**Perfluoroalkyl Substances Exposure and Hearing Impairment in US Adults: A Cross-sectional Study of NHANES 2003-2016**

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**Figure S1** Study design. The final analytic sample of adults 20 years and older.

**Table S1** Data availability in NHANES 2003-2016 cycles by age groups with complete PFAS measurements and audiometry.

|  |  |  |
| --- | --- | --- |
| Age range, years | 20-69 | ≥70 |
| NHANES cycle |  |  |
| 2003-2004 | √  N=262 |  |
| 2005-2006 |  | √  N=229 |
| 2009-2010 |  | √  N=286 |
| 2011-2012 | √  N=1139 |  |
| 2015-2016 | √  N=1268 |  |

**Table S2** Survey-weighted characteristics of the U.S. population age ≥70 years overall and by status of hearing impairment (HI).a,b

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Total**  **(N=449)** | **No HI**  **(N=26)** | **Any HI** | |
| **Characteristic** |  |  | **HFHI**  **(n=419)** | **LFHI**  **(n=275)** |
| Age (years), mean (SE) | 76.8 (0.2) | 74.2 (1.1) | 77.0 (0.2) | 77.6 (0.3) |
| BMI (kg/m2), mean (SE) | 27.7 (0.4) | 28.5 (1.7) | 27.6 (0.4) | 26.9 (0.4) |
| Sex, % (SE) |  |  |  |  |
| Male | 41.1 (2.1) | 31.5 (10.3) | 42.1 (2.2) | 41.7 (2.9) |
| Female | 58.9 (2.1) | 68.5 (10.3) | 57.9 (2.2) | 58.3 (2.9) |
| Race/ethnicity, % (SE) |  |  |  |  |
| Non-Hispanic White | 86.8 (2.1) | 62.7 (9.4) | 88.0 (2.0) | 87.9 (2.1) |
| Non-Hispanic Black | 6.8 (1.4) | 26.1 (8.6) | 5.8 (1.3) | 5.9 (1.4) |
| Other Race/ethnicity | 6.4 (1.5) | 11.2 (5.0) | 6.2 (1.5) | 6.2 (1.8) |
| Education, % (SE) |  |  |  |  |
| <High School | 31.4 (3.1) | 27.1 (10.9) | 32.0 (3.3) | 33.1 (3.7) |
| High School or Equivalent | 26.8 (2.3) | 14.0 (5.8) | 27.7 (2.4) | 26.9 (2.7) |
| Some College | 23.8 (2.2) | 44.4 (16.6) | 22.4 (2.3) | 23.0 (2.7) |
| College Graduate or Above | 18.0 (2.5) | 14.5 (8.5) | 17.9 (2.5) | 17.0 (2.7) |
| Poverty-to-income ratio, % (SE) |  |  |  |  |
| <1.0 | 8.6 (1.1) | 6.8 (4.2) | 8.2 (1.1) | 9.9 (1.6) |
| 1.0 | 91.4 (1.1) | 93.2 (4.2) | 91.8 (1.1) | 90.1 (1.6) |
| Cigarette Smoking, % (SE) |  |  |  |  |
| Never Smoker | 7.8 (1.6) | 4.2 (3.3) | 8.0 (1.7) | 8.7 (1.6) |
| Former Smoker | 43.2 (2.3) | 45.2 (13.0) | 43.2 (2.6) | 42.0 (3.4) |
| Current Smoker | 49.0 (2.0) | 50.6 (13.4) | 48.8 (2.2) | 49.3 (3.2) |
| Occupational noise exposure, % (SE) |  |  |  |  |
| Yes | 33.2 (2.4) | 19.3 (9.1) | 34.3 (2.5) | 39.2 (3.8) |
| No | 66.8 (2.4) | 80.7 (9.1) | 65.7 (2.5) | 60.8 (3.8) |
| Firearm noise exposure, % (SE) |  |  |  |  |
| Yes | 36.0 (2.4) | 28.9 (10.6) | 36.8 (2.4) | 38.8 (2.7) |
| No | 64.0 (2.4) | 71.1 (10.6) | 63.2 (2.4) | 61.2 (2.7) |
| Recreational noise exposure, % (SE) |  |  |  |  |
| Yes | 1.6 (0.6) | 0 | 0 | 1.7 (0.7) |
| No | 98.4 (0.6) | 100 | 100 | 98.3 (0.7) |
| Type-2 diabetes, % (SE) |  |  |  |  |
| Yes | 17.7 (1.5) | 26.5 (10.5) | 17.4 (1.7) | 16.9 (2.4) |
| No | 82.3 (1.5) | 73.5 (10.5) | 82.6 (1.7) | 83.1 (2.4) |
| Hypertension, % (SE) |  |  |  |  |
| Yes | 59.3 (3.9) | 82.0 (7.9) | 58.5 (4.0) | 55.5 (4.3) |
| No | 40.7 (3.9) | 18.0 (7.9) | 41.5 (4.0) | 44.5 (4.3) |
| NHANES cycles, % (SE) |  |  |  |  |
| 2005-2006 | 49.8 (4.1) | 27.5 (7.5) | 51.0 (4.2) | 49.7 (4.5) |
| 2009-2010 | 50.2 (4.1) | 72.5 (7.5) | 49.0 (4.2) | 50.3 (4.5) |
| PFAS concentrations (ng/mL), Median (IQR)c |  |  |  |  |
| PFHxS | 2.0 (1.2-3.3) | 1.7 (1.1-2.0) | 2.0 (1.2-3.3) | 2.0 (1.2-3.5) |
| PFOS | 18.0  (10.7-30.5) | 15.8  (10.5-27.9) | 18.0  (10.7-30.9) | 20.0  (10.8-31.3) |
| PFOA | 4.0 (2.6-5.7) | 3.8 (2.3-5.9) | 4.0 (2.6-5.7) | 4.0 (2.7-5.7) |
| PFNA | 1.2 (0.7-1.9) | 1.5 (1.0-1.8) | 1.2 (0.7-1.9) | 1.2 (0.7-1.9) |
| PFDA | 0.3 (0.1-0.5) | 0.4 (0.2-0.5) | 0.3 (0.1-0.5) | 0.3 (0.1-0.5) |

a Data from the National Health and Nutrition Examination Survey, 2005-2006 and 2009-2010.

b Complex survey design were considered in the analyses.

c Geometric mean and SE were calculated due to skewed distributions of serum PFAS concentrations.

Abbreviations: BMI, body mass index; GM, geometric mean; GSE, geometric standard error; IQR, interquartile range; PFDA, perfluorodecanoic acid; PFHxS, perfluorohexane sulfonic acid; PFNA, perfluorononanoic acid; PFOA, perfluorooctanoic acid; PFOS, perfluorooctane sulfonic acid; SE, standard error.

**Table S3** Adjusted odds ratios (ORs) and 95% confidence intervals (95% CIs) comparing hearing impairment in the worse ear with no hearing impairment per doubling increase in PFAS serum concentrations in adults ≥70 years from NHANES 2005-2006 and 2009-2010 (N=449).a

|  |  |  |
| --- | --- | --- |
|  | **LFHI**  **(N=275)** | **HFHI**  **(N=419)** |
| **Variable** | **OR**  **(95% CI)** | **OR**  **(95% CI)** |
| PFOS | 1.05 (0.76-1.44) | 0.93 (0.68-1.26) |
| PFOA | 1.19 (0.67-2.10) | 0.90 (0.55-1.45) |
| PFHxS | 1.28 (0.98-1.66) | 1.13 (0.81-1.58) |
| PFDeA | 1.01 (0.67-1.51) | 0.94 (0.67-1.31) |
| PFNA | 1.11 (0.76-1.63) | 0.94 (0.71-1.25) |

a All the models were adjusted for age, age square, sex, race/ethnicity, education level, poverty-income ratio, smoking status, body mass index, and noise exposures (occupational, recreational, and firearm noise), and NHANES cycles.

**Table S4** Adjusted odds ratios (ORs) and 95% confidence intervals (95% CIs) comparing hearing impairment in the worse ear with no hearing impairment by PFAS serum concentrations in adults 20-69 years from NHANES 2011-2012 and 2015-2016 (N=2208).a

|  |  |  |
| --- | --- | --- |
|  | **LFHI**  **(N=194)** | **HFHI**  **(N=671)** |
| **Variable** | **OR**  **(95% CI)** | **OR**  **(95% CI)** |
| **PFOS** |  |  |
| Per doubling | 0.89 (0.74-1.06) | 0.97 (0.85-1.10) |
| ≥90th vs. <90th percentile (15.3 ng/mL) | 0.99 (0.37-2.64) | 1.37 (0.75-2.50) |
| **PFOA** |  |  |
| Per doubling | 1.00 (0.73-1.36) | 0.97 (0.82-1.16) |
| ≥90th vs. <90th percentile (3.7 ng/mL) | 1.28 (0.51-3.20) | 1.15 (0.72-1.81) |
| **PFHxS** |  |  |
| Per doubling | 0.88 (0.71-1.09) | 0.92 (0.80-1.05) |
| ≥90th vs. <90th percentile (3.4 ng/mL) | 1.27 (0.58-2.77) | 0.96 (0.57-1.63) |
| **PFDA** |  |  |
| Per doubling | 0.92 (0.76-1.13) | 1.04 (0.89-1.22) |
| ≥90th vs. <90th percentile (0.5 ng/mL) | 1.57 (0.63-3.92) | 1.83 (0.98-3.41) |
| **PFNA** |  |  |
| Per doubling | 0.92 (0.70-1.21) | 1.07 (0.93-1.22) |
| ≥90th vs. <90th percentile (1.8 ng/mL) | 2.04 (0.97-4.31) | 1.85 (1.15-2.99) |

a All the models were adjusted for age, age square, sex, race/ethnicity, education level, poverty-income ratio, smoking status, body mass index, and noise exposures (occupational, recreational, and firearm noise), and NHANES cycles.

**Table S5** Adjusted odds ratios (ORs) and 95% confidence intervals (95% CIs) of hearing impairment in the worse ear by PFAS serum concentrations in adults 20 and 69 years with additional adjustments for diabetes and hypertension status.a

|  |  |  |
| --- | --- | --- |
|  | **LFHI**  **(N=204)** | **HFHI**  **(N=708)** |
| **Variable** | **OR**  **(95% CI)** | **OR**  **(95% CI)** |
| **PFOS** |  |  |
| Per doubling | 0.88 (0.74-1.04) | 0.98 (0.86-1.11) |
| ≥90th vs. <90th percentile (19.0 ng/mL) | 0.74 (0.30-1.80) | 1.34 (0.76-2.35) |
| **PFOA** |  |  |
| Per doubling | 1.01 (0.75-1.35) | 0.98 (0.83-1.15) |
| ≥90th vs. <90th percentile (4.2 ng/mL) | 1.48 (0.50-4.34) | 1.06 (0.62-1.82) |
| **PFHxS** |  |  |
| Per doubling | 0.87 (0.72-1.06) | 0.93(0.82-1.06) |
| ≥90th vs. <90th percentile (3.5 ng/mL) | 1.32 (0.64-2.72) | 1.06 (0.61-1.84) |
| **PFDA** |  |  |
| Per doubling | 0.93 (0.77-1.12) | 1.05 (0.91-1.22) |
| ≥90th vs. <90th percentile (0.5 ng/mL) | 1.47 (0.62-3.51) | 1.78 (1.03-3.09) |
| **PFNA** |  |  |
| Per doubling | 0.91 (0.70-1.17) | 1.06 (0.93-1.21) |
| ≥90th vs. <90th percentile (1.8 ng/mL) | 1.29 (0.68-2.45) | 1.70 (1.12-2.57) |

a All the models were adjusted for age, age square, sex, race/ethnicity, education level, poverty-income ratio, smoking status, body mass index, noise exposures (occupational, recreational, and firearm noise), NHANES cycles, and **additional adjustments for diabetes and hypertension status**.

**Table S6** Adjusted odds ratios (ORs) and 95% Confidence Intervals (95% CIs) comparing hearing impairment in the worse ear with no hearing impairment by PFAS serum concentrations in adults 20-69 years from NHANES 2003-2004, NHANES 2011-2012 and 2015-2016 (N=1480), with additional adjustment for blood lead and blood cadmium.a,b

|  |  |  |
| --- | --- | --- |
|  | **LFHI**  **(N=204)** | **HFHI**  **(N=709)** |
| **Variable** | **OR**  **(95% CI)** | **OR**  **(95% CI)** |
| **PFOS** |  |  |
| Per doubling | 0.90 (0.65-1.25) |  |
| ≥90th vs. <90th percentile (19.0 ng/mL) | 0.50 (0.14-1.72) | 1.27 (0.59-2.76) |
| **PFOA** |  |  |
| Per doubling | 1.15 (0.77-1.73) | 0.99 (0.75-1.31) |
| ≥90th vs. <90th percentile (4.2 ng/mL) | 1.16 (0.33-4.10) | 0.90 (0.44-1.88) |
| **PFHxS** |  |  |
| Per doubling | 0.93 (0.70-1.23) | 0.90 (0.75-1.08) |
| ≥90th vs. <90th percentile (3.5 ng/mL) | 2.58 (1.12-5.97) | 1.32 (0.72-2.42) |
| **PFDA** |  |  |
| Per doubling | 1.09 (0.78-1.53) | 1.15 (0.93-1.41) |
| ≥90th vs. <90th percentile (0.5 ng/mL) | 2.33 (0.73-7.41) | 2.59 (1.19-5.65) |
| **PFNA** |  |  |
| Per doubling | 1.22 (0.79-1.89) | 1.22 (0.95-1.57) |
| ≥90th vs. <90th percentile (1.8 ng/mL) | 1.38 (0.60-3.21) | 2.12 (1.24-3.63) |

a All the models were adjusted for age, age square, sex, race/ethnicity, education level, poverty-income ratio, smoking status, body mass index, and noise exposures (occupational, recreational, and firearm noise).



**Figure S1** Study design. The final analytic sample of adults 20 years and older. Abbreviations: BMI, body mass index; PIR, poverty-income ratio.