary pattern which included dry beans, Mexican foods, stews, etc. likely captured similar lifestyle aspects as our subsistence pattern but did not include any overlap in foods.[35] More broadly the “prudent” and the “western” diet are commonly reported in the literature[36]; of these our fruits and vegetables dietary pattern somewhat aligns with the prudent and our processed food pattern with the western diet. The INTERHEART study of acute myocardial infarction in 52 countries similarly found a dietary pattern comparable to the “prudent” and “western” dietary pattern, but also identified a distinct “oriental” dietary pattern.[37] In this Yup’ik population our processed foods and fruits and vegetables dietary patterns are consistent with dietary patterns found in other populations, but the subsistence dietary pattern is more unique to Alaska Native people.

Overall composite and test-retest reliability of dietary patterns from this FFQ were sufficient to be useful for future research in this population. Our two to three year test-rest reliability, particularly for the market-based dietary patterns (0.66 for processed foods and 0.54 for fruits and vegetables), was not dissimilar from the 0.63 to 0.73 range in reliability reported in studies of one year reliability.[14,17] In our study, composite reliability was more similar across the three dietary patterns and higher than the test-retest reliability, while test-retest reliability varied across the three dietary patterns. Test-rest reliability was greatest for processed foods, followed by fruits and vegetables, and finally subsistence foods. There are a number of possible reasons for this discrepancy. By evaluating test-retest reliability using FFQs administered two to three years apart, we measured the reliability of diet pattern analysis over the longer term; however in such analyses it is difficult to differentiate measurement error from true changes in diet. For example, the availability of fruits and vegetables in the market might be a result of seasonality and the difficulty of stocking perishable foods, while subsistence food availability can depend on environmental factors such as fish runs, migration patterns, ice pack, weather, and regulatory restrictions.[38] In contrast, the availability of processed foods such as snacks and cereals is likely to be more consistent throughout the year. It is also possible that the lower test-retest reliability for the subsistence foods could be a result of greater error in measurement of seasonally consumed foods. That is, when participants reported subsistence foods intake, they were asked whether the food was eaten year-round or only in season, a distinction that may have been too coarse or too confusing to participants to accurately capture intake. For example, a participant might preserve food to be eaten year-round, but the food did not last the full year. The challenge of measuring if foods were eaten year-round or only in season was further highlighted by the weak test-retest reliability for the seasonal consumption question (ranging from 0.17 to 0.22).

Indicator reliability for foods was similar, irrespective of the dietary pattern that the food measured. This is an indication that the strength of the various foods measuring each of the dietary patterns were similar, and thus that the foods measuring a particular dietary pattern were not substantially better at measuring that dietary pattern. In contrast, test-retest reliability was generally better for foods measuring the market-based dietary patterns, particularly processed foods, as compared to those foods measuring the subsistence food dietary pattern. Reasons for the lower test-retest reliability, particularly for subsistence foods, are probably similar to those influencing the dietary patterns as described above.

We observed a correlation between usual diet over the previous 12 months based on dietary patterns and diet over the previous two to three months, as measured by the stable isotope biomarkers. The nitrogen isotope ratio ($\delta^{15}N$), a validated biomarker of traditional marine food intake[11,12] was correlated with the subsistence food dietary pattern, but the correlation was weaker than expected based on previous studies.[11] This is likely because widely-consumed traditional marine foods, such as salmon, have a large effect on $\delta^{15}N$, but are not included in the subsistence food dietary pattern. Salmon was not included in our subsistence food dietary pattern because it did not load highly when we conducted the two-stage exploratory factor analysis.[7] This is likely because salmon is so frequently eaten by the entire population that it does not differentiate individual dietary consumption. The weaker correlation between the subsistence dietary pattern and $\delta^{15}N$ could also be the result of the error in measuring the subsistence foods with the FFQ as described above. The carbon isotope ratio ($\delta^{13}C$) was correlated with the processed foods dietary pattern and was elevated in many of the same foods (market meats, sweetened beverages, and corn-based cereals).

Use of objective biomarkers and the dietary patterns together could be valuable because dietary patterns can capture a more complete picture of the diet whereas biomarkers are more objective. Moreover, FFQs and stable isotope biomarkers measure diet over different time periods and are subject to different types of measurement error (e.g., recall bias versus laboratory error). The observed correlations between the validated stable isotope biomarkers and our dietary patterns provided us further confidence in the dietary patterns. However, in this study population no comparable biomarker of fruit and vegetable intake is available, so the fruit and vegetable dietary pattern is currently our best measure of this component of the diet. This highlights one of the advantages of the FFQ, that it measures a variety of foods for which biomarkers are not currently available. Depending on the research question of interest, it would be possible in this study population to reduce participant burden by either using a FFQ targeted specifically to fruit and vegetable intake or a FFQ collecting only the 18 foods used to measure the dietary patterns. However such an approach would not allow for measuring the diversity of the Yup'ik diet. If such a change were made to study protocols, additional studies should be conducted to ensure that the modified FFQ captured the same data as the full FFQ, e.g., to capture accurate intake of market berries in akutaq is it necessary to also ask about wild berries in akutaq.

The associations we observed between dietary patterns and demographic characteristics aligned well with other studies among indigenous arctic populations, including Yup'ik people. For example, a number of other studies reported an association between older age and greater consumption of traditional or subsistence foods.[6,10,11,29–31] We further observed an association between greater frequency of consumption of subsistence foods and living in a coastal community, an association observed in a Yup'ik population using both 24-hour food recalls and isotopic biomarkers.[6,11] The association between sex and subsistence food intake is inconsistent across studies in arctic indigenous populations,[11,29,30] however our finding of no association between sex and subsistence food frequency of consumption aligns with another study of Yup'ik people.[6] The observed associations between dietary patterns and participant characteristics using the full cohort were similar to those based on our exploratory FA study sample.[7] The majority of differences we observed were significant associations that were not significant in our smaller exploratory FA sample, specifically the associations of: processed foods with community location and sex; fruits and vegetables with age and sex; and subsistence foods with Kass'aq lifestyle. The consistency of associations between diet and demographic characteristics from our study and other studies in arctic indigenous populations as well as our previous exploratory FA analysis[7] further strengthens our confidence that we are capturing actual dietary patterns among Yup'ik people with this FFQ.

Strengths of this study include the use of FFQ data consistently collected since 2009 in a longitudinal cohort of Yup'ik study participants from inland and coastal communities. As such, we were able to rigorously test the dietary patterns we previously identified with exploratory FA in a new, but similar, study sample using confirmatory FA. Furthermore we were able to compare the dietary patterns with validated objectively measured biomarkers of diet. This study was also subject to limitations. Data collection involved convenience sampling, potentially limiting generalizability. Participants living in the same households were not excluded, and diet may be correlated among these individuals, potentially impacting factor loadings. Although our study sample size was limited, the confirmatory factor analysis included more than five participants for each parameter being estimated as recommended.[27] Further, the test-retest analysis had an adequate sample to measure the ICC with a two-sided alpha of 0.05 and power of 0.80 assuming an ICC of 0.60 and a minimally acceptable ICC of 0.40.[26] The FFQ used in the analysis has not been validated due to the challenge of obtaining a gold standard to compare against. Twenty-four hour food recalls, frequently used for validation studies are expensive and logistically challenging to obtain in this population during all seasons because of the inaccessibility and remoteness of communities. In addition, the FFQ we used did not capture serving size so that it is not possible to determine percent energy for food groups or specific nutrients. In our association analysis we compared 30 associations – these should be cautiously interpreted due to the potential for inflated type one errors. Finally, all food frequency data were collected using the same FFQ, and thus there is potential for systematic error violating the confirmatory FA assumption of no correlated errors between foods.

In conclusion, we confirmed the reproducibility and reliability of the three dietary patterns in this Yup'ik study population using FFQ data. Measures of model fit were acceptable and structural relationships were significant, suggesting that our hypothesized confirmatory factor analysis model of dietary patterns fit this new sample of Yup'ik people. Reliability, both composite and test-retest, was acceptable, an indication that the dietary patterns were stable over a multi-year period. Therefore, these dietary patterns will be useful for current pharmacogenetic and cardio-metabolic research as well as future research and development of dietary interventions in this underserved population.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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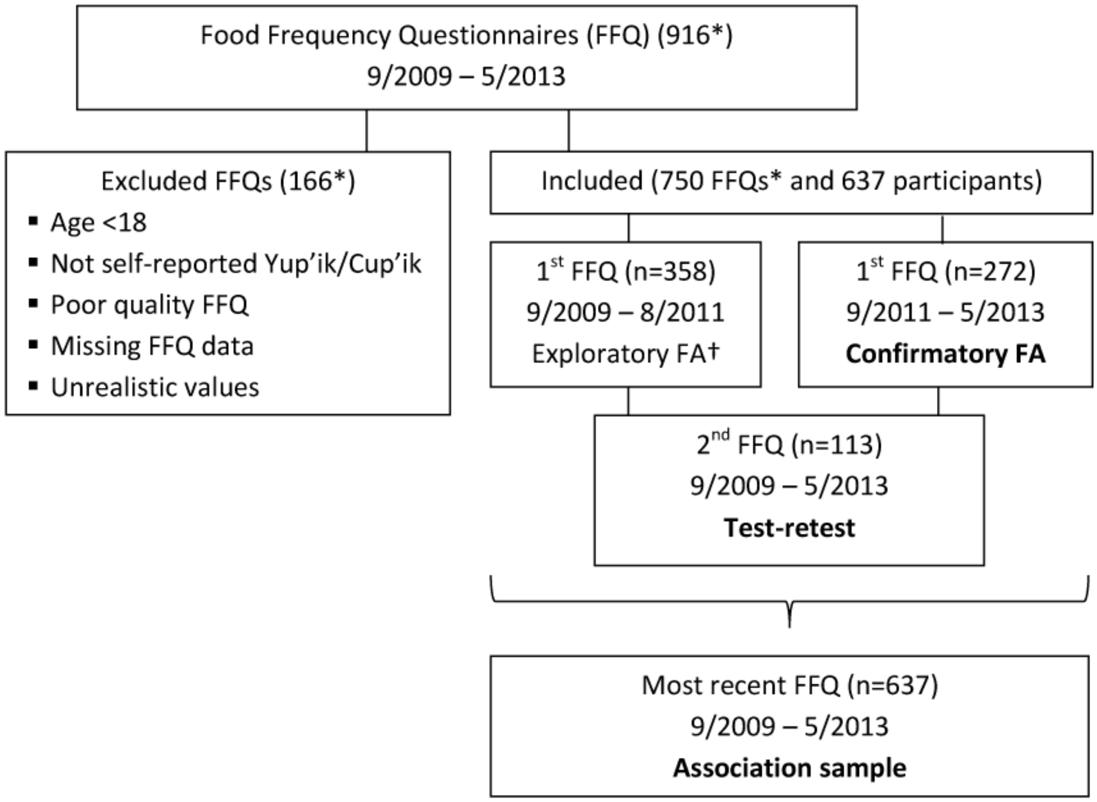

FIGURE 1.

Numbers of Food Frequency Questionnaires (FFQ) collected, numbers of participants, and dates of data collection for each of the three analyses: Confirmatory Factor Analysis (FA); Test-retest; and Association study.

*The number of FFQs is greater than the number of study participants since some participants completed >1 FFQ. These values are numbers of FFQs, not participants, participants are indicated using (n=) notation.

†Published elsewhere[(7)] (note: exclusion criteria differ slightly from current analysis)

TABLE 1

Characteristics of Yup'ik study participants included in confirmatory factor analysis, test-retest reliability analysis, and full cohort association analysis, by community location.

	All communities	Coastal communities	Inland communities
Confirmatory Factor Analysis (September 2011–May 2013)			
Sample size	272	176	96
Median age in years (25th–75th %tile)	33.0 (22.0–51.5)	29.0 (21.0–50.5)	34.5 (23.0–52.0)
Sex (% male)	52.9	52.8	53.1
Kass'aq (white) lifestyle (%)*			
Missing	0.4	0.6	0.0
Not at all/some	81.3	84.1	76.0
A lot	18.4	15.3	24.0
Yup'ik lifestyle (%)*			
Missing	0.7	0.6	1.0
Not at all/some	45.6	47.2	42.7
A lot	53.7	52.3	56.3
Test-retest (September 2009–May 2013)			
Sample size	113	83	30
Median age in years at FFQ1 (25th–75th %tile)	43.0 (29.0–58.0)	43.0 (26.0–62.0)	45.0 (33.0–52.0)
Median age in years at FFQ2 (25th–75th %tile)	45.0 (32.0–60.0)	45.0 (28.0–64.0)	47.0 (35.0–54.0)
Sex (% male)	38.9	37.4	43.3
Kass'aq (white) lifestyle (%)*			
Missing	0.0	0.0	0.0
Not at all/some	82.3	80.7	86.7
A lot	17.7	19.3	13.3
Yup'ik lifestyle (%)*			
Missing	0.9	1.2	0.0
Not at all/some	44.3	43.4	46.7
A lot	54.9	55.4	53.3
Association Study (September 2009–May 2013)			
Sample size	637	389	248
Median age in years (25th–75th %tile)	37.0 (23.0–54.0)	37.0 (23.0–54.0)	38.0 (23.5–54.0)
Sex (% male)	46.2	46.0	46.4
Kass'aq (white) lifestyle (%)*			
Missing	0.3	0.3	0.4
Not at all/some	82.4	81.2	84.3
A lot	17.3	18.5	15.3
Yup'ik lifestyle (%)*			
Missing	0.6	0.8	0.4
Not at all/some	45.5	47.3	42.7

	All communities	Coastal communities	Inland communities
A lot	53.9	51.9	56.9

*self-reported

TABLE 2

Mean, median, 25th percentile (%tile), and 75th percentile (%tile) of the untransformed and natural log transformed annual frequency of consumption for each of the 18 foods included in the confirmatory factor analysis (n=272), Yup'ik study participants, September 2009 – May 2013

	Untransformed values				Natural log transformed values			
Foods	**Mean**	**Median**	**25th %tile**	**75th %tile**	**Mean**	**Median**	**25th %tile**	**75th %tile**
Processed foods								
Salty snacks	60.52	30.00	12.00	104.35	1.88	3.40	2.48	4.65
Sweetened cereals	46.92	12.00	0.00	52.18	0.51	2.48	−4.61	3.95
Pizza	29.13	12.00	0.00	30.00	0.50	2.48	−4.61	3.40
Sweetened drinks	257.68	78.27	24.00	365.00	3.23	4.36	3.18	5.90
Hot dogs and lunch meat	36.66	12.00	0.00	30.00	1.31	2.48	−4.61	3.40
Fried chicken	21.29	12.00	0.00	30.00	0.47	2.48	−4.61	3.40
Canned tuna	10.00	0.00	0.00	12.00	−1.81	−4.61	−4.61	2.48
Fruits and vegetables								
Fresh citrus	35.02	12.00	0.00	30.00	1.35	2.48	−4.61	3.40
Potato salad	13.01	0.00	0.00	12.00	−1.06	−4.61	−4.61	2.48
Citrus juice	61.36	24.00	0.00	78.27	0.31	3.18	−4.61	4.36
Corn	67.11	30.00	12.00	104.35	2.48	3.40	2.48	4.65
Green beans	45.23	30.00	0.00	52.18	1.46	3.40	−4.61	3.95
Green salad	13.12	0.00	0.00	12.00	−2.00	−4.61	−4.61	2.48
Market berries in akutaq†	18.64	12.00	0.00	12.00	−0.54	2.48	−4.61	2.48
Subsistence foods								
Seal or walrus soup‡	25.56	12.00	0.00	30.00	0.98	2.48	−4.61	3.40
Non-oily fish (not dried)‡	19.38	3.96	0.00	14.61	−0.13	1.38	−4.61	2.67
Wild greens‡	7.46	0.00	0.00	5.10	−1.58	−4.61	−4.61	1.63
Bird soup‡	38.96	26.09	7.50	45.65	1.88	3.26	2.01	3.82

† Traditional dessert commonly made with berries, Crisco, sugar and sometimes fish

‡ Seasonal food items

TABLE 3

Confirmatory factor analysis standardized factor loadings for foods used to estimate dietary patterns (n=272), Yup'ik study participants, September 2011–May 2013

Foods	Processed foods	Fruits and vegetables	Subsistence foods
Salty snacks	0.64	0	0
Sweetened cereals	0.26	0	0
Pizza	0.68	0	0
Sweetened drinks	0.57	0	0
Hot dogs and lunch meat	0.56	0	0
Fried chicken	0.47	0	0
Canned tuna	0.45	0	0
Fresh citrus	0	0.53	0
Potato salad	0	0.60	0
Citrus juice	0	0.53	0
Corn	0	0.55	0
Green beans	0	0.55	0
Green salad	0	0.44	0
Market berries in akutaq*	0	0.43	0
Seal or walrus soup†	0	0	0.57
Non-oily fish (not dried)†	0	0	0.45
Wild greens†	0	0	0.48
Bird soup†	0	0	0.47

*Traditional dessert typically made from a combination of berries, sugar, and fat (historically seal oil and now primarily Crisco)

†Seasonal food items

TABLE 4

Reliability of dietary patterns and foods used to estimate dietary patterns, Yup'ik study participants. Composite reliability of dietary patterns and indicator reliability of foods based on confirmatory factor analysis (September 2011–May 2013). Test-retest reliability of dietary patterns and foods measured using intraclass correlation coefficients (September 2009–May 2013).

Dietary patterns Foods	Confirmatory Factor Analysis* (n=272)	Test-retest† (n=113)
Processed foods	0.73	0.66
Salty snacks	0.41	0.40
Sweetened cereals	0.07	0.41
Pizza	0.46	0.46
Sweetened drinks	0.32	0.50
Hot dogs and lunch meat	0.32	0.33
Fried chicken	0.23	0.25
Canned tuna	0.20	0.45
Fruits and vegetables	0.72	0.54
Fresh citrus	0.28	0.36
Potato salad	0.36	0.41
Citrus juice	0.28	0.34
Corn	0.31	0.33
Green beans	0.30	0.31
Green salad	0.20	0.32
Market berries in akutaq‡	0.18	0.11
Subsistence foods	0.56	0.34
Seal or walrus soup£	0.33	0.25
Non-oily fish (not dried)£	0.20	0.24
Wild greens£	0.23	0.22
Bird soup£	0.22	0.32

*Composite reliability of dietary patterns (i.e., internal consistency of foods measuring the dietary pattern) and indicator reliability of foods (i.e., the percent of the variance in the food explained by the dietary pattern)

†Values are intraclass correlation coefficients

‡Traditional dessert typically made from a combination of berries, sugar, and fat (historically seal oil and now primarily Crisco)

£Seasonal food items

TABLE 5

Associations between natural log transformed dietary pattern scores and Yup'ik study participant characteristics, single-predictor models include only the participant characteristic and multi-predictor models are adjusted for the other study participant characteristics (n=637), Yup'ik study participants, September 2009–May 2013.

	Processed foods				Fruits and vegetables				Subsistence foods			
	Single-predictor		Multi-predictor (R^2=0.31)		Single-predictor		Multi-predictor (R^2=0.08)		Single-predictor		Multi-predictor (R^2=0.14)	
	β	***P***	β	***P***	β	***P***	β	***P***	β	***P***	β	***P***
Inland community	0.29	<0.01	0.31	<0.01	0.34	<0.01	0.35	<0.01	−0.53	<0.01	−0.56	<0.01
Age (1 year)	−0.90	<0.01	−0.03	<0.01	−0.34	<0.01	−0.01	<0.01	0.18	0.02	0.00	0.98
Male sex	0.17	0.03	0.10	0.12	−0.15	0.05	−0.18	0.02	0.04	0.58	0.04	0.55
A lot for Kass'aq lifestyle*	0.58	<0.01	0.36	<0.01	0.17	0.11	0.12	0.23	−0.32	<0.01	−0.25	0.01
A lot for Yup'ik lifestyle†	−0.43	<0.01	−0.09	0.22	−0.02	0.80	0.12	0.13	0.49	<0.01	0.49	<0.01

*n=635 due to missing data

†n=633 due to missing data