RELATIONSHIP BETWEEN CARBON DIOXIDE LEVELS AND REPORTED CONGESTION AND HEADACHES ON THE INTERNATIONAL SPACE STATION

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Study Rational

- Congestion is a frequently reported spaceflight symptom
- Most crewmembers report using congestion meds during ISS missions
- Some findings challenge the historical attribution to fluid shifts
  - Fluid status equalizes during first week of spaceflight
  - Congestion continues to be reported throughout mission duration
  - Anecdotally reported in relation to ISS CO2 level
Goals

• Look for correlation between congestion and:
  ▪ CO2
  ▪ Headache
  ▪ Age of crewmember
  ▪ Mission duration
  ▪ Age of ISS
  ▪ Volume of ISS
Methods: CO2 Data

- Primarily from Major Constituent Analyzers (MCA) in USOS
- Back-up sensors used May 13, 2011 to Jan 28, 2012 due to MCA issues
- Missing data addressed with multiple imputation
- 24hr and 7 day average and peak CO2 levels computed
- First 7 days of space flight excluded to control for inability to obtain CO2 levels from transport vehicle

https://www.nasa.gov/mission_pages/station/multimedia/gallery/iss030e047174.html
Methods: Medical Data

• PMCs with reported episodes of headaches, congestion or congestion-like symptoms identified and merged
  ▪ Expeditions 13 to 30 from existing data sets
  ▪ First 7 days of space flight excluded to control for fluid shifts
  ▪ 24 astronauts, 71% male, mean age 47.6 (40.1 – 56.7)
  ▪ 529 PMCs in total merged database
  ▪ 458 PMCs occurred after the first 7 days and were included in the study
  ▪ Of the 458 PMCs used:
    o 26 reported congestion
    o 12 reported headache
Exclusion Criteria

- First 7 days of space flight
  - Control for fluid shifts
  - Control for inability to obtain CO2 levels from transport vehicle
Methods: Analysis

- SAS 9.4 statistical software
- Analysis completed using mixed effects logistic regression
- Random effect intercept term per individual used to adjust for longitudinal repeated observations
- Multiple imputation used to adjust for missing data
## Results

### Descriptive Statistics for CO2 Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>N</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg 24hr</td>
<td>458</td>
<td>2.9427</td>
<td>0.8476</td>
<td>2.8678</td>
<td>1.0029</td>
<td>5.4937</td>
</tr>
<tr>
<td>Peak 24hr</td>
<td>458</td>
<td>3.5347</td>
<td>1.0815</td>
<td>3.3937</td>
<td>1.1896</td>
<td>7.9000</td>
</tr>
<tr>
<td>Avg 7d</td>
<td>458</td>
<td>2.9733</td>
<td>0.7341</td>
<td>2.9246</td>
<td>1.1174</td>
<td>5.0514</td>
</tr>
<tr>
<td>Peak 7d</td>
<td>458</td>
<td>4.2660</td>
<td>1.2463</td>
<td>4.1910</td>
<td>1.4730</td>
<td>8.1156</td>
</tr>
</tbody>
</table>

*First 7 days of spaceflight excluded

Average 24hr and 7d values had best statistical significance and were used for next stage of analysis and modeling.
Goals

• Variables in relation to congestion

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient Estimate</th>
<th>Multiplicative Effect (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average 7-Day CO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>0.733</td>
<td>2.082 (0.884 – 4.903)</td>
</tr>
<tr>
<td>Average 24-hour CO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>0.630</td>
<td>1.878 (0.901 – 3.913)</td>
</tr>
<tr>
<td>Age of ISS (years)</td>
<td>0.616</td>
<td>1.852 (1.025 – 3.348)</td>
</tr>
<tr>
<td>Age of crew member at launch</td>
<td>0.263</td>
<td>1.301 (1.016 – 1.666)</td>
</tr>
<tr>
<td>Mission time elapsed (days)</td>
<td>-0.008</td>
<td>0.992 (0.983 – 1.002)</td>
</tr>
<tr>
<td>Volume of ISS (not including shuttles)</td>
<td>0.001</td>
<td>1.001 (1.000 – 1.001)</td>
</tr>
</tbody>
</table>

• Association between congestion and headache

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient Estimate</th>
<th>Multiplicative Effect (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congestion</td>
<td>2.006</td>
<td>7.435 (1.577 – 35.051)</td>
</tr>
</tbody>
</table>
Probability of Congestion Compared to CO2 Level

24 hour ppCO2 Average

7 Day ppCO2 Average
Probability of Headache and Congestion Based on CO2
Episodes of Congestion and Headache per Week

Average Episodes of Symptoms, Normalized By # of PMCs, Per Given Week

Episodes per PMC

Week
Limitations

• Did not account for localized pockets of CO2
• Some PMC reports were missing
• Under-reporting is likely
• Congestion and headaches are multifactorial
• Human variation to CO2 exposure
• All retrospective data
• Demonstrated associations but can’t prove cause and effect
• EVAs with 100% oxygen for hours, and different CO2 values than on ISS.
• Continued to count ISS CO2 levels after shuttle undock to landing
Conclusion

• Congestion was significant with both CO2 levels and headache

• Congestion odds double for each 1 mmHg increase in CO2

• To keep congestion risk under 5%, CO2 would need to be maintained below 4 mmHg. To keep risk below 1%, CO2 should be kept below 1.5 mmHg

• Congestion may be an early CO2 related symptom when compared to headache
  ▪ Not enough data to correlate time course between CO2 and Headache
  ▪ Congestion and headache probability curves are parallel when based on CO2