# Environmental Food Imbalance: The Neighborhood Context of Body Mass Index (BMI) Among Cowlitz American Indians

By

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## ABSTRACT

*Objectives.* We used the Retail Food Environment Index (RFEI) to evaluate the relationship between neighborhood food imbalance and obesity among Cowlitz American Indians (AIs) and non-Hispanic white residents of Washington State.

*Methods.* We examined adult Cowlitz AIs (n = 339) and adult white Washingtonians (n = 15,930) using a Behavioral Risk Factor Surveillance System (BRFSS) telephone survey and the 2010 Washington BRFSS. We defined obesity as BMI ≥ 30 kg/m$^2$ using self-reported height and weight. For each residential ZIP Code neighborhood, RFEI scores were calculated as the total number of limited service restaurants and convenience stores divided by the total number of grocery stores, produce vendors, and farmers markets. We used logistic regression to analyze the relationship between neighborhood food imbalance (RFEI ≥ 4.0) and obesity.

*Results.* The odds ratio for obesity in imbalanced versus balanced neighborhood food environments was 1.83 among Cowlitz AIs (95% CI = 1.12, 3.00) and 1.19 among white Washingtonians (95% CI = 1.07, 1.33). Neighborhood food imbalance was more strongly associated with obesity in moderately low poverty neighborhoods.

*Conclusions.* Neighborhood food imbalance may contribute to obesity in Cowlitz AIs, and warrants further investigation in other AI groups.

# INTRODUCTION

The obesity epidemic in the United States requires solutions that extend beyond promoting healthy food consumption and physical activity at the individual level.[1,2] Healthy People 2020 highlights the importance of social determinants of health and emphasizes neighborhood food environment as a key contributor to obesity.[3] Neighborhood prevalence of food-outlets such as supermarkets, produce markets, and farmers markets, may lower the risk of obesity,[2,4-11] while easy access to fast food restaurants and convenience stores may contribute to weight gain.[4,8,12-18] A growing body of literature suggests healthy and unhealthy neighborhood food-outlets are inequitably distributed according to income and race/ethnicity across the United States; residents of low-income and minority neighborhoods have limited access to supermarkets[19-28] and greater exposure to fast food and convenience outlets.[22,27,29-41] The distribution of known obesity risks is similarly inequitable, with the greatest burden of disease ultimately born by vulnerable populations.[2]

Among racial/ethnic minority groups with low socioeconomic position (SEP), American Indians and Alaska Natives (AIANs) may be especially vulnerable to health risks associated with food environment. Despite the federal trust obligation to ensure health and decency for AIAN people, age-adjusted mortality among AIANs has increased since the mid-1980s, in absolute terms and relative to white Americans.[42] These trends relate fundamentally to the problem of obesity and sequelae such as diabetes[a,43] and cardiovascular disease (CVD).[b,44] In addition, 23 percent of AIAN households are food insecure, compared to 15 percent of all U.S. households.[45]

Over the past several decades, AIANs have relocated to areas outside land reservations and tribal areas known as "Indian Country" – by force (federal relocation and termination policies) and by choice.[46] AIANs living outside Indian Country (78 percent of the AIAN population)[c,47] struggle

[a] AIANs have the highest rate of diabetes in the nation and one of the highest rates of diabetes in the world.

[b] CVD is the leading cause of death in AIAN communities.

[c] American Indian and Alaska Native alone or in combination (5.2 million).

with a combination of individual and intergenerational stressors resulting from significant lifestyle changes, cultural disruption, and poor access to education, employment, and health services. [46,48,49] This group may also face disproportionate exposure to unhealthy food environments.

Previous research has emphasized "access" (i.e. distance) to, and "availability" (i.e. number or density) of, specific types of food-outlets in neighborhood settings; however, measuring the *relative* prevalence of different food-outlets may be more germane to the American situation where traditional "food deserts" are in fact rare.[d, 4] Recent studies have used a ratio measure called the Retail Food Environment Index (RFEI) to characterize neighborhood food *imbalance* (i.e. greater relative prevalence of unhealthy food-outlets) and its association with obesity. [50-52] No prior research, however, has investigated the impact of neighborhood food environment (food-outlet access, availability, imbalance, or otherwise) on health outcomes in AIAN people. In this study, we examined the association between neighborhood food imbalance and obesity using RFEI scores in a group of American Indians (AIs) living outside Indian Country in Washington State; as means of comparison, we evaluated the same relationship in non-Hispanic white Washingtonians.

## METHODS

### *Study Populations*

Cowlitz American Indians (AIs) are a non-reservation-based tribe that gained federal recognition in 2000. The Cowlitz Tribe consists of roughly 3,000 members; 78 percent live in Washington State. Eligible Cowlitz participants were adult (at least 18 years old) members of the official tribal roster residing in Washington State (n = 1397) with a working telephone number (including land-line and cell phone numbers). Eligible white Washingtonian participants were adults (at least 18 years old) who self-identified as white and not Hispanic/Latino and participated in the 2010 Washington Behavioral Risk Factor Surveillance System (BRFSS).[53]

[d] The 2008 Farm Bill defined a food desert as an "area in the United States with limited access to affordable and nutritious food." In a study conducted by the USDA, only 2.2 percent of American households were located more than one mile from a supermarket without access to a vehicle.

*Cowlitz BRFSS Project*

We surveyed members of the Cowlitz Indian Tribe in 2009 and 2010 using an adapted BRFSS questionnaire (Cowlitz BRFSS Project).[e] Using a pre-tested script,[f] we attempted to contact all eligible tribal members with a maximum of three calls and one telephone message. Those who completed the survey received five dollars compensation.

The study protocol was approved by Institutional Review Boards at Northwest Portland Area Indian Health Board (NPAIHB) and Oregon Health and Science University (OHSU), as well as by Cowlitz tribal leadership. Researchers were committed to a community-based participatory research (CBPR) process. Cowlitz health administrators served as primary decision-makers to ensure that tribal values and objectives were appropriately represented and outcomes were directly usable by the tribal community. A community advisory board provided feedback and support for this manuscript.

*Washington State BRFSS*

Data for white Washingtonians were obtained from the 2010 Washington BRFSS through a cooperative agreement with the Washington State Department of Health (WSDOH).[g] The data were collected using a disproportionate stratified random sampling method. Study procedures are described on the WSDOH website.[53]

*Individual-level Measures*

Self-reported height and weight were used to calculate body mass index (BMI), dividing weight (kilograms) by height-squared (meters). We defined obesity (the primary outcome variable) as BMI

[e] 87% of questions were taken from the 2005 Suquamish BRFSS Project Questionnaire, which was previously modified from a standard BRFSS survey to address issues relevant to AIAN populations in the Pacific Northwest. Questions regarding healthcare access were drawn from the 2005 Oregon Health Care Survey (Office of Oregon Health Policy Research and Portland State University).

[f] The Cowlitz BRFSS Project questionnaire was pre-tested on Cowlitz members working in tribal health administration to ensure coherency and cultural appropriateness.

[g] Washington State Department of Health, Center for Health Statistics, Behavioral Risk Factor Surveillance System, supported in part by Centers for Disease Control and Prevention, Cooperative Agreement U58/CCU002118- 1 through 17 (1987-2003), U58/CCU022819-1 through 5 (2004-2008), U58 DP001996-1 through 2 (2009-2010), or U58/SO000047-1 through 3 (2011-2013).

greater or equal to 30 kg/m$^2$.[54] We also collected data on potential individual-level confounders of the relationship between neighborhood food imbalance and obesity, including demographic factors (age, sex, education level, household poverty level, and relationship status) and behavioral factors (exercise frequency per month and smoking tobacco status). Categories for education level, relationship status, exercise frequency per month, and smoking tobacco status were derived from standard BRFSS questions. Household poverty level was categorized using self-reported house size, household income categories (defined by BRFSS questions), and 2010 federal poverty guidelines.[55]

*Neighborhood Food Environment*

We defined neighborhoods as Zip Code Tabulation Areas[h] corresponding to the five-digit U.S. Postal ZIP Code reported by survey participants. There is evidence that associations between indices of neighborhood food environment and BMI are robust to changes in geo-spatial definitions of neighborhood;[56] however, community members tend to define their neighborhoods more broadly than census block groups,[57] and Zip Codes/ZCTAs have been used to approximate neighborhoods in previous studies of food environment.[2,28,32,33,58]

To calculate RFEI scores (the primary predictor variable), we collected food-outlet data for all ZIP Codes in Washington State using U.S. Census ZIP Code Business Pattern (ZBP) tables.[59] We tabulated food-outlets by type using the North American Industry Classification System (NAICS).[i] RFEI for each neighborhood was the total number of limited service restaurants (NAICS 722211), convenience stores (NAICS 445120), and gasoline stations with convenience stores (NAICS 447110), divided by the total number of supermarkets and other grocery stores (NAICS 445110), fruit and vegetable markets (NAICS 445230), and farmers markets. Farmers market data were obtained from the Washington State Farmers Market Association (WSFMA) website.[60] Consistent with prior methods,[51] if no supermarkets, produce stores, or farmers markets were found within a

[h] U.S. Census-drawn polygon approximations of U.S. Postal Service ZIP Codes.

[i] ZBP data were collected in 2009 from the Business Register and released in 2011. Automated and analytical edits removed data anomalies and validated geographic coding, addresses, and industry classification.

neighborhood, we added a constant of one to the denominator to preserve the observation in our analyses. We did not intend to capture a linear relationship between RFEI scores and BMI. Consequently, we dichotomized the RFEI variable at the median value of 4.0, and defined food imbalance as RFEI scores greater or equal to 4.0 and food balance as RFEI scores less than 4.0.

*Neighborhood-level Measures*

To independently assess the relationship between food imbalance and obesity, we evaluated three neighborhood-level variables for potential confounding and interaction effects: ZCTA population density (population per square mile of land), the percent of each ZCTA population living below federal poverty level (FPL), and rural/urban classification using Zip Code Rural-Urban Commuting Area (RUCA) codes. We obtained ZCTA population density and ZCTA percent poverty data from the 2010 U.S. Census and categorized these variables according to prior precedent.[61,62] RUCA codes were downloaded from the Washington, Wyoming, Alaska, Montana, and Idaho (WWAMI) Rural Health Research Center website.[63] The ZCTA percent poverty variable was intended to control for unobservable characteristics associated with SEP.[61,64]

*Data Analyses*

We tested for demographic, behavioral, and neighborhood differences between Cowlitz AIs and white Washingtonians using chi-square tests and student t tests. For continuous variables, we compared weighted means from the 2010 Washington BRFSS dataset to raw means from the Cowlitz BRFSS Project dataset; for categorical variables, we compared weighted proportions from the 2010 Washington BRFSS dataset to raw proportions from the Cowlitz BRFSS Project dataset. We tested for associations between RFEI and obesity using simple and multivariate logistic regression. Performing parallel analyses in the Cowlitz AI and white Washingtonian datasets, we looked systematically for individual variables and combinations of variables that changed the bivariate relationship between food imbalance and obesity by greater or equal to 10 percent (i.e. confounding effects). We also checked for interactions between RFEI and each independent variable (age, sex,

education, household poverty level, relationship status, exercise per month, smoking tobacco status, poverty in neighborhood, RUCA, population density); however, the sample size was too small to reliably evaluate interaction terms in the Cowlitz AI dataset. We defined a primary final model inclusive of RFEI and confounding variables in either dataset. We also created a model inclusive of all independent variables. We applied both models to both datasets to estimate the odds ratio of obesity in imbalanced versus balanced neighborhood food environments. We tested and found negligible intraclass correlations within neighborhoods where Cowlitz AIs reside (rho < 0.001), and consequently, did not pursue random effects modeling. All analyses were conducted using Stata/IC version 12.1 (StataCorp LP, College Station, TX).

## RESULTS

Telephone numbers for 34 percent of 1397 eligible Cowlitz participants were unavailable, invalid, or disconnected (Figure 1). The overall response proportion was 37 percent. The response proportion was 85% among Cowlitz members successfully contacted. By comparison, BRFSS telephone surveys across 53 states and territories achieved a median response proportion of 41 percent (range: 22 to 63 percent); however, 95 percent of households in these studies had telephone coverage. [65]

We excluded Cowlitz AIs (n = 3) and white Washingtonians (n = 774) missing BMI data. One tribal member excluded for missing BMI data lived in a balanced neighborhood food environment, two lived in imbalanced neighborhood food environments. Of white Washingtonians excluded for missing BMI data, 47 percent lived in balanced neighborhood food environments, 53 percent lived in imbalanced neighborhood food environments. We also excluded participants living in ZCTAs missing food-outlet data, which were used to calculate RFEI scores. No tribal members excluded due to missing RFEI data were obese (n = 3). Of white Washingtonians excluded for missing RFEI data (n = 199), 27.7 percent were obese and 72.3 percent were not obese. No other missing data served as grounds for exclusion, and the final samples of Cowlitz AIs and white Washingtonians were 331 and 15930 participants, respectively.

Cowlitz AIs lived in 149 ZCTA neighborhoods; median land area of Cowlitz AI neighborhoods was 56.4 square miles (10 to 90 percent range: 6.0 to 193.5 square miles). White Washingtonians lived in 553 ZCTA neighborhoods with median neighborhood land area of 46.6 square miles (10 to 90 percent range: 5.7 to 447.2 square miles).

Cowlitz AIs differed from white Washingtonians with respect to several demographic, behavioral, and neighborhood characteristics; only sex distribution and relationship status were similar between the two groups (Table 1). Compared to white Washingtonians, Cowlitz AIs were older, had lower educational attainment, earned lower household income, and were more likely to currently or formerly smoke tobacco. The proportion of Cowlitz households meeting federal poverty criteria was more than double the proportion of white Washingtonians. Although a significantly larger percentage of Cowlitz AIs were obese, a greater proportion reported exercising monthly. A smaller percentage of Cowlitz AIs lived in low poverty (i.e. wealthy) neighborhoods – proportionally more lived in neighborhoods with moderately low poverty. Cowlitz AIs more frequently lived in rural neighborhoods and neighborhoods with moderately low population density.

We found no significant difference between the overall percentage of Cowlitz AIs and white Washingtonians exposed to imbalanced neighborhood food environments (Table 1); however, the patterning of neighborhood food imbalance in Cowlitz AIs differed from white Washingtonians (Table 2). Impoverished Cowlitz members appeared more likely to experience neighborhood food imbalance than tribal members with higher household incomes, though these differences did not reach statistical significance (Table 2; household poverty level stratified by RFEI). Food imbalance was most concentrated in moderately low poverty neighborhoods (Table 2; poverty in neighborhood stratified by RFEI), where proportionately more Cowlitz AIs reside. Among Cowlitz AIs, *balanced* neighborhood food environments more often coexisted with high neighborhood poverty; this trend was reversed in white Washingtonians (Table 2; poverty in neighborhood stratified by RFEI). In

both groups, those exposed to food imbalance were more likely to live in urban neighborhoods and neighborhoods with moderately high population density.

The primary final model contained the RFEI variable and the only empirical confounder, neighborhood population density (Table 3; Model 3). Among Cowlitz AIs, the odds of obesity in imbalanced neighborhood food environments was 1.83 times the odds of obesity in balanced neighborhood food environments (95% confidence interval [CI] = 1.12, 3.00). The corresponding odds ratio (OR) among white Washingtonians was 1.19 (95% CI = 1.07, 1.33). These estimates were similar to crude associations and associations adjusted for demographic, behavioral, and neighborhood characteristics (Table 3; Model 1 and Model 2). Among Cowlitz AIs who are obese, 65.1 percent live in imbalanced neighborhood food environments and 34.9 percent live in balanced neighborhood food environments. By comparison, 53.3 percent of white Washingtonians who are obese live in imbalanced neighborhood food environments and 46.7 percent live in balanced neighborhood food environments. Among white Washingtonians, food imbalance was more strongly associated with greater odds of obesity in moderately low poverty areas (Table 4; OR = 1.32; 95% CI 1.10, 1.58; interaction p = .034). The interaction between neighborhood poverty and food imbalance was not statistically significant in Cowlitz AIs (Table 4; interaction p = .27), though the pattern of results was similar.

## DISCUSSION

We evaluated neighborhood food *imbalance* and its association with obesity in AIs living outside Indian Country, a population chronically understudied despite facing critical health challenges related to obesity. Using the RFEI, we found a significant association between neighborhood food imbalance and obesity in Cowlitz AIs. We also found a significant, though less pronounced, association between food imbalance and obesity in white residents of Washington State. Among white Washingtonians, the association between food imbalance and obesity was significantly greater

in neighborhoods with moderately low poverty. Evaluation of this interaction effect in Cowlitz AIs was limited by a much smaller sample size.

Our findings illustrate the complexity of obesity risk profiles in vulnerable populations, and raise questions about the role of relative disparities in environments that have not traditionally been considered "high risk" – specifically, moderately low poverty neighborhoods. In our study, Cowlitz AIs were poor with less access to education relative to white Washingtonians; however, they did not predominantly live in high poverty neighborhoods. Rather, Cowlitz AIs tended to live in neighborhoods with moderately low poverty, and our data indicate these neighborhoods have high burden of food imbalance. While multiple studies have investigated food environment in high poverty neighborhoods, the interface between racial/ethnic minority status, low SEP, and food environment in moderately low poverty neighborhoods requires further clarification. For example – in moderately low poverty neighborhoods, do racial/ethnic minorities with low SEP access different aspects of food environment than their white neighbors with high SEP? – how is the relationship between food imbalance and obesity in Cowlitz AIs similar to or different from other AIAN groups and other racial/ethnic minorities?

Findings from our study should be interpreted alongside several considerations. The validity of self-reported BMI has been called into question by evidence that respondents tend to overreport height and underreport weight.[66] This tendency may impact the accuracy of our obesity estimates; however, misreporting was unlikely correlated with neighborhood characteristics, and the ultimate effect on the associations we found is likely toward the null. Discrepancies between definitions of ZCTAs and U.S. Postal ZIP Codes are a second potential source of unsystematic measurement error, which may bias our results toward the null.

We used publicly available U.S. Census business lists to identify food-outlets and define RFEI scores. We did not use "ground-truthing" or on-site verification procedures to confirm these data. While validation studies suggest that commercial business lists contain error,[67-69] this error likely applies

comparably across all food establishments, with minimal impact on our RFEI ratio measure. Furthermore, this limitation is balanced by our examination of a critical race/ethnic group and a large population of non-Hispanic whites residing across a broad geographic range.

Our analyses accounted for many demographic, behavioral, and neighborhood characteristics, but residual confounding is possible. Exercise frequency per month and household poverty level were defined by broad, potentially heterogeneous, categories due to phrasing of survey questions. Other potential confounding factors were not included, such as street connectivity and walkability within neighborhoods.

Our study was limited to adult participants with a working telephone number and may consequently lack generalizability. Differences between the true and sampled population may be greater for Cowlitz AIs than white Washingtonians because a significant proportion did not have a working telephone number. Differential sampling methods prevented combination of data from the Cowlitz BRFSS Project and 2010 Washington BRFSS into one larger dataset and restricted our ability to draw direct comparisons. Though neighborhood food imbalance was associated with 83% greater odds of obesity in Cowlitz AIs versus 19% greater odds of obesity in white Washingtonians, this difference is difficult to interpret. The odds of obesity associated with neighborhood food imbalance may truly be greater among Cowlitz AIs, but may also reflect sample size differences.

The cross-sectional nature of our data raises concern for reverse causality. That is, people who are obese may deliberately move to neighborhoods with greater relative prevalence of unhealthy food options. Consequently, we cannot infer causation from our data. Our results suggest a link between food imbalance and obesity, but the precise mechanism remains unknown. For example, RFEI may be a marker for environmental characteristics affecting peoples' propensity to walk, bike, or drive.

Despite these limitations, we offer the first examination of how a new research paradigm – *relative* balance of unhealthy versus healthy food-outlets as a determinant of body weight – applies to

American Indians living outside Indian Country. At a fundamental level, we address the notion of "Fair Treatment" in American neighborhoods – the expectation that "no population, due to policy or economic disempowerment, be forced to bear disproportionate exposure to and burden of harmful environmental conditions." [70] Our results suggest neighborhood food imbalance is indeed a harmful environmental condition affecting American Indians living outside Indian Country. The stability and strength of this association, and its relationship with other risk factors, warrants further investigation.

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**TABLE 1 —Demographic, exercise and neighborhood characteristics of Cowlitz American Indians and non-Hispanic White Washingtonians: Cowlitz BRFSS Project, 2010 Washington State BRFSS**

| Characteristic | Cowlitz American Indians (n = 339) Mean +/-SD or No. (%) | Non-Hispanic White Washingtonians (n = 15,930) Mean +/-SD or No. (weighted %) |
|---|---|---|
| DEMOGRAPHIC | | |
| Age, y*** | 54.4 +/-14.8 | 48.1 +/-17.6 |
| Sex | | |
| Females | 185 (54.6) | 9472 (50.0) |
| Males | 154 (45.4) | 6458 (50.0) |
| Education*** | | |
| Did not graduate high school | 40 (11.8) | 664 (4.6) |
| Graduated high school | 112 (33.0) | 3854 (23.7) |
| Attended college/technical school | 118 (34.8) | 5098 (30.9) |
| Graduated college/technical school | 69 (20.4) | 6296 (40.8) |
| Household poverty level*** | | |
| > 200% of Federal Poverty Level | 234 (79.6) | 13 485 (85.7) |
| 100 – 200% of Federal Poverty Level | 26 (8.8) | 1743 (9.5) |
| ≤ Federal Poverty Level | 34 (11.6) | 702 (4.8) |
| Relationship status | | |
| Single[a] | 104 (30.7) | 6247 (32.8) |
| Unmarried couple | 20 (5.9) | 388 (3.5) |
| Married | 215 (63.4) | 9268 (63.7) |
| BMI[b]*** | | |
| Not obese | 193 (56.9) | 11 500 (74.3) |
| Obese | 146 (43.1) | 4430 (25.7) |
| BEHAVIORAL | | |
| Exercise per month*** | | |
| Less than once per month | 35 (10.3) | 3050 (17.0) |
| At least once per month | 304 (89.7) | 12 880 (83.0) |
| Smoking tobacco status*** | | |
| Never | 157 (46.4) | 8361 (57.9) |
| Formerly | 126 (37.3) | 5364 (27.3) |
| Currently | 55 (16.3) | 2105 (14.8) |
| NEIGHBORHOOD | | |
| Poverty in neighborhood,[c] %*** | | |
| Low | 19 (5.6) | 1709 (14.1) |
| Moderately low | 168 (49.5) | 5995 (44.2) |
| Moderately high | 125 (36.9) | 6352 (30.4) |
| High | 27 (8.0) | 1874 (11.3) |
| RUCA** | | |
| Rural | 79 (23.3) | 4765 (16.6) |
| Urban | 260 (76.7) | 11 165 (83.4) |
| Population density of neighborhood[d]*** | | |
| Low | 18 (5.2) | 2492 (6.1) |
| Moderately low | 125 (36.9) | 3095 (20.7) |
| Moderately high | 173 (51.0) | 8327 (63.0) |
| High | 23 (6.8) | 1216 (10.3) |
| RFEI[e] | | |
| Balanced food environment (< 4.0) | 139 (41.0) | 3207 (42.5) |
| Imbalanced food environment (≥ 4.0) | 200 (59.0) | 4320 (57.5) |

*Note*. BRFSS = Behavioral Risk Factor Surveillance System; RUCA = Rural Health Research Center Rural-Urban Commuting Area Codes; RFEI = Retail Food Environment Index. An *effective N* was calculated for Washington BRFSS categorical variables using the weighted proportion (p) and estimated standard error (SE) for each cell, averaging p*(1 – p)/SE^2

across all levels. For age, e*ffective N* = (standard deviation/SE)^2. *Effective Ns* were used to calculate Pearson's $\chi^2$ statistics for categorical variables and t score for age.
*p < .05; **p < .01; ***p < .001 (two tailed tests).
[a]Single = Widowed, Separated, Divorced, or Never Married/lived with a partner
[b]Not Obese = BMI < 30 kg/m$^2$; Obese = BMI ≥ 30 kg/m$^2$.
[c]Percent of households in US Census Zip Code Tabulation Area living below the federal poverty level. Cut off points consistent with literature[61]: <5%, 5% to <10%, 10% to <20%, and ≥20%.
[d]Population per square mile of land in Zip Code Tabulation Area. Cut off points based on prior precedent[62]: ≤100, >100 – 400, >400 – 2500, and >2500 people.
[e]RFEI = (No. limited service restaurants + No. convenience stores + No. gasoline stations with convenience stores) / (No. supermarkets and other grocery stores + No. fruit and vegetable markets + No. farmers markets) per US Census Zip Code Tabulation Area.

**T A B L E 2 —Descriptive statistics for Cowlitz American Indians and non-Hispanic white Washingtonians, stratified by RFEI: Cowlitz BRFSS Project, 2010 Washington State BRFSS**

| | Cowlitz American Indians (n = 339) Mean +/-SD or No. (%) | | | Non-Hispanic White Washingtonians (n = 15,930) Mean +/-SD, or No. (weighted %) | | |
|---|---|---|---|---|---|---|
| | Balanced RFEI < 4.0 | Imbalanced RFEI ≥ 4.0 | P | Balanced RFEI < 4.0 | Imbalanced RFEI ≥ 4.0 | P |
| D E M O G R A P H I C | | | | | | |
| Age, y | 55.9 +/-14.7 | 53.3 +/-14.8 | .11 | 48.5 +/-18.8 | 47.8 +/-16.7 | .13 |
| Sex | | | | | | |
| Females | 73 (52.5) | 112 (56.0) | .53 | 4620 (49.5) | 4852 (50.0) | .68 |
| Males | 66 (47.5) | 88 (44.0) | | 3165 (50.5) | 3293 (50.0) | |
| Education | | | | | | |
| Did not graduate high school | 20 (14.4) | 20 (10.0) | | 341 (4.3) | 323 (4.8) | |
| Graduated high school | 46 (33.1) | 66 (33.0) | .17 | 1940 (22.1) | 1914 (24.8) | .002 |
| Attended college/technical school | 52 (37.4) | 66 (33.0) | | 2419 (30.1) | 2679 (31.6) | |
| Graduated college/technical school | 21 (15.1) | 48 (24.0) | | 3076 (43.6) | 3220 (38.8) | |
| Household poverty level | | | | | | |
| > 200% of FPL | 103 (85.1) | 131 (75.7) | | 6518 (86.0) | 6944 (85.4) | |
| 100 – 200% of FPL | 6 (5.0) | 20 (11.6) | .092 | 899 (9.2) | 844 (9.6) | .78 |
| ≤ FPL | 12 (9.9) | 22 (12.7) | | 356 (4.7) | 346 (4.9) | |
| Relationship status | | | | | | |
| Single[a] | 44 (31.7) | 60 (30.0) | .83 | 3054 (32.3) | 3193 (33.1) | .28 |
| Unmarried couple | 7 (5.0) | 13 (6.5) | | 213 (4.0) | 175 (3.2) | |
| Married | 88 (63.3) | 127 (63.5) | | 4502 (63.7) | 4766 (63.7) | |
| BMI[b] | | | | | | |
| Not Obese | 88 (63.3) | 105 (52.5) | .048 | 5716 (76.3) | 5784 (72.8) | <.001 |
| Obese | 51 (36.7) | 95 (47.5) | | 2069 (23.7) | 2361 (27.2) | |
| B E H A V I O R A L | | | | | | |
| Exercise per month | | | | | | |
| Less than once per month | 14 (10.1) | 21 (10.5) | .90 | 1476 (15.7) | 1574 (17.5) | .035 |
| At least once per month | 125 (89.9) | 179 (89.5) | | 6290 (84.3) | 6559 (82.5) | |
| Smoking tobacco status | | | | | | |
| Never | 61 (43.9) | 96 (48.2) | | 4010 (57.3) | 4351 (58.3) | |
| Formerly | 51 (36.7) | 75 (37.7) | .41 | 2697 (28.1) | 2667 (26.7) | .44 |
| Currently | 27 (19.4) | 28 (14.1) | | 1018 (14.6) | 1087 (15.0) | |
| N E I G H B O R H O O D | | | | | | |
| Poverty in neighborhood,[c] % | | | | | | |
| Low | 9 (6.5) | 10 (5.0) | | 1025 (18.0) | 684 (11.1) | |
| Moderately low | 55 (39.6) | 113 (56.5) | .001 | 2192 (39.5) | 3803 (47.7) | <.001 |
| Moderately high | 56 (40.3) | 69 (34.5) | | 3670 (32.0) | 2682 (29.3) | |
| High | 19 (13.7) | 8 (4.0) | | 898 (10.5) | 976 (11.9) | |
| RUCA | | | | | | |
| Rural | 55 (39.6) | 24 (12.0) | <.001 | 3202 (22.7) | 1563 (12.1) | <.001 |
| Urban | 84 (60.4) | 176 (88.0) | | 4583 (77.3) | 6577 (87.9) | |
| Population Density of neighborhood[d] | | | | | | |
| Low | 17 (12.2) | 1 (0.5) | | 2148 (10.6) | 344 (2.7) | |
| Moderately low | 59 (42.5) | 66 (33.0) | <.001 | 1848 (22.0) | 2047 (19.7) | <.001 |
| Moderately high | 44 (31.7) | 129 (64.5) | | 2959 (50.1) | 5368 (72.5) | |
| High | 19 (13.7) | 4 (2.0) | | 830 (17.3) | 386 (5.1) | |

*Note.* BRFSS = Behavioral Risk Factor Surveillance System; RFEI = Retail Food Environment Index; RUCA = Rural Health Research Center Rural-Urban Commuting Area Codes. Comparisons across age are based on t score; comparisons across all other variables are based on Pearson's $\chi^2$ statistics.

[a]Single = Widowed, Separated, Divorced, or Never Married/lived with a partner

[b]Not Obese = BMI < 30 kg/m$^2$; Obese = BMI ≥ 30 kg/m$^2$.

[c]Percent of households in US Census Zip Code Tabulation Area living below the federal poverty level. Cut off points consistent with literature[61]: <5%, 5% to <10%, 10% to <20%, and ≥20%.

[d]Population per square mile of land in Zip Code Tabulation Area. Cut off points based on prior precedent[62]: ≤100, >100 – 400, >400 – 2500, and >2500 people.

**T A B L E 3 —Association between food imbalance (RFEI ≥ 4.0) and obesity among Cowlitz American Indians and non-Hispanic white Washingtonians: Cowlitz BRFSS Project, 2010 Washington State BRFSS**

| | Cowlitz American Indians | | | Non-Hispanic White Washingtonians | | |
|---|---|---|---|---|---|---|
| | OR | 95% CI | P | OR | 95% CI | P |
| RFEI[a] (imbalanced vs. balanced food environment) | | | | | | |
| **Model 1.** Crude[b] | 1.56 | 1.00 – 2.43 | .047 | 1.20 | 1.08 – 1.33 | <.001 |
| **Model 2.** Controlling all independent variables[c] | 1.91 | 1.07 – 3.40 | .028 | 1.14 | 1.02 – 1.27 | .024 |
| **Model 3.** Controlling population density[d] | 1.83 | 1.12 – 3.00 | .017 | 1.19 | 1.07 – 1.33 | .002 |

*Note.* BRFSS = Behavioral Risk Factor Surveillance System; RFEI = Retail Food Environment Index; Imbalanced = RFEI < 4.0; balanced = RFEI ≥ 4.0; CI = confidence interval; OR = odds ratio (i.e. exponentiated log-odds parameter estimate).
[a]RFEI = (No. limited service restaurants + No. convenience stores + No. gasoline stations with convenience stores) / (No. supermarkets and other grocery stores + No. fruit and vegetable markets + No. farmers markets) in Zip Code.
[b]Simple logistic regression estimation of RFEI–obesity relationship
[c]Multivariate logistic regression estimation of RFEI–obesity relationship, controlling for all demographic, behavioral, and neighborhood characteristics
[d]Multivariate logistic regression estimation of RFEI–obesity relationship, controlling for the confounding effect of neighborhood population density. Neighborhood population density is a significant confounder in the Cowlitz dataset only; to maximize comparability, population density was included in both Cowlitz AI and white Washingtonian models. No other variables are significant confounders in either dataset.

**T A B L E 4 —Association between neighborhood food imbalance and obesity stratified by neighborhood poverty to illustrate interaction: Cowlitz BRFSS Project, 2010 Washington State BRFSS**

| | Percent of Neighborhood Population Living Below Federal Poverty Level | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Low Poverty | | Moderately Low Poverty | | Moderately High Poverty | | High Poverty | | |
| Imbalanced RFEI ≥4.0 vs. Balanced RFEI <4.0 | OR | 95% CI | OR | 95% CI | OR | 95% CI | OR | 95% CI | P |
| Cowlitz American Indians | 0.16 | 0.01 – 1.86 | 2.00 | 1.01 – 3.93 | 1.84 | 0.82 – 4.10 | 2.19 | 0.40 – 12.11 | .27 |
| Non-Hispanic White Washingtonians | 1.06 | 0.77 – 1.47 | 1.32 | 1.10 – 1.58 | 1.17 | 0.98 – 1.39 | 0.79 | 0.58 – 1.06 | .034 |

*Note.* BRFSS = Behavioral Risk Factor Surveillance System; RFEI = Retail Food Environment Index; Low Poverty = <5% below Federal Poverty Level (FPL); Moderately Low Poverty = 5% to <10% below FPL; Moderately High Poverty = 10% to <20% below FPL; High Poverty = ≥20% below FPL; CI = confidence interval; OR = odds ratio (i.e. exponentiated log-odds parameter estimate). Neighborhood population density is a significant confounder of the RFEI–obesity relationship in the Cowlitz dataset only; we control for this variable in both populations to maximize comparability.

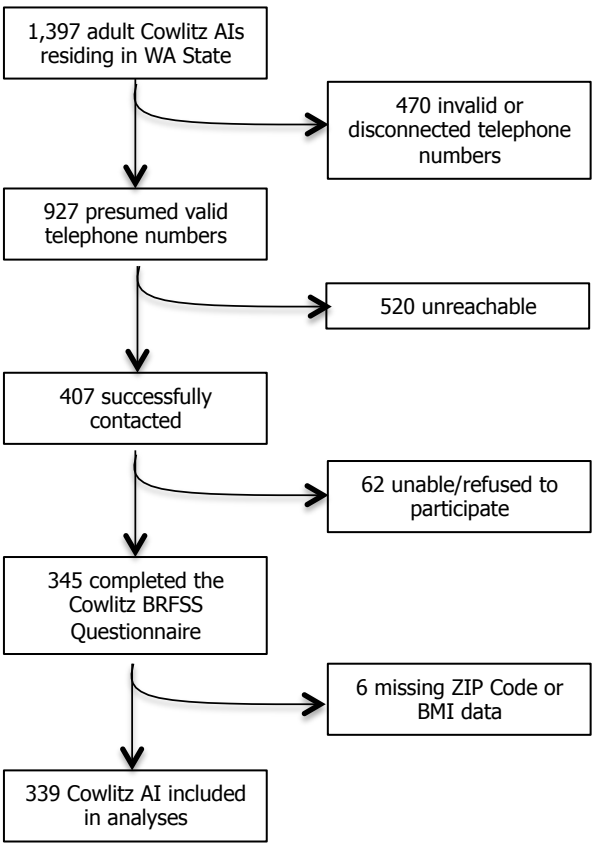


**FIGURE 1 —Cowlitz American Indian Participant Selection Flowchart: Cowlitz BRFSS Project**

**TABLE A —Description and summary statistics of neighborhood food-outlet density (food-outlets per 100 people per square mile of land) for Cowlitz American Indians and non-Hispanic White Washingtonians: 2010 U.S. Census**

| Neighborhood Food-outlets | Description (NAICS code) | Cowlitz American Indians Median (Range) | Non-Hispanic White Washingtonians Median (Range) |
|---|---|---|---|
| Limited-service restaurants | Establishments where patrons generally order or select items and pay before eating, including: fast-food restaurants, pizza delivery shops, drive-in restaurants, and carryout restaurants (NAICS 722211) | 20 (0 – 1093) | 14 (0 – 1976) |
| Convenience stores | Establishments known as convenience stores or food marts (except those with fuel pumps) primarily engaged in retailing a limited line of goods that generally includes milk, bread, soda, and snacks (NAICS 445120) | 2 (0 – 119) | 1 (0 – 853) |
| Gasoline stations with convenience stores | Establishments engaged in retailing automotive fuels (e.g., diesel fuel, gasohol, gasoline) in combination with convenience store or food mart items. (NAICS 447110) | 8 (1 – 469) | 6 (1 – 1383) |
| Supermarkets and other grocery (except convenience) | Establishments known as supermarkets and grocery stores engaged in retailing a general line of food, such as canned and frozen foods; fresh fruits and vegetables; and fresh and prepared meats, fish, and poultry. (NAICS 445110) | 5 (0 – 624) | 4 (0 – 792) |
| Fruit and vegetable markets | Establishments primarily engaged in retailing fresh fruits and vegetables. (NAICS 445230) | 0 (0 – 10) | 0 (0 – 224) |
| Farmers markets | Physical retail market featuring foods sold directly by farmers to consumers. | 0 (0 – 156) | 0 (0 – 156) |

*Note.* NAICS = North American Industry Classification System; AIs = American Indians; NHW = non-Hispanic White.

**T A B L E B —Statistical confounding analysis for Cowlitz American Indian model**

| Model | RFEI OR | RFEI P | "Confounder" OR | "Confounder" P | Model P | % Change[a] |
|---|---|---|---|---|---|---|
| RFEI alone *(crude model)* | 1.56 | .047 | | | .047 | |
| RFEI + age | 1.56 | .051 | .99 | .50 | .10 | 0.0% |
| RFEI + sex | 1.58 | .044 | 1.28 | .27 | .076 | 1.9% |
| RFEI + education | 1.60 | .040 | .85<br>.76<br>.69 | .79 | .29 | 3.1% |
| RFEI + poverty level | 1.53 | .066 | 2.13<br>2.27<br>1.83 | .51 | .17 | 1.3% |
| RFEI + relationship status | 1.55 | .053 | 1.76<br>1.12 | .52 | .15 | 0.6% |
| RFEI + exercise | 1.56 | .048 | 1.16 | .69 | .13 | 0.0% |
| RFEI + smoking | 1.55 | .056 | 1.85<br>.99 | .026 | .011 | 0.6% |
| RFEI + percent poverty | 1.59 | .052 | 2.11 | .33 | .097 | 2.5% |
| RFEI + RUCA | 1.68 | .030 | 2.34<br>.77<br>.66 | .34 | .089 | 7.7% |
| RFEI + population density | 1.83 | .017 | .61<br>1.27 | .42 | .15 | **15.3%** |

[a]Magnitude of confounding = $(OR_{crude} - OR_{adjusted}) / OR_{adjusted}$

**T A B L E C —Statistical confounding analysis for non-Hispanic white Washingtonian model**

| Model | RFEI OR | RFEI P | "Confounder" OR | "Confounder" P | Model P | % Change[a] |
|---|---|---|---|---|---|---|
| RFEI alone *(crude model)* | 1.20 | .001 | | | .001 | |
| RFEI + age | 1.21 | <.001 | 1.01 | .001 | <.001 | 0.8% |
| RFEI + sex | 1.20 | .001 | 1.10 | .085 | <.001 | 0.0% |
| RFEI + education | 1.18 | .002 | .72<br>.81<br>.53 | <.001 | <.001 | 1.7% |
| RFEI + poverty level | 1.20 | .001 | 1.21<br>1.52 | <.001 | <.001 | 0.0% |
| RFEI + relationship status | 1.21 | <.001 | 1.60<br>1.03 | .022 | <.001 | 0.8% |
| RFEI + exercise | 1.18 | .001 | .50 | <.001 | <.001 | 1.7% |
| RFEI + smoking | 1.21 | <.001 | 1.31<br>.98 | <.001 | <.001 | 0.8% |
| RFEI + percent poverty | 1.19 | .001 | 1.16<br>1.37 | .002 | <.001 | 0.8% |
| RFEI + RUCA | 1.21 | <.001 | 1.28<br>.87 | .033 | <.001 | 0.8% |
| RFEI + population density | 1.19 | .002 | .76<br>.56<br>.41 | <.001 | <.001 | 0.8% |

[a]Magnitude of confounding = $(OR_{crude} - OR_{adjusted}) / OR_{adjusted}$