Pilot Fatigue and Safety Events: Results from Analysis of Investigation Reports

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PACDEFF Conference, 3-5 September 2019, Gold Coast, QLD, Australia

Current situation

- Pilot fatigue remains a determinative parameter in aviation safety.
- (Pilot) fatigue levels have been associated with:
  - age and other individual physiological characteristics
  - length of wakefulness
  - work pressure
  - length of duty time periods
  - flight phases
  - complexity of tasks
  - level of automation
  - teamwork and resource management
  - daypart of activities
Study motivation

- Most of the fatigue-related studies in aviation are based on:
  - experiments
  - self-evaluations

- How are fatigue factors reflected in safety investigation reports?

- Are there associations of pilot characteristics and event parameters with fatigue-attributed incidents and accidents, as expected according to literature?
Sample & variables

- 296 randomly selected safety investigation reports published in English by five safety authorities (318 cases).
- Dependent variable: had the event been attributed to fatigue as causal or contributing factor?
- Independent variables for the Captains and First Officers:
  1. Age (years)
  2. Flying experience (hours) in the aircraft type involved in the event and total
  3. Hours on duty until the event
  4. Duration of latest sleep before reporting for duty (hours)
  5. Duration of rest before reporting for duty (hours)
  6. Arithmetic mean (additive power), geometric mean (multiplicative relationships) and harmonic mean (varying time periods) for the variables No 1-5 above
More variables - Tests

- Independent variables for event:
  - Aircraft registration region (5 regions; identity not disclosed)
  - Daypart of occurrence (morning, afternoon, evening, night)
  - Aircraft age
  - Aircraft type (jet, propeller, rotary)
  - Type of operation (passenger, non-passenger & commercial, non-commercial)
  - Flight phase (en-route, ground, other)
- Mann-Whitney tests for numerical variables
- Chi-square/Fisher’s Exact tests for nominal variables
Results – Nonsignificant associations

- Pilots’ age
- Flying experience
- Duration of rest
- Duration of latest sleep
- Country of registration
- Aircraft age
- Aircraft type
- Operational type
## Significant associations: Duty duration

- Longer duty times were associated more often with fatigue-attributed occurrences
- The picture was the same when considering the arithmetic, geometric and harmonic means

<table>
<thead>
<tr>
<th>Variable</th>
<th>Fatigue case</th>
<th>Test results</th>
<th>Highest Mean Rank (Fatigue YES/NO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duty Duration</td>
<td>Captain</td>
<td>p = 0.000</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>First Officer</td>
<td>p = 0.017</td>
<td>YES</td>
</tr>
<tr>
<td>Duty Duration Arithmetic Mean</td>
<td>Event</td>
<td>p = 0.001</td>
<td>YES</td>
</tr>
<tr>
<td>Duty Duration Geometric Mean</td>
<td>Event</td>
<td>p = 0.001</td>
<td>YES</td>
</tr>
<tr>
<td>Duty Duration Harmonic Mean</td>
<td>Event</td>
<td>p = 0.003</td>
<td>YES</td>
</tr>
</tbody>
</table>
Significant associations: Daypart

- Safety events occurred in the night were the ones where fatigue was stated as contributing/causal factor more frequently.
- Events attributed to fatigue were more frequent in the:
  - morning compared to afternoon
  - evening compared to morning and afternoon

<table>
<thead>
<tr>
<th>Time of day</th>
<th>Event</th>
<th>Captain</th>
<th>First Officer</th>
<th>Event</th>
<th>Captain</th>
<th>First Officer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not attributed to fatigue (%)</td>
<td>Fatigue as contributory/causal factor (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Morning (06:00-12:00)</td>
<td>92.6</td>
<td>92.6</td>
<td>93.5</td>
<td>7.4</td>
<td>7.4</td>
<td>6.5</td>
</tr>
<tr>
<td>Afternoon (12:00-18:00)</td>
<td>95.1</td>
<td>95.1</td>
<td>98.3</td>
<td>4.9</td>
<td>4.9</td>
<td>1.7</td>
</tr>
<tr>
<td>Evening (18:00-24:00)</td>
<td>87.3</td>
<td>87.3</td>
<td>94.0</td>
<td>12.7</td>
<td>12.7</td>
<td>6.0</td>
</tr>
<tr>
<td>Night (24:00-06:00)</td>
<td>62.5</td>
<td>62.5</td>
<td>71.4</td>
<td>37.5</td>
<td>37.5</td>
<td>28.6</td>
</tr>
</tbody>
</table>

Event (DF=3, $\chi^2 = 19.313$, p=0.000), Captain (DF=3, $\chi^2 = 19.313$, p=0.000), First Officer (DF=3, $\chi^2 = 17.988$ p=0.003)
Significant associations: Flight phase

‘Other flight phases’ category (i.e. take-off, climb, descend and landing) was associated with occurrences attributed to fatigue more frequently, followed by ground-related phases.

<table>
<thead>
<tr>
<th>Flight phase</th>
<th>Event Not attributed to fatigue (%)</th>
<th>Event Fatigue as contributory/causal factor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Event 96.9</td>
<td>Captain 96.9</td>
</tr>
<tr>
<td>En-route</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground</td>
<td>95.6</td>
<td>95.6</td>
</tr>
<tr>
<td>Other flight phases</td>
<td>84.0</td>
<td>84.0</td>
</tr>
</tbody>
</table>

Event (DF=3, $\chi^2 = 14.578$, $p=0.000$), Captain (DF=3, $\chi^2 = 14.578$, $p=0.000$), First Officer (Fisher’s Exact, $p=0.001$)
Implications – Fatigue factors in reports

• Factors associated:
  • Time of day
  • Duty period length

• Factors not associated:
  • Sleep duration
  • Rest duration
  • Age
  • Type of operation

• Other remarks:
  • No differences across regions: similar implementation of fatigue risk management strategies (?
  • Expected associations not found: flying experience, aircraft age and type
Limitations – Further research

• The samples of events attributed or not to fatigue were unequal (8.3% fatigue-related), yet representative of the overall frequency of fatigue-related events.
  -> future research with stratified sampling

• Insufficient sample to employ statistics with layer variables (e.g., duty duration vs fatigue when controlling for flight phase or daypart)
  -> future studies with larger samples to allow tests with layer variables

• The recording of fatigue as a contributory factor was entirely dependent on the investigations’ quality and comprehensiveness
  -> support investigators in the examination of fatigue as possible factor???

• Studies use, almost exclusively, arithmetic means
  -> consider the exploitation of geometric and harmonic means
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Any questions?