**Supplementary Figure 1** Flowchart of population included in the final analysis (N=40,074).

**Supplementary Figure 2** The flow chart of development and validation of empirical dietary index for hyperinsulinemia (EDIH).

**Supplementary Figure 3** The flow chart of development and validation of empirical dietary index for insulin resistance (EDIR).

**Supplementary Figure 4** Time trend of energy from 39 food groups in NHANES (1999-2014).

**Supplementary Table 1** Thirty-nine foods or food groups used in the dietary pattern analyses.

**Supplementary Table 2** Components of EDIH and EDIR in NHANES.

**Supplementary Table 3** Details of categorizations of adjusted covariates.

**Supplementary Table 4** The associations of EDIH and EDIR score with risk of all-cause and cause-specific mortality with further adjustment for body mass index and diabetes or the primary sampling unit NHANES (1999-2014).

**Supplementary Table 5** Associations between 20 food groups in the dietary indices and all-cause mortality risk in NHANES (1999-2014).



**Supplementary Figure 1** Flowchart of population included in the final analysis (N=40,074).

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**Supplementary Figure 2** The flow chart of development and validation of empirical dietary index for hyperinsulinemia (EDIH).

NHANES, National Health and Nutrition Examination Survey.

**Supplementary Figure 3** The flow chart of development and validation of empirical dietary index for insulin resistance (EDIR).

HOMA-IR, homeostasis model assessment for insulin resistance; NHANES, National Health and Nutrition Examination Survey.

HOMA-IR=fasting insulin (uU/mL) x fasting plasma glucose (mmol/L)/22.5.



**Supplementary Figure 4** Time trend of energy from 39 food groups in NHANES (1999-2014). NHANES, National Health and Nutrition Examination Survey.

**Supplementary Table 1** Thirty-nine foods or food groups used in the dietary pattern analyses.

|  |  |
| --- | --- |
| **Foods or food groups** \* | **Food items** |
| Processed meats | Processed meats, ham, bacon, frankfurter, hot dog |
| Red meat | Beef, pork, lamb, veal, game, hamburger |
| Organ meat | Liver, tripe, gizzards, and other organ meats |
| Poultry | Chicken, turkey, duck, Cornish game hen |
| Eggs | Eggs |
| Dark meat fish | Tuna steak, anchovy, herring, mackerel, salmon, sardines, bluefish, swordfish |
| Other fish | Canned tuna, shrimp, lobster, scallops, fish and other seafood other than dark meat fish |
| Dark yellow vegetables | Deep yellow or orange vegetables such as carrots, pumpkin, winter squash, and sweet potatoes; mixtures having deep yellow vegetables as a main ingredient, such as peas and carrots and sweet potato casserole |
| Leafy green vegetables | Dark green leafy vegetables such as romaine, collards, turnip greens, and spinach |
| Legumes | Cooked dry beans, peas, and lentils; mixtures having legumes as a main ingredient, such as baked beans or lentil soup; soybean-derived products |
| Tomatoes | Tomatoes; tomato juice; catsup, chili sauce, salsa, and other tomato sauces; and mixtures having tomatoes as a main ingredient |
| Potatoes | Baked, boiled, and mashed potatoes; and mixtures having potatoes as a main ingredient, such as potato salad, stuffed baked potatoes, and potato soup |
| Cruciferous vegetables | Broccoli, cabbage, cauliflower, brussels sprouts, kale, mustard, and chard greens; sauerkraut, kohlrabi, rutabaga |
| Garlic | Garlic |
| Other vegetables | Corn, mushrooms, green pepper, celery, eggplant, summer squash |
| Whole grains | Cooked oatmeal, dark bread, brown rice, brown rice flour, other grains, bran added to food, wild rice, whole wheat flour, whole grain cracked wheat |
| Refined grains | White bread, English muffins, bagels or rolls, muffins or biscuits, white rice, barley malt flour, pancakes or waffles, Wheat flour and cracked wheat (not whole grain), couscous |
| High fat dairy | Whole milk, cream, sour cream, ice cream, cream cheese, other cheese |
| Low fat dairy | Skim or low-fat milk, sherbet or ice milk, yogurt |
| Regular fruit juice drinks and fruit flavored drinks | All fruit juice drinks and fruit flavored drinks except low-calorie and low-sugar types |
| Low-calorie fruit juice drinks and fruit flavored drinks | Low-calorie and low-sugar fruit juice drinks and fruit flavored drinks |
| Regular carbonated soft drinks | All carbonated soft drinks except unsweetened and sugar-free types |
| Low-calorie carbonated soft drinks | Unsweetened and sugar-free carbonated soft drinks, and unsweetened carbonated water |
| Fruits | Citrus fruits, dried fruits, and other fruits; mixtures having fruit as a main ingredient |
| Fruit juice | Citrus fruit juices, apple juice, orange juice, grapefruit juice, other fruit juice |
| Beer | Beer, light (lite) beer |
| Wine | Wine, light wine, and mixtures made with wine, such as wine coolers |
| Liquor | Liquor |
| Tea | Tea |
| Coffee | Coffee |
| Nuts | Nuts, nut butters, and nut mixtures |
| Snacks | Potato chips or corn chips, crackers, popcorn |
| Sweets desserts | Candy containing chocolate, candy not containing chocolate cookies, cakes, pies, pastries, sweet roll, coffee cake |
| Pizza | Pizza |
| Butter | Butter |
| Margarine | Margarine |
| Mayonnaise and other creamy salad dressings | Mayonnaise and other creamy salad dressings |
| Oil and vinegar salad dressing | Oil and vinegar salad dressing |
| Condiments | Soy or Worcestershire sauce, jam, jelly, syrups, honey, molasses, sweet toppings |

\* The unit for foods or food groups is gram per day, except for the daily intake of whole grains (oz. eq.) and refined grains (oz. eq.).

**Supplementary Table 2** Components of EDIH and EDIR in NHANES.

|  |  |  |
| --- | --- | --- |
| **Weight** |  | **Weight** |
| Food group | **EDIH \*** | **1st alternative version †** | **2nd alternative version ‡** |  | Food group | **EDIR §** | **1st** **alternative version** **||** | **2nd alternative version ¶** |
| Intercept | 0.09439000 | 0.04272000 | 0.08649000 |  | Intercept | 0.94799000 | 0.98473000 | 1.02635000 |
| **Positive association** |  |  |  |  | **Positive association** |  |  |  |
| Processed meat | 0.00063709 | - | - |  | Processed meat | 0.00022036 | 0.00011081 | 0.00023307 |
| Potatoes | 0.00068173 | 0.00080941 | 0.00081142 |  | Red meat | 0.00013639 | 0.00018052 | 0.00024097 |
| Low calorie carbonated drinks | 0.00025666 | 0.00025538 | 0.00018087 |  | Potatoes | 0.00040180 | 0.0004103 | - |
| Eggs | 0.00119000 | - | - |  | Low calorie carbonated drinks | 0.00017915 | - | - |
| Other fish | - | 0.00069144 | 0.00065938 |  | Other fish | - | - | 0.00025979 |
| Regular carbonated drinks | - | 0.00010924 | - |  | Low calorie carbonated drinks | - | 0.00018893 | 0.00022116 |
| Low calorie fruit drinks | - | 0.00080823 | - |  | Low calorie fruit drinks | - | 0.00033166 | 0.00022355 |
| **Inverse association** |  |  |  |  | Margarine | 0.00400000 | - | - |
| Beer | -0.00019401 | -0.00017089 | -0.00017896 |  | Eggs | 0.00051271 | 0.00031461 | - |
| Wine | -0.00060249 | -0.00062332 | -0.00072679 |  | Regular carbonated drinks | - | - | 0.00010511 |
| Coffee | -0.00012690 | -0.00010389 | -0.00009307 |  | Regular fruit drinks | - | - | 0.00009763 |
| Snacks | -0.00181000 | -0.00293000 | -0.00166000 |  | Tea | - | - | 0.00006452 |
| Fruit juice | -0.00028548 | - | - |  | **Inverse association** |  |  |  |
| Nuts | -0.00226000 | - | - |  | Dark yellow vegetables | -0.00091032 | - | - |
| Sweets desserts | -0.00064442 | -0.00078451 | - |  | Leafy green vegetables | -0.00073669 | -0.00071028 | -0.00120000 |
| Oil and vinegar salad dressing | -0.00667000 | - | - |  | Beer | -0.00012289 | -0.00016442 | -0.00020920 |
| Mayonnaise and other creamy salad dressings | -0.00468000 | - | - |  | Wine | -0.00062316 | -0.00060693 | -0.00094032 |
| Leafy green vegetables | - | -0.00213000 | - |  | Liquor | -0.00064007 | -0.00059810 | -0.00082176 |
| Margarine | - | 0.00928000 | - |  | Coffee | -0.00009138 | -0.00005707 | - |
| Nuts | - | -0.00297000 | - |  | Oil and vinegar salad dressing | -0.00256000 | -0.00257000 | -0.00383000 |
| Whole fruits | - | - | -0.00046828 |  | Pizza | -0.00025916 | - | - |
|  |  |  |  |  | Sweets desserts | -0.00036372 | -0.00039071 | - |
|  |  |  |  |  | Snacks | -0.00107000 | -0.00134000 | -0.00163000 |
|  |  |  |  |  | Condiments | -0.00116000 | - | - |
|  |  |  |  |  | Fruit juice | -0.00008685 | - | - |
|  |  |  |  |  | Whole fruits | - | -0.00012750 | -0.00020618 |
|  |  |  |  |  | Low fat dairy | - | -0.00011814 | - |
|  |  |  |  |  | Butter | - | -0.00522000 | - |
|  |  |  |  |  | Dark meat fish | - | - | -0.00062299 |
|  |  |  |  |  | Whole grains | - | - | -0.00987000 |
|  |  |  |  |  | Nuts | - | - | -0.00085315 |

EDIH, Empirical dietary index for hyperinsulinemia; EDIR, empirical dietary index for insulin resistance; NHANES, National Health and Nutrition Examination Survey. Of note, considering the influence of possible changes in the long-term dietary habits, we created the following two alternative versions, in addition to the main version. Of note, the unit for foods or food groups in the regression models is gram per day, except for the daily intake of whole grains (oz. eq.) and refined grains (oz. eq.).

\* An EDIH with the use of data from the NHANES 1999-2002;

† An EDIH with the use of data from the NHANES 1999-2000 and 2003-2004;

‡ An EDIH with the use of data from the NHANES 2001-2004;

§ An EDIR with the use of data from the NHANES 1999-2008;

**||**An EDIR with the use of data from the NHANES 1999-2000, 2003-2004, 2007-2008, 2011-2012, 2015-2016;

¶ An EDIR with the use of data from the NHANES 2009-2018.

**Supplementary Table 3** Details of categorizations of adjusted covariates.

|  |  |
| --- | --- |
| Variable name | Variable categorizations |
| Age | As restricted cubic spline term with three knots in model(1) |
| Total energy intake  | As restricted cubic spline term with three knots in model(1) |
| Sex  | 1. Male
 |
|  | 1. Female
 |
| Race/ethnicity | 1. Mexican American
 |
|  | 1. Other Hispanic
 |
|  | 1. Non-Hispanic white
 |
|  | 1. Non-Hispanic black
 |
|  | 1. Other races
 |
| Education | 1. ≤ 12th grade
 |
|  | 1. High school graduate/GED or equivalent
 |
|  | 1. More than high school
 |
| Marital status | 1. Married
 |
|  | 1. Widowed/divorced/separated
 |
|  | 1. Never married
 |
| Ratio of family income to poverty | 1. <1.30
 |
|  | 1. 1.30-3.49
 |
|  | 1. ≥3.50
 |
| Physical activity | 1. <8.3 METS-h/week
 |
|  | 1. 8.3-16.7 METS-h/week
 |
|  | 1. >16.7 METS-h/week
 |
| Smoking | 1. Never smokers
 |
|  | 1. Former smokers
 |
|  | 1. Current smokers
 |
| BMI | 1. <18.5 kg/m2
 |
|  | 1. 18.5-24.9 kg/m2
 |
|  | 1. 25.0-29.9 kg/m2
 |
|  | 1. ≥30.0 kg/m2
 |
| Diabetes | 1. No
 |
|  | 1. Yes
 |

GED, general educational development; BMI, body mass index; METS, metabolic equivalent tasks;

**Supplementary Table 4** The associations of EDIH and EDIR score with risk of all-cause and cause-specific mortality with further adjustment for body mass index and diabetes or the primary sampling unit NHANES (1999-2014).

|  |  |
| --- | --- |
|  | HR (95% CI) |
|  | Quintile 1 | Quintile 2 | Quintile 3 | Quintile 4 | Quintile 5 | Per 1-SD |
| **EDIH** |  |  |  |  |  |  |
| All-cause mortality |  |  |  |  |  |  |
| No. of deaths/person-years | 818/67,648 | 949/64,536 | 1066/63,604 | 1027/64,089 | 1044/66,028 |  |
| HR (95% CI) \* | 1 (Reference) | 1.00 (0.91-1.10) | 1.07 (0.97-1.18) | 1.02 (0.92-1.12) | 1.12 (1.02-1.23) | 1.03 (1.00-1.07) |
| HR (95% CI) † | 1 (Reference) | 1.00 (0.91-1.11) | 1.09 (0.99-1.20)  | 1.07 (0.97-1.17)  | 1.20 (1.09-1.32)  | 1.06 (1.03-1.10) |
| CVD mortality |  |  |  |  |  |  |
| No. of deaths/person-years | 153/67648 | 190/64536 | 252/63604 | 195/64089 | 239/66028 |  |
| HR (95% CI) \* | 1 (Reference) | 1.04 (0.83-1.29) | 1.24 (1.01-1.53) | 0.94 (0.75-1.18) | 1.27 (1.02-1.57) | 1.07 (0.99-1.15) |
| HR (95% CI) † | 1 (Reference) | 1.04 (0.84-1.29) | 1.29 (1.04-1.59) | 1.01 (0.81-1.27) | 1.41 (1.14-1.74) | 1.11 (1.04-1.20) |
| Cancer mortality |  |  |  |  |  |  |
| No. of deaths/person-years | 197/67648 | 207/64536 | 252/63604 | 208/64089 | 204/66028 |  |
| HR (95% CI) \* | 1 (Reference) | 1.00 (0.82-1.22) | 1.25 (1.03-1.52) | 1.05 (0.85-1.29) | 1.05 (0.86-1.29) | 1.03 (0.96-1.10) |
| HR (95% CI) † | 1 (Reference) | 1.00 (0.82-1.22) | 1.26 (1.03-1.53) | 1.05 (0.86-1.29) | 1.05 (0.86-1.29) | 1.03 (0.96-1.10) |
| **EDIR** |  |  |  |  |  |  |
| All-cause mortality |  |  |  |  |  |  |
| No. of deaths/person-years | 850/66864 | 937/64353 | 1014/62604 | 1005/64338 | 1098/67747 |  |
| HR (95% CI) \* | 1 (Reference) | 0.98 (0.89-1.07) | 1.03 (0.94-1.13) | 1.07 (0.97-1.17) | 1.09 (0.99-1.19) | 1.03 (1.00-1.06) |
| HR (95% CI) † | 1 (Reference) | 0.98 (0.89-1.08) | 1.06 (0.96-1.16) | 1.11 (1.00-1.22) | 1.18 (1.07-1.29) | 1.06 (1.03-1.09) |
| CVD mortality |  |  |  |  |  |  |
| No. of deaths/person-years | 152/66864 | 205/64353 | 227/62604 | 211/64338 | 234/67747 |  |
| HR (95% CI) \* | 1 (Reference) | 1.15 (0.93-1.42) | 1.20 (0.97-1.48) | 1.16 (0.93-1.45) | 1.19 (0.97-1.48) | 1.06 (0.99-1.14) |
| HR (95% CI) † | 1 (Reference) | 1.16 (0.93-1.43) | 1.25 (1.01-1.55) | 1.23 (0.99-1.53) | 1.35 (1.09-1.66) | 1.11 (1.04-1.20) |
| Cancer mortality |  |  |  |  |  |  |
| No. of deaths/person-years | 221/66864 | 219/64353 | 219/62604 | 186/64338 | 223/67747 |  |
| HR (95% CI) \* | 1 (Reference) | 0.96 (0.80-1.17) | 1.00 (0.82-1.22) | 0.90 (0.74-1.11) | 0.99 (0.81-1.20) | 0.97 (0.91-1.03) |
| HR (95% CI) † | 1 (Reference) | 0.97 (0.80-1.17) | 1.01 (0.83-1.22) | 0.91 (0.74-1.12) | 0.99 (0.82-1.20) | 0.97 (0.91-1.03) |

BMI, body mass index; CI, confidence interval; CVD, Cardiovascular diseases; EDIH, Empirical dietary index for hyperinsulinemia; EDIR, empirical dietary index for insulin resistance; HR, hazard ratio; NHANES, National Health and Nutrition Examination Survey; PSU, primary sampling unit; SD, standard deviation.

\* Adjusted for sex, age, total energy intake, race/ethnicity, education, [marital status](https://wwwn.cdc.gov/Nchs/Nhanes/2015-2016/DEMO_I.htm%22%20%5Cl%20%22DMDMARTL), ratio of family income to poverty, physical activity, and smoking, **plus** body mass index (BMI, calculated as weight in kilograms divided by height in meters squared; <18.5, 18.5-24.9, 25.0-29.9, and ≥30.0) and diabetes (no, yes).

† Adjusted for sex, age, total energy intake, race/ethnicity, education, [marital status](https://wwwn.cdc.gov/Nchs/Nhanes/2015-2016/DEMO_I.htm%22%20%5Cl%20%22DMDMARTL), ratio of family income to poverty, physical activity, and smoking, **plus** primary sampling unit.

**Supplementary Table 5** Associations between 20 food groups in the dietary indices and all-cause mortality risk in NHANES (1999-2014) \*.

|  |  |  |
| --- | --- | --- |
| **Food groups** | SD  | HR (95%CI) |
| Processed meat (g/day) | 70.58 | 1.02 (0.99-1.05) |
| Potatoes (g/day) | 67.75 | 1.01 (0.99 1.04) |
| Low calorie carbonated drinks (g/day) | 297.46 | 1.03 (1.00-1.06) |
| Eggs (g/day) | 50.94 | 1.03 (1.00-1.06) |
| Red meat (g/day) | 122.97 | 1.03 (1.00-1.05) |
| Margarine (g/day) | 4.54 | 1.01 (0.99-1.03) |
| Beer (g/day) | 421.07 | 1.02 (0.99-1.06) |
| Wine (g/day) | 68.32 | 0.97 (0.94-1.01) |
| Coffee (g/day) | 405.89 | 0.96 (0.93-0.99) |
| Snacks (g/day) | 25.31 | 1.02 (0.98-1.05) |
| Fruit juice (g/day) | 177.19 | 1.03 (0.99-1.06) |
| Nuts (g/day) | 21.76 | 0.96 (0.92-1.00) |
| Sweets desserts (g/day) | 64.59 | 0.97 (0.95-1.00) |
| Oil vinegar salad dressing (g/day) | 6.94 | 0.97 (0.94-1.01) |
| Mayonnaise and other creamy salad dressing (g/day) | 11.65 | 0.98 (0.95-1.01) |
| Dark yellow vegetables (g/day) | 29.82 | 0.97 (0.95-1.00) |
| Leafy green vegetables (g/day) | 26.86 | 0.99 (0.97-1.02) |
| Liquor (g/day) | 28.95 | 1.04 (1.01-1.06) |
| Pizza (g/day) | 70.57 | 0.95 (0.91-1.00) |
| Condiments (g/day) | 16.43 | 1.00 (0.98-1.03) |

CI, confidence interval; NHANES, National Health and Nutrition Examination Survey; HR, hazard ratios; SD, standard deviation.

\* Model was adjusted for sex, age, total energy intake, race/ethnicity, education, [marital status](https://wwwn.cdc.gov/Nchs/Nhanes/2015-2016/DEMO_I.htm%22%20%5Cl%20%22DMDMARTL), ratio of family income to poverty, physical activity, and smoking.

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