NIOSH Air Crew Studies

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April 15, 2015

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The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.
Overview

- Origins/objectives of air crew program
- What sets NIOSH research apart
- Exposures
- Health Studies
  - Exposure assessment of US pilots
  - Miscarriage in Flight Attendants
- Implications
Background

• 200,000 US workers and 500,000 workers worldwide in commercial aircraft cabins

• Other workers with air travel
  • unscheduled business jets
  • air couriers
  • frequent business fliers
  • military

• Air cabin exposures
  • Galactic cosmic (GCR) and Solar particle event (SPE) radiation
  • Circadian rhythm disruption
  • Airborne contaminants
  • Ergonomic factors
  • Stress
NIOSH Approach: Flight Exposure Assessment

- **2.5 M+ Individual flight histories available**
  - Individual flight exposure estimates
  - “Windows of exposure”
  - Misclassification in epidemiologic analyses

- **Individual flight histories not available**
  - Domicile-era-specific estimates of exposure
  - Link with work histories for individuals’ estimates
What worker group is most exposed to workplace radiation?

- 250,000 air crew worldwide monitored for radiation
- 0 US air crew monitored for radiation
Ionizing Radiation

- IARC known human carcinogen
- Linked to adverse reproductive outcomes

Exposure Assessment

- 2.5+ M individual flights
- GCR particle and total doses: FAA’s CARI 6P
- Evaluate every flight for SPE status
- Solar storm data from NOAA
  - Moderate-large events, approximate S2-S3 range
  - “Date gates” to determine if flight occurred during SPE
Radiation Exposure Assessment

- Estimated SPE doses from NASA’s Nowcast of Atmospheric Ionizing Radiation Safety (NAIRAS)
  - Real-time prediction of exposure rates at aviation altitudes

- 2 NAIRAS data sets for each SPE:
  - Dynamic (hour-by-hour) radiation absorbed and effective dose rates covering each storm period
    - 5x5 degree grid at altitudes 0-90 km
    - ~230,000 data points /hour
  - Event-averaged dose rates
SPE Dose Estimation

\[
D_{SPE} = D_{CARI} \times \frac{1}{2} \left[ \frac{1}{t} \sum_{i=1}^{t} \left( \frac{\dot{D}_{i,SPE}}{\dot{D}_{i,GCR}} \right)_{ori} + \frac{1}{t} \sum_{i=1}^{t} \left( \frac{\dot{D}_{i,SPE}}{\dot{D}_{i,GCR}} \right)_{dest} \right]
\]

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D_{SPE} = D_{CARI} \times \frac{1}{2} \left[ \left( \frac{\dot{D}_{SPE}}{\dot{D}_{GCR}} \right)_{ori} + \left( \frac{\dot{D}_{SPE}}{\dot{D}_{GCR}} \right)_{dest} \right]
\]

Circadian disruption:

“The swing shift is the killer”

—Josephine Arendt

- NHS: Night shift work increases risk of fetal loss
- Shift work with circadian disruption: IARC probable human carcinogen

NIOSH Approach

- Monitor sleep and a circadian biomarker
- Identify useful metrics for larger studies
## Air Crew Research Program

### Health Effect Studies

- **Reproductive Health**
  - Ovulatory Function/Menstrual Cycle
  - Pregnancy Outcomes

- **Cancer**
  - Cytogenetic Effects among Pilots

- **Other**
  - Respiratory Symptoms
  - Effects of Downsizing on Mortality

### Exposure Studies

- **Radiation**
  - GCR and SPE Radiation
  - Retrospective Estimation of Dose

- **Cabin Air Quality**
  - Cabin Environmental Exposures
  - Bioaerosol Levels in Aircraft

- **Other Factors**
  - Physical Work Demands
  - Psychosocial Work Conditions
  - Circadian Rhythm Disruption

### Status

- Completed
- Ongoing
Exposure assessment for the NIOSH study of chromosomal aberrations in pilots

Grajewski B, Waters MA, Yong LC et al. Airline pilot cosmic radiation and circadian disruption exposure assessment from logbooks and company records.

Editor’s Choice, Ann Occ Hyg 2011; 55: 465–475 and online supplement

Design

• 83 full time male pilots from a major US airline

• Data extracted/imputed from pilot records 1963-2003
  • Airline records
  • Pilot logbooks
  • Summary records
  • Commuter travel
  • Recreational (“pass”) travel
  • Questionnaire

• Radiation and circadian disruption assessed
  • GCR: FAA’s CARI6P, CARI6PM
  • SPEs: binary exposure based on equipment, geomagnetic latitude, and NOAA satellite data
  • Time zones crossed and time spent working during normal sleep hours
Results

• A hypothetical (median) pilot incurred a cumulative radiation dose of 34.4 mSv, with 1.9 mSv in the last study year.

• Pilots incurred possible SPE exposure a median of 6 times (range 1-14), or once every 3.7 years of work (range 1.6 – 16.8 y).

• Dose and circadian disruption metrics were only moderately correlated with years of flying.

• Median doses and circadian disruption metrics per flight segment rose markedly from the 1990s to 2003 ($p_{\text{trend}} <0.0001$).
Impact

This is the first study to report

- Air crew career exposure assessment from individual flight segments
- Long-term assessment of circadian disruption in air crew
- Assessment of cumulative solar particle event exposure.
Flight Attendant Reproductive Risks

- Flight attendants may experience increased risk of:
  - Miscarriage
  - Menstrual disorders
  - Other adverse reproductive outcomes

- Is work as a female flight attendant associated with adverse reproductive effects?
Reproductive Outcomes Questionnaire Study

3 Airlines, 2654 FA

Assess ~2M flight segments for radiation, CD

1992-1996
- Miscarriage
- Major BDs
- Endometriosis
- Time to pregnancy
- Gender ratio
- Birthweight Preterm

1999 - 2001
- Respiratory
- Menstrual Fx
- Sleep
Exposure assessment

1.9M company records of individual flights

Questionnaire data for each pregnancy

Exposure assessment

Time-dependent exposure metrics for each week of pregnancy
- GCR and SPE radiation
- Time zones crossed
- Work during normal sleep hours

Fixed workplace exposure metrics
- Physical job demands
- Passive smoking
- Psychosocial stressors

Analysis
- Cox Proportional Hazards regression, discrete time data
Effective dose per flight segment from GCR and SPE radiation for study period A (1411 flight segments) and study period B (6593 flight segments). Lines indicate data ranges (min, max) and boxes indicate interquartile ranges. Only segments with significant (nonzero) estimated SPE dose are represented.
Results

- 2654 women interviewed, 87% participation; 958 pregnancies analyzed

- Miscarriage in the first trimester was 50% more likely for a pregnant flight attendant who flew 15 hours or more during her normal sleep hours (OR=1.5; 95% CI=1.1 – 2.2).

- Miscarriage in the first trimester was about 2.5 times as likely for a pregnant flight attendant with high physical job demands (OR=2.5; 95% CI=1.5 – 4.2).

- There is evidence that cosmic radiation dose of 0.1 mGy or more in the first trimester increases the risk of miscarriage by 70% (OR=1.7; 95% CI=0.95 – 3.2).

- 2% of study pregnancies were exposed to an SPE. The two highest study SPE exposures were 1.2 and 0.8 mSv, both from single flights.
**Implications**

- Circadian disruption and ergonomic guidelines being developed for pregnant workers should be adapted for pregnant air crew.
- Flying 1-2 flights during an SPE could exceed ICRP, NCRP pregnancy guidelines/limits.
- 50% of our flight attendants had estimated annual effective doses of 1.5 – 4.9 mSv prior to pregnancy.
- There are no official dose limits and no mandatory training for this most highly exposed group of radiation workers in the United States.

**Strengths**

- First assessment of flight attendant radiation and circadian disruption from individual flight records
- First direct estimation of SPE radiation dose in flight attendants
US: Future Directions

- Air crew radiation exposures are occupational exposures
- Clarify regulatory responsibility for air crew occupational exposures
- Optimize protection: focus on highest exposed
- Implement management systems for dose estimation and recordkeeping
- Implement air crew exposure training & education

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http://www.cdc.gov/niosh/topics/aircrew/