Project 003 Cardiovascular Disease and Aircraft Noise Exposure

Boston University

Project Lead Investigator

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University Participants

Boston University

- P.I.s: Prof. Jonathan Levy (university P.I.), Prof. Junenette Peters (project P.I.)
- FAA Award Number: 13-C-AJFE-BU-032
- Period of Performance: October 1, 2023, to September 30, 2024

Massachusetts Institute of Technology

- Sub-P.I. and co-P.I.: Prof. R. John Hansman (sub-P.I.), Dr. Florian Allroggen (sub-co-P.I.)
- Tasks:

  Boston University

  1. Present on aircraft noise and health research in the United States (U.S.).
  2. Write up and publish final results on hypertension and nighttime aircraft noise exposure.
  3. Write up and publish final results on the intermediary risk factor of adiposity and aircraft noise exposure.
  4. Perform preliminary analyses of an intermediary risk factor (diabetes) and aircraft noise exposure.
  5. Perform data linking with new cohort and develop data use procedures.
  6. Define request for noise data for additional year and airports.

  Boston University and Massachusetts Institute of Technology

  7. Prepare a third draft of the report on study results related to 2018 FAA Reauthorization, Section 189 for policymakers.

Project Funding Level

Total funding (3-year funding): $2,161,609
Matching funds: $2,161,609
Sources of matching funds: Nonfederal donors to the Nurses' Health Study (NHS) and Women's Health Initiative (WHI) cohorts

Investigation Team

Boston University

Prof. Junenette Peters (P.I.)
Prof. Jonathan Levy (P.I.)

Dr. Levy participates in noise exposure assessment and provides expertise in the areas of predictive modeling and air pollution. Dr. Peters is responsible for directing all aspects of the proposed study, including study coordination, design and analysis plans, and co-investigator meetings.

Harvard University/Brigham and Women's Hospital
Prof. Francine Laden
Prof. Jaime Hart
Dr. Tianyi Huang (*now at the National Institutes of Health*)
Dr. Susan Redline

Dr. Laden and Dr. Hart are our NHS sponsors for this ancillary study. Dr. Hart assigns aircraft noise exposures to the geocoded address history coordinates of each cohort member. Dr. Laden and Dr. Hart also assist in documenting data from the NHS, on the basis of their previous experience in research on air pollution and chronic disease outcomes in these cohorts and in performing appropriate analyses of hypertension and cardiovascular outcomes. Dr. Redline and Dr. Tianyi Huang guide efforts related to noise and sleep disturbance in the NHS and WHI.

University of North Carolina
Dr. Eric Whitsel
James Stewart

Dr. Whitsel is our WHI, National Longitudinal Study of Adolescent to Adult Health (Add Health), and Hispanic Community Health Study/Study of Latinos (HCHS/SOL) sponsor for the ancillary studies. Along with James Stewart, Dr. Whitsel assigns aircraft noise exposure to the geocoded addresses of cohort members. Dr. Whitsel also assists in documenting data from these cohorts based on multiple years of combined leadership and service for the WHI and Add Health morbidity and mortality classification, outcomes adjudication, and ancillary study committees.

Massachusetts Institute of Technology
Prof. R. John Hansman (sub-P.I.)
Dr. Florian Allroggen (sub-co-P.I.)

Dr. Hansman and Dr. Allroggen are responsible for the economic impact analysis and visibility analysis (both analyses reported in previous reports) and participate in drafting the report for policymakers.

Project Overview

Exposure to aircraft noise has been associated with physiological responses and psychological reactions (Bluhm & Eriksson, 2011; Hatfield et al., 2001), including sleep disturbances, sleep-disordered breathing, nervousness, and annoyance (Hatfield et al., 2001; Rosenlund et al., 2001). However, the extent to which aircraft noise exposure increases the risk of adverse health outcomes is still not well understood. The literature, formerly primarily European studies, provided early evidence of a relationship between aircraft noise and self-reported hypertension (Rosenlund et al., 2001), increased blood pressure (Haralabidis et al., 2008; Jarup et al., 2008; Haralabidis et al., 2011; Evrard et al., 2017), antihypertensive medication use (Bluhm & Eriksson, 2011; Greiser et al., 2007; Franssen et al., 2004; Floud et al., 2011), and incidence of hypertension (Eriksson et al., 2010; Dimakopoulou et al., 2017). One study found that aircraft noise exposure was associated with incident diabetes (Eze et al., 2017). Other studies found a stronger but marginal association between aircraft noise and incident diabetes in women and an association with waist circumference (Eriksson et al., 2014; Sakhvidi et al., 2018). Experimental, "everyday," and traffic noise exposures have been related to heart rate variability (El Aarbaoui & Chaix, 2020; El Aarbaoui et al., 2017; Sim et al., 2015; Walker et al., 2016; Kraus et al., 2013), but no study, to date, has reported on heart rate variability relative to aircraft noise. Findings of a cardiovascular relationship were supported by a report by the World Health Organization European Centre for Environmental Health, which evaluated the association between residential exposure to environmental noise and cardiovascular disease and found substantial evidence for biological plausibility and positive associations between environmental noise and hypertension, myocardial infarction, and ischemic heart disease (Babisch & Kim, 2011; WHO, 2018).

The goal of this ongoing project is to continue to examine the potential health impacts attributable to noise exposure resulting from aircraft flights. This project also leverages ongoing work within ASCENT and is responsive to Section 189 of the FAA Reauthorization Act of 2018 (Pub. L. 115-254), which called for a study on the potential health and economic impacts attributable to aircraft overflight noise and an assessment of the relationship between a perceived increase in aircraft noise and increases in aircraft visibility. To date, our work has leveraged existing collaborations with well-recognized and respected studies that have followed over 250,000 participants through the course of their lives to understand factors that affect health. These studies include the NHS and Nurses' Health Study II (NHSII) as well as the

Health Professionals Follow-Up Study. Furthermore, this work has aligned with a concluded effort funded by the National Institutes of Health to examine these associations in the WHI. The research team continues to leverage aircraft noise data for 90 U.S. airports from 1995 to 2015 and has linked these data to demographic, lifestyle, and health data for the participants of long-term health studies. These studies have provided considerable geographic coverage of the U.S., including all of the geographic areas specified in Section 189. Furthermore, our work to date has also included a first-of-its-kind empirical assessment of the economic impacts on businesses located beneath flight paths at selected U.S. airports responsive to the requirements set forth in Section 189 of the FAA Reauthorization Act of 2018.

Our team recently added to the literature by reporting on U.S. studies evaluating the degree to which aircraft noise affects health. A suggestive positive association was found between aircraft noise exposure and the risk of hypertension (Kim et al., 2022). However, there are fewer studies on the potential effect of noise on mental health (Seidler et al., 2017; Wright et al., 2018). Updated guidelines from the World Health Organization reported a lack of high-quality evidence for aircraft noise and mental health and highlighted the need for additional high-quality studies (WHO, 2018; Clark et al., 2020). Potential biological mechanisms of action of noise on health include induced release of stress hormones (Ising & Kruppa, 2004; Spreng, 2000; Selander et al., 2009; Lefevre et al., 2017) and markers of inflammation and oxidative stress, effects on vascular function (Münzel et al., 2017), and indirect effects on sympathetic activity, which is associated with adverse metabolic outcomes (Selander et al., 2009; Grassi, 2006; Mancia et al., 2006; Mancia et al., 2007). To better understand these potential relationships, our team increased the diversity of participants in our studies with a focus on vulnerable populations by adding the HCHS/SOL and Add Health cohorts. Furthermore, the potential impacts of aircraft noise on additional health outcomes beyond those previously explored are being evaluated, including cardiovascular intermediaries and mental health outcomes in NHS, NHSII, WHI, HCHS/SOL, and Add Health.

The overall aims for this multi-year project as it relates to our continuing efforts are as follows:

Tasks under Amendment No. 38:

1. Assign new aircraft noise exposures to geocoded participant addresses for NHS.
   a. Intersect geocoded addresses with day–night average sound level (DNL) aircraft noise exposure levels newly available for 2019 for the currently included 90 airports and for 2015 and 2019 for additional airports.
2. Increase personnel effort (postdoctoral fellow) on noise and health analyses.

Tasks under Amendment No. 32:

1. Assign aircraft noise exposures over time to geocoded participant addresses for HCHS/SOL and Add Health.
   a. Intersect geocoded addresses with DNL and equivalent sound levels for night (L_{night}) and day (L_{day}) aircraft noise exposure levels currently available from 1995 to 2015.
   b. Estimate the percent of participants across noise exposure categories and assess overall trends in participant noise exposure levels over time, including an evaluation of sociodemographic and other predictors of aircraft noise exposure to facilitate the design and interpretation of epidemiological analyses.
2. Estimate the potential association between cardiovascular intermediaries and aircraft noise exposure.
   a. Develop analysis plans and manuscript proposals to gain approval to investigate potential relationships between aircraft noise exposure and health intermediaries or cardiometabolic markers such as adiposity and heart rate variability in the NHS, WHI, HCHS/SOL, and Add Health cohorts.
   b. Perform statistical analyses, undergo manuscript reviews, and present and publish results.
3. Investigate the potential impact of aircraft noise exposure on mental health.
   a. Conduct an in-depth literature search to identify relevant mental health outcomes.
   b. Determine the applicable assessments of these outcomes (i.e., depression and anxiety) within the various cohort studies.
   c. For each cohort, develop an analysis plan and gain approval of manuscript proposals on the potential relationships between aircraft noise exposure and mental health outcomes.
   d. Perform statistical analyses, undergo manuscript reviews, and present and publish results.
4. Explore the addition of noise-related survey questions to Nurses' Health Study 3 (NHS3).

Tasks under Amendment No. 16 as it relates to Section 189 are as follows:

1. Prepare a final draft of the study report related to Section 189 of the FAA Reauthorization Act of 2018 (Pub. L. 115-254) for policymakers.

Task 1 – Present on Aircraft Noise and Health Research in the United States

Boston University

Objective

The aim of this task is to present on U.S.-based research on aircraft noise exposure and health outcomes.

Research Approach

Presentations highlighting published, current, and planned research on aircraft noise exposure and health outcomes in U.S. cohorts were developed and delivered.

Milestone

- Presented on research efforts and results.

Major Accomplishments

- Presented on aircraft noise and health research to the following organizations (example Figure 1):
  - International Society for Environmental Epidemiology (ISEE) Conference
  - Airports Council International (ACI)-North America/American Association of Airport Executives (AAAE) Airport Noise Conference
  - Department of Transportation and FAA Office of Policy, International Affairs, and Environment, and New England regional office

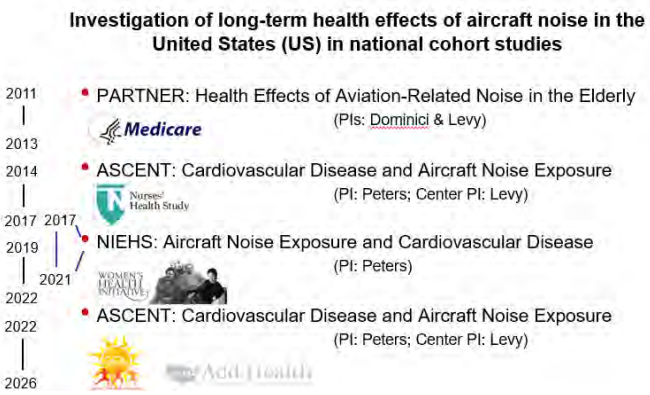


Figure 1. Overview of U.S.-based studies funded through FAA Centers of Excellence (COE) PARTNER and ASCENT and the National Institute of Environmental Health Science (NIEHS) over time, investigating the health effects of aircraft noise in U.S. cohorts.

Task 2 – Write up and Publish Final Results on Hypertension and Night-time Aircraft Noise Exposure

Boston University, Harvard University

Objective

The aim of this task is to write up and publish the final results of our analyses of aircraft noise (L_{night}) and hypertension.

Research Approach

Our team intersected modeled noise exposure surfaces for 1995, 2000, 2005, 2010, and 2015 based on geocoded addresses of the participants over the follow-up period in NHS and NHSII. A large set of a priori variables were selected to

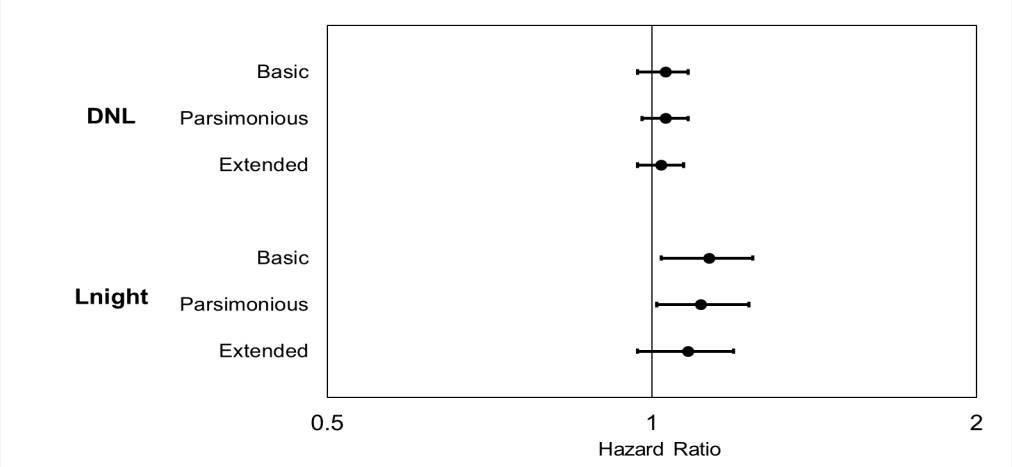
be examined as confounders and/or effect modifiers and used time-varying Cox proportional hazards models to estimate the hypertension risk associated with time-varying night-time aircraft noise exposure, while adjusting for both fixed and time-varying covariates. Sensitivity analyses were also performed to address potential biases.

Milestone

- Published manuscript on aircraft noise (L_{night}) and hypertension.

Major Accomplishments

- Submitted manuscript reporting results on analyses of L_{night} noise and hypertension.
- Responded to journal reviewer comments and revised our manuscript accordingly.
- Published "Long-term nighttime aircraft noise exposure and risk of hypertension in a prospective cohort of female nurses" in the *International Journal of Hygiene and Environmental Health* (Peters et al., 2024).



Basic model adjustment: age and calendar year.
Parsimonious model adjustment: basic model + race, physical activity, smoking status, alcohol use, Dietary Approaches to Stop Hypertension, spouse's education attainment, neighborhood socioeconomic status, region of residence, nitrogen dioxide, and fine particulate matter ($PM_{2.5}$).
Extended model adjustment: parsimonious model + body mass index, menopausal status, medications, and family history of hypertension.

Figure 2. Hazard ratios (95% confidence intervals) of the association between aircraft noise at 45 dB and hypertension, comparing previous findings of day-night average sound level (DNL) (Kim et al., 2021) and night-time noise (L_{night}) in the NHS and NHSII (Peters et al., 2024).

Interpretation of night-time noise and hypertension results using the L_{night} 45-dB cut point (Figure 2)
In the combined parsimonious model, the participants in NHS and NHSII exposed to L_{night} levels ≥45 dB had an 11% greater risk of hypertension than the participants exposed to L_{night} levels <45 dB, with a 95% confidence interval (CI) of 1%–23%. In the combined fully adjusted model, the participants exposed to L_{night} ≥45 dB had an 8% greater risk (95% CI: −3%, 19%) than the unexposed individuals. The hazard ratios were relatively stable across the sensitivity analyses, even after controlling for air pollution and shiftwork.

Task 3 – Write Up and Publish Final Results on the Intermediary Risk Factor of Adiposity and Aircraft Noise

Boston University, Harvard University

Objective

The aim of this task is to write up and publish the final results of our analyses on aircraft noise and an intermediary risk marker (adiposity, a measure of cardiometabolic disease).

Research Approach

An analysis plan was developed for studying adiposity and aircraft noise and obtained approval from the NHS oversight committee. Statistical analysis was designed, and a large set of a priori variables were selected to be examined as confounders and/or effect modifiers. The appropriate datasets were compiled and a descriptive statistics analysis was performed. Multivariable multinomial logistic regression was used to estimate the relationship between aircraft noise and longitudinal, repeated measures of adiposity (body mass index [BMI]).

Milestone

- Published analyses on aircraft noise and adiposity.

Major Accomplishments

- Completed and submitted a manuscript reporting the results of analyses on aircraft noise and adiposity.
- Responded to journal reviewer comments and revised our manuscript based on comments.
- Published a paper entitled "Aircraft noise exposure and body mass index among female participants in two Nurses" Health Study prospective cohorts living around 90 airports in the U.S. in *Environment International* (Bozigar et al., 2024).

Table 1. Odds ratio of increasing body mass index (BMI) groups (reference: 18.5–24 kg/m^2) for exposure day–night average sound level ≥55 vs. <55 dB (Bozigar et al., 2024).

Model	BMI Group (kg/m^2)		
	18.5–24.9	25.0–29.9	≥30.0
Model 0: Age	Ref.	1.20 (1.09, 1.31)	1.27 (1.14, 1.42)
Model 1: 0 + demographics & lifestyle	Ref.	1.14 (1.04, 1.24)	1.14 (1.02, 1.28)
Model 2: 1 + environmental	Ref.	1.13 (1.03, 1.24)	1.12 (1.00, 1.25)

Model 0: age, age^2, survey period, cohort; Model 1: 0 + demographics: region, race, individual socioeconomic status, parity, menopausal status, hormone therapy, smoking status, alcohol use, diet quality, physical activity; Model 2: 1 + neighborhood socioeconomic status, greenness, environmental noise, population density.

Interpretation using DNL ≥55 dB as an example (Table 1)
From Model 2, there was 13% higher odds (95% CI: 3%, 24%) of being in the 25.0–29.9 BMI category and 12% higher odds (95% CI: 0%, 25%) of being in the ≥30.0 BMI category versus being in the 18.5–24.9 BMI category among those exposed to aircraft noise (DNL) ≥55 dB compared with those exposed to <55 dB.

Task 4 – Perform Preliminary Analyses of an Intermediary Risk Factor (Diabetes) and Aircraft Noise Exposure

Boston University, Harvard University

Objective

The aim of this task is to generate preliminary results on aircraft noise and diabetes.

Research Approach

An analysis plan was developed for studying diabetes and aircraft noise and obtained approval from the NHS oversight committee. Statistical analysis was designed, and a large set of a priori variables were selected to be examined as confounders and/or effect modifiers. Appropriate datasets were compiled to perform descriptive statistics analysis. We ran preliminary analysis of the form of the relationship between aircraft noise and diabetes risk.

Milestones

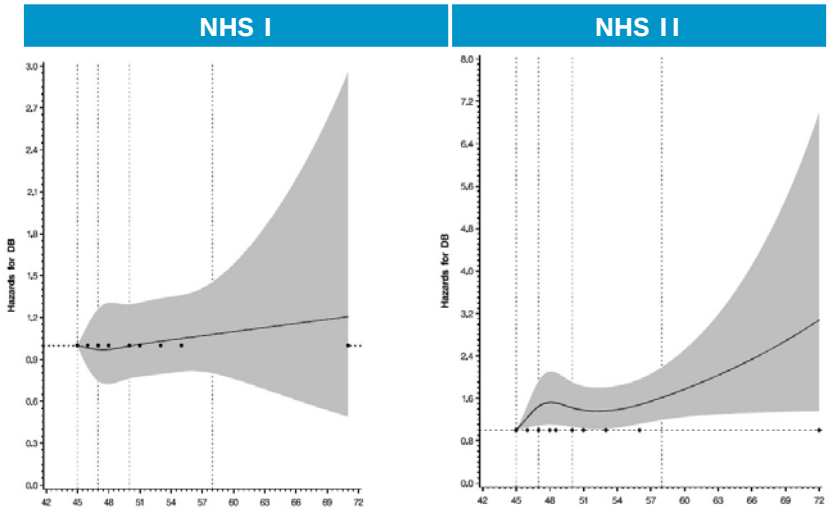
- Produced preliminary results to investigate aircraft noise and the risk of diabetes.

Major Accomplishments

- Performed preliminary analyses on the relationship between aircraft noise and risk of diabetes (Table 2 and Figure 3).

Table 2. Number of participants in the Nurses' Health Study (NHS) and Nurses' Health Study 2 (NHSII) at risk for diabetes (did not have diabetes at the time of the first noise measure) and those who developed diabetes during the study period according to day-night average sound level (DNL) categories.

Model	NHS		NHSII	
DNL (dB)	**At Risk**	**Cases**	**At Risk**	**Cases**
<45	90,946	7,076	100,968	6,391
45–49	4,340	313	5,281	276
50–54	2,018	165	2,419	137
55–59	751	60	954	56
60–64	179	17	238	20
≥65	39	3	55	7
Total	98,273	7,634	109,915	6,887



Adjusted for race/ethnicity, individual-level and neighborhood-level socioeconomic status, physical activity, diet, alcohol intake, smoking, family history of Type 2 Diabetes Mellitus, and air pollution

Figure 3. Hazard ratios (line; 95% confidence intervals (gray shade)) of the association between aircraft noise across decibels (dB) and diabetes risk in the Nurses' Health Study (NHS) and Nurses' Health Study 2 (NHSII).

Task 5 – Perform Data Linking with New Cohort and Develop Data Use Procedures

Boston University, University of North Carolina

Objective

The aim of this task is to link airport noise data to participants geocoded addresses.

Research Approach
The geocoded addresses for Add Health participants were intersected with noise contours available from 1995 to 2015. Given the longitudinal nature of this study, noise exposures will be assigned reflecting specific residential addresses over time based on the participant address histories. Our team collaborated in the development and execution of a data use agreement and procedures for use of aircraft noise exposure estimates.

Milestones
- Assigned aircraft noise exposures in Add Health.
- Executed data use agreement.

Major Accomplishments
- Adapted procedures for linking DNL, L_{night}, and L_{day} aircraft noise exposure data to the new cohort.
- Estimated noise exposure for participants of Add Health.
- Developed an Add Health Noise User Guide.
- Executed a memorandum of understanding between the FAA and the University of North Carolina.
- Gained approvals to create a data portal and to access health, sociodemographic, noise exposure, and other relevant cohort data.

Task 6 – Define Request for Noise Data for Additional Year and Airports
Boston University, University of North Carolina, Harvard University

Objective
The aim of this task is to define aircraft noise data request and obtain data for an additional year and additional airports.

Research Approach
More recent data were requested to add to the 5-year incremental data received for 1995 to 2015. The year 2019 was chosen as the additional year to avoid anomalies related to 2020. The locations of participants were reviewed, particularly in new cohorts such as HCHS/SOL, to request 2015 and 2019 data for additional relevant airports not included in the 90 airports previously provided. For the 2019 DNL data, a quality and format review will be performed for the 90 airports before requesting additional metrics and airports.

Milestone
- Requested and obtained data for additional years and airports.

Major Accomplishments
- Investigated study locations and proximate airports to inform the request for additional airports.
- Received the 2019 data and performed the initial review.

Task 7 – Prepare a Third Draft of the Report on Study Results Related to 2018 FAA Reauthorization, Section 189 for Policymakers
Boston University, Massachusetts Institute of Technology

Objective
The aim of this task is to develop a report of overall study results in response to 2018 FAA Reauthorization, Section 189 for policymakers.

Research Approach
Summarized Section FAA Reauthorization Act of 2018 (Pub. L. 115-254), Section 189, *STUDY ON POTENTIAL HEALTH AND ECONOMIC IMPACTS OF OVERFLIGHT NOISE* and provided the background of the study, study methods and data, study findings, and conclusions.

Milestone

- Generated a third draft of the report on overall study results in response to Section 189 for policymakers.

Major Accomplishments

- Provided a revised third draft report summarizing the overall study results in relation to Section 189.

Publications

Peer-Reviewed Journal Publications

Peters, J. L., Grady, S. T., Laden, F., Nelson, E., Bozigar, M., Hart, J. E., Manson, J. E., Huang, T., Redline, S., Kaufman, J. D., Forman, J. P., Rexrode, K. M., & Levy, J. I. (2024). Long-term nighttime aircraft noise exposure and risk of hypertension in a prospective cohort of female nurses. *International Journal of Hygiene and Environmental Health, 12*(263), 114457. doi: 10.1016/j.ijheh.2024.114457. PMID: 39270405

Bozigar, M., Laden, F., Hart, J. E., Redline, S., Huang, T., Whitsel, E. A., Nelson, E. J., Grady, S. T., Levy, J. I., & Peters, J. L. (2024). Aircraft noise exposure and body mass index among female participants in two Nurses' Health Study prospective cohorts living around 90 airports in the United States. *Environment International, 187*, 108660. doi: 10.1016/j.envint.2024.108660. PMID: 38677085

Nguyen, D. D., Levy, J. I., Kim, C., Lane, K. J., Simon, M. C., Hart, J. E., Whitsel, E. A., VoPham, T., Malwitz, A., & Peters, J. L. (2023). Characterizing temporal trends in populations exposed to aircraft noise around U.S. airports: 1995–2015. *Journal of Exposure Science and Environmental Epidemiology.* https://doi.org/10.1038/s41370-023-00575-5

Grady, S. T., Hart, J. E., Laden, F., Roscoe, C., Nguyen, D. D., Nelson, E. J., Bozigar, M., VoPham, T., Manson, J. E., Weuve, J., Adar, S. D., Forman, J. P., Rexrode, K., Levy, J. I., & Peters, J. L. (2023). Associations between long-term aircraft noise exposure, cardiovascular disease, and mortality in US cohorts of female nurses. *Environmental Epidemiology, 7*(4), e259. doi: 10.1097/EE9.0000000000000259

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Outreach Efforts

Presentations

- Presented an oral presentation on current progress during the ASCENT Fall Meeting (October 24–26, 2023) and ASCENT Spring Noise and Operations Meeting (April 9–10, 2024)
- Virtually presented an oral presentation entitled "Aircraft noise research in the U.S. – studies in multiple national cohorts" at the 35th Annual ISEE Conference (September 17–21, 2023).
- Presented an oral presentation entitled "Research on Aircraft Noise and Health in U.S. Cohorts" at the 2023 ACI-North America/AAAE Airport Noise Conference (October 23–25, 2023).

Awards

None.

Student Involvement

The dissertation of Daniel Nguyen (doctoral graduate, Boston University) included a characterization of the temporal trends in aviation noise surrounding U.S. airports. Daniel Nguyen graduated in the spring of 2022 and is currently working for the Centers for Disease Control and Prevention.

The dissertation of Stephanie Grady (doctoral candidate, Boston University) includes developing and performing statistical analyses on noise and hypertension risk, cardiovascular event risk, and biomarkers of neurodegeneration. Stephanie Grady graduated in the spring of 2024 and is currently working as a postdoctoral fellow at Boston University.

Plans for Next Period

(October 1, 2024, to September 30, 2025)

- Submit proposals/analysis plans and generate preliminary results to estimate the relationship between aircraft noise exposure and mental health outcomes (e.g., depression and anxiety).
- Submit proposals/analysis plans and generate preliminary results to estimate the relationship between aircraft noise exposure and sleep outcomes.
- Review analyses, draft the manuscript, and publish on aircraft noise exposure and cardiovascular disease.
- Link aircraft noise data to geocoded addresses of participants in the additional cohort.
- Develop the protocol for accessing aircraft noise exposure data in the additional cohort.
- Document results for policymakers in a final report.

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