Long-Chain Monounsaturated Fatty Acids and Incidence of Congestive Heart Failure in 2 Prospective Cohorts

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Background—Decades-old animal experiments suggested that dietary long-chain monounsaturated fatty acids (LCMUFAs) caused cardiotoxicity, leading, for example, development of Canola oil (Canadian oil low in erucic acid) from rapeseed oil. However, potential cardiotoxicity in humans and contemporary dietary sources of LCMUFAs are unknown.

Methods and Results—We prospectively investigated the associations of plasma phospholipid LCMUFAs (20:1, 22:1, and 24:1), assessed as objective biomarkers of exposure, with incident congestive heart failure in 2 independent cohorts: 3694 older adults (mean age, 75.2±5.2 years) in the Cardiovascular Health Study (CHS; 1992–2006) and 3577 middle-aged adults (mean age, 54.1±5.8 years) in the Atherosclerosis Risk in Communities Study, Minnesota subcohort (ARIC; 1987–2008). We further examined dietary correlates of circulating LCMUFAs in CHS and ARIC and US dietary sources of LCMUFAs in the 2003–2010 National Health and Nutrition Examination Survey (NHANES). In CHS, 997 congestive heart failure events occurred during 39 238 person-years; in ARIC, 330 events congestive heart failure events occurred during 64 438 person-years. After multivariable adjustment, higher levels of 22:1 and 24:1 were positively associated with greater incident congestive heart failure in both CHS and ARIC; hazard ratios were 1.34 (95% confidence interval, 1.02–1.76) and 1.57 (95% confidence interval, 1.11–2.23) for highest versus lowest quintiles of 22:1, respectively, and 1.75 (95% confidence interval, 1.23–2.50) and 1.92 (95% confidence interval, 1.22–3.03) for 24:1, respectively (P for trend ≤0.03 each). A variety of foods were related to circulating LCMUFAs in CHS and ARIC, consistent with food sources of LCMUFAs in NHANES, including fish, poultry, meats, whole grains, and mustard.

Conclusions—Higher circulating levels of 22:1 and 24:1, with apparently diverse dietary sources, were associated with incident congestive heart failure in 2 independent cohorts, suggesting possible cardiotoxicity of LCMUFAs in humans. (Circulation. 2013;127:1512-1521.)

Key Words: diet ● epidemiology ● fatty acids ● heart failure ● longitudinal studies

In the 1960s to 1980s, feeding experiments in rodents, pigs, and nonhuman primates suggested that consumption of erucic acid (22:1n9) and cetoleic acid (22:1n11) caused cardiac steatosis.1–4 Although potential effects in humans were never studied, mechanistic studies suggest that exposure to long-chain monounsaturated fatty acids (LCMUFAs; 20:1, 22:1, and 24:1 fatty acids) might impair myocardium. The heart preferentially uses fatty acids as fuel.5–7 Long-chain fatty acids, including LCMUFAs, are predominantly oxidized in peroxisomes rather than mitochondria, which lack membrane-transporting enzymes for long-chain fatty acids.5–8 Peroxisomal fatty acid oxidation produces reactive oxygen species and various cytosolic lipid metabolites9 that stimulate several signaling pathways, thereby inhibiting mitochondrial fatty acid oxidation, synthesizing cardiac lipid droplets, inhibiting glycolysis, and inducing apoptosis.5–7 In sum, such effects can cause cardiotoxicity.5–7

Clinical Perspective on p 1521

This decades-old evidence led Canadian farmers to modify rapeseed oil, a major source of erucic acid (~30% to 60% of fatty acids), and market it as Canola oil (Canadian oil low in erucic acid),9 as well as some governments to limit content of erucic acid in rapeseed oil.9,10 Thereafter, the potential cardiotoxicity and dietary sources of LCMUFAs have been largely forgotten and, to the best of our knowledge, never

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studied in humans. However, food composition data indicate that LCMUFAs remain present in mustard oils (20%–50%) and related products, some fish species (5%–30%), and meat and poultry products (0%–5%). Given experimental induction of cardiac fibrosis and steatosis, key risk factors for congestive heart failure (CHF), we hypothesized that LCMUFA exposure may increase the incidence of CHF. To address this hypothesis, we investigated prospective associations between LCMUFA exposure, assessed as objective biomarkers in plasma phospholipids, and incident CHF in 2 independent US cohorts: the Cardiovascular Health Study (CHS) and the Atherosclerosis Risk in Communities Study (ARIC). We further characterized dietary factors related to LCMUFA biomarker levels and evaluated potential dietary sources of LCMUFA consumption based on the US National Health and Nutrition Examination Survey (NHANES) and the US Department of Agriculture food composition database.

**Methods**

**Design and Population**

In 1989 to 1990, CHS recruited 5201 ambulatory, noninstitutionalized adults 265 years of age who were randomly selected from Medicare lists in 4 US communities; an additional 687 black participants were similarly recruited in 1992 to 1993. ARIC recruited 15792 adults 45 to 64 years of age in 4 US communities in 1987 to 1989 from multiple databases, including driver’s license listings, community lists, local health Census lists, and area sampling. In CHS and ARIC, 57% and 60% of eligible adults, respectively, agreed to enroll and gave informed consent. Circulating fatty acid concentrations were measured in 3941 CHS participants using blood samples from 1992 to 1993 and in 3705 ARIC participants in the Minneapolis subcohort using blood samples from 1987 to 1989. These years of fatty acid measurement were considered the baseline for all analyses. Sociodemographic characteristics, lifestyle behaviors, dietary consumption, and laboratory measures were assessed as previously described (see the online-only Data Supplement for details). After the exclusion of participants with prevalent CHF in CHS (n=247) and ARIC (n=128) and without circulating fatty acid measures, the present analyses included 3694 CHS and 3577 ARIC participants.

**Phospholipid Fatty Acids**

Methods for assessing plasma phospholipid fatty acids in CHS and ARIC slightly differed, as described in the online-only Data Supplement. In CHS, 42 known individual fatty acids were quantified; in ARIC, 29 fatty acids. In this study, we evaluated LCMUFAs as the main exposure variables: gadoleic acid (20:1; the first number referring to the number of carbons and the second referring to the number of double bonds in the fatty acid), erucic acid (22:1), and nervonic acid (24:1). Intra-assay coefficients of variation were <5% for 20:1 and 24:1 and 15% for 22:1. We assessed reproducibility of LCMUFA levels potentially affected by both measurement error and biological variation over time that would attenuate findings toward the null, evaluating serial measures from blood samples drawn in 1992 to 1993, 1998 to 1999, and 2005 to 2006 in a subset (n=100) of CHS participants. Within-individual correlations were highest for 24:1 (r=0.66 at 6 years and 0.43 at 13 years) and lower for 22:1 (r=0.26 and 0.18) and 20:1 (r=0.26 and 0.26). This reproducibility for 24:1 was comparable or superior to the reproducibility for major cardiovascular risk factors such as blood pressure.

**Cardiovascular Risk Factors and Incident CHF**

In each cohort, we evaluated cross-sectional associations of LCMUFA levels with cardiovascular risk factors (see the online-only Data Supplement for the assessments) and longitudinal associations of LCMUFAs with incident CHF. In CHS, potential CHF events were identified from annual examinations, interim 6-month phone contacts, and hospital discharge records, with review and classification by a centralized committee of physicians. A CHF event was confirmed when all 3 criteria were met: (1) CHF symptoms (shortness of breath, fatigue, orthopnea, paroxysmal nocturnal dyspnea) and signs (edema, rales, tachycardia, gallop, displaced apical impulse) or clinical findings from echocardiography, ventriculography, or chest radiography; (2) diagnosis of CHF by a treating physician; and (3) CHF medical therapy (a diuretic plus either digitalis or a vasodilator). In ARIC, potential CHF events were first identified by annual phone contacts, review of hospital discharge codes, and death certificates and then ascertained by either a hospitalization including a CHF discharge diagnosis (International Classification of Diseases, Ninth Revision, code 428) or a death certification listing CHF. In CHS, CHF events with sufficient information were further subclassified as due primarily to ischemic or nonischemic causes and to valvular or nonvalvular causes.

To determine whether LCMUFA-CHF associations were myocardial specific, we analyzed incident stroke as a prespecified negative-control outcome. We selected stroke because it shares many risk factors with CHF (eg, hypertension) but should be unaffected by any causal processes specific to cardiac steatosis, ie, the hypothesized cardiotoxicity of LCMUFAs. Each cohort defined stroke as a neurological deficit of rapid onset lasting >24 hours or as a subarachnoid hemorrhage confirmed by computed tomography or magnetic resonance imaging when available.

**Dietary Correlates of Circulating LCMUFAs and Estimated US LCMUFA Consumption**

To examine independent dietary correlates to circulating LCMUFA levels, we assessed cross-sectional associations of habitual food consumption with phospholipid LCMUFA levels. We evaluated 43 food groups in CHS and 41 food groups in ARIC derived from interviewer-administered validated food-frequency questionnaires (mustard consumption and fried fish were available only in CHS). In CHS, we related averaged dietary intakes over the 2 questionnaires in 1989 to 1990 and 1996 to 1997 to LCMUFA levels in 1992 to 1993, as previously performed. In ARIC, dietary intakes were related to LCMUFA levels at the same data collection cycle in 1987 to 1989. To evaluate the validity of dietary correlates to LCMUFA biomarkers in CHS and ARIC and to consider current consumption levels in the United States, we assessed major food sources of LCMUFAs, evaluating food-composition databases and food intakes in the 2003–2010 NHANES (n=20150 adults) that implemented two 24-hour dietary recalls per person (see the online-only Data Supplement for the analytical methods). Food consumption data were available for 20:1 and 22:1 but not for 24:1.

**Statistical Analyses**

We assessed independent dietary correlates to circulating LCMUFA levels by multivariable-adjusted stepwise linear regression (P<0.05 to retain and P>0.1 to remove) as performed previously, relating food groups (servings per week) to LCMUFA levels that were standardized to a standard deviation after log transformation to improve normality. To assess cross-sectional associations of LCMUFAs with cardiovascular risk factors, we evaluated LCMUFA levels as independent variables and cardiovascular risk factors as dependent variables by multivariable-adjusted linear regression. Prospective relationships of phospholipid LCMUFAs with incident CHF were examined by multivariable-adjusted Cox proportional hazards in each cohort separately, and then estimates for quintile category scores were pooled by random-effects meta-analysis. The proportionality assumption was not rejected by examining cross-product terms of follow-up time by...
exposure ($P>0.3$). Time at risk was from time of blood draw to the first CHF (or stroke) diagnosis, death, loss of follow-up, or administrative censoring (2006 in CHS; 2008 in ARIC). Loss of follow-up was 52% of person-times in both CHS and ARIC.

To minimize confounding, we adjusted for covariates based on previously published associations or clinical relevance, including demographics, clinical histories, and lifestyle factors. We recognized that numerous dietary factors and circulating fatty acids could be confounders. Consumption of both generally healthful foods such as plant oils and fish could influence circulating levels of LCMUFAs, other fatty acids, and incident CHF. Importantly, fish consumption has been associated with lower CHF incidence in CHS and ARIC. To select and control for potential confounders of diet and circulating fatty acids, we adopted a confounder selection strategy developed previously. Briefly, we selected covariates when their removal caused >5% change in the measure of association of LCMUFA levels with CHF.

To assess whether the associations between LCMUFAs and incident CHF were independent of traditional cardiovascular risk factors or potential mediators, we further adjusted for body mass index, waist circumference, blood lipids, inflammatory markers, and incident CHF during follow-up as a time-varying covariate. We tested multiplicative interactions by prespecified factors of age, sex, race, and prevalent CHF by evaluating the Wald test for a cross-product term of exposure and covariate in the model. We also evaluated interaction by prevalent diabetes mellitus post hoc.

In longitudinal analyses, time-dependent misclassification in both exposures and covariates causes regression dilution bias and residual confounding. We performed sensitivity analyses to correct for this bias by means of multivariate regression calibration based on within-individual correlations of serial measures of physical activity, dietary habits, and phospholipid fatty acids (in a subset) in CHS. Because comparable serial measures were unavailable in ARIC, we extended regression dilution ratios in CHS to analysis in ARIC, recognizing the limited generalizability and thus considering these corrected risk values in ARIC as only estimates. We examined nonlinear associations in each cohort using 4-knot restricted cubic splines. Statistical analyses were performed with STATA 10.0 (2-tailed $\alpha=0.05$).

Results

Participants in CHS were older at baseline (age, 75.2±5.2 years) than participants in ARIC (age, 54.1±5.8 years), with concomitantly higher prevalence of chronic diseases (Table I in the online-only Data Supplement). The majority were white: 88% in CHS and 100% in ARIC. Both cohorts included broad mixtures of sex, education, and smoking. Lifestyle habits were relatively similar in both cohorts.

Mean±SD levels of 24:1 were 1.96±0.44% and 0.57±0.17% of total fatty acids in CHS and ARIC, respectively. The interdecile ranges (10th and 90th percentiles) of 24:1 were 1.21% in CHS and 0.41% in ARIC. Levels of 20:1 and 22:1 were much lower than 24:1 levels; in ARIC, 43% of adults exhibited 22:1 levels lower than the detection limit (0.01%). Levels of the 3 LCMUFAs were interrelated moderately in CHS (Pearson correlation coefficient, $r=0.25$–0.63) and weakly in ARIC ($r=0.10$–0.27). In both cohorts, LCMUFA levels were also weakly or moderately correlated with levels of other phospholipid fatty acids: 20:0, 22:0, and 24:0 ($r=0.16$–0.67); 20:3n6 and 22:6n3 ($r=0.49$); 18:3n6 and trans-18:2n6 ($r=-0.17$ to –0.36); 16:1n7 and 18:1n9 ($r=-0.13$ to –0.15), and most strongly 20:0 (with 24:1) ($r=0.54$ in CHS and $r=0.67$ in ARIC).

Cross-sectional Associations of Circulating LCMUFAs With Cardiovascular Risk Factors

Higher levels of 24:1 were independently associated with several cardiovascular risk factors in directions toward both favorable and unfavorable associations with cardiovascular disease risks (Table I). These included greater adiposity (body mass index and waist circumference) and higher levels of C-reactive protein, fibrinogen, and leukocyte counts, but also a trend toward lower diastolic blood pressure, higher high-density lipoprotein cholesterol, and substantially lower triglycerides. Results were concordant across the 2 cohorts. Levels of 20:1 were associated with generally healthier profiles of adiposity and physiological measures, and 22:1 showed either weaker or null results (Table II in the online-only Data Supplement).

Prospective Associations of Circulating LCMUFAs With the Incidence of CHF

In CHS, 997 CHF events were documented during 39,238 person-years; and in ARIC, 330 CHF events were documented during 64,438 person-years. In multivariable-adjusted analyses, higher levels of both 22:1 and 24:1, but not 20:1, were significantly associated with higher CHF incidence ($P_{\text{trend}}=0.01$ and 0.004, respectively; Table 2). As expected, adjustment for other individual phospholipid fatty acids strengthened the associations. In CHS, individuals in the highest quintile of 22:1 had 34% higher CHF incidence (hazard ratio [HR], 1.34; 95% confidence interval [CI], 1.02–1.74; $P_{\text{trend}}=0.01$) compared with those in the lowest quintile; in ARIC, 57% higher incidence (HR, 1.57; 95% CI, 1.11–2.23; $P_{\text{trend}}=0.03$); and when pooled together, 42% higher incidence (HR, 1.42; 95% CI, 1.15–1.76; $P_{\text{trend}}=0.001$). Results were more robust for 24:1, with 75% higher CHF incidence comparing the top and bottom quintiles in CHS (HR, 1.75; 95% CI, 1.23–2.50; $P_{\text{trend}}<0.001$); 92% higher incidence in ARIC (HR, 1.92; 95% CI, 1.22–3.03; $P_{\text{trend}}=0.002$); and 82% higher incidence when pooled (HR, 1.82; 95% CI, 1.37–2.40; $P_{\text{trend}}<0.001$).

Further adjustment for potential mediators, including body mass index, waist circumference, high-density lipoprotein cholesterol, fibrinogen, C-reactive protein (CHS only), and leukocyte counts, partly attenuated the associations. In CHS, the extreme-quintile HRs were 1.27 (95% CI, 0.96–1.67; $P_{\text{trend}}=0.04$) for 22:1 and 1.62 (95% CI, 1.12–2.34; $P_{\text{trend}}=0.003$) for 24:1; and in ARIC, 1.55 (95% CI, 1.09–2.20; $P_{\text{trend}}=0.06$) for 22:1 and 1.53 (95% CI, 0.96–2.42; $P_{\text{trend}}=0.04$) for 24:1. We examined incident CHD (n=471 in CHS, n=349 in ARIC) as a potential mediator. Adjusted for the incident events as time-varying variables, results were generally similar. In CHS, the extreme-quintile HR was 1.39 (95% CI, 1.11–1.74) for 22:1 and 1.44 (95% CI, 1.06–1.94) for 24:1 ($P_{\text{trend}}=0.002$ each); in ARIC, these HRs were 1.72 (95% CI, 1.21–2.45) and 1.43 (95% CI, 0.89–2.28; $P_{\text{trend}}=0.01$ and 0.11), respectively. We assessed multiplicative interaction for association of circulating LCMUFAs with incident CHF in each cohort according to age, sex, race, prevalent CHD, and prevalent diabetes mellitus. None of these factors appeared to be significantly modified the associations ($P_{\text{interaction}}>0.05$ each).

Subtypes of CHF

We separately evaluated CHF subtypes centrally adjudicated in 857 cases (86%) in CHS, including ischemic CHF,
valvular CHF, and nonischemic nonvalvular CHF. There was no evidence of substantial differences in associations of LCMUFAs with CHF overall and CHF subtypes (Table III in the online-only Data Supplement). For example, the multivariable-adjusted HR across the interdecile range (90th–10th percentile) of plasma phospholipid 24:1 fatty acids (1.21% of total fatty acids in CHS and 0.42% of total fatty acids in ARIC), adjusted for age (years), sex, enrollment sites (in CHS), employment status (in ARIC), education (less than high school, high school or vocational school, or college or higher), smoking (current, former, never), physical activity (kcal/wk in CHS; 5-point score in ARIC), alcohol consumption (servings/week), hypertension medication (yes/no), prevalent coronary heart disease (yes/no), prevalent diabetes mellitus (yes/no), total caloric intake (kcal/week), and dietary factors (serving/week; eggs, salad dressing, and mustard use in CHS; and eggs, whole grains, margarines, and dairy products in ARIC). Individual phospholipid fatty acids were further adjusted for, after backward selection (see text in detail), including cis-trans-18:2n6, 22:2n6, 17:1n9, 20:0, and 18:1n7 in CHS, and 17:0, 20:2n6, 16:0, 18:2n6, 20:3n6, and 23:0 in ARIC. Covariates also included body mass index and waist circumference, except when they were outcomes.

**Regression Dilution Bias**

In sensitivity analyses, we evaluated the associations of 22:1 and 24:1 with incident CHF after correcting for regression dilution bias (measurement error over time) in both LCMUFA levels and time-varying covariates. In multivariable-adjusted models (as in Table 2, fully adjusted model) further corrected for the bias, the observed associations were estimated to be 4.0-fold stronger for 20:1, 4.2-fold stronger for 22:1, and 3.0-fold stronger for 24:1. For example, the multivariable-adjusted HR comparing the top with the bottom quintile of 22:1 was 3.37 (95% CI, 1.19–9.52) in CHS and 6.58 (95% CI, 1.74–24.8) in ARIC; and of 24:1, 5.44 (95% CI, 1.81–16.3) in CHS and 7.14 (95% CI, 1.75–29.1) in ARIC.

**Dose-Response Relationships**

Dose-response relationships between circulating LCMUFA levels and incident CHF were evaluated by restricted cubic splines. Although nonlinear associations of 22:1 levels were suggested in CHS ($P_{\text{curve}}<0.01$), higher levels of LCMUFAs, in particular 24:1 levels, appeared to be monotonically associated with a higher incidence CHF in both cohorts ($P_{\text{linear}}<0.001$ in CHS and $P_{\text{linear}}=0.003$ in ARIC; Figure 1).

**Incident Stroke**

Given the many shared risk factors for CHF and stroke, we evaluated whether LCMUFAs were associated with stroke as a prespecified negative control, that is, to evaluate the specificity for CHF. None of the LCMUFAs were associated with incident stroke when evaluated separately in both cohorts and when pooled by meta-analysis (Table III in the online-only Data Supplement). The multivariable-adjusted pooled HRs per an interdecile range were 1.13 (95% CI, 0.94–1.36) for 20:1, 0.96 (95% CI, 0.75–1.25) for 22:1, and 1.12 (95% CI, 0.78–1.63) for 24:1.

**Dietary Correlates of Circulating LCMUFAs and Estimated US LCMUFA Consumption**

A variety of foods were positively associated with LCMUFA levels consistently between CHS and ARIC (Figure 2 and Figure I in the online-only Data Supplement). These included both generally more healthful foods such as seafood and whole grains and generally less healthful foods such as meat products.
### Table 2. Incidence of CHF According to Plasma Phospholipid LCMUFAs

<table>
<thead>
<tr>
<th>Fatty Acid</th>
<th>Quintiles of LCMUFAs</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>P for Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>20:1 Fatty acid</strong></td>
<td></td>
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</tr>
<tr>
<td>CHS</td>
<td>Median percent of total fatty acids</td>
<td>0.09</td>
<td>0.11</td>
<td>0.12</td>
<td>0.13</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>Cases, n (rate/1000 person-years)</td>
<td>209 (25.8)</td>
<td>190 (22.9)</td>
<td>211 (26.2)</td>
<td>189 (25.3)</td>
<td>198 (27.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multivariable-adjusted HR (95% CI)*</td>
<td>1.0</td>
<td>0.81 (0.64–1.03)</td>
<td>0.98 (0.77–1.25)</td>
<td>1.00 (0.78–1.29)</td>
<td>0.88 (0.68–1.14)</td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td>Plus further adjustment for fatty acids†</td>
<td>1.0</td>
<td>0.82 (0.65–1.04)</td>
<td>1.02 (0.80–1.30)</td>
<td>1.09 (0.84–1.42)</td>
<td>0.95 (0.72–1.26)</td>
<td>0.81</td>
<td></td>
</tr>
<tr>
<td>ARIC Study</td>
<td>Median percent of total fatty acids</td>
<td>0.10</td>
<td>0.11</td>
<td>0.12</td>
<td>0.14</td>
<td>0.16</td>
<td></td>
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<tr>
<td>Cases, n (rate/1000 person-years)</td>
<td>91 (6.3)</td>
<td>51 (4.4)</td>
<td>101 (4.7)</td>
<td>39 (5.9)</td>
<td>48 (4.7)</td>
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<tr>
<td>Multivariable-adjusted HR (95% CI)*</td>
<td>1.0</td>
<td>0.76 (0.54–1.08)</td>
<td>0.78 (0.58–1.04)</td>
<td>0.99 (0.67–1.45)</td>
<td>0.84 (0.59–1.21)</td>
<td>0.74</td>
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<tr>
<td>Plus further adjustment for fatty acids†</td>
<td>1.0</td>
<td>0.78 (0.55–1.11)</td>
<td>0.85 (0.62–1.16)</td>
<td>1.13 (0.74–1.72)</td>
<td>1.05 (0.69–1.59)</td>
<td>0.37</td>
<td></td>
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<tr>
<td>Pooled estimates‡</td>
<td>1.0</td>
<td>0.79 (0.65–0.98)</td>
<td>0.89 (0.71–1.10)</td>
<td>1.00 (0.81–1.23)</td>
<td>0.87 (0.70–1.07)</td>
<td>0.89</td>
<td></td>
</tr>
<tr>
<td>Plus further adjustment for fatty acids†</td>
<td>1.0</td>
<td>0.81 (0.66–0.98)</td>
<td>0.95 (0.78–1.15)</td>
<td>1.10 (0.88–1.38)</td>
<td>0.98 (0.78–1.23)</td>
<td>0.77</td>
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<tr>
<td><strong>22:1 Fatty acid</strong></td>
<td></td>
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<tr>
<td>CHS</td>
<td>Median percent of total fatty acids</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
<td>0.04</td>
<td>0.05</td>
<td></td>
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<tr>
<td>Cases, n (rate/1000 person-years)</td>
<td>239 (24.9)</td>
<td>154 (21.5)</td>
<td>189 (23.0)</td>
<td>181 (24.8)</td>
<td>234 (33.8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multivariable-adjusted HR (95% CI)*</td>
<td>1.0</td>
<td>0.97 (0.75–1.25)</td>
<td>0.88 (0.69–1.12)</td>
<td>0.99 (0.78–1.25)</td>
<td>1.20 (0.93–1.53)</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>Plus further adjustment for fatty acids†</td>
<td>1.0</td>
<td>0.97 (0.75–1.26)</td>
<td>0.89 (0.70–1.14)</td>
<td>1.04 (0.81–1.34)</td>
<td>1.34 (1.02–1.76)</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>ARIC Study</td>
<td>Median percent of total fatty acids</td>
<td>0.00</td>
<td>0.01</td>
<td>0.02</td>
<td>0.03</td>
<td>0.06</td>
<td></td>
</tr>
<tr>
<td>Cases, n (rate/1000 person-years)</td>
<td>187 (5.0)</td>
<td>45 (5.5)</td>
<td>37 (4.2)</td>
<td>20 (5.5)</td>
<td>41 (6.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multivariable-adjusted HR (95% CI)*</td>
<td>1.0</td>
<td>1.25 (0.90–1.74)</td>
<td>0.79 (0.55–1.13)</td>
<td>1.23 (0.77–1.96)</td>
<td>1.48 (1.05–2.09)</td>
<td>0.06</td>
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</tr>
<tr>
<td>Plus further adjustment for fatty acids†</td>
<td>1.0</td>
<td>1.23 (0.88–1.72)</td>
<td>0.79 (0.55–1.13)</td>
<td>1.32 (0.82–2.11)</td>
<td>1.57 (1.11–2.23)</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>Pooled estimates‡</td>
<td>1.0</td>
<td>1.07 (0.84–1.36)</td>
<td>0.85 (0.70–1.04)</td>
<td>1.03 (0.84–1.27)</td>
<td>1.29 (1.05–1.58)</td>
<td>0.01</td>
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<tr>
<td>Plus further adjustment for fatty acids†</td>
<td>1.0</td>
<td>1.07 (0.86–1.32)</td>
<td>0.86 (0.70–1.05)</td>
<td>1.10 (0.88–1.37)</td>
<td>1.42 (1.15–1.76)</td>
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<td><strong>24:1 Fatty acid</strong></td>
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<tr>
<td>CHS</td>
<td>Median percent of total fatty acids§</td>
<td>1.40</td>
<td>1.71</td>
<td>1.93</td>
<td>2.16</td>
<td>2.61</td>
<td></td>
</tr>
<tr>
<td>Cases, n (rate/1000 person-years)</td>
<td>200 (24.9)</td>
<td>185 (22.5)</td>
<td>187 (23.4)</td>
<td>219 (28.9)</td>
<td>206 (27.9)</td>
<td></td>
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</tr>
<tr>
<td>Multivariable-adjusted HR (95% CI)*</td>
<td>1.0</td>
<td>1.00 (0.77–1.32)</td>
<td>1.10 (0.85–1.44)</td>
<td>1.31 (1.02–1.68)</td>
<td>1.27 (0.97–1.66)</td>
<td>0.019</td>
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<tr>
<td>Plus further adjustment for fatty acids†</td>
<td>1.0</td>
<td>1.10 (0.84–1.44)</td>
<td>1.26 (0.95–1.69)</td>
<td>1.62 (1.22–2.16)</td>
<td>1.75 (1.23–2.50)</td>
<td>&lt;0.001</td>
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<tr>
<td>ARIC Study</td>
<td>Median percent of total fatty acids§</td>
<td>0.39</td>
<td>0.49</td>
<td>0.56</td>
<td>0.65</td>
<td>0.80</td>
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<tr>
<td>Cases (rate/1,000 person-years)</td>
<td>75 (5.1)</td>
<td>50 (4.0)</td>
<td>67 (5.3)</td>
<td>61 (5.0)</td>
<td>77 (6.2)</td>
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<tr>
<td>Multivariable-adjusted HR (95% CI)*</td>
<td>1.0</td>
<td>0.84 (0.58–1.20)</td>
<td>1.11 (0.79–1.56)</td>
<td>1.01 (0.72–1.43)</td>
<td>1.27 (0.92–1.76)</td>
<td>0.09</td>
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<tr>
<td>Plus further adjustment for fatty acids†</td>
<td>1.0</td>
<td>1.01 (0.68–1.48)</td>
<td>1.41 (0.97–2.05)</td>
<td>1.43 (0.95–2.16)</td>
<td>1.92 (1.22–3.03)</td>
<td>0.002</td>
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<tr>
<td>Pooled estimates‡</td>
<td>1.0</td>
<td>0.94 (0.76–1.17)</td>
<td>1.11 (0.90–1.36)</td>
<td>1.19 (0.93–1.51)</td>
<td>1.27 (1.03–1.57)</td>
<td>0.004</td>
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<tr>
<td>Plus further adjustment for fatty acids†</td>
<td>1.0</td>
<td>1.07 (0.85–1.33)</td>
<td>1.32 (1.05–1.65)</td>
<td>1.56 (1.23–1.97)</td>
<td>1.82 (1.37–2.40)</td>
<td>&lt;0.001</td>
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ARIC indicates Atherosclerosis Risk in Communities Study; CHF, congestive heart failure; CHS, Cardiovascular Health Study; CI, confidence interval; HR, hazard ratio; LCMUFA, long-chain monounsaturated fatty acid; *HR and 95% CI, with the first quintile category as the reference, adjusted for the same covariates as those in Table 1, except phospholipid fatty acids were not incorporated into this first model. †Further adjusted for phospholipid fatty acids after backward selection (for details, see text and the footnote for Table 1). ‡CHS and ARIC estimates were pooled by use of random-effects meta-analysis; there was little evidence for heterogeneity across estimates for each fatty acid (I²<3%). §For unclear reasons, 24:1 fatty acid levels were significantly higher in CHS than ARIC. Evaluated continuously in each cohort: in CHS, fully adjusted HR=1.82 (95% CI, 1.33–2.49) per interdecile range (1.21%); in ARIC, fully adjusted HR=1.74 (95% CI, 1.19–2.54) per interdecile range (0.41%); when pooled, fully adjusted HR=1.78 (95% CI, 1.40–2.27).
In NHANES 2003 to 2010, mean±SD intakes of 20:1 and 22:1 were 239±23 and 34±15 mg/d, respectively. Many of the food sources of LCMUFA consumption in the United States were similar to those seen to be associated with circulating phospholipid LCMUFA levels in CHS and ARIC, including seafood, poultry, meats, and mustard (Figure 3). Because 24:1 consumption was not reported in NHANES, we assessed the US Department of Agriculture nutrient database to identify possible sources of LCMUFA consumption. Reported sources included mustard, seafood, and edible oil products (Table IV and V in the online-only Data Supplement), although only 6% of all items indexed 24:1 food contents.

Discussion

In 2 independent community-based prospective cohorts, we found higher circulating levels of 22:1 and 24:1 to be associated with a higher incidence of CHF. Each plasma phospholipid LCMUFA, in particular 24:1, was also associated with specific physiological risk factors. In both cohorts, we identified diverse dietary correlates of circulating LCMUFA concentrations, including fish, poultry, nuts, mustard, and meat products. These findings were broadly consistent with the current major food sources of estimated LCMUFA consumption in the United States.

Existing evidence from animal experiments of LCMUFA-rich oil feeding and human studies on cardiac steatosis supports our observations, providing plausible biological pathways whereby LCMUFA exposure increases CHF risk, including CHF with both preserved and reduced ejection fraction. In studies in rodents, pigs, and nonhuman primates, experimental feeding of LCMUFA caused cardiac steatosis and fibrosis, which relate to both systolic and diastolic dysfunction in humans. For example, among patients with aortic valve disease and healthy volunteers without known cardiac diseases, the presence of greater cardiac fibrosis and greater myocardial lipid content, as quantified by cardiac biopsy or magnetic resonance imaging, are independently associated with lower ejection fraction, greater passive ventricular stiffness, and other indexes of impaired early and late diastolic function.

The potential cardiotoxicity of LCMUFA may relate to their oxidative metabolism, to which the heart is likely to be especially susceptible because of its preferential use of fatty acids for energy. Experimental studies suggest that, in contrast to most other fatty acids, long-chain fatty acids, including LCMUFA, are poorly oxidized in mitochondria as a result of a lack of mitochondrial membrane-transporting enzymes. Consequently, long-chain fatty acids predominantly undergo peroxisomal oxidation, which generates reactive oxygen species, including H₂O₂, and releases various lipid metabolites into the cytosol. Accumulated lipids include malonyl-CoA, which could inhibit mitochondrial fatty acid transport mediated by carnitine palmitoyltransferase-1; other acyl-CoAs that could stimulate lipogenic signals, suppressing glycolysis and forming lipid droplets linked to cardiac steatosis; ceramides, which serve as a second messenger for apoptotic signaling; and phospholipids and diacylglycerols, which alter membrane lipid composition and electrophysiological homeostasis, enhancing calcium overload linked to apoptosis, as well as contractile dysfunction and arrhythmia. These exacerbations have been partly demonstrated by research in transgenic animals. For example, mice with myocardium-specific overexpression of peroxisome proliferator-activated receptor-α exhibited interrelated phenotypes, including greater peroxisomal fatty acid oxidation; greater cytosolic lipid accumulation; inhibition of pyruvate dehydrogenase, a rate-limiting enzyme of glycolysis; greater left ventricular size and wall thickness; and reduced systolic function. Other evidence supports the notion of links between mitochondrial dysfunction and cardiac steatosis and heart failure. In cardiomyocytes biopsied from patients with aortic regurgitation, cardiac steatosis was associated with greater systolic dysfunction and overexpression of lipogenic enzymes, including sterol-regulatory element binding protein-1c. As described above, a potential mechanism of cardiotoxicity is malonyl-CoA accumulation, resulting in inhibition...
of carnitine palmitoyltransferase-1. However, in animal studies and small clinical studies, antianginal drugs include carnitine palmitoyltransferase-1 inhibitors, which block mitochondrial oxidation, activating glycolysis and resulting in lower myocardial oxygen consumption.6,31 Thus, our findings highlight the need for better understanding of

**Figure 2.** Dietary factors independently associated with plasma phospholipid long-chain monounsaturated fatty acid (LCMUFA) concentrations: the Cardiovascular Health Study (CHS) and the Atherosclerosis Risk in Communities (ARIC) Study (Minneapolis subcohort). Values represent each standard deviation difference of LCMUFA levels according to 1 serving per week of each food group. Means±SD of 20:1, 22:1, and 24:1 levels (percent fatty acids) were 0.12±0.04, 0.03±0.01, and 1.96±0.44 in CHS and 0.12±0.03, 0.01±0.03, and 0.57±0.17 in ARIC, respectively. Food groups were selected by backward stepwise approach ($P_{\text{retain}}<0.05$ and $P_{\text{remove}}>0.1$). Covariates were the same as those in the Table 1, except that the other phospholipid fatty acids, which were potential mediators in this analysis, were not adjusted for. Negative correlates of LCMUFAs included margarine, butter, and other sugary foods (Figure I in the online-only Data Supplement) that may have reflected high levels of major shorter-chain fatty acids. *Vegetables were first grouped into 7 categories based on 30. Vegetables included here were celery, beet, zucchini, garlic, vegetable sauces, and mixed vegetables. Mixed meals included pasta, lasagna, pizza, and other miscellaneous meals.

**Figure 3.** Contribution of food groups to consumption of 20:1 and 22:1 fatty acids in US adults ($\geq$20 years of age): the US National Health and Nutrition Examination Survey, 2003 to 2010 (n=20,150). The food groups presented here contributed to 62.4% of total 20:1 fatty acid consumption and 86.2% of total 22:1 fatty acid consumption. No data on 24:1 fatty acid consumption are available in the survey.
the potential mechanisms that might underlie the observed toxicity of LCMUFAs, including investigation of pathways related to mitochondrial function and energetic changes induced by fatty acids of all types.

When we evaluated subtypes of incident CHF in CHS, 24:1 appeared similarly associated with all subtypes. Conversely, 22:1 appeared most strongly related to ischemic CHF; however, we cannot rule out the possibility that the associations for CHF subtypes were similar because the 95% CIs were broad and associations for different CHF subtypes were not significantly different. Potential harms of LCMUFAs for diverse mechanisms of CHF onset are consistent with the multiple pathophysiologic pathways implicated in experimental studies, which together could lead to both systolic and diastolic dysfunction, both in the setting of ischemia and in the absence of ischemia. Interestingly, we also found that higher LCMUFA levels were associated with substantially lower triglyceride levels and higher inflammatory biomarkers, consistent with hepatic mitochondrial toxicity exhibiting hepatic inflammation and impaired hepatic lipid secretion. Our findings demonstrate the need for future studies to better characterize associations of LCMUFA exposure with differing origins of CHF and with measures of steatosis, fibrosis, and function of both cardiac and noncardiac tissues, for example, as assessed by cardiac and hepatic magnetic resonance imaging.

Circulating levels of 22:1 and 24:1 were robustly and consistently associated with CHF in both cohorts. Findings for 22:1 are consistent with animal experimental evidence of cardiotoxicity resulting from consumption of oil rich in 22:1. In addition, dietary 22:1 appears to be elongated to 24:1 in humans, which, together with our findings, suggests that experimentally observed cardiotoxicity of dietary 22:1 could be partly attributable to effects of its metabolite 24:1. In contrast to 22:1 and 24:1, we did not find significant associations of 20:1 with incident CHF. Evidence from cellular studies suggests that 20:1 undergoes mitochondrial oxidation to a greater extent than 22:1, which could limit its cardiotoxicity, and explain our findings. Additionally, why the potential cardiotoxicity of 22:1 and 24:1 may be greater than for other long-chain fatty acids is unknown. One study suggested that peroxisomal oxidation of 24:1 is faster than that of 24:0, supporting greater toxicity of the former.

Animal experimental evidence of cardiotoxicity resulting from LCMUFA consumption stimulated Canadian farmers to develop Canola oil, which became commercially available during the 1960s. Thereafter, governmental regulations in Canada (1975), the United Kingdom (1977), and the United States (1985), as well as recommendations by Food and Agriculture Organization of the United Nations/World Health Organization (1982), were instituted to lower the content of 22:1n9 in rapeseed-derived oils. For instance, the US Food and Drug Administration mandated producers to reduce the 22:1n9 content in rapeseed oil from the original 30% to 60% to <2% by weight. Although these steps might reduce the population exposure to LCMUFAs in these countries, our findings indicate remaining dietary exposure to LCMUFAs in the United States. Additionally, in other countries, LCMUFA exposure could be even higher because of habitual consumption of unaltered rapeseed oil and mustard oil.

We found that many different foods could influence LCMUFA exposure, including generally more healthful foods (fish, mustard seeds and oil, salad oils, poultry) and less healthful foods (processed meats and mixed meals, eg, pizza and meat sandwiches). This indicates that the potential cardiotoxicity of LCMUFAs cannot be attributed to any single dietary source and depends on overall exposure to LCMUFAs. As a corollary of this, the net effects of any food would depend not just on its LCMUFA content but also on other constituents in the food. For example, in the case of fish, which has been inversely associated with incident CHF in these cohorts, potential benefits of long-chain omega-3 polyunsaturated fatty acids in fish would plausibly outweigh any harmful effects of LCMUFA content. This does not obviate the suggestion of our findings that LCMUFA exposure itself increases the risk of CHF compared with the absence of such exposure. Our results support the need for interventional studies to determine whether lowering LCMUFAs in foods could reduce their harms or, in the case of beneficial foods such as fish, further increase their benefits. Although diet clearly influences circulating LCMUFA levels, the contribution of metabolic pathways remains uncharacterized. Few studies suggest that both diet and metabolism may influence circulating LCMUFA levels. For example, in a small (n=29) 2-year intervention among patients with inherited peroxisomal disorder (X-linked adrenoleukodystrophy) to reduce circulating levels of long-chain saturated fatty acids, 22:1 feeding (0.3 g/kg/d) elevated levels of both circulating 22:1 and 24:1 by 3-fold. These findings suggest that dietary 22:1 directly influences circulating 22:1 levels and is elongated to 24:1.

To the best of our knowledge, this is the first investigation to evaluate LCMUFAs and any health outcome in humans. Despite our findings and the prior animal experimental evidence, any single study should not alter dietary guidelines or clinical practice. Policy makers and clinicians should recognize the potential cardiotoxicity of LCMUFA exposure and be supportive of and watchful for further investigations. Our findings highlight the clear need to understand how LCMUFAs may influence health. This includes research to characterize details of dietary sources of LCMUFAs in various populations, as well as intervention studies to explore possible benefits of lowering LCMUFA exposure in populations having or at risk for CHF, examining end points such as cardiac imaging metrics, left ventricular systolic and diastolic function, symptoms and exercise tolerance, and clinical CHF.

Potential limitations deserve consideration. Methods for assessing study variables were somewhat different in each cohort. Methodological differences in fatty acid measurements could partly explain the observed differences in absolute levels of 24:1 in the 2 cohorts. Despite these differences, the consistency of our findings between the 2 cohorts increases confidence in the validity and generalizability of our findings. Our findings should be interpreted cautiously because causality is unknown owing to confounding and exposure misclassification. Lesser reproducibility over time could partly explain weaker associations for 20:1 and 22:1 compared with 24:1. Although we performed multivariate adjustment and...
regression dilution correction, such methods are imperfect, and remaining residual errors could bias our results toward or away from the null. In examinations of potential confounding, circulating LCMUFAs were not associated with incident stroke, which shares many CHF risk factors. Moreover, both generally healthful and unhealthful foods were associated with LCMUFA exposure. These results, together with the magnitude and consistency of our findings, suggest that residual confounding could not entirely explain the observed associations. Our analysis was based on cohorts generally made up of white Americans, stimulating future research on LCMUFA exposure and CHF events and causes in other races/ethnicities.

Conclusions
Our observations indicate that higher circulating LCMUFA levels are associated with a greater incidence of CHF. Our findings in 2 cohorts, together with prior animal experiments, support the need to better characterize dietary sources of LCMUFAs, to further elucidate molecular mechanisms of effects, and to design and implement interventions to test the effects of reducing LCMUFA exposure.

Acknowledgments
We thank the participants and staff of CHS and ARIC (see http://www.chs-nhlbi.org/ and http://www.cscc.unc.edu/aric/).

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Disclosures
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Decades ago, animal experiments demonstrated that feeding of long-chain monounsaturated fatty acids (LCMUFAs) such as erucic acid (22-carbon fatty acid, 22:1) caused cardiotoxicity, including cardiac lipid accumulation. In the 1970s, this evidence stimulated Canadian farmers to modify rapeseed oil, a major source of LCMUFA, to lower its 22:1 content and rename it Canola oil (Canadian oil low in erucic acid). Potential health effects and dietary sources of LCMUFAs (20:1, 22:1, and 24:1) were never studied in humans and subsequently largely forgotten. To elucidate both potential cardiotoxicity and dietary sources, we evaluated blood LCMUFA biomarkers in relation to incident congestive heart failure in 2 independent cohorts and LCMUFA dietary consumption in both cohorts and in the 2003–2010 US National Health and Nutrition Examination Survey. In multivariable-adjusted analyses, compared with the bottom quintiles, individuals in the highest quintile of 22:1 levels experienced ≈50% greater incident congestive heart failure and those in the highest quintile of 24:1 levels experienced 2-fold greater incidence, with consistent results in both cohorts. On the basis of both biomarkers and food composition data, major food sources of LCMUFAs were mustard, salad oils, poultry, fish, processed meats, and mixed meals (eg, pizza). No single food contributed >35% of LCMUFA consumption. In summary, blood LCMUFAs were significantly associated with incident congestive heart failure in 2 cohorts. Diverse identified dietary sources suggest that potential cardiotoxicity cannot be attributable to any single food, for which net health effects might depend on both LCMUFAs and other constituents. Our findings demonstrate the need for additional experimental, observational, and interventional studies to characterize the cardiovascular effects of LCMUFAs and their implications for clinical and public health guidelines.
Long-Chain Monounsaturated Fatty Acids and Incidence of Congestive Heart Failure in 2 Prospective Cohorts
Fumiaki Imamura, Rozenn N. Lemaitre, Irena B. King, Xiaoling Song, Lyn M. Steffen, Aaron R. Folsom, David S. Siscovick and Dariush Mozaffarian

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SUPPLEMENTAL MATERIAL


“Long-chain monounsaturated fatty acids and incidence of congestive heart failure in two prospective cohorts”

Assessments of Cardiovascular Risk Factors and Covariates

Demographic characteristics, cardiometabolic risk factors, and lifestyle behaviors were derived from in-clinic evaluations in Cardiovascular Health Study (CHS) and in-home interviews and in-clinic evaluations in Atherosclerosis Risk in Communities Study (ARIC). Anthropometric and blood pressure measurements were obtained using standard procedures and equipment. Fasting levels of triglycerides, HDL-cholesterol, glucose, insulin, fibrinogen, leukocytes, and C-reactive protein (only assessed in CHS) were measured by standardized methods including enzymatic assays, radioimmunoassays, coagulation tests, or cell counts. Levels of LDL-cholesterol were derived using the Friedewald formula in both cohorts. Left-ventricular hypertrophy was derived from 12-lead electrocardiograms according to voltage criteria in both cohorts.

Physical activity was assessed using a modified Minnesota Leisure-Time Activities questionnaire in CHS and the Baecke sports questionnaire in ARIC. Dietary habits were assessed by serial interviewer-administered validated food frequency questionnaires in both cohorts. CHS participants completed a picture-sort questionnaire in 1989-90 and a Willett questionnaire in 1996-97, and ARIC participants completed Willett questionnaires in 1987-89 and 1993-95.

Assessments of Phospholipid Fatty Acids

Methods of assessments of plasma phospholipid fatty acids slightly differed between CHS and ARIC. In both cohorts, plasma lipids were extracted by the Folch method, and plasma phospholipids were isolated by thin-layer chromatography using silica-gel columns and mobile-phase of organic solvents. In CHS, phospholipid moieties were directly transesterified by a one-step procedure; and in ARIC, by boron trifluoride catalysis. After recovery as fatty acid methyl-esters, each fatty acid was chromatographically separated and quantified as a percentage of total phospholipid fatty acids. CHS used SP-2560 capillary columns (100 m, Agilent Technologies Inc., CA) that produced 42 peaks of known individual fatty acids; and ARIC, FFAP WCOT glass capillary columns (50 m, J&W Scientific, CA) that produced 29 peaks of known individual fatty acids. In CHS, we excluded three fatty acids (trans,trans-18:2n-6, cis-14:1n-5, and cis-18:1n-8) due to identified laboratory drift and one trace fatty acid (22:5n-6) that was only measured in the latter half of FA samples.


To qualitatively examine generalizability and validity of our findings in the Cardiovascular Health Study (CHS) and Atherosclerosis Risk in Communities Study (ARIC), we evaluated food sources of LCMUFA intakes in the nationally representative adults (≥20 years old) in the four cycles of NHANES 2003-2004, 2005-2006, 2007-2008, and 2009-2010.

In NHANES 2003-2010, the multiple dietary recalls from 2,0150 adults identified 3,724 food items consumed, allowing estimation of intake of 20:1 and 22:1 LCMUFA (but not 24:1, for which consumption was not estimated in NHANES). After deleting foods containing 0 gram of LCMUFA (n=24) and systematic and manual food grouping, 3,700 items were retained. Subsequently, they were grouped into 1,083 food groups according to food codes identifying the same food items with minor difference (cooking methods or different condiments). Of the 1,083 food groups, we calculated each percent contribution (%) by the method used previously. Briefly, the intakes of total and each
LCMUFA were estimated by the weighted sum of LCMUFA from all food consumptions reported; the percent contribution (%) provided by each food item was then calculated by the following equation:

\[
\sum_{j=1}^{20,150} \sum_{k=0}^{S_{ij}} \frac{d_{ij} LCMUFA_{ijk} \times w_j}{\sum_{i=1}^{20,150} \sum_{j=1}^{1,083} \sum_{k=0}^{S_{ij}} d_{ij} S_{ij} LCMUFA_{ijk} \times w_j} \times 100
\]

where \(i\) = food items (1, 2, ..., 1,083); \(j\) = individuals (1, 2, ..., 20,150); \(k\) = servings of that food item of individual (0, 1, 2, ..., \(S_{ij}\)); \(S_{ij}\) = number of servings of \(i\)th food consumed by \(j\)th individual; \(d_{ij}\) = 1 if \(j\)th person consumed \(i\)th food, =0 otherwise; \(LCMUFA_{ijk}\) = amount of LCMUFA contained in serving \(k\) of food \(i\) to individual \(j\); \(w_j\) = sample weight for that individual.

We identified 200 food groups contributing to 90% of LCMUFA intake in the population (Supplemental Table 4). The 200 food groups were further grouped into 17 food groups to identify major food groups contributing to LCMUFA population intake. Of 20:1 and 22:1 LCMUFA, the 200 food groups contributed to 89.4% and 94.1% of total intake of LCMUFA in the US population, respectively.

Evaluation of LCMUFA contents of 7,538 food items in the United States Department of Agriculture National Nutrient Database for Standard Reference Release 22

In CHS, ARIC and NHANES, estimates of LCMUFA intakes had limitation in the nutrient database not compiling 24:1 LCMUFA, although 24:1 accounted for >80% of plasma phospholipid LCMUFA and for positive association of LCMUFA with incident CHF in both CHS and ARIC. Therefore, we examined LCMUFA contents in the recent USDA nutrient database to identify food items rich in LCMUFA.

In the USDA database, 7,538 food items were complied. Of the food items, 5,331 (70%), 4,746 (63%) and 467 (6%) food items had data on contents of 20:1, 22:1, and 24:1 fatty acids, respectively. Of each LCMUFA, we separately ranked food items in order of high to low LCMUFA contents. Food items originally categorized into “Ethnic foods” contain high LCMUFA; for example, for 24:1, 12 of 20 food items are “Ethnic foods”. As these food items may be less commonly consumed in the general US population, we performed separate analyses for “Ethnic foods” and the remaining types of food categories. The results from the USDA database are presented in the Supplemental Table 4.

For total LCMUFA, 20:1 and 22:1 LCMUFA, mustard and fish products were ranked as the top food sources. For 24:1 LCMUFA, plant-based oils were among the top food sources, although fish products categorized as “Ethnic foods” also contained 24:1 LCMUFA (contents of 24:1 LCMUFA in fish products categorized as “Finfish and Shellfish Products” were not recorded in the database).

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### Supplemental Table 1. Baseline characteristics of participants

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<th>Atherosclerosis Risk in Communities Study*</th>
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</thead>
<tbody>
<tr>
<td>N</td>
<td>3,694</td>
<td>3,577</td>
</tr>
<tr>
<td>Plasma phospholipid fatty acid, percent of total fatty acids</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20:1 fatty acid</td>
<td>0.12 (0.03)</td>
<td>0.12 (0.03)</td>
</tr>
<tr>
<td>22:1 fatty acid</td>
<td>0.03 (0.01)</td>
<td>0.01 (0.03)</td>
</tr>
<tr>
<td>24:1 fatty acid</td>
<td>1.96 (0.44)</td>
<td>0.57 (0.17)</td>
</tr>
<tr>
<td>Age, years†</td>
<td>75.2 (5.2)</td>
<td>54.1 (5.8)</td>
</tr>
<tr>
<td>White, %</td>
<td>88</td>
<td>100</td>
</tr>
<tr>
<td>Male sex, %</td>
<td>40</td>
<td>49</td>
</tr>
<tr>
<td>Education, some college or higher, %</td>
<td>45</td>
<td>46</td>
</tr>
<tr>
<td>Income, $25,000/year or higher, %</td>
<td>42</td>
<td>82</td>
</tr>
<tr>
<td>Employed, %</td>
<td>---‡</td>
<td>71</td>
</tr>
<tr>
<td>Smoking, Never, %</td>
<td>49</td>
<td>34</td>
</tr>
<tr>
<td>Former, %</td>
<td>43</td>
<td>46</td>
</tr>
<tr>
<td>Current, %</td>
<td>8</td>
<td>20</td>
</tr>
<tr>
<td>Menopause among women, %</td>
<td>100</td>
<td>52</td>
</tr>
<tr>
<td>Estrogen ever-users among women, %</td>
<td>35</td>
<td>36</td>
</tr>
<tr>
<td>Hypertension medication, %</td>
<td>48</td>
<td>20</td>
</tr>
<tr>
<td>Type 2 diabetes, %</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>Coronary heart disease, %</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td>Stroke, %</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>26.7 (4.6)</td>
<td>27.0 (4.0)</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>97.0 (13.0)</td>
<td>94.0 (13.0)</td>
</tr>
<tr>
<td>Leisure-time physical activity, kcal/week§</td>
<td>1,063 (1,450)</td>
<td>---</td>
</tr>
<tr>
<td>Physical activity score§</td>
<td>---</td>
<td>2.6 (0.8)</td>
</tr>
<tr>
<td>Alcohol drinkers, %</td>
<td>46</td>
<td>59</td>
</tr>
<tr>
<td>Fiber intake, g/day</td>
<td>14.9 (5.4)</td>
<td>14.4 (6.4)</td>
</tr>
<tr>
<td>Total fat, % energy</td>
<td>33.6 (7.2)</td>
<td>31.2 (8.0)</td>
</tr>
<tr>
<td>Saturated fat, % energy</td>
<td>11.8 (3.1)</td>
<td>12.7 (4.2)</td>
</tr>
<tr>
<td>Trans fat intake, g/day</td>
<td>2.7 (1.4)</td>
<td>3.2 (1.9)</td>
</tr>
<tr>
<td>Fish, servings/week</td>
<td>1.6 (1.6)</td>
<td>1.3 (1.8)</td>
</tr>
<tr>
<td>Processed meat, servings/week</td>
<td>1.2 (1.5)</td>
<td>2.3 (3.2)</td>
</tr>
<tr>
<td>Eggs, servings/week</td>
<td>1.3 (1.4)</td>
<td>1.8 (2.3)</td>
</tr>
<tr>
<td>Whole grains, servings/week</td>
<td>6.8 (6.9)</td>
<td>7.4 (7.3)</td>
</tr>
<tr>
<td>Fruits, servings/week</td>
<td>10.3 (8.6)</td>
<td>9.5 (8.2)</td>
</tr>
<tr>
<td>Sugar-sweetened beverages, servings/week</td>
<td>0.6 (1.4)</td>
<td>2.2 (5.0)</td>
</tr>
</tbody>
</table>

Values are mean (SD) for continuous variables and percent for categorical variables.

*The subcohort enrolled from Minnesota, in whom phospholipid fatty acids were measured.
† According to eligibility criteria at baseline: age ≥65 y in CHS, and 45-64 y in ARIC
‡ Not assessed
§ Leisure-time physical activity was calculated from Minnesota Leisure-Time Activities questionnaire in the Cardiovascular Health Study. Five-point score was calculated from the Baecke sports questionnaire in Atherosclerosis Risk in Communities Study.
<table>
<thead>
<tr>
<th></th>
<th>Cardiovascular Health Study (CHS, n=3,694)</th>
<th>Atherosclerosis Risk in Communities Study (ARIC, n=3,577)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Difference (95% CI)*</td>
<td>p value</td>
</tr>
<tr>
<td><strong>20:1 fatty acids</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>1.0 (0.7 to 1.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>3.5 (2.5 to 4.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Systolic BP, mm Hg</td>
<td>-1.2 (-3.1 to 0.7)</td>
<td>0.232</td>
</tr>
<tr>
<td>Diastolic BP, mm Hg</td>
<td>0.0 (-1.0 to 1.0)</td>
<td>0.961</td>
</tr>
<tr>
<td>LDL cholesterol, mmol/L</td>
<td>0.04 (-0.06 to 0.13)</td>
<td>0.469</td>
</tr>
<tr>
<td>HDL cholesterol, mmol/L</td>
<td>-0.08 (-0.11 to -0.04)</td>
<td>0.001</td>
</tr>
<tr>
<td>Triglyceride, mmol/L</td>
<td>0.05 (-0.06 to 0.11)</td>
<td>0.289</td>
</tr>
<tr>
<td>Glucose, mmol/L</td>
<td>4.7 (-1.1 to 10.3)</td>
<td>0.111</td>
</tr>
<tr>
<td>Fibrinogen, µmol/L</td>
<td>0.13 (-0.03 to 0.28)</td>
<td>0.114</td>
</tr>
<tr>
<td>Leukocyte count, 10^3/mm^3</td>
<td>-0.1 (-0.2 to 0.1)</td>
<td>0.402</td>
</tr>
<tr>
<td>C-reactive protein, mmol/L</td>
<td>-2.8 (-5.9 to 0.2)</td>
<td>0.069</td>
</tr>
<tr>
<td>Left-ventricular hypertrophy, yes or no†</td>
<td>0.84 (0.56 to 1.28)</td>
<td>0.12</td>
</tr>
<tr>
<td><strong>22:1 fatty acids</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>1.0 (0.7 to 1.4)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Waist circumference, cm</td>
<td>3.5 (2.5 to 4.5)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Systolic BP, mm Hg</td>
<td>-1.2 (-3.1 to 0.7)</td>
<td>0.232</td>
</tr>
<tr>
<td>Diastolic BP, mm Hg</td>
<td>0.0 (-1.0 to 1.0)</td>
<td>0.961</td>
</tr>
<tr>
<td>LDL cholesterol, mmol/L</td>
<td>0.04 (-0.06 to 0.13)</td>
<td>0.469</td>
</tr>
<tr>
<td>HDL cholesterol, mmol/L</td>
<td>-0.08 (-0.11 to -0.04)</td>
<td>0.000</td>
</tr>
<tr>
<td>Triglyceride, mmol/L</td>
<td>0.03 (-0.06 to 0.11)</td>
<td>0.519</td>
</tr>
<tr>
<td>Glucose, mmol/L</td>
<td>0.05 (-0.05 to 0.15)</td>
<td>0.289</td>
</tr>
<tr>
<td>Insulin, pmol/L</td>
<td>4.7 (-1.1 to 10.5)</td>
<td>0.111</td>
</tr>
<tr>
<td>Fibrinogen, µmol/L</td>
<td>0.23 (0.04 to 0.41)</td>
<td>0.016</td>
</tr>
<tr>
<td>Leukocyte count, 10^3/mm^3</td>
<td>0.1 (-0.1 to 0.3)</td>
<td>0.561</td>
</tr>
<tr>
<td>C-reactive protein, mmol/L</td>
<td>14.4 (9.6 to 19.1)</td>
<td>0.001</td>
</tr>
<tr>
<td>Left-ventricular hypertrophy, yes or no†</td>
<td>1.03 (0.63 to 1.70)</td>
<td>0.50</td>
</tr>
</tbody>
</table>

* Difference (95% confidence interval, CI) in risk factors according to 10th to 90th percentile range of plasma phospholipid 20:1 and 22:1 fatty acid was estimated. The estimates were based on multivariable-linear regression adjusting for age, sex, clinical sites (only in CHS), employment status (only ARIC), education status, smoking status, physical activity, alcohol consumption, hypertension medication, prevalent coronary heart disease, prevalent diabetes, caloric intake, and dietary factors. Individual phospholipid fatty acids were further adjusted for, after backward selection (see text in detail), including cis-trans-18:2n6, 22:2n6, 17:1n9, 20:0, and 18:1n7 in CHS, and 17:0, 20:2n6, 16:0, 18:2n6, 20:3n6, and 23:0 in ARIC. The dietary and fatty acid covariates were selected in each cohort (see text in the main article). Body-mass index (BMI) and waist circumference were also used as covariates for non-adiposity measures. BP, blood pressure; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol.

† Odds ratio (95% CI) for left-ventricular hypertrophy evaluated by multivariable-adjusted logistic regression.
### Supplemental Table 3. Incidence of congestive heart failure (CHF) and stroke according to circulating phospholipid long-chain mono-unsaturated fatty acids

<table>
<thead>
<tr>
<th>Incident disease</th>
<th>Cases</th>
<th>Hazard ratio (95% confidence interval) *</th>
<th>20:1</th>
<th>22:1</th>
<th>24:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall and subtypes of CHF in CHS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>997</td>
<td>1.10 (0.92, 1.32)</td>
<td>1.23 (1.01, 1.49)†</td>
<td>1.65 (1.19, 2.29)†</td>
<td></td>
</tr>
<tr>
<td>Ischemic CHF §</td>
<td>483</td>
<td>1.21 (0.98, 1.49)</td>
<td>1.46 (1.16, 1.85)†</td>
<td>1.70 (1.06, 2.71)†</td>
<td></td>
</tr>
<tr>
<td>Valvular CHF §</td>
<td>236</td>
<td>1.24 (1.04, 1.47)</td>
<td>1.17 (0.80, 1.73)</td>
<td>1.83 (0.93, 3.60)</td>
<td></td>
</tr>
<tr>
<td>Non-ischemic non-valvular CHF</td>
<td>267</td>
<td>0.69 (0.46, 1.04)</td>
<td>1.03 (0.69, 1.54)</td>
<td>1.85 (1.04, 3.30)†</td>
<td></td>
</tr>
<tr>
<td>Incident stroke (negative control)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHS</td>
<td>555</td>
<td>1.16 (0.94, 1.42)</td>
<td>1.13 (0.83, 1.55)</td>
<td>0.95 (0.58, 1.56)</td>
<td></td>
</tr>
<tr>
<td>ARIC</td>
<td>165</td>
<td>1.00 (0.65, 1.54)</td>
<td>0.86 (0.69, 1.07)</td>
<td>1.39 (0.80, 2.42)</td>
<td></td>
</tr>
<tr>
<td>Pooled estimate ‡</td>
<td>720</td>
<td>1.13 (0.94, 1.36)</td>
<td>0.96 (0.75, 1.25)</td>
<td>1.12 (0.78, 1.63)</td>
<td></td>
</tr>
</tbody>
</table>

* Risk according to the interdecile range (90th versus 10th percentile) of each LCMUFA. The model covariates were the same as those in the fully adjusted model in the Table 2 in the main manuscript.

† *p* <0.04 for associations of LCMUFA with incident CHF.

‡ To pool estimates in CHS and ARIC, we performed random-effect meta-analysis.

§ Ischemic and valvular CHF overlapped, as 124 cases developed with CHF with ischemia and valvular disease. There was no significant heterogeneity in associations between each circulating LCMUFA and different subtypes of CHF (*p*>0.05), assessed by multivariable-adjusted Cox proportional hazard models treating the subtype s of CHF events as competing risks (Lunn M and M Don, Applying Cox regression to competing risks, Biometrics, 1995;51(2): 524-532).
Supplemental Figure 1. Dietary factors independently associated with plasma phospholipid long-chain monounsaturated fatty acid (LCMUFA) concentrations in two cohort studies. Values represent each standard deviation (SD) difference of log-transformed LCMUFA levels according to 1.
servings/week of each food group; mean±SD of 20:1, 22:1, and 24:1 levels (% fatty acids) were 0.12±0.04, 0.03±0.01, and 1.96±0.44 in CHS and 0.12±0.03, 0.01±0.03, and 0.57±0.17 in ARIC, respectively. Food groups were selected by backward stepwise selection (p<0.05 to retain and p>0.1 to remove), after adjustment for age (years), sex, clinical sites (in CHS), employment status (in ARIC), education (<high school, high school or vocational school, or ≥college), smoking (current, former, never), physical activity (kcal/week in CHS; ordinal score in ARIC), alcohol consumption (servings/week), hypertension medication (yes, no), prevalent coronary heart disease (yes, no), prevalent diabetes (yes, no), total caloric intake (kcal/week). *Vegetables were first categorized into 7 categories based on 30; vegetables herein included celery, beet, zucchini, garlic, vegetable sauces, and mixed vegetables. Mixed meals included pasta, lasagna, pizza and other miscellaneous mixed meals.
**Supplemental Table 4. 200 food groups that contributed to 90% of US intake of long-chain monounsaturated fatty acids (LCMUFA) in the National Health and Nutrition Examination Survey (2003-2010)**

<table>
<thead>
<tr>
<th>Food group ^i</th>
<th>Descriptions (number of food items grouped)(^j)</th>
<th>20:1 LCMUFA %(^i)</th>
<th>Cum%(^i)</th>
<th>22:1 LCMUFA %(^i)</th>
<th>Cum%(^i)</th>
<th>Total LCMUFA %(^i)</th>
<th>Cum%(^i)</th>
<th>Food group(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>75506 Mustard (2)</td>
<td>1.1</td>
<td>1.1</td>
<td>27.9</td>
<td>27.9</td>
<td>4.4</td>
<td>4.4</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>42202 Peanut butter (6)</td>
<td>4.5</td>
<td>5.5</td>
<td>0.0</td>
<td>27.9</td>
<td>3.9</td>
<td>8.3</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>26137 Salmon, raw (8)</td>
<td>3.0</td>
<td>8.5</td>
<td>8.9</td>
<td>36.8</td>
<td>3.7</td>
<td>12.0</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>42111 Peanuts, NFS (8)</td>
<td>4.2</td>
<td>12.8</td>
<td>0.0</td>
<td>36.8</td>
<td>3.7</td>
<td>15.7</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>58106 Pizza, cheese, prepared from frozen, thin crust (67)</td>
<td>3.3</td>
<td>16.0</td>
<td>2.6</td>
<td>39.4</td>
<td>3.2</td>
<td>18.9</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>25221 Pepperoni (18)</td>
<td>3.5</td>
<td>19.5</td>
<td>0.6</td>
<td>40.0</td>
<td>3.1</td>
<td>22.0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>25210 Frankfurter, wiener, or hot dog, NFS (7)</td>
<td>2.2</td>
<td>21.7</td>
<td>7.5</td>
<td>47.5</td>
<td>2.8</td>
<td>24.9</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>83112 Green Goddess dressing (6)</td>
<td>2.2</td>
<td>23.9</td>
<td>1.1</td>
<td>48.5</td>
<td>2.1</td>
<td>26.9</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>25220 Cold cut, NFS (18)</td>
<td>1.6</td>
<td>25.5</td>
<td>1.4</td>
<td>49.9</td>
<td>1.6</td>
<td>28.5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>22600 Bacon, NS as to type of meat, cooked (2)</td>
<td>1.7</td>
<td>27.2</td>
<td>0.0</td>
<td>49.9</td>
<td>1.5</td>
<td>30.0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>54401 Salty snacks, corn or cornmeal base, corn chips, corn-cheese chips (6)</td>
<td>1.6</td>
<td>28.8</td>
<td>1.2</td>
<td>51.1</td>
<td>1.5</td>
<td>31.6</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>27510 Pepperoni, on bun (45)</td>
<td>1.5</td>
<td>30.3</td>
<td>1.3</td>
<td>52.4</td>
<td>1.5</td>
<td>33.1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>27146 Chicken or turkey with barbecue sauce, skin eaten (11)</td>
<td>1.7</td>
<td>32.0</td>
<td>0.1</td>
<td>52.6</td>
<td>1.5</td>
<td>34.5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>71401 White potato, french fries, NS as to from fresh or frozen (4)</td>
<td>1.7</td>
<td>33.6</td>
<td>0.0</td>
<td>52.6</td>
<td>1.5</td>
<td>36.0</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>32105 Egg omelet or scrambled egg, fat added in cooking (35)</td>
<td>1.6</td>
<td>35.2</td>
<td>0.5</td>
<td>53.1</td>
<td>1.4</td>
<td>37.4</td>
<td>5</td>
<td></td>
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<tr>
<td>51121 Bread, garlic (2)</td>
<td>1.5</td>
<td>36.7</td>
<td>0.0</td>
<td>53.1</td>
<td>1.3</td>
<td>38.8</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>24198 Chicken skin (8)</td>
<td>1.5</td>
<td>38.2</td>
<td>0.1</td>
<td>53.2</td>
<td>1.3</td>
<td>40.1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>71201 White potato, chips (6)</td>
<td>1.2</td>
<td>39.5</td>
<td>0.0</td>
<td>53.2</td>
<td>1.1</td>
<td>41.2</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>26151 Trout, cooked, NS as to cooking method (6)</td>
<td>0.5</td>
<td>40.0</td>
<td>4.9</td>
<td>58.1</td>
<td>1.1</td>
<td>42.3</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>22701 Pork, sparerribs, cooked, NS as to fat eaten (6)</td>
<td>1.2</td>
<td>41.2</td>
<td>0.0</td>
<td>58.1</td>
<td>1.0</td>
<td>43.3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>24167 Chicken, wing, coated, baked or fried, prepared with skin, NS as to skin/coating eaten (3)</td>
<td>1.1</td>
<td>42.3</td>
<td>0.1</td>
<td>58.2</td>
<td>1.0</td>
<td>44.3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>14410 Cheese, processed, American and Swiss blends (5)</td>
<td>1.1</td>
<td>43.4</td>
<td>0.0</td>
<td>58.2</td>
<td>1.0</td>
<td>45.3</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>24100 Chicken, NS as to part and cooking method, NS as to skin eaten (2)</td>
<td>1.1</td>
<td>44.5</td>
<td>0.0</td>
<td>58.2</td>
<td>1.0</td>
<td>46.2</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>26119 Herring, raw (7)</td>
<td>0.5</td>
<td>45.0</td>
<td>4.1</td>
<td>62.3</td>
<td>0.9</td>
<td>47.1</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>21500 Ground beef or patty, cooked, NS as to percent lean (formerly NS as to regular, lean, or extra lean) (4)</td>
<td>1.0</td>
<td>46.0</td>
<td>0.0</td>
<td>62.3</td>
<td>0.9</td>
<td>48.1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>26100 Fish, NS as to type, raw (15)</td>
<td>0.7</td>
<td>46.8</td>
<td>2.1</td>
<td>64.4</td>
<td>0.9</td>
<td>49.0</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>22101 Pork chop, NS as to cooking method, NS as to fat eaten (21)</td>
<td>1.0</td>
<td>47.8</td>
<td>0.0</td>
<td>64.5</td>
<td>0.9</td>
<td>49.9</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>26139 Sardines, cooked (4)</td>
<td>0.3</td>
<td>48.1</td>
<td>4.5</td>
<td>69.0</td>
<td>0.9</td>
<td>50.7</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>58100 Burrito with beef, no beans (39)</td>
<td>1.0</td>
<td>49.1</td>
<td>0.1</td>
<td>69.1</td>
<td>0.8</td>
<td>51.6</td>
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<tr>
<td>21501 Ground beef, less than 80% lean, cooked (formerly regular) (5)</td>
<td>0.9</td>
<td>50.0</td>
<td>0.0</td>
<td>69.1</td>
<td>0.8</td>
<td>52.4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>31105 Egg, whole, fried (2)</td>
<td>0.8</td>
<td>50.8</td>
<td>0.4</td>
<td>69.4</td>
<td>0.8</td>
<td>53.1</td>
<td>5</td>
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</tr>
<tr>
<td>58132 Spaghetti with tomato sauce, meatless (14)</td>
<td>0.9</td>
<td>51.7</td>
<td>0.1</td>
<td>69.5</td>
<td>0.8</td>
<td>53.9</td>
<td>12</td>
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</tr>
<tr>
<td>27560 Corn dog (frankfurter or hot dog with cornbread coating) (11)</td>
<td>0.7</td>
<td>52.4</td>
<td>0.8</td>
<td>70.3</td>
<td>0.7</td>
<td>54.6</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>27540 Chicken sandwich, with spread (23)</td>
<td>0.7</td>
<td>53.1</td>
<td>0.4</td>
<td>70.8</td>
<td>0.6</td>
<td>55.3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>24122 Chicken, breast, roasted, broiled, or baked, NS as to skin eaten (3)</td>
<td>0.7</td>
<td>53.8</td>
<td>0.0</td>
<td>70.8</td>
<td>0.6</td>
<td>55.9</td>
<td>4</td>
<td></td>
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<tr>
<td>27450 Crab salad (29)</td>
<td>0.4</td>
<td>54.2</td>
<td>2.2</td>
<td>73.0</td>
<td>0.6</td>
<td>56.5</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>42110 Mixed nuts, NFS (5)</td>
<td>0.7</td>
<td>54.9</td>
<td>0.0</td>
<td>73.0</td>
<td>0.6</td>
<td>57.1</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>
Supplemental Table 4. 200 food groups that contributed to 90% of US intake of long-chain monounsaturated fatty acids (LCMUFA) in the National Health and Nutrition Examination Survey (2003-2010)

<table>
<thead>
<tr>
<th>Food group</th>
<th>Food descriptions (number of food items grouped)</th>
<th>20:1 LCMUFA</th>
<th>Cum%</th>
<th>22:1 LCMUFA</th>
<th>Cum%</th>
<th>Total LCMUFA</th>
<th>Cum%</th>
<th>Food group</th>
</tr>
</thead>
<tbody>
<tr>
<td>24127</td>
<td>Chicken, breast, coated, baked or fried, prepared with skin, NS as to skin/coating eaten (6)</td>
<td>0.7</td>
<td>55.6</td>
<td>0.1</td>
<td>73.1</td>
<td>0.6</td>
<td>57.7</td>
<td>4</td>
</tr>
<tr>
<td>14010</td>
<td>Cheese, NFS (2)</td>
<td>0.7</td>
<td>56.2</td>
<td>0.0</td>
<td>73.1</td>
<td>0.6</td>
<td>58.3</td>
<td>11</td>
</tr>
<tr>
<td>25230</td>
<td>Ham, sliced, prepackaged or deli, luncheon meat (11)</td>
<td>0.6</td>
<td>56.8</td>
<td>0.4</td>
<td>73.5</td>
<td>0.5</td>
<td>58.9</td>
<td>1</td>
</tr>
<tr>
<td>54403</td>
<td>Popcorn, popped in oil, unbuttered (7)</td>
<td>0.7</td>
<td>57.5</td>
<td>0.0</td>
<td>73.5</td>
<td>0.5</td>
<td>59.5</td>
<td>14</td>
</tr>
<tr>
<td>26107</td>
<td>Catfish, cooked, NS as to cooking method (6)</td>
<td>0.4</td>
<td>57.9</td>
<td>1.5</td>
<td>74.9</td>
<td>0.6</td>
<td>60.0</td>
<td>6</td>
</tr>
<tr>
<td>58101</td>
<td>Flauta with beef (26)</td>
<td>0.6</td>
<td>58.6</td>
<td>0.0</td>
<td>75.0</td>
<td>0.6</td>
<td>60.6</td>
<td>2</td>
</tr>
<tr>
<td>71403</td>
<td>White potato, home fries (2)</td>
<td>0.6</td>
<td>59.2</td>
<td>0.2</td>
<td>75.2</td>
<td>0.5</td>
<td>61.2</td>
<td>13</td>
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<tr>
<td>58145</td>
<td>Macaroni or noodles with cheese (10)</td>
<td>0.6</td>
<td>59.7</td>
<td>0.1</td>
<td>75.3</td>
<td>0.5</td>
<td>61.7</td>
<td>12</td>
</tr>
<tr>
<td>81102</td>
<td>Margarine, NFS (3)</td>
<td>0.6</td>
<td>60.3</td>
<td>0.2</td>
<td>75.5</td>
<td>0.5</td>
<td>62.2</td>
<td>9</td>
</tr>
<tr>
<td>58104</td>
<td>Nachos with beef, beans, cheese, and sour cream (24)</td>
<td>0.5</td>
<td>60.8</td>
<td>0.1</td>
<td>75.6</td>
<td>0.5</td>
<td>62.7</td>
<td>12</td>
</tr>
<tr>
<td>24164</td>
<td>Chicken, wing, fried, no coating, NS as to skin eaten (3)</td>
<td>0.6</td>
<td>61.4</td>
<td>0.0</td>
<td>75.6</td>
<td>0.5</td>
<td>63.1</td>
<td>4</td>
</tr>
<tr>
<td>42501</td>
<td>Nut mixture with dried fruit and seeds (1)</td>
<td>0.5</td>
<td>61.9</td>
<td>0.0</td>
<td>75.6</td>
<td>0.5</td>
<td>63.6</td>
<td>10</td>
</tr>
<tr>
<td>27111</td>
<td>Beef with tomato-based sauce (mixture) (12)</td>
<td>0.5</td>
<td>62.4</td>
<td>0.1</td>
<td>75.8</td>
<td>0.5</td>
<td>64.1</td>
<td>3</td>
</tr>
<tr>
<td>32202</td>
<td>(19)</td>
<td>0.5</td>
<td>62.9</td>
<td>0.0</td>
<td>75.8</td>
<td>0.4</td>
<td>64.5</td>
<td>2</td>
</tr>
<tr>
<td>83105</td>
<td>Fruit dressing, made with fruit juice and cream (3)</td>
<td>0.2</td>
<td>63.1</td>
<td>2.1</td>
<td>77.9</td>
<td>0.4</td>
<td>65.0</td>
<td>7</td>
</tr>
<tr>
<td>27250</td>
<td>Clams, stuffed (29)</td>
<td>0.3</td>
<td>63.4</td>
<td>1.2</td>
<td>79.1</td>
<td>0.4</td>
<td>65.4</td>
<td>6</td>
</tr>
<tr>
<td>58150</td>
<td>Rice, fried, meatless (6)</td>
<td>0.5</td>
<td>63.9</td>
<td>0.0</td>
<td>79.1</td>
<td>0.4</td>
<td>65.8</td>
<td>16</td>
</tr>
<tr>
<td>24162</td>
<td>Chicken, wing, roasted, broiled, or baked, NS as to skin eaten (3)</td>
<td>0.5</td>
<td>64.4</td>
<td>0.0</td>
<td>79.1</td>
<td>0.4</td>
<td>66.2</td>
<td>4</td>
</tr>
<tr>
<td>26113</td>
<td>Eel, cooked, NS as to cooking method (2)</td>
<td>0.4</td>
<td>64.8</td>
<td>0.0</td>
<td>79.1</td>
<td>0.4</td>
<td>66.6</td>
<td>6</td>
</tr>
<tr>
<td>27445</td>
<td>Chicken or turkey and vegetables (including carrots, broccoli, and/or dark-green leafy (no potatoes)), soy-based sauce (mixture) (8)</td>
<td>0.4</td>
<td>65.3</td>
<td>0.0</td>
<td>79.1</td>
<td>0.4</td>
<td>67.0</td>
<td>4</td>
</tr>
<tr>
<td>24102</td>
<td>Chicken, NS as to part, roasted, broiled, or baked, NS as to skin eaten (3)</td>
<td>0.4</td>
<td>65.7</td>
<td>0.0</td>
<td>79.1</td>
<td>0.4</td>
<td>67.4</td>
<td>4</td>
</tr>
<tr>
<td>91715</td>
<td>Fudge, caramel and nut, chocolate-coated candy (4)</td>
<td>0.3</td>
<td>66.0</td>
<td>1.2</td>
<td>80.4</td>
<td>0.4</td>
<td>67.7</td>
<td>14</td>
</tr>
<tr>
<td>91731</td>
<td>Peanuts, chocolate covered (5)</td>
<td>0.4</td>
<td>66.4</td>
<td>0.0</td>
<td>80.4</td>
<td>0.4</td>
<td>68.1</td>
<td>10</td>
</tr>
<tr>
<td>54328</td>
<td>Crackers, sandwich-type, NFS (3)</td>
<td>0.4</td>
<td>66.8</td>
<td>0.0</td>
<td>80.4</td>
<td>0.4</td>
<td>68.5</td>
<td>16</td>
</tr>
<tr>
<td>24157</td>
<td>prepared with skin, NS as to skin/coating eaten (6)</td>
<td>0.4</td>
<td>67.2</td>
<td>0.0</td>
<td>80.4</td>
<td>0.4</td>
<td>68.8</td>
<td>4</td>
</tr>
<tr>
<td>83107</td>
<td>Mayonnaise, regular (2)</td>
<td>0.4</td>
<td>67.6</td>
<td>0.0</td>
<td>80.4</td>
<td>0.3</td>
<td>69.2</td>
<td>7</td>
</tr>
<tr>
<td>27120</td>
<td>Ham or pork with gravy (mixture) (10)</td>
<td>0.4</td>
<td>68.0</td>
<td>0.0</td>
<td>80.4</td>
<td>0.3</td>
<td>69.5</td>
<td>1</td>
</tr>
<tr>
<td>27214</td>
<td>Meat loaf made with beef (2)</td>
<td>0.4</td>
<td>68.4</td>
<td>0.0</td>
<td>80.4</td>
<td>0.3</td>
<td>69.9</td>
<td>3</td>
</tr>
<tr>
<td>41205</td>
<td>Refried beans (6)</td>
<td>0.4</td>
<td>68.7</td>
<td>0.0</td>
<td>80.5</td>
<td>0.3</td>
<td>70.2</td>
<td>17</td>
</tr>
<tr>
<td>71601</td>
<td>Potato salad with egg (1)</td>
<td>0.1</td>
<td>68.9</td>
<td>1.6</td>
<td>82.1</td>
<td>0.3</td>
<td>70.5</td>
<td>15</td>
</tr>
<tr>
<td>21420</td>
<td>Fish with cream or white sauce, not tuna or lobster (mixture) (1)</td>
<td>0.4</td>
<td>69.3</td>
<td>0.0</td>
<td>82.1</td>
<td>0.3</td>
<td>70.9</td>
<td>2</td>
</tr>
<tr>
<td>27150</td>
<td>Fish omelet or scrambled egg, NS as to fat added in cooking (2)</td>
<td>0.2</td>
<td>69.5</td>
<td>1.2</td>
<td>83.3</td>
<td>0.3</td>
<td>71.2</td>
<td>6</td>
</tr>
<tr>
<td>32104</td>
<td>Egg omelet or scrambled egg, NS as to fat added in cooking (22)</td>
<td>0.3</td>
<td>69.8</td>
<td>0.1</td>
<td>83.5</td>
<td>0.3</td>
<td>71.5</td>
<td>5</td>
</tr>
<tr>
<td>27347</td>
<td>Chicken or turkey pot pie (7)</td>
<td>0.4</td>
<td>70.2</td>
<td>0.0</td>
<td>83.5</td>
<td>0.3</td>
<td>71.8</td>
<td>4</td>
</tr>
<tr>
<td>54402</td>
<td>Salty snacks, corn or cornmeal base,</td>
<td>0.3</td>
<td>70.5</td>
<td>0.2</td>
<td>83.7</td>
<td>0.3</td>
<td>72.1</td>
<td>14</td>
</tr>
</tbody>
</table>
Supplemental Table 4. 200 food groups that contributed to 90% of US intake of long-chain monounsaturated fatty acids (LCMUFA) in the National Health and Nutrition Examination Survey (2003-2010)

<table>
<thead>
<tr>
<th>Food group†</th>
<th>Descriptions (number of food items grouped)†</th>
<th>20:1 LCMUFA %‡</th>
<th>Cum%‡</th>
<th>22:1 LCMUFA %‡</th>
<th>Cum%‡</th>
<th>Total LCMUFA %‡</th>
<th>Cum%‡</th>
<th>Food group§</th>
</tr>
</thead>
<tbody>
<tr>
<td>42104</td>
<td>tortilla chips, unsalted (5)</td>
<td>0.3</td>
<td>70.8</td>
<td>0.0</td>
<td>83.7</td>
<td>0.3</td>
<td>72.4</td>
<td>10</td>
</tr>
<tr>
<td>41104</td>
<td>Cashew nuts, NFS (6)</td>
<td>0.3</td>
<td>71.1</td>
<td>0.1</td>
<td>83.8</td>
<td>0.3</td>
<td>72.7</td>
<td>17</td>
</tr>
<tr>
<td>81103</td>
<td>Pinto, calico, or red Mexican beans, dry, cooked, NS as to fat added in cooking (2)</td>
<td>0.3</td>
<td>71.5</td>
<td>0.0</td>
<td>83.8</td>
<td>0.3</td>
<td>73.0</td>
<td>9</td>
</tr>
<tr>
<td>22400</td>
<td>Pork roast, NS as to cut, cooked, NS as to fat eaten (3)</td>
<td>0.3</td>
<td>71.8</td>
<td>0.0</td>
<td>83.8</td>
<td>0.3</td>
<td>73.3</td>
<td>3</td>
</tr>
<tr>
<td>24147</td>
<td>Chicken, drumstick, coated, baked or fried, prepared with skin, NS as to skin/coating eaten (6)</td>
<td>0.3</td>
<td>72.1</td>
<td>0.0</td>
<td>83.8</td>
<td>0.3</td>
<td>73.5</td>
<td>4</td>
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<tr>
<td>81101</td>
<td>Butter, stick, salted (3)</td>
<td>0.3</td>
<td>72.3</td>
<td>0.0</td>
<td>83.8</td>
<td>0.3</td>
<td>73.8</td>
<td>11</td>
</tr>
<tr>
<td>22000</td>
<td>Pork, NS as to cut, cooked, NS as to fat eaten (9)</td>
<td>0.3</td>
<td>72.6</td>
<td>0.0</td>
<td>83.8</td>
<td>0.3</td>
<td>74.0</td>
<td>3</td>
</tr>
<tr>
<td>58103</td>
<td>Tamale with meat (6)</td>
<td>0.3</td>
<td>72.9</td>
<td>0.0</td>
<td>83.8</td>
<td>0.3</td>
<td>74.3</td>
<td>2</td>
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<tr>
<td>58403</td>
<td>Chicken noodle soup (6)</td>
<td>0.2</td>
<td>73.1</td>
<td>0.4</td>
<td>84.3</td>
<td>0.2</td>
<td>74.5</td>
<td>12</td>
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<tr>
<td>52215</td>
<td>Tortilla, NFS (5)</td>
<td>0.2</td>
<td>73.4</td>
<td>0.0</td>
<td>84.3</td>
<td>0.2</td>
<td>74.8</td>
<td>16</td>
</tr>
<tr>
<td>26319</td>
<td>Shrimp, cooked, NS as to cooking method (5)</td>
<td>0.2</td>
<td>73.7</td>
<td>0.3</td>
<td>84.5</td>
<td>0.2</td>
<td>75.0</td>
<td>6</td>
</tr>
<tr>
<td>91734</td>
<td>Peanut butter, chocolate covered (7)</td>
<td>0.3</td>
<td>73.9</td>
<td>0.0</td>
<td>84.5</td>
<td>0.2</td>
<td>75.2</td>
<td>10</td>
</tr>
<tr>
<td>71405</td>
<td>White potato, hash brown, NS as to from fresh, frozen, or dry mix (2)</td>
<td>0.3</td>
<td>74.2</td>
<td>0.0</td>
<td>84.5</td>
<td>0.2</td>
<td>75.4</td>
<td>15</td>
</tr>
<tr>
<td>27420</td>
<td>Cabbage with ham hocks (mixture) (20)</td>
<td>0.2</td>
<td>74.4</td>
<td>0.0</td>
<td>84.5</td>
<td>0.2</td>
<td>75.7</td>
<td>2</td>
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<tr>
<td>51301</td>
<td>Milk, cow's, fluid, 2% fat (2)</td>
<td>0.2</td>
<td>74.7</td>
<td>0.0</td>
<td>84.5</td>
<td>0.2</td>
<td>75.9</td>
<td>11</td>
</tr>
<tr>
<td>52302</td>
<td>Bread, wheat or cracked wheat (16)</td>
<td>0.2</td>
<td>74.9</td>
<td>0.0</td>
<td>84.6</td>
<td>0.2</td>
<td>76.1</td>
<td>16</td>
</tr>
<tr>
<td>58148</td>
<td>Macaroni or pasta salad (10)</td>
<td>0.2</td>
<td>75.3</td>
<td>0.6</td>
<td>85.2</td>
<td>0.2</td>
<td>76.5</td>
<td>12</td>
</tr>
<tr>
<td>27343</td>
<td>Chicken or turkey, noodles, and vegetables (including carrots, broccoli, and/or dark-green leafy), no sauce (mixture) (11)</td>
<td>0.2</td>
<td>75.5</td>
<td>0.1</td>
<td>85.3</td>
<td>0.2</td>
<td>76.7</td>
<td>4</td>
</tr>
<tr>
<td>28500</td>
<td>Gravy, poultry (7)</td>
<td>0.2</td>
<td>75.8</td>
<td>0.0</td>
<td>85.3</td>
<td>0.2</td>
<td>77.0</td>
<td>2</td>
</tr>
<tr>
<td>53105</td>
<td>Cake, chocolate, devil's food, or fudge, made from home recipe or purchased ready-to-eat, NS as to icing (7)</td>
<td>0.2</td>
<td>76.0</td>
<td>0.1</td>
<td>85.4</td>
<td>0.2</td>
<td>77.2</td>
<td>16</td>
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<tr>
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<td>0.1</td>
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<td>86.4</td>
<td>0.2</td>
<td>77.4</td>
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</tr>
<tr>
<td>21101</td>
<td>Beef steak, NS as to cooking method, NS as to fat eaten (6)</td>
<td>0.2</td>
<td>76.3</td>
<td>0.0</td>
<td>86.4</td>
<td>0.2</td>
<td>77.6</td>
<td>3</td>
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<tr>
<td>27520</td>
<td>Bacon, chicken, and tomato club sandwich, with lettuce and spread (16)</td>
<td>0.2</td>
<td>76.5</td>
<td>0.0</td>
<td>86.4</td>
<td>0.2</td>
<td>77.8</td>
<td>2</td>
</tr>
<tr>
<td>22201</td>
<td>Pork steak or cutlet, NS as to cooking method, lean and fat eaten (16)</td>
<td>0.2</td>
<td>76.8</td>
<td>0.0</td>
<td>86.4</td>
<td>0.2</td>
<td>78.0</td>
<td>3</td>
</tr>
<tr>
<td>26125</td>
<td>Ocean perch, baked or broiled (5)</td>
<td>0.1</td>
<td>76.9</td>
<td>0.8</td>
<td>87.2</td>
<td>0.2</td>
<td>78.2</td>
<td>6</td>
</tr>
<tr>
<td>24152</td>
<td>Chicken, thigh, roasted, broiled, or baked, NS as to skin eaten (3)</td>
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<td>77.1</td>
<td>0.0</td>
<td>87.2</td>
<td>0.2</td>
<td>78.4</td>
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<tr>
<td>58160</td>
<td>Rice with beans (21)</td>
<td>0.2</td>
<td>77.3</td>
<td>0.0</td>
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<td>78.5</td>
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<tr>
<td>58136</td>
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<td>0.2</td>
<td>78.7</td>
<td>12</td>
</tr>
<tr>
<td>28340</td>
<td>Chicken, broth, bouillon, or consomme (22)</td>
<td>0.2</td>
<td>77.7</td>
<td>0.1</td>
<td>87.3</td>
<td>0.2</td>
<td>78.9</td>
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</tr>
<tr>
<td>83102</td>
<td>Caesar dressing (1)</td>
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<td>78.0</td>
<td>0.0</td>
<td>87.3</td>
<td>0.2</td>
<td>79.1</td>
<td>7</td>
</tr>
<tr>
<td>24124</td>
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<td>78.2</td>
<td>0.0</td>
<td>87.3</td>
<td>0.2</td>
<td>79.3</td>
<td>4</td>
</tr>
<tr>
<td>83114</td>
<td>Thousand Island dressing (1)</td>
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<td>78.4</td>
<td>0.0</td>
<td>87.3</td>
<td>0.2</td>
<td>79.5</td>
<td>7</td>
</tr>
<tr>
<td>31103</td>
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<td>0.2</td>
<td>78.6</td>
<td>0.1</td>
<td>87.5</td>
<td>0.2</td>
<td>79.7</td>
<td>5</td>
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<tr>
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<td>0.2</td>
<td>79.8</td>
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</tr>
<tr>
<td>26115</td>
<td>Flounder, cooked, NS as to cooking</td>
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<td>78.8</td>
<td>0.2</td>
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<td>0.2</td>
<td>80.0</td>
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</tr>
<tr>
<td>Food group method (6)</td>
<td>Food group descriptions (number of food items grouped)</td>
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<td>Cum 20:1 %</td>
<td>22:1 LCMUFA %</td>
<td>Cum 22:1 %</td>
<td>Total LCMUFA %</td>
<td>Cum Total %</td>
<td>Food group §</td>
</tr>
<tr>
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<td>------------</td>
<td>----------------</td>
<td>-------------</td>
<td>------------</td>
</tr>
<tr>
<td>27446</td>
<td>Chicken or turkey chow mein or chop suey, no noodles (13)</td>
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<td>79.0</td>
<td>0.0</td>
<td>88.3</td>
<td>0.2</td>
<td>80.2</td>
<td>4</td>
</tr>
<tr>
<td>53104</td>
<td>Cake, carrot, NS as to icing (9)</td>
<td>0.2</td>
<td>79.2</td>
<td>0.1</td>
<td>88.4</td>
<td>0.2</td>
<td>80.4</td>
<td>16</td>
</tr>
<tr>
<td>83104</td>
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<td>79.4</td>
<td>0.0</td>
<td>88.4</td>
<td>0.2</td>
<td>80.5</td>
<td>7</td>
</tr>
<tr>
<td>27363</td>
<td>Gumbo with rice (New Orleans type with shellfish, pork, and/or poultry, tomatoes, okra, rice) (2)</td>
<td>0.2</td>
<td>79.6</td>
<td>0.0</td>
<td>88.4</td>
<td>0.2</td>
<td>80.7</td>
<td>12</td>
</tr>
<tr>
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<td>Waffle, plain (1)</td>
<td>0.2</td>
<td>79.8</td>
<td>0.0</td>
<td>88.4</td>
<td>0.2</td>
<td>80.9</td>
<td>16</td>
</tr>
<tr>
<td>71501</td>
<td>White potato, mashed, NFS (13)</td>
<td>0.2</td>
<td>80.0</td>
<td>0.0</td>
<td>88.4</td>
<td>0.2</td>
<td>81.0</td>
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</tr>
<tr>
<td>57123</td>
<td>Cheerios (1)</td>
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<td>80.1</td>
<td>0.3</td>
<td>88.7</td>
<td>0.2</td>
<td>81.2</td>
<td>14</td>
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<tr>
<td>27246</td>
<td>Chicken or turkey with dumplings (mixture) (6)</td>
<td>0.2</td>
<td>80.3</td>
<td>0.0</td>
<td>88.7</td>
<td>0.2</td>
<td>81.3</td>
<td>4</td>
</tr>
<tr>
<td>71603</td>
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<td>0.1</td>
<td>80.4</td>
<td>0.8</td>
<td>89.5</td>
<td>0.2</td>
<td>81.5</td>
<td>15</td>
</tr>
<tr>
<td>56205</td>
<td>Rice, cooked, NFS (16)</td>
<td>0.2</td>
<td>80.5</td>
<td>0.0</td>
<td>89.5</td>
<td>0.1</td>
<td>81.7</td>
<td>16</td>
</tr>
<tr>
<td>51300</td>
<td>Bread, whole grain white (9)</td>
<td>0.2</td>
<td>80.7</td>
<td>0.0</td>
<td>89.5</td>
<td>0.1</td>
<td>81.8</td>
<td>16</td>
</tr>
<tr>
<td>24120</td>
<td>Chicken, breast, NS as to cooking method, NS as to skin eaten (3)</td>
<td>0.2</td>
<td>80.9</td>
<td>0.0</td>
<td>89.5</td>
<td>0.1</td>
<td>81.9</td>
<td>4</td>
</tr>
<tr>
<td>58147</td>
<td>Pasta with pesto sauce (7)</td>
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<td>81.0</td>
<td>0.0</td>
<td>89.5</td>
<td>0.1</td>
<td>82.1</td>
<td>12</td>
</tr>
<tr>
<td>26155</td>
<td>Tuna, canned, NS as to oil or water pack (1)</td>
<td>0.1</td>
<td>81.1</td>
<td>0.8</td>
<td>90.3</td>
<td>0.1</td>
<td>82.2</td>
<td>6</td>
</tr>
<tr>
<td>53206</td>
<td>Cookie, chocolate chip (6)</td>
<td>0.2</td>
<td>81.3</td>
<td>0.0</td>
<td>90.3</td>
<td>0.1</td>
<td>82.4</td>
<td>14</td>
</tr>
<tr>
<td>24132</td>
<td>Chicken, leg (drumstick and thigh), roasted, broiled, or baked, NS as to skin eaten (3)</td>
<td>0.2</td>
<td>81.4</td>
<td>0.0</td>
<td>90.3</td>
<td>0.1</td>
<td>82.5</td>
<td>4</td>
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<tr>
<td>27345</td>
<td>Cornbread, made from home recipe (mixture) (12)</td>
<td>0.2</td>
<td>81.6</td>
<td>0.0</td>
<td>90.4</td>
<td>0.1</td>
<td>82.7</td>
<td>4</td>
</tr>
<tr>
<td>52202</td>
<td>Cornbread, made from home recipe (1)</td>
<td>0.1</td>
<td>81.7</td>
<td>0.1</td>
<td>90.5</td>
<td>0.1</td>
<td>82.8</td>
<td>16</td>
</tr>
<tr>
<td>53234</td>
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<td>0.2</td>
<td>81.9</td>
<td>0.0</td>
<td>90.5</td>
<td>0.1</td>
<td>82.9</td>
<td>10</td>
</tr>
<tr>
<td>58110</td>
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<td>0.2</td>
<td>82.0</td>
<td>0.0</td>
<td>90.5</td>
<td>0.1</td>
<td>83.1</td>
<td>16</td>
</tr>
<tr>
<td>82104</td>
<td>Olive oil (1)</td>
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<td>82.2</td>
<td>0.0</td>
<td>90.5</td>
<td>0.1</td>
<td>83.2</td>
<td>7</td>
</tr>
<tr>
<td>71508</td>
<td>White potato, stuffed, baked, peel eaten, stuffed with butter or margarine (6)</td>
<td>0.1</td>
<td>82.3</td>
<td>0.0</td>
<td>90.5</td>
<td>0.1</td>
<td>83.3</td>
<td>15</td>
</tr>
<tr>
<td>26127</td>
<td>Perch, cooked, NS as to cooking method (6)</td>
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<td>82.5</td>
<td>0.0</td>
<td>90.5</td>
<td>0.1</td>
<td>83.5</td>
<td>6</td>
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<tr>
<td>83100</td>
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<td>82.6</td>
<td>0.1</td>
<td>90.6</td>
<td>0.1</td>
<td>83.6</td>
<td>7</td>
</tr>
<tr>
<td>53209</td>
<td>Cookie, chocolate, chocolate sandwich or chocolate-coated or striped (5)</td>
<td>0.1</td>
<td>82.7</td>
<td>0.0</td>
<td>90.6</td>
<td>0.1</td>
<td>83.7</td>
<td>14</td>
</tr>
<tr>
<td>13412</td>
<td>Milk gravy, quick gravy (1)</td>
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<td>82.9</td>
<td>0.0</td>
<td>90.6</td>
<td>0.1</td>
<td>83.8</td>
<td>11</td>
</tr>
<tr>
<td>74601</td>
<td>Tomato soup, NFS (2)</td>
<td>0.1</td>
<td>83.0</td>
<td>0.4</td>
<td>91.0</td>
<td>0.1</td>
<td>84.0</td>
<td>12</td>
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<tr>
<td>24137</td>
<td>Chicken, leg (drumstick and thigh), coated, baked or fried, prepared with skin, NS as to skin/coating eaten (5)</td>
<td>0.1</td>
<td>83.1</td>
<td>0.0</td>
<td>91.0</td>
<td>0.1</td>
<td>84.1</td>
<td>4</td>
</tr>
<tr>
<td>81302</td>
<td>Hollandaise sauce (5)</td>
<td>0.1</td>
<td>83.2</td>
<td>0.0</td>
<td>91.0</td>
<td>0.1</td>
<td>84.2</td>
<td>7</td>
</tr>
<tr>
<td>58421</td>
<td>Sopa seca (dry soup), Mexican style, NFS (5)</td>
<td>0.1</td>
<td>83.4</td>
<td>0.0</td>
<td>91.0</td>
<td>0.1</td>
<td>84.3</td>
<td>12</td>
</tr>
<tr>
<td>26105</td>
<td>Carp, cooked, NS as to cooking method (3)</td>
<td>0.0</td>
<td>83.4</td>
<td>0.8</td>
<td>91.8</td>
<td>0.1</td>
<td>84.4</td>
<td>6</td>
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<tr>
<td>28315</td>
<td>Beef vegetable soup with potato, stew type (6)</td>
<td>0.1</td>
<td>83.5</td>
<td>0.0</td>
<td>91.8</td>
<td>0.1</td>
<td>84.6</td>
<td>3</td>
</tr>
<tr>
<td>53235</td>
<td>Cookie, peanut (2)</td>
<td>0.1</td>
<td>83.7</td>
<td>0.0</td>
<td>91.8</td>
<td>0.1</td>
<td>84.7</td>
<td>16</td>
</tr>
<tr>
<td>14108</td>
<td>Cheese, Parmesan, dry grated (2)</td>
<td>0.1</td>
<td>83.8</td>
<td>0.0</td>
<td>91.8</td>
<td>0.1</td>
<td>84.8</td>
<td>11</td>
</tr>
<tr>
<td>51101</td>
<td>Bread, white (4)</td>
<td>0.1</td>
<td>83.9</td>
<td>0.0</td>
<td>91.8</td>
<td>0.1</td>
<td>84.9</td>
<td>16</td>
</tr>
</tbody>
</table>
Supplemental Table 4. 200 food groups that contributed to 90% of US intake of long-chain monounsaturated fatty acids (LCMUFA) in the National Health and Nutrition Examination Survey (2003-2010)

<table>
<thead>
<tr>
<th>Food group</th>
<th>Descriptions (number of food items grouped)</th>
<th>20:1 LCMUFA %</th>
<th>Cum%</th>
<th>22:1 LCMUFA %</th>
<th>Cum%</th>
<th>Total LCMUFA %</th>
<th>Cum%</th>
<th>Food group</th>
</tr>
</thead>
<tbody>
<tr>
<td>41102</td>
<td>Black, brown, or Bayo beans, dry, cooked, NS as to fat added in cooking (4)</td>
<td>0.1</td>
<td>84.0</td>
<td>0.0</td>
<td>91.8</td>
<td>0.1</td>
<td>85.0</td>
<td>17</td>
</tr>
<tr>
<td>71402</td>
<td>White potato, french fries, breaded or battered (5)</td>
<td>0.1</td>
<td>84.2</td>
<td>0.0</td>
<td>91.8</td>
<td>0.1</td>
<td>85.1</td>
<td>15</td>
</tr>
<tr>
<td>58407</td>
<td>Instant soup, NFS (4)</td>
<td>0.1</td>
<td>84.3</td>
<td>0.0</td>
<td>91.8</td>
<td>0.1</td>
<td>85.2</td>
<td>12</td>
</tr>
<tr>
<td>63105</td>
<td>Avocado, raw (1)</td>
<td>0.1</td>
<td>84.4</td>
<td>0.0</td>
<td>91.8</td>
<td>0.1</td>
<td>85.3</td>
<td>15</td>
</tr>
<tr>
<td>74602</td>
<td>Tomato soup, prepared with water (5)</td>
<td>0.1</td>
<td>84.5</td>
<td>0.3</td>
<td>92.1</td>
<td>0.1</td>
<td>85.4</td>
<td>12</td>
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<tr>
<td>27212</td>
<td>Beef and noodles, no sauce (mixture) (9)</td>
<td>0.1</td>
<td>84.6</td>
<td>0.2</td>
<td>92.3</td>
<td>0.1</td>
<td>85.6</td>
<td>3</td>
</tr>
<tr>
<td>58130</td>
<td>Lasagna with meat (7)</td>
<td>0.1</td>
<td>84.7</td>
<td>0.0</td>
<td>92.3</td>
<td>0.1</td>
<td>85.7</td>
<td>12</td>
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<tr>
<td>27242</td>
<td>Chicken or turkey and noodles, no sauce (mixture) (8)</td>
<td>0.1</td>
<td>84.8</td>
<td>0.0</td>
<td>92.3</td>
<td>0.1</td>
<td>85.8</td>
<td>4</td>
</tr>
<tr>
<td>58163</td>
<td>Rice with gravy (11)</td>
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<td>85.0</td>
<td>0.0</td>
<td>92.3</td>
<td>0.1</td>
<td>85.9</td>
<td>16</td>
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<tr>
<td>24142</td>
<td>Chicken, drumstick, roasted, broiled, or baked, NS as to skin eaten (3)</td>
<td>0.1</td>
<td>85.1</td>
<td>0.0</td>
<td>92.3</td>
<td>0.1</td>
<td>86.0</td>
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</tr>
<tr>
<td>22709</td>
<td>Pork skin, rinds, deep-fried (2)</td>
<td>0.1</td>
<td>85.2</td>
<td>0.0</td>
<td>92.3</td>
<td>0.1</td>
<td>86.1</td>
<td>3</td>
</tr>
<tr>
<td>42116</td>
<td>Walnuts (2)</td>
<td>0.1</td>
<td>85.3</td>
<td>0.0</td>
<td>92.3</td>
<td>0.1</td>
<td>86.2</td>
<td>10</td>
</tr>
<tr>
<td>11320</td>
<td>Milk, soy, ready-to-drink, not baby's (2)</td>
<td>0.1</td>
<td>85.4</td>
<td>0.0</td>
<td>92.3</td>
<td>0.1</td>
<td>86.3</td>
<td>17</td>
</tr>
<tr>
<td>81104</td>
<td>Margarine-like spread, reduced calorie, about 40% fat, tub, salted (3)</td>
<td>0.1</td>
<td>85.5</td>
<td>0.0</td>
<td>92.4</td>
<td>0.1</td>
<td>86.4</td>
<td>9</td>
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<td>27550</td>
<td>Fish sandwich, on bun, with spread (5)</td>
<td>0.1</td>
<td>85.6</td>
<td>0.2</td>
<td>92.6</td>
<td>0.1</td>
<td>86.5</td>
<td>6</td>
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<tr>
<td>81100</td>
<td>Butter, NFS (1)</td>
<td>0.1</td>
<td>85.7</td>
<td>0.0</td>
<td>92.6</td>
<td>0.1</td>
<td>86.6</td>
<td>11</td>
</tr>
<tr>
<td>75141</td>
<td>Cabbage salad or coleslaw, with dressing (3)</td>
<td>0.1</td>
<td>85.8</td>
<td>0.0</td>
<td>92.6</td>
<td>0.1</td>
<td>86.7</td>
<td>15</td>
</tr>
<tr>
<td>75205</td>
<td>Beans, string, cooked, NS as to form, NS as to color, NS as to fat added in cooking (12)</td>
<td>0.1</td>
<td>86.0</td>
<td>0.0</td>
<td>92.6</td>
<td>0.1</td>
<td>86.8</td>
<td>17</td>
</tr>
<tr>
<td>42109</td>
<td>Macadamia nuts, unroasted (2)</td>
<td>0.1</td>
<td>86.1</td>
<td>0.1</td>
<td>92.7</td>
<td>0.1</td>
<td>86.9</td>
<td>10</td>
</tr>
<tr>
<td>21401</td>
<td>Beef, roast, roasted, NS as to fat eaten (4)</td>
<td>0.1</td>
<td>86.2</td>
<td>0.0</td>
<td>92.7</td>
<td>0.1</td>
<td>87.0</td>
<td>3</td>
</tr>
<tr>
<td>27311</td>
<td>Beef, potatoes, and vegetables (including carrots, broccoli, and/or dark-green leafy), no sauce (mixture) (16)</td>
<td>0.1</td>
<td>86.3</td>
<td>0.1</td>
<td>92.8</td>
<td>0.1</td>
<td>87.1</td>
<td>3</td>
</tr>
<tr>
<td>55101</td>
<td>Pancakes, plain (3)</td>
<td>0.1</td>
<td>86.4</td>
<td>0.0</td>
<td>92.8</td>
<td>0.1</td>
<td>87.2</td>
<td>16</td>
</tr>
<tr>
<td>42114</td>
<td>Pistachio nuts (1)</td>
<td>0.1</td>
<td>86.5</td>
<td>0.0</td>
<td>92.8</td>
<td>0.1</td>
<td>87.3</td>
<td>10</td>
</tr>
<tr>
<td>58126</td>
<td>Bierock (turnover filled with ground beef and cabbage mixture) (12)</td>
<td>0.1</td>
<td>86.6</td>
<td>0.0</td>
<td>92.8</td>
<td>0.1</td>
<td>87.4</td>
<td>2</td>
</tr>
<tr>
<td>71507</td>
<td>White potato, stuffed, baked, peel not eaten, NS as to topping (7)</td>
<td>0.1</td>
<td>86.7</td>
<td>0.0</td>
<td>92.8</td>
<td>0.1</td>
<td>87.5</td>
<td>15</td>
</tr>
<tr>
<td>54301</td>
<td>Cracker, snack (2)</td>
<td>0.1</td>
<td>86.8</td>
<td>0.0</td>
<td>92.9</td>
<td>0.1</td>
<td>87.6</td>
<td>14</td>
</tr>
<tr>
<td>53540</td>
<td>Breakfast bar, NFS (14)</td>
<td>0.1</td>
<td>86.9</td>
<td>0.0</td>
<td>92.9</td>
<td>0.1</td>
<td>87.6</td>
<td>16</td>
</tr>
<tr>
<td>27141</td>
<td>Chicken or turkey cacciatore (4)</td>
<td>0.1</td>
<td>87.0</td>
<td>0.0</td>
<td>92.9</td>
<td>0.1</td>
<td>87.7</td>
<td>12</td>
</tr>
<tr>
<td>58137</td>
<td>Pad Thai, NFS (5)</td>
<td>0.1</td>
<td>87.1</td>
<td>0.0</td>
<td>92.9</td>
<td>0.1</td>
<td>87.8</td>
<td>16</td>
</tr>
<tr>
<td>26158</td>
<td>Tilapia, cooked, NS as to cooking method (5)</td>
<td>0.1</td>
<td>87.2</td>
<td>0.0</td>
<td>92.9</td>
<td>0.1</td>
<td>87.9</td>
<td>6</td>
</tr>
<tr>
<td>26313</td>
<td>Mussels, cooked, NS as to cooking method (2)</td>
<td>0.1</td>
<td>87.3</td>
<td>0.1</td>
<td>93.0</td>
<td>0.1</td>
<td>88.0</td>
<td>6</td>
</tr>
<tr>
<td>83204</td>
<td>Mayonnaise, low-calorie or diet (3)</td>
<td>0.1</td>
<td>87.3</td>
<td>0.3</td>
<td>93.3</td>
<td>0.1</td>
<td>88.1</td>
<td>7</td>
</tr>
<tr>
<td>51184</td>
<td>Bread stick, soft, prepared with garlic and parmesan cheese (2)</td>
<td>0.1</td>
<td>87.4</td>
<td>0.0</td>
<td>93.3</td>
<td>0.1</td>
<td>88.2</td>
<td>16</td>
</tr>
<tr>
<td>11836</td>
<td>Muscle Milk, powdered, not reconstituted (2)</td>
<td>0.1</td>
<td>87.5</td>
<td>0.2</td>
<td>93.5</td>
<td>0.1</td>
<td>88.2</td>
<td>11</td>
</tr>
<tr>
<td>83101</td>
<td>Blue or roquefort cheese dressing (3)</td>
<td>0.1</td>
<td>87.6</td>
<td>0.0</td>
<td>93.5</td>
<td>0.1</td>
<td>88.3</td>
<td>7</td>
</tr>
</tbody>
</table>
### Supplemental Table 4. 200 food groups that contributed to 90% of US intake of long-chain monounsaturated fatty acids (LCMUFA) in the National Health and Nutrition Examination Survey (2003-2010)

<table>
<thead>
<tr>
<th>Food group</th>
<th>Descriptions (number of food items grouped)</th>
<th>20:1 LCMUFA</th>
<th>Cum%</th>
<th>22:1 LCMUFA</th>
<th>Cum%</th>
<th>Total LCMUFA</th>
<th>Cum%</th>
</tr>
</thead>
<tbody>
<tr>
<td>75652</td>
<td>Vegetable beef soup, home recipe (3)</td>
<td>0.1</td>
<td>87.7</td>
<td>0.0</td>
<td>93.5</td>
<td>0.1</td>
<td>88.4</td>
</tr>
<tr>
<td>56203</td>
<td>Oatmeal, cooked, regular, fat not added in cooking (19)</td>
<td>0.1</td>
<td>87.8</td>
<td>0.0</td>
<td>93.5</td>
<td>0.1</td>
<td>88.5</td>
</tr>
<tr>
<td>51160</td>
<td>Roll, sweet (4)</td>
<td>0.1</td>
<td>87.9</td>
<td>0.0</td>
<td>93.5</td>
<td>0.1</td>
<td>88.6</td>
</tr>
<tr>
<td>58131</td>
<td>Ravioli, NS as to filling, no sauce (14)</td>
<td>0.1</td>
<td>88.0</td>
<td>0.0</td>
<td>93.6</td>
<td>0.1</td>
<td>88.7</td>
</tr>
<tr>
<td>27260</td>
<td>Meat loaf, NS as to type of meat (8)</td>
<td>0.1</td>
<td>88.0</td>
<td>0.0</td>
<td>93.6</td>
<td>0.1</td>
<td>88.7</td>
</tr>
<tr>
<td>42204</td>
<td>Peanut sauce (2)</td>
<td>0.1</td>
<td>88.1</td>
<td>0.0</td>
<td>93.6</td>
<td>0.1</td>
<td>88.8</td>
</tr>
<tr>
<td>26315</td>
<td>Oysters, raw (8)</td>
<td>0.1</td>
<td>88.2</td>
<td>0.1</td>
<td>93.6</td>
<td>0.1</td>
<td>88.9</td>
</tr>
<tr>
<td>28355</td>
<td>Clam chowder, New England, NS as to prepared with water or milk (13)</td>
<td>0.1</td>
<td>88.3</td>
<td>0.1</td>
<td>93.7</td>
<td>0.1</td>
<td>89.0</td>
</tr>
<tr>
<td>54420</td>
<td>Multigrain mixture, pretzels, cereal and/or crackers, nuts (3)</td>
<td>0.1</td>
<td>88.4</td>
<td>0.0</td>
<td>93.7</td>
<td>0.1</td>
<td>89.0</td>
</tr>
<tr>
<td>55301</td>
<td>French toast, plain (2)</td>
<td>0.1</td>
<td>88.5</td>
<td>0.0</td>
<td>93.8</td>
<td>0.1</td>
<td>89.1</td>
</tr>
<tr>
<td>26149</td>
<td>Swordfish, baked or broiled (3)</td>
<td>0.1</td>
<td>88.5</td>
<td>0.1</td>
<td>93.9</td>
<td>0.1</td>
<td>89.2</td>
</tr>
<tr>
<td>71104</td>
<td>White potato, roasted, NS as to fat added in cooking (2)</td>
<td>0.1</td>
<td>88.6</td>
<td>0.0</td>
<td>93.9</td>
<td>0.1</td>
<td>89.3</td>
</tr>
<tr>
<td>71900</td>
<td>Plantain, fried, NS as to green or ripe (1)</td>
<td>0.1</td>
<td>88.7</td>
<td>0.0</td>
<td>93.9</td>
<td>0.1</td>
<td>89.3</td>
</tr>
<tr>
<td>53120</td>
<td>Cake, white, made from home recipe or purchased ready-to-eat, NS as to icing (7)</td>
<td>0.1</td>
<td>88.8</td>
<td>0.0</td>
<td>94.0</td>
<td>0.1</td>
<td>89.4</td>
</tr>
<tr>
<td>22401</td>
<td>Pork roast, loin, cooked, NS as to fat eaten (3)</td>
<td>0.1</td>
<td>88.9</td>
<td>0.0</td>
<td>94.0</td>
<td>0.1</td>
<td>89.5</td>
</tr>
<tr>
<td>43102</td>
<td>Sunflower seeds, hulled, unroasted (3)</td>
<td>0.1</td>
<td>88.9</td>
<td>0.0</td>
<td>94.0</td>
<td>0.1</td>
<td>89.6</td>
</tr>
<tr>
<td>27320</td>
<td>Ham pot pie (20)</td>
<td>0.1</td>
<td>89.0</td>
<td>0.0</td>
<td>94.0</td>
<td>0.1</td>
<td>89.6</td>
</tr>
<tr>
<td>27513</td>
<td>Roast beef sandwich (5)</td>
<td>0.1</td>
<td>89.1</td>
<td>0.0</td>
<td>94.0</td>
<td>0.1</td>
<td>89.7</td>
</tr>
<tr>
<td>27415</td>
<td>Beef and vegetables (including carrots, broccoli, and/or dark-green leafy (no potatoes)), soy-based sauce (mixture) (5)</td>
<td>0.1</td>
<td>89.2</td>
<td>0.0</td>
<td>94.0</td>
<td>0.1</td>
<td>89.8</td>
</tr>
<tr>
<td>75510</td>
<td>Olives, NFS (4)</td>
<td>0.1</td>
<td>89.3</td>
<td>0.0</td>
<td>94.0</td>
<td>0.1</td>
<td>89.9</td>
</tr>
<tr>
<td>41101</td>
<td>Beans, dry, cooked, NS as to type and as to fat added in cooking (5)</td>
<td>0.1</td>
<td>89.3</td>
<td>0.0</td>
<td>94.1</td>
<td>0.1</td>
<td>89.9</td>
</tr>
<tr>
<td>27220</td>
<td>Meat loaf made with ham (not luncheon meat) (14)</td>
<td>0.1</td>
<td>89.4</td>
<td>0.0</td>
<td>94.1</td>
<td>0.1</td>
<td>90.0</td>
</tr>
</tbody>
</table>

Food groups aggregated from the 8-digits food codes of food items consumed in the NHANES 2003-2010

† Number of food items grouped together into each 5-digits food group.

‡ % of contribution to total population intake and cumulative percentage. The order is based on the ranking of proportional contribution (%) to US LCMUFA intake (the third last column). For 22:1 LCMUFA, food groups not contributing to total intake (% contribution=0) have blank cells in the column of cumulative percentage.

Supplemental Table 5. Top 20 foods containing the highest amount of total and each of LCMUFA (20:1, 22:1, 24:1)
LCMUFA, and ethnic foods with the highest LCMUFA contents according to the United States Department of
Agriculture National Nutrient Database for Standard Reference Release 22. *

<table>
<thead>
<tr>
<th>Food items</th>
<th>Original Food groups</th>
<th>LCMUFA contents gram/100 gram</th>
<th>% of total fat</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>20:1</td>
<td>22:1</td>
</tr>
<tr>
<td>Total LCMUFA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil, mustard</td>
<td>Fats and Oils</td>
<td>6.2</td>
<td>41.2</td>
</tr>
<tr>
<td>Fish oil, herring</td>
<td>Fats and Oils</td>
<td>13.6</td>
<td>20.6</td>
</tr>
<tr>
<td>Fish oil, cod liver</td>
<td>Fats and Oils</td>
<td>10.4</td>
<td>7.3</td>
</tr>
<tr>
<td>Spices, mustard seed, ground</td>
<td>Spices and Herbs</td>
<td>4.0</td>
<td>9.4</td>
</tr>
<tr>
<td>Fish oil, sardine</td>
<td>Fats and Oils</td>
<td>6.0</td>
<td>5.6</td>
</tr>
<tr>
<td>Fish, herring, Atlantic, pickled</td>
<td>Finfish and Shellfish Products</td>
<td>3.6</td>
<td>5.2</td>
</tr>
<tr>
<td>Fish oil, salmon</td>
<td>Fats and Oils</td>
<td>3.9</td>
<td>3.4</td>
</tr>
<tr>
<td>Fish, halibut, Greenland, cooked, dry heat</td>
<td>Finfish and Shellfish Products</td>
<td>2.9</td>
<td>2.5</td>
</tr>
<tr>
<td>Fish, halibut, Greenland, raw</td>
<td>Finfish and Shellfish Products</td>
<td>2.2</td>
<td>2.0</td>
</tr>
<tr>
<td>Fish, mackerel, Atlantic, cooked, dry heat</td>
<td>Finfish and Shellfish Products</td>
<td>1.6</td>
<td>2.5</td>
</tr>
<tr>
<td>Fish, eel, mixed species, cooked, dry heat</td>
<td>Finfish and Shellfish Products</td>
<td>3.8</td>
<td>0</td>
</tr>
<tr>
<td>Fish, herring, Pacific, cooked, dry heat</td>
<td>Finfish and Shellfish Products</td>
<td>1.7</td>
<td>1.9</td>
</tr>
<tr>
<td>Fish, sablefish, smoked</td>
<td>Finfish and Shellfish Products</td>
<td>1.9</td>
<td>1.7</td>
</tr>
<tr>
<td>Fish, sablefish, cooked, dry heat</td>
<td>Finfish and Shellfish Products</td>
<td>1.8</td>
<td>1.7</td>
</tr>
<tr>
<td>Fish, eel, mixed species, raw</td>
<td>Finfish and Shellfish Products</td>
<td>3.0</td>
<td>0</td>
</tr>
<tr>
<td>Fish, herring, Pacific, raw</td>
<td>Finfish and Shellfish Products</td>
<td>1.4</td>
<td>1.5</td>
</tr>
<tr>
<td>Nuts, beechnuts, dried</td>
<td>Nut and Seed Products</td>
<td>2.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Fish, sablefish, raw</td>
<td>Finfish and Shellfish Products</td>
<td>1.4</td>
<td>1.3</td>
</tr>
<tr>
<td>Fish, mackerel, salted</td>
<td>Finfish and Shellfish Products</td>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>Fish, mackerel, Atlantic, raw</td>
<td>Finfish and Shellfish Products</td>
<td>1.0</td>
<td>1.4</td>
</tr>
<tr>
<td>Total 20:1 LCMUFA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fish oil, herring</td>
<td>Fats and Oils</td>
<td>13.6</td>
<td>20.6</td>
</tr>
<tr>
<td>Fish oil, cod liver</td>
<td>Fats and Oils</td>
<td>10.4</td>
<td>7.3</td>
</tr>
<tr>
<td>Oil, mustard</td>
<td>Fats and Oils</td>
<td>6.2</td>
<td>41.2</td>
</tr>
<tr>
<td>Fish oil, sardine</td>
<td>Fats and Oils</td>
<td>6.0</td>
<td>5.6</td>
</tr>
<tr>
<td>Spices, mustard seed, ground</td>
<td>Spices and Herbs</td>
<td>4.0</td>
<td>9.4</td>
</tr>
<tr>
<td>Fish oil, salmon</td>
<td>Fats and Oils</td>
<td>3.9</td>
<td>3.4</td>
</tr>
<tr>
<td>Fish, eel, mixed species, cooked, dry heat</td>
<td>Finfish and Shellfish Products</td>
<td>3.8</td>
<td>0</td>
</tr>
<tr>
<td>Fish, herring, Atlantic, pickled</td>
<td>Finfish and Shellfish Products</td>
<td>3.6</td>
<td>5.2</td>
</tr>
<tr>
<td>Fish, eel, mixed species, raw</td>
<td>Finfish and Shellfish Products</td>
<td>3.0</td>
<td>0</td>
</tr>
<tr>
<td>Fish, halibut, Greenland, cooked, dry heat</td>
<td>Finfish and Shellfish Products</td>
<td>2.9</td>
<td>2.5</td>
</tr>
<tr>
<td>Nuts, beechnuts, dried</td>
<td>Nut and Seed Products</td>
<td>2.8</td>
<td>2.8</td>
</tr>
<tr>
<td>Fish, halibut, Greenland, raw</td>
<td>Finfish and Shellfish Products</td>
<td>2.2</td>
<td>2.0</td>
</tr>
<tr>
<td>Nuts, macadamia nuts, dry roasted, without salt added</td>
<td>Nut and Seed Products</td>
<td>1.9</td>
<td>0.24</td>
</tr>
<tr>
<td>Nuts, macadamia nuts, dry roasted, with salt added</td>
<td>Nut and Seed Products</td>
<td>1.9</td>
<td>0.24</td>
</tr>
</tbody>
</table>
Supplemental Table 5. Top 20 foods containing the highest amount of total and each of LCMUFA (20:1, 22:1, 24:1) LCMUFA, and ethnic foods with the highest LCMUFA contents according to the United States Department of Agriculture National Nutrient Database for Standard Reference Release 22. *

<table>
<thead>
<tr>
<th>Food items</th>
<th>Original Food groups †</th>
<th>LCMUFA contents (gram/100 gram)</th>
<th>Total</th>
<th>% of total fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuts, macadamia nuts, raw</td>
<td>Nut and Seed Products</td>
<td>1.9 0.23 0.02</td>
<td>2.1</td>
<td>3.0</td>
</tr>
<tr>
<td>Fish, sablefish, smoked</td>
<td>Finfish and Shellfish Products</td>
<td>1.9 1.7</td>
<td>3.6</td>
<td>20.5</td>
</tr>
<tr>
<td>Fish, sablefish, cooked, dry heat</td>
<td>Finfish and Shellfish Products</td>
<td>1.8 1.7</td>
<td>3.5</td>
<td>20.5</td>
</tr>
<tr>
<td>Fish, herring, Pacific, cooked, dry heat</td>
<td>Finfish and Shellfish Products</td>
<td>1.7 1.9</td>
<td>3.7</td>
<td>22.7</td>
</tr>
<tr>
<td>Fish, mackerel, Atlantic, cooked, dry heat</td>
<td>Finfish and Shellfish Products</td>
<td>1.6 2.5</td>
<td>4.1</td>
<td>26.5</td>
</tr>
<tr>
<td>Fish, sablefish, raw</td>
<td>Finfish and Shellfish Products</td>
<td>1.4 1.3</td>
<td>2.7</td>
<td>20.5</td>
</tr>
<tr>
<td>22:1 LCMUFA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil, mustard</td>
<td>Fats and Oils</td>
<td>6.2 41.2</td>
<td>47.4</td>
<td>51.5</td>
</tr>
<tr>
<td>Fish oil, herring</td>
<td>Fats and Oils</td>
<td>13.6 20.6</td>
<td>34.2</td>
<td>36.6</td>
</tr>
<tr>
<td>Spices, mustard seed, ground</td>
<td>Spices and Herbs</td>
<td>4.0 9.4 0.64</td>
<td>14.0</td>
<td>40.4</td>
</tr>
<tr>
<td>Fish oil, cod liver</td>
<td>Fats and Oils</td>
<td>10.4 7.3</td>
<td>17.8</td>
<td>19.3</td>
</tr>
<tr>
<td>Fish oil, sardine</td>
<td>Fats and Oils</td>
<td>6.0 5.6</td>
<td>11.6</td>
<td>12.1</td>
</tr>
<tr>
<td>Fish, herring, Atlantic, pickled</td>
<td>Finfish and Shellfish Products</td>
<td>3.6 5.2</td>
<td>8.8</td>
<td>55.1</td>
</tr>
<tr>
<td>Fish oil, salmon</td>
<td>Fats and Oils</td>
<td>3.9 3.4</td>
<td>7.2</td>
<td>8.1</td>
</tr>
<tr>
<td>Fish, halibut, Greenland, cooked, dry heat</td>
<td>Finfish and Shellfish Products</td>
<td>2.9 2.5</td>
<td>5.4</td>
<td>34.6</td>
</tr>
<tr>
<td>Fish, mackerel, Atlantic, cooked, dry heat</td>
<td>Finfish and Shellfish Products</td>
<td>1.6 2.5</td>
<td>4.1</td>
<td>26.5</td>
</tr>
<tr>
<td>Fish, halibut, Greenland, raw</td>
<td>Finfish and Shellfish Products</td>
<td>2.2 2.0</td>
<td>4.2</td>
<td>34.6</td>
</tr>
<tr>
<td>Fish, herring, Pacific, cooked, dry heat</td>
<td>Finfish and Shellfish Products</td>
<td>1.7 1.9</td>
<td>3.7</td>
<td>22.7</td>
</tr>
<tr>
<td>Fish, sablefish, smoked</td>
<td>Finfish and Shellfish Products</td>
<td>1.9 1.7</td>
<td>3.6</td>
<td>20.5</td>
</tr>
<tr>
<td>Fish, sablefish, cooked, dry heat</td>
<td>Finfish and Shellfish Products</td>
<td>1.8 1.7</td>
<td>3.5</td>
<td>20.5</td>
</tr>
<tr>
<td>Fish, sardine, Pacific, canned in tomato sauce, drained solids with bone</td>
<td>Finfish and Shellfish Products</td>
<td>0.7 1.6</td>
<td>2.3</td>
<td>24.3</td>
</tr>
<tr>
<td>Fish, mackerel, salted</td>
<td>Finfish and Shellfish Products</td>
<td>1.0 1.5</td>
<td>2.6</td>
<td>11.9</td>
</tr>
<tr>
<td>Fish, herring, Pacific, raw</td>
<td>Finfish and Shellfish Products</td>
<td>1.4 1.5</td>
<td>2.9</td>
<td>22.7</td>
</tr>
<tr>
<td>Fish, mackerel, Atlantic, raw</td>
<td>Finfish and Shellfish Products</td>
<td>1.0 1.4</td>
<td>2.4</td>
<td>20.3</td>
</tr>
<tr>
<td>Fish, sablefish, raw</td>
<td>Finfish and Shellfish Products</td>
<td>1.4 1.3</td>
<td>2.7</td>
<td>20.5</td>
</tr>
<tr>
<td>Fish, shad, american, raw</td>
<td>Finfish and Shellfish Products</td>
<td>1.1 1.3</td>
<td>2.4</td>
<td>19.7</td>
</tr>
<tr>
<td>24:1 LCMUFA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mustard, prepared, yellow</td>
<td>Spices and Herbs</td>
<td>0.3 1.3 0.08</td>
<td>1.7</td>
<td>43.9</td>
</tr>
<tr>
<td>Spices, mustard seed, ground</td>
<td>Spices and Herbs</td>
<td>4.0 9.4 0.64</td>
<td>14.0</td>
<td>40.4</td>
</tr>
<tr>
<td>Oil, vegetable, Natren canola, high stability, non trans, high oleic (70%)</td>
<td>Fats and Oils</td>
<td>1.3 0.2 0.15</td>
<td>1.7</td>
<td>1.8</td>
</tr>
<tr>
<td>Margarine, 80% fat, tub, CANOLA HARVEST Soft Spread (canola, palm and palm kernel oils)</td>
<td>Fats and Oils</td>
<td>1.3 0.03 0.13</td>
<td>1.4</td>
<td>1.8</td>
</tr>
<tr>
<td>Mustard, prepared, yellow</td>
<td>Spices and Herbs</td>
<td>0.3 1.3 0.08</td>
<td>1.7</td>
<td>43.9</td>
</tr>
<tr>
<td>Seeds, flaxseed</td>
<td>Nut and Seed Products</td>
<td>0.1 0.01 0.06</td>
<td>0.1</td>
<td>0.4</td>
</tr>
<tr>
<td>Margarine, regular, 80% fat, composite, tub, with salt</td>
<td>Fats and Oils</td>
<td>0.7 0.03 0.06</td>
<td>0.8</td>
<td>0.9</td>
</tr>
</tbody>
</table>
Supplemental Table 5. Top 20 foods containing the highest amount of total and each of LCMUFA (20:1, 22:1, 24:1) LCMUFA, and ethnic foods with the highest LCMUFA contents according to the United States Department of Agriculture National Nutrient Database for Standard Reference Release 22. *

<table>
<thead>
<tr>
<th>Food items</th>
<th>Original Food groups†</th>
<th>LCMUFA contents gram/100 gram</th>
<th>% of total fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Margarine, regular, 80% fat, composite, tub, with salt, with added vitamin D</td>
<td>Fats and Oils</td>
<td>0.7</td>
<td>0.3</td>
</tr>
<tr>
<td>Margarine-like spread, SMART BALANCE Regular Buttery Spread with flax oil</td>
<td>Fats and Oils</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Seeds, sesame seed kernels, dried (decorticated)</td>
<td>Nut and Seed Products</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Cookies, chocolate sandwich, with creme filling, regular</td>
<td>Baked Products</td>
<td>0.06</td>
<td>0.2</td>
</tr>
<tr>
<td>Nuts, macadamia nuts, raw</td>
<td>Nut and Seed Products</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>Salad dressing, honey mustard dressing, reduced calorie</td>
<td>Fats and Oils</td>
<td>0.21</td>
<td>0.7</td>
</tr>
<tr>
<td>Quinoa, uncooked</td>
<td>Cereal Grains and Pasta</td>
<td>0.09</td>
<td>0.2</td>
</tr>
<tr>
<td>Mayonnaise, made with tofu</td>
<td>Fats and Oils</td>
<td>0.11</td>
<td>0.2</td>
</tr>
<tr>
<td>KENTUCKY FRIED CHICKEN, Fried Chicken, EXTRA CRISPY, Skin and Breading</td>
<td>Fast Foods</td>
<td>0.134</td>
<td>0.2</td>
</tr>
<tr>
<td>Nuts, macadamia nuts, dry roasted, without salt added</td>
<td>Nut and Seed Products</td>
<td>1.9</td>
<td>2.4</td>
</tr>
<tr>
<td>Nuts, macadamia nuts, dry roasted, with salt added</td>
<td>Nut and Seed Products</td>
<td>1.9</td>
<td>2.4</td>
</tr>
<tr>
<td>Margarine-like spread, SMART BALANCE Omega Plus Spread (with plant sterols &amp; fish oil)</td>
<td>Fats and Oils</td>
<td>0.36</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Ethnic foods

<table>
<thead>
<tr>
<th>Food items</th>
<th>Ethnic Foods</th>
<th>LCMUFA contents gram/100 gram</th>
<th>% of total fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil, spotted seal (Alaska Native)</td>
<td>Ethnic Foods</td>
<td>15.0</td>
<td>5.9</td>
</tr>
<tr>
<td>Oil, beluga, whale (Alaska Native)</td>
<td>Ethnic Foods</td>
<td>9.6</td>
<td>3.5</td>
</tr>
<tr>
<td>Oil, bearded seal (Oogruk) (Alaska Native)</td>
<td>Ethnic Foods</td>
<td>4.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Fish, salmon, king, with skin, kippered, (Alaska Native)</td>
<td>Ethnic Foods</td>
<td>1.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Fish, salmon, chum, dried (Alaska Native)</td>
<td>Ethnic Foods</td>
<td>1.4</td>
<td>1.2</td>
</tr>
<tr>
<td>Seal, bearded (Oogruk), meat, dried, in oil (Alaska Native)</td>
<td>Ethnic Foods</td>
<td>1.7</td>
<td>0.1</td>
</tr>
<tr>
<td>Fish, salmon, red, canned, bones removed (Alaska Native)</td>
<td>Ethnic Foods</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Salmon, red (sockeye), filets with skin, smoked (Alaska Native)</td>
<td>Ethnic Foods</td>
<td>0.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Fish, salmon, king (chinook), raw (Alaska Native)</td>
<td>Ethnic Foods</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Fish, salmon, sockeye (red), raw (Alaska Native)</td>
<td>Ethnic Foods</td>
<td>0.6</td>
<td>0.5</td>
</tr>
</tbody>
</table>

* No record is presented as a blank. When ranking food items in the order of the high to low 24:1 LCMUFA contents, 11 out of top 20 food items were among “Ethnic foods’ and thus food items in “Ethnic foods” are separately presented.
† Food groups are from the original database. Fish oil precuts are categorized into “fats and oils” and thus they are underlined as general dietary studies categorize them into “Finish and Shellfish Products”, respectively.