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# Perspectives on fatigue in short-haul flight operations from US pilots: A focus group study

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ABSTRACT

There are few studies investigating the impact of fatigue in short-haul flight operations conducted under United States (US) 14 Code of Federal Regulations Part 117 flight and duty limitations and rest requirements. In order to understand the fatigue factors unique to short-haul operations, we conducted a series of focus groups across four major commercial passenger airlines in the US. Ninety short-haul pilots were recruited through emails distributed by airline safety teams and labor representatives. Fourteen focus groups were conducted via an online conferencing platform in which participants were asked to identify short-haul schedules and operations that they felt: a) elevated fatigue, b) were not fatiguing, and c) were important to study. Data were collected anonymously and coded using conventional qualitative content analysis, with axial coding and summative analysis used to identify main themes and over-arching categories. The six fatigue factor categories identified were: circadian disruption, high workload, inadequate rest opportunity, schedule changes, regulation implementation and policy issues, and long sits. It appears that additional mitigation strategies may be needed to manage fatigue in short-haul operations beyond the current regulations. Future field studies of short-haul operations in the US should investigate the prevalence and impact of these factors.

## 1. Introduction

Pilot fatigue is a known contributor to aviation accidents (National Transportation Safety Board [NTSB], 2019; Rosekind et al., 1994) and continues to be a risk factor to alertness and performance due to the nature of commercial air scheduling (Caldwell, 2012; Coombes et al., 2020). While most research on fatigue in aviation has focused on long-haul (LH) and ultra-long-range (ULR) operations, limited evidence also suggests that fatigue is a factor in short-haul (SH) operations. In the United States (US), updated flight, duty, and rest time regulations were introduced in 2012 and fully implemented in 2014 (14 Code of Federal Regulations [CFR] Federal Aviation Regulation [FAR] Part 117) in an effort to minimize the impact of schedules on fatigue (Federal Aviation Administration, 2012). To date, however, no studies have investigated fatigue in SH operations under these regulations. Therefore, more research is needed to understand the fatigue risks that US SH pilots are exposed to during flight operations under 14 CFR Part 117.

Using qualitative research methods, our study aimed to identify fatigue factors perceived by active US SH pilots and to define the scope of future investigations of fatigue in SH operations.

### 1.1. 14 Code of Federal Regulations Part 117

14 CFR Part 117 provides regulatory guidance for the maximum flight and duty durations and minimum rest requirements between duties (14 CFR Part 117 Flightcrew Member Duty and Rest

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Requirements; FAA, 2012). In consultation with a working group of sleep and circadian scientists, Part 117 updated prior regulations (14 CFR Parts 119 and 121) to further protect sleep opportunities and limit flight and duty hours. These new, holistic, science-based regulations take into account the extra workload associated with multiple flights within a duty period, and the circadian influence of time of day. For example, as the number of flights in a duty day increases, the maximum length of a duty is progressively reduced. Similarly, duty periods starting during the nighttime have reduced maximum duty duration periods (see Part 117 Table B, Flight Duty Period: Unaugmented Operations). 14 CFR Part 117 also provided new guidance for a number of other important aspects of fatigue management, including restricting maximum flight hours based on crew complement size, increasing minimum rest periods to at least 10 h pre-duty period (the 10-h rest period must provide the flightcrew member with a minimum of eight uninterrupted hours of sleep opportunity), and requiring fatigue education and awareness programs for all employees responsible for administering provisions of the rule.

### *1.2. Research gap and objectives*

Extant SH literature reports on data collected from international airlines operating under different flight, duty, and rest time regulations to those in the US, or use US data from before the implementation of 14 CFR Part 117 in 2014. Further, many of these studies collected data based on pre-determined hypotheses as to which fatigue factors to assess. Such an approach may fail to capture the broad spectrum of fatigue issues pilots experience, particularly those that are unique to SH operations. Given the breadth of scope and potential for unknown sources of fatigue in these unique operations, we chose to conduct a series of focus groups of SH pilots to qualitatively and systematically identify the factors influencing fatigue in major US SH commercial passenger operations.

The aim of this focus group study was to collect feedback from active US SH pilots on the factors that they identify as related to fatigue. We did not aim to directly assess the impact of 14 CFR Part 117 on fatigue, nor collect the views of pilots on this regulation specifically. The primary factors identified from this focus group study are intended to inform the scope of a larger observational field study addressing the impact of these fatigue factors on the sleep, sleepiness, workload, and cognitive performance of US-based SH pilots.

## 2. Literature review

Most research regarding fatigue in aviation has focused on LH and ULR operations, with less attention paid to SH or medium-haul operations. For example, a PubMed search returned 187 articles for [“ultra-long-range/haul” OR “long-range/haul” AND “fatigue”], and only returned 36 articles for [“short-haul” OR “medium-haul” AND “fatigue”]. For the current study, we have defined SH to include flights up to 6 h in duration. This definition is in line with previous literature in this area (Sallinen et al., 2017) and includes flights sometimes referred to as “medium-haul” (Reis et al., 2016). This was a deliberate decision to include all operations that are typically excluded from LH studies.

Despite the relative paucity of SH fatigue studies, SH schedules include many of the fatigue factors inherent in LH flying and may also introduce unique operational challenges to obtaining sufficient sleep and maintaining in-flight alertness (Venus and Holtforth, 2021; Coombes et al., 2020). In addition, many of the countermeasures available in LH and ULR operations may not be available in SH, for example, crew augmentation, which allows for in-flight rest breaks (Powell et al., 2008). Indeed, studies comparing fatigue across SH and LH pilots report equivalent or higher levels of fatigue for SH pilots (Bourgeois-Bougrine et al., 2003; Reis et al., 2016; Venus and Holtforth, 2021).

Several factors can disrupt sleep and increase fatigue during SH operations including overnight flights (Gander et al., 1998a), early starting duties (Åkerstedt et al., 2021; Arsintescu et al., 2021; Bostock and Steptoe, 2013; Bourgeois-Bougrine et al., 2003; Flynn-Evans et al., 2018; Kecklund et al., 1997; Roach et al., 2012; Sallinen et al., 2017; Simons and Valk, 1997; Vejvoda et al., 2014), late finishing duties (Bostock and Steptoe, 2013; Flynn-Evans et al., 2018; Sallinen et al., 2017, 2021; Vejvoda et al., 2014), the number of flights in a duty period (Arsintescu et al., 2020; Honn et al., 2016; Powell et al., 2007), rest quality and duration between duties (Avers et al., 2009; Chidester, 1990; Gander et al., 1998b; Houston et al., 2012); and consecutive duties (Åkerstedt et al., 2021; Flynn-Evans et al., 2018; Gander et al., 1998a, 1998b; Arsintescu et al., 2021; Coombes et al., 2020). The Colgan Air Flight 3407 accident in 2009 exemplifies the culmination of several of these sleep loss and circadian factors and the potential catastrophic consequences (NTSB, 2010). The ways in which these factors contribute to sleep loss and circadian misalignment in SH operations are discussed below. For a full review of fatigue factors in SH operations, see Flynn-Evans et al. (2022).

Overnight duties (also referred to as “red-eyes”) often overlap with a pilot’s normal sleep opportunity, thus both disrupting sleep timing and requiring high performance during periods of low alertness. Obtaining sufficient preparatory sleep before and recovery sleep after an overnight flight can be challenging. Compared to other nighttime sleep opportunities, daytime sleep associated with overnight SH duties is approximately 40% shorter and of poorer subjective quality (Gander et al., 1998a).

Daytime duties can also have a significant impact on sleep in SH operations. Studies investigating duties with early report times (e.g., before 0630) have consistently shown that sleep prior to the duty is significantly shortened relative to sleep on days off (Åkerstedt et al., 2021; Bostock and Steptoe, 2013; Bourgeois-Bougrine et al., 2003; Flynn-Evans et al., 2018; Kecklund et al., 1997; Roach et al., 2012; Sallinen et al., 2017; Simons and Valk, 1997; Vejvoda et al., 2014). Late duties (e.g., finishing after 0000), on the other hand, typically allow for sufficient sleep ahead of the duty (Åkerstedt et al., 2021; Bostock and Steptoe, 2013; Flynn-Evans et al., 2018; Sallinen et al., 2017; Vejvoda et al., 2014). Instead, the late finish is often associated with extended wakefulness at the end of the duty (Sallinen et al., 2017; Vejvoda et al., 2014). In addition, recovery sleep after a late duty may be truncated due to subsequent duties or daytime sleep disruptions (Flynn-Evans et al., 2018; Gander and Graeber, 1987). Therefore, even ‘daytime’ duties can encroach on normal sleep periods and, therefore, reduce the opportunity for circadian-aligned sleep.

When the duty days described above are scheduled consecutively, sleep loss is further exacerbated (Åkerstedt et al., 2021; Flynn-Evans et al., 2018; Gander et al., 1998a). Adaptation to out-of-hours schedules is typically only partial, with circadian phase only shifting 1–3 h across multiple days (Flynn-Evans et al., 2018; Gander et al., 1998a). Further, inadequate rest opportunities between consecutive duties – both in duration and quality - can lead to cumulative sleep loss across a work schedule. Sleep away from home between consecutive duties (e.g., during a “layover”) is common in short-haul operations, with an average of over 10 days per month spent away from home (Avers et al., 2009; Wollmuth, 2017). Compared to sleep at home, sleep away is often shorter and of poorer quality due to interruptions, such as hotel noise (Avers et al., 2009; Chidester, 1990; Gander et al., 1998b; Houston et al., 2012; Roma et al., 2010).

Finally, workload is thought to contribute to fatigue in SH operations, but there are surprisingly few studies on this topic (Arsintescu et al., 2020; Honn et al., 2016). The number of flights in a duty day, self-rated fatigue, and poor performance have all been associated with higher subjective workload ratings in SH operations (Arsintescu et al., 2020). Little is known, however, about how other operational and scheduling factors associated with SH flying contribute to workload and, ultimately, fatigue.

The studies discussed above provide evidence that there are unmanaged fatigue issues in SH operations. The literature to-date, however, is based on non-US pilots and US pilots operating prior to the implementation of 14 CFR Part 117. Therefore, it is unknown which factors US SH pilots perceive to be most fatiguing under the current flight, duty, and rest regulations.

Early assessments of pilot (Rudari et al., 2014) and airline personnel (Rudari et al., 2016) perceptions of the impact of 14 CFR Part 117 on overall fatigue and safety compared to previous regulations reported largely neutral to slightly positive views. However, these surveys were conducted within months of 14 CFR 117 implementation, within which time the impacts of the changes may not have been fully understood or assessed by the respondents. To our knowledge, no further studies have evaluated fatigue in US SH commercial passenger operations under 14 CFR Part 117 (FAA, 2012). Therefore, a scoping assessment of fatigue factors under 14 CFR Part 117 is needed in order to further our understanding of the efficacy of fatigue management in SH operations. The results of this study will then inform field studies collecting objective data to characterize the impact of the identified factors. These future studies will, in turn, provide a baseline to assess the efficacy of any additional mitigations.

## 3. Methods

### 3.1. Objectives

The research focus of this study was to capture responses from active US SH pilots regarding scheduling and operational factors they found most fatiguing, with a view to identifying key themes and categories. The results were intended to provide insight into fatigue factors in this understudied operational setting and to identify targets for future research and mitigations strategies. Pilots were not asked to directly comment on 14 CFR Part 117 but were free to discuss it if they felt it was relevant to their response regarding factors that cause fatigue.

### 3.2. Qualitative research methods

Qualitative research methods are a valuable tool for collecting rich, contextual data. Focus groups with open-ended questions, minimal facilitation, and inductive analysis allow for an unbiased, participant-driven approach to identify themes with minimal influence from the researcher (Milne and Oberle, 2005). We chose to use a combined content and summative analysis approach. With this method, qualitative data can be distilled and quantified to identify main themes, while retaining the rich context from which the themes emerge (Hsieh and Shannon, 2005). The methods are presented in accordance with the consolidated criteria for reporting qualitative research checklist (COREQ) (Tong et al., 2007).

Focus groups are common in operational safety populations such as health care and emergency services (Bérastégui et al., 2018; Morrow et al., 2014; Wolf et al., 2017). However, fewer qualitative studies of fatigue have been published in the aviation setting (Van den Berg et al., 2020; Morrow et al., 2014). This is understandable given the barriers to such an approach including the labor and time investment for researchers as well as a greater burden on participants. In the commercial pilot population, coordinating times for group meetings is challenging due to demanding schedules and dynamic time zones.

Surveys are a more common research tool in aviation (Gregory et al., 2010; Hilditch and Flynn-Evans, 2022; Bourgeois-Bougrine et al., 2003) due to the considerable reduction in burden on both researchers and participants and the ability to capture a larger sample size. Collecting data via a survey, however, often includes questions with a list of response options to choose from which may introduce bias and limit the ability to capture unexpected factors. Further, without real-time interaction with participants, questions may be misinterpreted, or response options not sufficiently capture the responder's perspective.

Data collection in the field, while critical in providing evidence for the impacts of schedules, workload, sleep, and fatigue on performance and alertness, is the most prohibitive research design due to cost, time, and burden to participants (Arsintescu et al., 2019). Therefore, establishing the scope of future field studies is important to ensure that resources are allocated to investigate the most important factors.

### 3.3. Participants and focus group sessions

Current commercial pilots from four major carriers in the US were recruited through emails distributed by airline fatigue safety management and labor representatives. The only inclusion criterion was to self-identify as a SH commercial passenger pilot. Interested pilots were scheduled for a virtual focus group hosted through an online conferencing platform. Each focus group contained a maximum of nine pilots from a single airline. Pilots provided written informed consent prior to joining the focus groups. Participants communicated with a researcher (NGB) via email to be scheduled into a focus group session but otherwise did not establish a relationship with the focus group facilitator (CJH) prior to participation. The study was approved in advance by the NASA Institutional Review Board (NASA IRB STUDY00000441).

To protect the anonymity of participants, pilots were instructed to keep their cameras off during the focus group and were provided a two-letter code (e.g., BB) to use as a name when joining the meeting. These codes have not been used here as identifiers; instead, generic numeric codes have been assigned to identify individual participant quotes where applicable. Those unable to join online were able to dial-in by telephone, stating their two-letter code as identification. Participants were instructed to preserve anonymity of themselves and other participants. To foster open, honest responses, no audio or visual recordings were taken. Responses were recorded using an auto-generated transcript and at least two dedicated note-takers.

The following questions were presented to each focus group both verbally and visually:

Q1. Are there any types of short-haul operations that you think lead to elevated fatigue?

Q2. Are there any types of short-haul operations that you think are not fatiguing?

Q3. What types of short-haul operations do you think are the most important for us to study?

All participants were individually invited to respond to a question before moving on to the next question. A probe statement was added to each question (Hsieh and Shannon, 2005), prompting participants to describe why they felt the factors they identified were related to fatigue. Two further questions were posed after these primary questions but are not presented here as they relate to internal study design processes.

All focus groups were facilitated by a single researcher (CJH: Ph.D., female, sleep researcher) who appeared on camera during the sessions. Focus groups were conducted throughout January and February 2022 and included as many pilots as could be scheduled within this data collection interval (i.e., a data saturation approach was not used). A standardized script introduced the researchers and described the aims and rules of the sessions. The International Civil Aviation Organization (ICAO) definition of fatigue (ICAO, 2015) oriented participants, but no other pre-conceived definitions were introduced. The facilitator explained that the aim of the discussions was not to reach a consensus, but rather to hear the personal opinions of each participant whether they reflect previous responses or not. As we employed a secondary summative approach, participants were encouraged to repeat ideas that they agreed with, even if they had already been mentioned by other participants. Participants were allowed to verbalize all of their thoughts and were not interrupted during their responses. Once they had indicated that they had finished responding, the facilitator followed up with probe statements for clarity or depth of response as needed.

To ensure each participant had an opportunity to respond, participants were called upon one at a time in a randomized order to provide a response to each question. This ensured that responses were not influenced by the same participant starting each question and that all voices were heard. Once all participants had responded to a question, the facilitator asked if there were any additional comments before continuing on to the next question. Each focus group lasted approximately 2 h but varied slightly depending on the size of the group. At the end of the session, participants were thanked for their time and asked to complete an anonymous demographics questionnaire online.

### 3.4. Transcript cleaning

Each focus group was transcribed live using the online conferencing software transcription tool. In addition, two dedicated note takers were assigned to each session. Following each focus group session, both note takers immediately reviewed the transcript for transcriptional errors. Note takers compared the transcript to their detailed notes and conferred with each other to correct any mis-transcribed text and remove any identifiable information. Any outstanding issues were flagged and discussed in a larger group for consensus. All edits were tracked so that the original and corrected text was available. Transcripts were not provided to participants for review.

### 3.5. Content analysis

Cleaned transcripts were analyzed using a conventional qualitative content analysis approach using inductive, open coding (Hsieh and Shannon, 2005). Conventional qualitative content analysis is the systematic reduction and classification of text data (e.g., transcripts) into codes based on both explicit and inferred content, which can then be grouped based on related concepts to identify trends (Hsieh and Shannon, 2005; Milne and Oberle, 2005). An inductive, open coding approach derives all insights from the data with no pre-conceived themes or categorization of ideas (for example, comments regarding 14 CFR Part 117 were not a pre-determined theme). Codes are thus participant-generated and not researcher-driven (Milne and Oberle, 2005). See Table 1 for an example of the content analysis approach. Three researchers with over 75 years of combined experience in fatigue and/or aviation research ("coders": CJH, 16 years of experience; KBG, >30 y; LA, >30 y) independently reviewed each transcript for relevant text based on the research focus. At least two of these coders had been present during every session as facilitator or primary note taker.

In order to establish a code book, each coder independently highlighted relevant text within the transcripts from the first two focus group sessions. They then assigned descriptive codes in the margins of the transcripts for the repeating ideas identified within the relevant text (note: codes are displayed in UPPER CASE throughout the manuscript).

**Table 1**
Example of conventional qualitative content analysis approach.

| Relevant text | Repeating idea | Code (definition/ notes) | Theme | Category |
|---|---|---|---|---|
| "... *the type of short-haul to look at is the 5:00 and 6:00* a.m. *departure type stuff and how much duty is allowed while you're waking up during the WOCL [window of circadian low] even though you're not working during the WOCL.*" – Pilot 1 | Waking up during the WOCL [window of circadian low] even though you're not working during the WOCL. | EARLY WAKE/ REPORT (Mentioning having to wake up early -often mention within WOCL- in order to be ready for early van pick up or show time, etc. Distinct from EARLY STARTS, e.g., the departure/check-in time may be > 0600h, but wakeup/report is < 0600h.) | *Earlies* | Circadian disruption |

Codes were added to and defined in a shared code book (see Supplemental Material for an example). The code book was jointly reviewed by the three coders following coding of the first two focus group sessions to achieve consensus and validation of definitions. Any changes to definitions, including merging or splitting of codes, were noted in the code book for reference. An internal reference glossary defined terms and acronyms.

Each focus group session transcript was analyzed by each coder using the content analysis approach (i.e., identifying relevant text and repeating ideas, see Table 1) and codes were assigned using the code book as a reference. Codes could still be added or edited (e.g., definitions changed, codes merged or split) during this iterative process to ensure that all new ideas were captured and defined. All code changes were documented in the 'Notes' column of the code book (see Supplemental Material). All code book entries were color-coded to indicate which coder had made the contribution. The code book was organized according to broad emerging categories for ease of reference (e.g., timing of duties, rest). Once all three coders had independently coded each transcript, one coder (CJH) reviewed all transcripts for consistency and resolved any remaining discrepancies.

### 3.6. Summative analysis

We applied a summative approach to calculate the frequency of codes using a net sum. Net sum was defined as the sum of unique contributions to the code. First, an individual code was only assigned once per participant per question in the transcript margins, even if the participant repeated the idea within their response. Second, if a participant had the same code in Q1 and Q2, the code would only be counted once for that participant in the summative analysis. Codes were counted and double-entered by two researchers into a code counting template. Discrepancies between data entry were reviewed and resolved to produce a final count of codes.

### 3.7. Axial coding

Axial coding was performed by the three coders to group codes into themes based on shared concepts (note: themes are displayed in *italics* throughout the manuscript). An individual code could only be included in one theme. See Fig. 1 for a schematic of the axial coding process and hierarchy of data. While losing some resolution in this step, themes allow for a more manageable approach to determining relevant fatigue factors of interest for future studies, while having code level detail available for a deeper understanding of each theme. Themes were ranked by the frequency of the codes within them based on the net sum across questions as described above. Themes were further grouped into over-arching categories based on general principles of sleep and circadian science. An individual theme could only be included in one

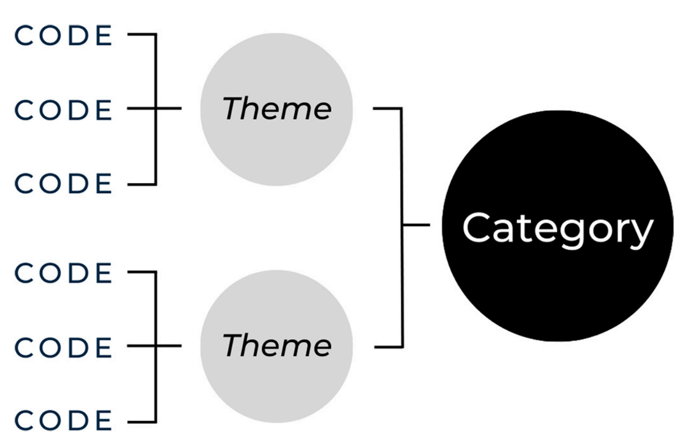


**Fig. 1.** Schematic of the axial coding process and data hierarchy structure.

category. Although categories provide a useful summarization of the overall content, the value of the qualitative approach is the resolution of data at theme and code level. Therefore, the core themes and codes contributing to each category are described in the results. Final results were presented to aviation stakeholders to assess resonance with their understanding of the issues and to review for potential researcher bias.

## 4. Results

### *4.1. Participants*

Fourteen focus groups were conducted with a total of 90 pilots across four airlines. Focus group size ranged from three to nine participants (mean ± SD, 6.4 ± 2.1). One participant left a focus group early and had a follow up one-on-one session to capture responses to all questions. One participant joined late and was provided the opportunity to respond to missed questions at the end of the session. Participant demographics are displayed in Table 2. Five additional participants consented to the study but did not join a focus group due to scheduling issues.

### *4.2. Codes and themes*

From the repeating ideas within the transcripts, 146 unique codes were identified. Given the large number of codes, axial coding was used to group related codes into themes. A full list of codes can be found in the Supplementary Material. Using axial coding, 22 unique themes were identified. All themes were ranked by the frequency of codes within that theme and are displayed in Table 3.

**Table 2**
Demographics of focus group participants.

| | N (%) |
|---|---|
| Role | |
| Captain | 41 (45.6) |
| First Officer | 48 (53.3) |
| No response | 1 (1.1) |
| **Base time zone** | |
| Eastern | 39 (43.3) |
| Central | 19 (21.1) |
| Mountain | 13 (14.4) |
| Pacific | 18 (20.0) |
| Other | 1 (1.1) |
| **Office fatigue role** | |
| Yes | 28 (31.1) |
| No | 61 (67.8) |
| No response | 1 (1.1) |
| **Total flight hours (h)** | |
| <5000 | 9 (10.0) |
| 5000 - <10,000 | 24 (26.7) |
| 10,000 - <15,000 | 26 (28.9) |
| 15,000 - <20,000 | 15 (16.7) |
| ≥20,000 | 16 (17.8) |
| **Monthly flight hours (h)** | |
| <20 | 1 (1.1) |
| 20 - <40 | 2 (2.2) |
| 40 - <60 | 10 (11.1) |
| 60 - <80 | 42 (46.7) |
| ≥80 | 35 (38.9) |
| **SH flying (%)** | |
| <20 | 0 (0.0) |
| 20 - <40 | 3 (3.3) |
| 40 - <60 | 5 (5.6) |
| 60 - <80 | 8 (8.9) |
| ≥80 | 74 (82.2) |

*Table Note*: Base time zone = time zone of the airport at which the participant is based; Office fatigue role = participant has previously been, or is currently, involved in a ground-based fatigue working group within an airline's relevant safety or flight operations department; SH flying (%) = self-reported percentage of a participant's schedule that includes SH operations; h = hours.

### *4.3. Categories*

The six over-arching fatigue factor categories identified include: 1) circadian disruption, 2) high workload, 3) inadequate rest opportunity, 4) schedule changes, 5) regulation implementation and policy issues, and 6) long sits. Fig. 2 shows the themes contributing to these categories. The primary themes and codes contributing to these categories are described within each category in the sections below.

#### *4.3.1. Circadian disruption*

This category includes all themes related to inconsistent schedules (*Circadian switches*), duties outside of daytime hours (*Red-eyes, Early duties, Late duties, Out-of-hours work*), rest opportunities during the day (*Rest timing*), and rest breaks that involve a circadian switch between duties (*Rest – circadian disruption*).

The most common theme identified overall, *Circadian switches,* refers to changes in duty start times within a trip, for example switching from an early start time to a late start time. This theme was made up of codes including: CIRCADIAN SWAPS (34% of codes in this theme), INCONSISTENT DUTY TIMES (25%), and SWITCHING TIME ZONES (18%). SWITCHING TIME ZONES refers to the sentiment that while a schedule

**Table 3**
Themes ranked by frequency of codes within each theme.

| Theme | Description | N | % |
|---|---|---|---|
| *Circadian switches* | Changing from early to late starts (or *vice versa*) | 171 | 10.5 |
| *Rest duration (layover)* | Inadequate rest opportunity between FDPs | 153 | 9.4 |
| *High workload/hassle factors* | Factors adding to workload | 151 | 9.3 |
| *Number of flights* | Multiple flights in an FDP | 121 | 7.4 |
| 14 CFR *Part 117 matters* | Matters related to flight/duty/rest regulations | 93 | 5.7 |
| *Long sits* | Long wait time between flights within an FDP | 85 | 5.2 |
| *Red-eyes* | Overnight flights | 83 | 5.1 |
| *Unpredictability* | Last minute schedule changes | 79 | 4.9 |
| *Aircraft & crew swaps* | Changing aircraft or crewmembers within an FDP | 73 | 4.5 |
| *Rest timing* | Inappropriate timing of rest opportunities | 73 | 4.5 |
| *Out-of-hours work* | Any duty period outside of "9am-5pm" | 68 | 4.2 |
| *Early duties* | Early duty start times | 64 | 3.9 |
| *Short turn time* | Lack of time between flights within an FDP | 53 | 3.3 |
| *Length of duty* | Long duty hours | 46 | 2.8 |
| *Rest quality* | Quality of rest environment (e.g., hotel) | 45 | 2.8 |
| *Schedule design* | Design of trip and monthly schedule | 38 | 2.3 |
| *Trip length* | Multiple consecutive FDPs | 37 | 2.3 |
| *Late duties* | Late duty finish times | 25 | 1.5 |
| *Fatigue call issues* | Issues related to reporting fatigue | 24 | 1.5 |
| *Length of flights* | Short flights | 20 | 1.2 |
| *Rest - circadian disruption* | Rest opportunities during long (24–30h) layovers | 20 | 1.2 |
| *Deadheading* | Positioning flight with pilot as a passenger | 14 | 0.9 |
| **Total** | | **1625**[a] | |

*Table Note.*
[a] = total includes codes that did not fit a defined theme. Percentage column reflects the proportion of all codes counted within each theme. FDP: Flight Duty Period, includes all flights, pre-flight, between-flight, and post-flight duties within a work period; CFR: Code of Federal Regulations Part 117 refers to flight, duty, and rest limits; trip: consecutive FDPs worked without a day off in between; layover: time spent between FDPs within a trip, often at a hotel.

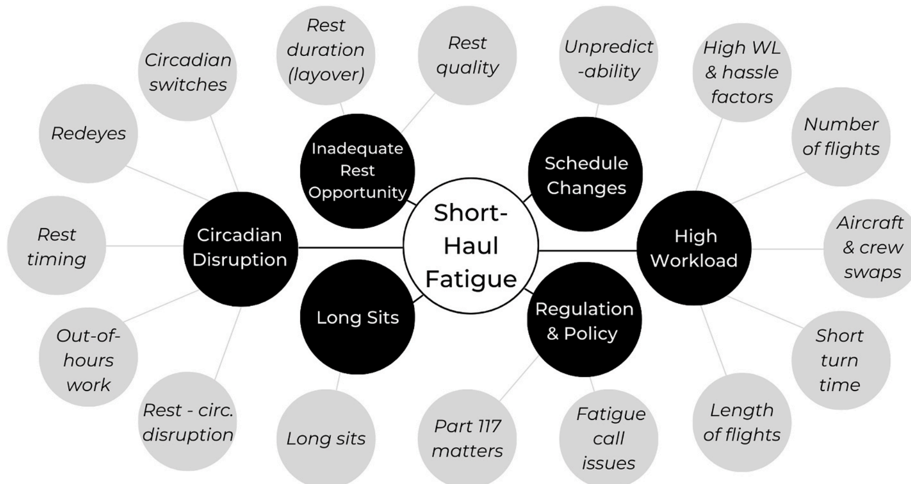


**Fig. 2.** Themes (gray circles) associated with over-arching categories (black circles). Circ. = circadian; WL = workload.

may look consistent based on local departure times, similar local start times in different time zones could lead to circadian shifts of up to 3 h. For example, a west coast-based pilot may start day 1 of a trip at 0600h on Pacific Time (PT) and then have a 0600h report time on day 2 on Eastern Time (ET), which is effectively 0300h PT.

Below is an example response coded within the *Circadian switches* theme:

> *"There's a, you know, 9:00 AM show and then a 2:00 PM show, and then a 5:00 AM show. That changing unwillingly is what I find to be most fatiguing because you just never catch up, like, your body doesn't know what it's doing."* – Pilot 2

### 4.3.2. High workload

This category includes all themes related to increased workload such as *High workload & hassle factors, Number of flights, Aircraft & crew swaps, Short turn times, and Length of flights*. The third most common theme identified overall was *High workload & hassle factors,* which refers to a collection of operational challenges contributing to fatigue. Often these factors add to overall workload through increased mental effort or creating time pressure and not allowing for mental recovery during or between flights. Some factors also extend duty times, leading to extended time awake and reduced rest opportunity. This theme was made up of codes including: WEATHER (30%), MAINTENANCE (19%), GROUND OPS (18%), and BUSY AIRPORTS/REGIONS (14%).

Below is an example response coded within the *High workload & hassle factors* theme:

> *"You throw me an airplane with 4 MELs [minimum equipment list], one of which is done incorrectly, you throw in weather, de-icing - suddenly that one leg, 2-hour day becomes fatiguing."* – Pilot 3

This category also includes the fourth most common theme, *Number of flights.* This theme refers to the number of flights within a duty period. While LH operations typically only involve one flight within a duty period, SH operations typically include two or more flights within a duty period. Most responses within this theme (41%) indicated that duty periods with more than four flights were considered fatiguing. However, approximately one-third (36%) of the codes in this theme indicated a preference for duty periods with two or fewer flights in order to avoid fatigue, with approximately one-quarter (23%) suggesting that any duty with more than one flight is automatically fatiguing due to the nature of the operations.

The following example illustrates how multiple legs common in SH operations can exacerbate workload through repeated exposure to hassle factors (coded within the *Number of flights* theme):

> *"Multiple leg days as opposed to a one leg day for a long-haul: you have to get acquainted with the airplane, you have to work through the MELs [minimum equipment list] every single time on every single different airplane, so swapping airplanes in the middle of the day … just increases workload. You know the weather issues, the deicing, all these little factors, you have to do multiple times in a day versus once, if that, in long-haul. And then the recoup time from those factors in long-haul is, you know, cruise flight, the lowest workload portion of the flight … but there just isn't very much of that [in short-haul], so there's - I don't want to call it "down time" because you're still flying and monitoring, but relative to the other phases of flight it is "down time" and you just don't get a lot of it with these multiple legs and short layovers."* – Pilot 4

### 4.3.3. Inadequate rest opportunity

This category includes themes related to rest opportunities independent from the timing of those opportunities (e.g., see Circadian disruption category for *Rest timing*) including *Rest duration (layover)* and *Rest quality*. *Rest quality* covered codes related to hotel sleep environment (e.g., noise, temperature). *Rest duration (layover)* was the second most common theme and refers to insufficient rest opportunity between duties. This theme was made up of codes including: SHORT REST (42%), and PERSONAL TIME (30%). SHORT REST referred to comments indicating that the 14 CFR Part 117 minimum rest requirement of 10 h is too short for sufficient sleep opportunity. PERSONAL TIME includes comments regarding the need for time to eat, exercise, wind down, and prepare for the next duty within the allocated rest period. In a short rest period, often there is not enough time for all these factors, leading to skipping important daily needs and/or reducing the amount of time available for sleep. The relationship between duty day and layover rest duration was also raised as a fatigue factor within this theme (9%). Pilots suggested a matched duty-rest scheme in which rest duration was at least as long as the prior duty period, rather than combining long duty days with short rest periods.

Below is an example response coded within the *Rest duration (layover)* theme:

> *"You know when they factor in, like, [a] 10- or 11-hour overnight, that doesn't factor in the time it takes to get up, get ready get for the van … all that stuff is not factored into your duty day … They kind of expect you're narcoleptic and then as soon as you get to the hotel you can dive into bed and be asleep. But you need that decompression time where you can get something to eat and then just a little bit of time to decompress. But on those really short ones you're just not allowed it."* – Pilot 5

#### 4.3.4. Schedule changes

This category emerged from the theme, *Unpredictability*, which covered codes such as SCHEDULE CHANGES (43%), PLANNED VS OPERATIONS (29%, planned schedules being different from operational reality), and EXTENSIONS and DIVERSIONS (28%). Schedule changes affected fatigue by extending flight or duty time, adding workload, and/or changing the timing of duty and rest opportunities.

Below is an example response coded within the *Unpredictability* theme:

> *"I think most of us can say we're pretty good at looking at our schedule and being responsible for conducting our lives to be rested. It's when the schedule changes due to weather, unforeseen circumstances, operational needs, the plan goes to the wind and all of a sudden you're expected to be rested for something you weren't originally rested for. I think that generates a tremendous amount of fatigue calls."* – Pilot 6

#### 4.3.5. Regulation implementation and policy issues

This category includes the fifth most common theme, 14 CFR *Part 117 matters*, as well as *Fatigue call issues*. 14 CFR *Part 117 matters* refers to comments from participants regarding the regulations (14 CFR Part 117) dictating the current flight, duty, and rest time requirements and how they are implemented. Thirty-seven percent of the codes in this theme related to the use of Part 117 regulations by airlines as goals or targets, rather than limits. A further 24% recommended revisions to the regulations in order to effectively manage fatigue. Some participants felt that the scheduling software used to create pairings lacked human insight into what they considered to be obviously fatiguing duties and trips (15%). With regard to *Fatigue call issues*, participants commented on barriers to submitting fatigue calls (BARRIERS, 42%) such as lack of pay protection and the drive to "get the job done". A third of codes in this theme (RESPONSIBILITY, 33%) reflected the pilots' disagreement with the fatigue call system putting the responsibility on the pilot to call out fatigued, and felt that more responsibility should lie with the airline to provide less fatiguing schedules.

Below is an example response coded within the 14 CFR *Part 117 matters* theme:

> *"I think that the companies look at these restrictions in [14 CFR Part] 117 not so much as limits to stay away from, but scheduling goals to get close to."* – Pilot 7

#### 4.3.6. Long sits

This category emerged from the theme, *Long sits*, which in turn was derived from the code LONG SITS. Sit time refers to the time between flights within a duty period during which the pilot has to wait in the airport until the next flight. The general consensus among participants was that a long sit would be defined as a sit time greater than 2 h. The concept of long sits was so prevalent in the transcripts, that despite not merging with any other codes, it was the sixth most common theme. The concept was also unrelated to the other themes, hence warranting its own category in order to capture this unique concept.

Below is an example response coded within the *Long sits* theme:

> *"I agree with what everyone said about the sit times 'cause you know if you have a 4-hour sit, …it's really hard to get your mind back in the game and, on top of that, …that 4 hours is coming from somewhere. That's 4 hours that you could have had in the hotel at the end of the day."* – Pilot 8

## 5. Discussion

We are the first to qualitatively assess the perceptions of commercial passenger pilots in the US with regards to fatigue factors in SH operations under 14 CFR Part 117. Our large focus group study revealed a range of fatigue factors, the most common of which were related to circadian disruption, high workload, inadequate rest opportunity, schedule changes, regulation implementation and policy issues, and long sit times. Our rich qualitative data, together with a systematic content analysis approach, provided high resolution insight into these categories, allowing us to better understand the complexities of fatigue in SH operations and to inform future investigations in this area.

Circadian disruption was the most common category of fatigue factors identified. Despite crossing fewer time zones relative to LH operations, our study showed that SH pilots are still exposed to circadian disruption through abrupt changes to start times within a trip, overnight flights (e.g., transcontinental red-eyes), and moderate jetlag due to time zone shifts up to 3 h. While overnight flights have previously been identified as a fatigue factor in SH operations (Gander et al., 1998a), less attention has been paid to more subtle changes in duty start times, or time zone crossings within a trip. Inconsistent duty times associated with shift work may lead to irregular sleeping patterns and mistimed sleep relative to the body clock, factors which are known to reduce sleep duration and quality, and impact overall fatigue, cognitive performance, mood, and health (Boivin and Boudreau, 2014; Ganesan et al., 2019; Rajaratnam et al., 2013).

High workload was the second most common fatigue factor identified. While, intuitively, high workload is a factor uniquely contributing to short-haul operations, few studies have directly addressed this factor (Arsintescu et al., 2020; Honn et al., 2016). As one pilot pointed out, while hassle factors and uncontrollable events such as weather can disrupt LH flying, the impact is minimal as these factors occur once – if at all, versus multiple times in SH flying. In addition, a delay on the first flight of a multi-segment duty day can lead to compounding workload and fatigue across the duty as time pressures increase (e.g., short turn times, limited access to meal breaks). This may also lead to duty extensions beyond scheduled limits due to delays, which subsequently encroach into already compressed layover recovery time. Further, on SH flights, there is less time to reset during the cruise phase of flight in order to prepare for the next descent. Another unique challenge inherently tied to multiple flights in SH operations is swapping aircraft and crew mid-duty day. Pilots explained that the mental effort required to become familiarized with a new aircraft (including minimum equipment lists) and to brief a new crew multiple times a day added to their fatigue across the duty day. A compounding factor to multiple flights is the type of airport or region involved in departures and arrivals. Pilots reported busy airspace or airports with terrain or frequent weather events were associated with more hassle factors, higher workload, and thus greater fatigue. While many external factors may be unavoidable, planning schedules which account for the expected extra workload on these flights may help to minimize the accumulation of fatigue across duty periods and trips.

We are the first to report on the perceived fatigue associated with long sit times between flights during a duty day. This scheduling practice increased during the COVID-19 pandemic (Hilditch and Flynn-Evans, 2022) to allow airlines to maximize the pairing of airplanes and pilots. These long sits are taken in the public side of the airport or in crew facilities, if available. While these breaks might intuitively seem like a rest opportunity between periods of high workload, pilots lamented the feeling of having to "spool back up" again following an extended period of not being engaged in work. While not directly articulated by pilots, it is possible that these periods of low workload are unmasking latent fatigue that is otherwise suppressed by active engagement in a task. We recently demonstrated that driving an autonomous vehicle led to markers of drowsiness and sleep onset much faster than being manually engaged in a driving task under the same levels of habitual chronic mild sleep restriction (Flynn-Evans et al., 2021). Thus, part of the fatigue experience related to long sits may be the expression of sleepiness which is then difficult to mitigate, especially when there are few options for sleeping during this time. Pilots also mentioned that long sits extend duty days and thus not only extend the time required to be alert, but also encroach on the opportunity to rest at the end of the day, reducing potentially much needed recovery time.

The rest opportunity between duty days can be affected by a number of factors including some already mentioned above (e.g., rest timing, duty extensions). Independent of these secondary factors, inadequate rest duration on layover was a prominent theme across focus groups. The 14 CFR Part 117 rest requirements set a minimum rest between duty periods of 10 consecutive hours. This 10-h period includes an uninterrupted 8-h sleep opportunity, meals (after and before duties), personal hygiene, exercise, winding down, preparing for duty (e.g., ironing uniform), and commuting to and from the airport. The travel time, including the wait for hotel transport, can often significantly encroach into this rest period, leaving little time for personal activities and adequate sleep opportunity. Pilots commented that while one short rest layover may be manageable, when consecutive long duty days are combined with short rests repeatedly, there is little time to catch up on sleep, leading to an accumulation of fatigue across the trip. A common suggestion was to balance rest time with duty time, such that rest hours are at least equivalent to duty hours, e.g., minimum 14-h rest period following a 14-h duty period. Further, the quality of sleep during hotel layovers was raised as an issue, with noise being the most common complaint in line with previous studies (Avers et al., 2009; Houston et al., 2012). Compared to sleep at home, layover sleep during SH operations is typically shorter and of poorer quality (Avers et al., 2009; Chidester, 1990; Gander et al., 1998b). Further, rest opportunity during a duty day is typically limited by unaugmented flightcrew (i.e., two pilots) on SH flights, compared to LH crews that may have the ability to rest in-flight during scheduled rest periods in designated rest facilities (Powell et al., 2008). Protecting both the duration and quality of sleep during layovers is critical in order to provide an opportunity for pilots to be adequately rested for their next duty.

Unpredictability in work schedules is a known fatigue factor across industries (Harknett et al., 2020; Scholarios et al., 2017) and is common in business (or corporate) aviation (Wollmuth, 2017). Our data suggest that this factor appears to be prevalent in regularly scheduled commercial passenger flights as well. Last minute swaps from early duties to late duties, for example, completely disrupt a pilot's ability to plan to be rested for the duty period. Further, changes which extend duty periods may push pilots into extended wakefulness, during which alertness is difficult to maintain. Pilots also mentioned experiencing mental fatigue resulting from schedule changes, including dealing with related operational hassle factors and having to organize accommodations for an entire aircrew who suddenly ended up in a different city than planned. Pilots also plan for the particular city where they will layover (e.g., food availability, type of hotel). Changes to these plans can add stress to the layover experience and disruptions to routines. Currently, staff shortages due to lagging recruitment together with the rapid return to service following the COVID-19 pandemic may be exacerbating the issue of schedule changes (Charman M, 2021; Bureau of Transportation Statistics, 2022; Hilditch and Flynn-Evans, 2022), with pilots constantly receiving reassignments in order to meet operational needs.

Commercial passenger SH schedules operated in the US are governed by 14 CFR Part 117. These regulations were developed using scientific principles to provide limits beyond which predicted group-level fatigue would be associated with risk to alertness and cognitive performance (FAA, 2012). Prescriptive duty and rest regulations are provided with the proviso that airlines are responsible for managing fatigue within these limits. Assessing how these limits are applied and which schedules are fatiguing within these limits is an important process within a fatigue risk management program. While we did not directly ask for comment on 14 CFR Part 117, several pilots referred to aspects of the regulation as part of their response to questions regarding fatigue factors. Pilots felt that the limits in 14 CFR Part 117 were being used as scheduling targets through optimization software, rather than how they were intended. Further, barriers to internal fatigue management policies such as making a "fatigue call" were raised, again highlighting the challenge of reducing the difference between regulations and policies as intended versus as implemented.

The issues the pilots raised suggest that further detailed study is needed to characterize the impact of 14 CFR Part 117 and to develop further mitigations as appropriate. For example, while 14 CFR Part 117 introduced consideration of the number of flights in a duty when calculating maximum FDP durations (see 14 CFR Part 117 Table B, Flight Duty Period: Unaugmented Operations), multi-flight days were still a prevalent cause of fatigue in this cohort. Similarly, under 14 CFR Part 117, in an effort to account for circadian factors, the timing of duty start is considered when calculating maximum FDP durations. However, circadian disruption was the most common fatigue category, with many pilots citing circadian disruption resulting from switching from early duties to late duties, or *vice versa*, which is an issue not explicitly addressed by 14 CFR Part 117. The implementation of a minimum 10-h rest period may also be inadequate due to issues not considered in the regulation such as long commutes to and from the airport and availability of food.

Further, when considering the fatigue factors identified in SH operations outside of the US or in the US prior to 14 CFR Part 117 as described in the literature review, we see that many of these factors persist in the current study as core themes, e.g., rest duration between FDPs, number of flights in an FDP, overnight flights, early starting duties, late finishing duties, rest quality between FDPs, and trip length (consecutive FDPs). Importantly, we also identified additional fatigue factors that may be unique to 14 CFR Part 117 including circadian switches, long sit times, and scheduling up to 14 CFR Part 117 limits. Overall, our results suggest that fatigue is experienced by pilots operating eligible schedules under 14 CFR Part 117 and that additional mitigations may be necessary to address these issues.

By following a conventional qualitative content analysis approach, our study adhered to best practice principles of qualitative research to promote credibility, authenticity, criticality, and integrity in our findings (Milne and Oberle, 2005; Hsieh and Shannon, 2005). Our large sample size fostered a range of participants reflecting a range of opinions and experiences within the broader pilot population. Our data are participant driven, with broad questions and no pre-conceived codes to allow for open feedback, with the facilitator only speaking to clarify and probe for depth of responses. Transcripts were cleaned and reviewed by multiple, experienced researchers in a timely fashion to ensure aviation-specific jargon was understood and content meaning was preserved. Further, research notes and codes were appended directly to the transcript so that they were always viewed within the context of the larger narrative.

### 5.1. Limitations

Despite these methodological strengths, our study is not without limitations. Due to COVID-19 restrictions, we held focus groups online rather than in-person. While this allowed for anonymity, this relatively impersonal setting may have influenced the trust of the participants in sharing with the research team. Given the sensitivity of the data and to protect the anonymity of participants, demographics such as gender and age were not collected for this study. While this limits our ability to determine the generalizability of our sample to the broader pilot population, this was a deliberate decision. To protect confidentiality of responses, demographic information was provided anonymously in a separate survey and not linked to the participant identification code. Thus, given the strictly confidential and anonymous nature of our data collection, we are unable to analyze the influence of demographic factors on responses (e.g., Captains vs. First Officers). In providing feedback to the participating airline stakeholder groups, the demographics presented (i.e., rank, home base, experience [lifetime hours], and workload [monthly hours]) were seen as representative of the short-haul population at each airline. While the coders' expertise in the area was a strength to ensure accurate cleaning of transcripts and to preserve contextual meaning, there is the possibility of researcher bias. We sought to minimize this influence by using an open, inductive coding approach, employing three independent coders, and reflecting on our potential biases during code book review discussions. Further, our review of results with relevant aviation stakeholders confirmed our findings as reflective of anecdotal issues within the airlines and pilot groups. While our sampling methods were intended to be random with advertisements sent to all pilots within the participating airlines, pilots with a specific interest in fatigue may have been more likely to volunteer to participate. As a consequence, we had an overrepresentation of pilots with a previous or current role in a fatigue working group. In qualitative research, purposeful sampling is a common approach in order to capture responses from participants with in-depth knowledge on a certain topic. While we did not purposefully sample from fatigue working groups, the inclusion of these participants is a strength as they can also provide insight from the experiences of their peers. Finally, without a baseline comparison, we are unable to directly assess the impact of 14 CFR Part 117 regulations on fatigue factors in US SH operations. Instead, we present the first cross-sectional view of current fatigue conditions under the regulation with a view to identifying, implementing, and assessing the efficacy of future fatigue mitigation strategies.

## 6. Conclusions

Our systematic content analysis of transcripts from a large focus group study highlighted a range of fatigue issues faced by commercial passenger SH pilots from four major US airlines. The most common factors were related to circadian disruption, high workload, inadequate rest opportunity, schedule changes, regulation implementation and policy issues, and long sit times. While many of these factors mirror findings from SH operations under different regulations, we also observed novel factors such as long sit times between flights, circadian switching between early starting and late finishing duties, and the implementation of regulations. These findings highlight the value of our open, qualitative approach to capture fatigue factors in this unique operational setting.

Given the prevalence of perceived fatigue factors in SH schedules legally operated under 14 CFR Part 117, future research with objective measures is needed to further characterize fatigue risk in SH operations. Our study design does not allow for conclusions as to whether 14 CFR Part 117 has improved fatigue relative to the previous regulations (14 CFR Parts 119 and 121).

The primary factors identified in this scoping study should be investigated in future field studies that collect objective data to evaluate the relative impact of each factor on pilot sleep, sleepiness, workload, and cognitive performance in SH operations under 14 CFR Part 117. The findings of future field studies, in combination with the current study, should form the basis for developing fatigue mitigation strategies targeting the fatigue factors identified. These studies will serve as a baseline to assess the efficacy of future fatigue management initiatives.

## CRediT roles

Cassie J. Hilditch: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Supervision; Visualization; Writing - original draft; Writing - review & editing; Kevin B. Gregory: Data curation; Formal analysis; Funding acquisition; Investigation; Writing - review & editing; Lucia Arsintescu: Data curation; Formal analysis; Funding acquisition; Investigation; Writing - review & editing; Nicholas G. Bathurst: Investigation; Project administration; Writing - review & editing; Thomas E. Nesthus: Conceptualization; Funding acquisition; Writing - review & editing; Hannah M. Baumgartner: Conceptualization; Funding acquisition; Writing - review & editing; Amanda C.M. Lamp: Methodology; Writing - review & editing; Laura K. Barger: Methodology; Writing - review & editing; Erin E. Flynn-Evans: Conceptualization; Funding acquisition; Investigation; Methodology; Supervision; Writing - review & editing.

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## Declaration of competing interest

TEN and HMB: The Short Haul Multi-Segment Fatigue Study and Analysis is conducted and funded through an Interagency Agreement between the Federal Aviation Administration (FAA) and the National Aeronautics and Space Administration (NASA), Ames Research Center, IAA No. SAA2-403611. Drs. Thomas E. Nesthus and Hannah M. Baumgartner are employed by the FAA Civil Aerospace Medical Institute (CAMI) and are collaborators on said research study. Neither have a financial interest in either institution participating in this protocol; do not have a covered relationship with or related to an institution participating in this protocol; do not have other personal relationships with individuals, such as friends, relatives, or other persons, affiliated with these institutions that would either give rise to a conflict of interest or an appearance of use of public office for private gain or of giving preferential treatment.

LKB: Received stipends from the University of Helsinki (dissertation review), NIOSH (grant review), and AAA Foundation (expert panel) and funding from a participating airline through a contract with the Brigham and Women's Physician's Organization.

ACML: Is a scientific consultant for one of the airlines involved in the study and otherwise has no other financial interest or connection to any companies or bodies affiliated or connected to this study.

## Data availability

Data are accessible upon reasonable request as far as allowed by the data sharing policy and guidelines established by NASA Ames Research Center.

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## Appendix A. Supplementary data

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