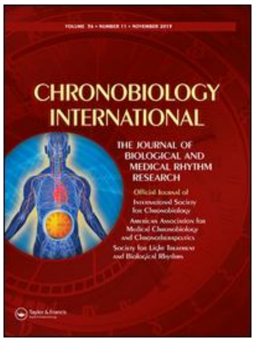

Chronobiology International
The Journal of Biological and Medical Rhythm Research

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/icbi20

Mitigating fatigue on the flight deck: how is controlled rest used in practice?

Cassie J Hilditch , Lucia Arsintescu , Kevin B Gregory & Erin E Flynn-Evans

CHRONOBIOLOGY INTERNATIONAL
https://doi.org/10.1080/07420528.2020.1803898

Taylor & Francis
Taylor & Francis Group

SELECTED PROCEEDINGS: SHIFTWORK 2019

Mitigating fatigue on the flight deck: how is controlled rest used in practice?

Cassie J Hilditch[a], Lucia Arsintescu[a], Kevin B Gregory[b], and Erin E Flynn-Evans[b]

[a]Fatigue Countermeasures Laboratory, San José State University Research Foundation, Moffett Field, CA, USA; [b]Fatigue Countermeasures Laboratory, NASA Ames Research Center, Moffett Field, CA, USA

ABSTRACT

Controlled Rest (CR) refers to a short, unscheduled, voluntary nap opportunity taken by pilots on the flight deck as a countermeasure to unanticipated fatigue in flight. This study explores the profile of CR use in a long-haul commercial airline. Forty-four pilots wore actiwatches and filled in an application-based sleep/work diary for approximately 2 weeks resulting in complete records from 239 flights. Timing of sleep periods and flight schedules were analyzed relative to home-base time. Pearson correlations were used to assess the influence of pilot demographics on CR use. A mixed-effects logistic regression was used to analyze the impact of schedule factors on CR. CR was taken on 46% (n = 110) of flights, with 80% (n = 106/133) of all CR attempts (accounting for multiple CR attempts on 23 flights) estimated by actigraphy to have successfully achieved sleep. Average sleep duration during successful rest periods was estimated as 31.7 ± 12.2 min. CR was more frequent on 2-pilot (69%, n = 83) vs. >2-pilot flights (23%, n = 27); return (60%, n = 71) vs. outbound flights (33%, n = 39); night (55%, n = 76) vs. day flights (34%, n = 34); and <10 h (63%, n = 80) vs. >10 h duration flights (27%, n = 30) (all p ≤ 0.001). There was no significant difference for direction of travel (eastbound: 51%, n = 57; westbound: 40%, n = 44; *p* = .059). Of note, 22% (n = 26) of augmented flights contained both CR and bunk rest. Data from this airline show that CR is most commonly used on flights with 2-pilot crews (<10 h duration) and nighttime flights returning to base. Future studies are required to determine the generalizability of these results to other airlines.

ARTICLE HISTORY
Received 15 January 2020
Revised 24 July 2020
Accepted 27 July 2020

KEYWORDS
Napping; aviation; fatigue management; countermeasures; sleep

Introduction

Fatigue due to sleep loss, extended wakefulness, and circadian disruption is commonly reported amongst commercial airline pilots (Caldwell 2012; Hartzler 2014; Rosekind et al. 1994a). Fatigue leads to performance impairment, which ultimately leads to errors and accidents that can pose a hazard to flight safety, which is why the National Transportation Safety Board has fatigue on their most wanted list of 2019–2020 ([NTSB] National Transportation Safety Board 2019). The need to minimize and manage the risks associated with fatigue and related impairments has led to the development of fatigue risk management (FRM), which encompasses a range of strategies and tools to help operators and individuals manage fatigue (Dawson et al. 2012; Gander 2015). FRM is a shared responsibility between operators and flight crew, with the operator agreeing to provide adequate rest opportunities, and crew agreeing to use these rest opportunities to the best of their ability to fulfill their responsibility to report fit for duty. Despite optimized scheduling and effective use of off-duty rest periods, however, unexpected fatigue can occur in-flight. Therefore, as part of FRM, a range of countermeasures to fatigue have been proposed for use on the flight deck when unanticipated fatigue occurs. For example, the strategic use of caffeine to promote alertness, or increased use of crew resource management to ensure safe operations (Caldwell et al. 2009). Another countermeasure available in some global regions is Controlled Rest (CR).

CR refers to a short, in-seat nap taken by a pilot on the flight deck, within the constraints of a defined policy ([ICAO] International Civil Aviation Organisation 2015). CR differs from bunk rest, undertaken exclusively by augmented crews (>2-pilots), in which a pilot can leave the flight deck to take rest in a designated crew rest facility, often for at least an hour. Further, whereas augmentation of flights to accommodate bunk rest is a preplanned scheduling tool, CR should not be used in this way. CR is also distinct from unintentional napping (i.e., falling asleep involuntarily on the flight deck) or uncontrolled rest (i.e. intentionally taking a nap without an approved CR policy). CR is supported by the International Civil Aviation Organization ([ICAO] International Civil Aviation Organisation 2015), Aerospace Medical Association (Caldwell et al. 2009), and European Aviation Safety Agency ([EASA]

CONTACT Cassie J Hilditch cassie.hilditch@sjsu.edu NASA Ames Research Center Fatigue Countermeasures Laboratory, CA 94035, USA

European Aviation Safety Agency 2018) as an effective fatigue management strategy. Despite the use and support of CR by many operators across the world (Fatigue Countermeasures Working Group 2018; Petrie et al. 2004), little is known about how and when CR is used in real-world operations.

The use of naps to counteract the negative effects of sleep loss and circadian pressure has been widely studied in the laboratory and in operational settings. While the benefits appear to depend on nap duration, timing, quality, sleep-wake history, sleep environment, and individual differences, an overwhelming majority of studies demonstrate a clear benefit of naps on alertness and performance (Ruggiero and Redeker 2014; Sallinen et al. 1998; Shea et al. 2014).

A few studies have translated these findings from the laboratory to the flight deck, with promising results for alertness management (Rosekind et al. 1994b; Valk and Simons 1997). For example, a comprehensive study by Rosekind et al. (1994b) trialed the effectiveness of a 40-min nap opportunity on the flight deck. The study reported reduced micro-events (defined as >5 s increase in alpha activity (8–12 Hz), theta activity (3–7 Hz), or slow-rolling eye movements) recorded by electroencephalography (EEG) and electrooculography (EOG) during the descent, approach, and landing phases of flight, as well as faster reaction times as measured by the psychomotor vigilance task (PVT). Since this seminal study, further in-flight studies have demonstrated a benefit of CR for alertness and performance (Spencer and Robertson 1999; Valk and Simons 1997).

The current study investigates the use of CR in a naturalistic setting, that is, CR was not scheduled but rather taken by pilots as needed across a range of normally scheduled flights. Previous studies investigating the real-world use of CR in operations have been limited to retrospective surveys asking about CR use in the past 12 months (Co et al. 1999; Petrie et al. 2004; Rosekind et al. 2000), while others have captured limited data on CR use incidentally as part of larger studies (European Commission 2018; Gander et al. 1991). The current observational study aimed to take a snapshot of natural CR use over a 5-month period (mid-May to mid-October) in a cohort of pilots from a long-haul commercial airline working normally scheduled operations.

Materials and methods

Participants

Long-haul pilots at a non-US airline were invited to participate in the study. There were no additional exclusion criteria. The study was approved by the Institutional Review Board at NASA Ames Research Center (Protocol HRI-346). All data were de-identified.

Protocol

Each participant collected data over an approximately 2-week period of normal summer scheduling. Participants were provided with an iPod touch (6th gen, 10.3.3, Apple Inc., Cupertino, CA, USA) featuring a custom-built application which allowed them to record the start time and duration of their in-flight rest periods, and to designate whether they were controlled rest or bunk rest periods. Participants also wore an activity monitor (Actiwatch Spectrum PRO, Philips Respironics, Murrysville, PA, USA) on their non-dominant wrist to objectively monitor sleep-wake activity in 1-min epochs. Participants were trained on how to use the data collection equipment, but were not given any extra guidance on CR use other than what was included in standard Fatigue Risk Management System (FRMS) training provided by the airline. The airline's policy on CR states that CR should be used in line with fatigue management principles, and that rest breaks should be a maximum of 45 min, with 20 min for recovery before returning to flight duties. In addition, CR should be used only during the cruise phase of the flight up until 30 min prior to top of descent. Crew must have a briefing on the allocation of CR and implement minimum safeguards during the CR period, including back-up systems for waking the resting pilot.

In-flight rest periods were defined by the rest start and end times provided by pilots in the in-flight rest section of the custom-built application. The Actiware algorithm (v6.0.9, Philips Respironics, Murrysville, PA, USA) was then used to estimate sleep duration within these rest periods. The software was set to the medium threshold (wake threshold 40) with sleep onset/offset thresholds set at 10 min of immobility. Successful rest periods were defined as rest periods in which the Actiware estimated at least one epoch (1 min) of sleep. To allow for analysis of the influence of scheduling factors on in-flight rest, sleep data were matched to flight schedules provided by the airline. The dataset was cleaned for complete and matching data collected within the enrollment period on long-haul flights (>6.5-h flight duty period) excluding dead headings (i.e., traveling on an aircraft as a passenger to commute to/from the work location).

Statistical analyses

All analyses were performed using IBM SPSS Statistics v25. The association between pilot demographics and CR was assessed using a Pearson correlation. The influence of scheduling factors and pilot qualification (Captain vs. First Officer) on CR was assessed using a mixed-effects logistic regression model with participant as a random intercept. Due to low numbers, north/south flights were excluded from the direction of travel analysis. For completeness, this analysis was repeated with north/south flights included, which yielded the same outcome. The analysis excluding north/south flights is presented here.

Results

Forty-five pilots consented to participate (3 female). One participant was excluded from analysis due to loss of actigraphy data. Specific analyses related to in-flight rest timing excluded an additional two participants due to a device failure. Participant demographics are displayed in Table 1. Participants included 19 Captains and 25 First Officers.

Flight summary

The final dataset included 239 flights. Each participant contributed an average (± SD) of 5.5 (± 1.8) flights. Table 2 displays the distribution of flight types in the 'Total Flights' column. Overall, flight types were evenly distributed and reflective of the typical long-haul operations of the airline.

In-flight rest summary

CR was attempted on 46% (n = 110) of all observed flights (Table 2), with 10% of all flights (n = 23) including two CR periods. Bunk rest was taken on 48% (n = 115) of all observed flights. CR was combined with bunk rest on 11% of all flights (n = 26). CR was taken before bunk rest on 62% (n = 16) of these combined rest flights. When CR followed bunk rest, the bunk opportunity always began outside of the home-base night (00:00–08:00 h). No rest was reported on 17% (n = 40) of all flights. Five pilots (contributing to 10% of all flight observations) did not report any CR periods.

Of the 133 CR periods reported, 80% (n = 106) were estimated by actigraphy to have been successful (i.e., sleep was initiated). Average CR attempt duration was 43.1 (± 11.0) min (range 15–70 min). The mean (± SD) of estimated sleep in successful CR periods was 31.7 (± 12.2) min. When considering all CR attempts (successful and unsuccessful) the estimated average sleep was 25.3 (± 16.8) min. Figure 1 shows the distribution of CR attempts across time of day. CR attempts were most common during the participants' home-base night (00:00–08:00 h).

Table 1. Participant demographics ($N = 44$).

	Mean ± SD	Range
Age (years)	43.7 ± 10.0	30–60
BMI (kg/m^2)	24.7 ± 2.5	19.8–33.2
Experience (total commercial flight hours)	9539.8 ± 5191.1	2800–20000
Self-reported sleep need (hours)	7.7 ± 0.8	6–9

SD, standard deviation; BMI, body mass index; kg/m^2, kilograms per meter squared.

Influence of pilot demographics on controlled rest

Captains reported taking CR on 38% of flights (n = 39/102), compared to First Officers reporting 52% (n = 71/137) of flights with CR, but this was not significantly different ($F_{1,37} = 2.4$; $p = .131$; OR: 1.92; 95% CI: 0.82–4.51). Of note, four of the five pilots who did not report any CR on any flight were Captains. Age, experience, BMI, and sleep need were not associated with the percentage of flights with CR (all $p > .244$).

Influence of scheduling factors on controlled rest

The distribution of CR across different flight types can be seen in Table 2. CR was significantly more likely to be taken on return flights vs. outbound flights ($F_{1,237} = 19.9$; $p < .001$; OR: 3.78. 95% CI: 2.10–6.79), 2-pilot vs. >2-pilot flights ($F_{1,237} = 39.0$; $p < .001$; OR: 9.20; 95% CI: 4.57–18.52), <10 h vs. >10 h flight duration ($F_{1,237} = 24.6$; $p < .001$; OR: 5.55; 95% CI: 2.81–10.97), and night (flights departing between 16:00–04:00 h home-base time, which includes flights taking-off or landing during the night) vs. day flights ($F_{1,237} = 12.0$; $p = .001$; OR: 2.86; 95% CI: 1.57–5.20). Direction of flight (eastward vs. westward) did not significantly influence CR ($F_{1,219} = 3.6$; $p = .059$; OR: 1.75; 95% CI: 0.98–3.11), although there was a trend toward more frequent use on eastward flights.

Closer inspection of outbound and return flights revealed that most return flights were scheduled at night, and most outbound flights were scheduled during the day (Figure 2). Similarly, most 2-pilot flights were <10 h and most augmented flights were >10 h. To determine the relative contribution of each factor, a secondary analysis using a model including each scheduling factor was used. When controlling for other factors, this model revealed that significant effects remained for number of crew ($F_{1,232} = 15.4$; $p < .001$; OR: 51.37, 95%CI: 7.13–370.27), time of day ($F_{1,232} = 6.1$; $p = .014$; OR: 3.15, 95% CI: 1.26–7.87), and outbound/return ($F_{1,232} = 6.0$; $p = .015$; OR: 2.83, 95% CI: 1.22–6.53), but not for flight duration ($F_{1,232} = 1.33$; $p = .250$; OR: 0.39, 95% CI: 0.05–2.21).

Table 2. Number of flights (% of flight subcategory) with an attempted Controlled Rest (CR) and/or Bunk Rest (BR) period by schedule factor.

Flight type	Controlled Rest (CR)	Bunk Rest (BR)	CR with BR	No rest	Total flights
ALL	110 (46%)	115 (48%)	26 (11%)	40 (17%)	239
Flight Leg					
Outbound	39 (33%)*	57 (48%)	10 (8%)	34 (28%)	120
Return	71 (60%)	58 (49%)	16 (13%)	6 (5%)	119
Direction of Travel					
Eastward	57 (51%)	51 (46%)	9 (8%)	12 (11%)	111
Westward	44 (40%)	53 (48%)	11 (10%)	24 (22%)	110
North/South	9 (50%)	11 (61%)	6 (33%)	4 (22%)	18
Crew Size					
>2 pilots	27 (23%)*	113 (95%)	26 (22%)	5 (4%)	119
2 pilots	83 (69%)	2 (2%)	0 (0%)	35 (29%)	120
Duration					
≤8 h	35 (80%)	0 (0%)	0 (0%)	9 (20%)	44
>8–10 h	45 (54%)	15 (18%)	1 (1%)	25 (30%)	84
>10–12 h	25 (27%)	83 (89%)	20 (22%)	5 (5%)	93
>12 h	5 (28%)	17 (94%)	5 (28%)	1 (6%)	18
Short (≤10 h)	80 (63%)*	15 (12%)	1 (1%)	34 (27%)	128
Long (>10 h)	30 (27%)	100 (90%)	25 (23%)	6 (5%)	111
Departure Time					
00:00–03:59	27 (61%)	21 (48%)	5 (11%)	1 (2%)	44
04:00–07:59	7 (41%)	12 (71%)	2 (12%)	0 (0%)	17
08:00–11:59	11 (61%)	1 (6%)	0 (0%)	6 (33%)	18
12:00–15:59	16 (25%)	31 (48%)	0 (0%)	19 (30%)	66
16:00–19:59	8 (33%)	16 (67%)	7 (29%)	8 (33%)	25
20:00–23:59	41 (59%)	34 (49%)	12 (17%)	6 (9%)	69
Day (04:00–15:59)	34 (34%)*	44 (44%)	2 (2%)	25 (25%)	101
Night (16:00–03:59)	76 (55%)	71 (51%)	24 (18%)	15 (11%)	138

*Indicates $p < .001$ compared to the cell below. Test of significance only applied to CR column. See text for further statistical details.

Discussion

This is the first study to report on the prevalence and distribution of naturalistic Controlled Rest (CR) during regular commercial airline operations. The study showed that CR was used on nearly half of all long-haul flights and that pilots were able to obtain sleep in the majority of these CR attempts. CR was most commonly taken on 2-pilot return flights during the home-base night, but was also observed in combination with bunk rest on augmented flights. These results suggest that CR is a frequently used in-flight countermeasure to fatigue, especially during night flights and when bunk rest is not available.

In our study, 80% of CR periods were estimated by actigraphy to have contained sleep. Of those successful CR periods, pilots were able to achieve 32 min of sleep on average. This sleep duration is greater than that reported by Rosekind et al. (26 min; Rosekind et al.

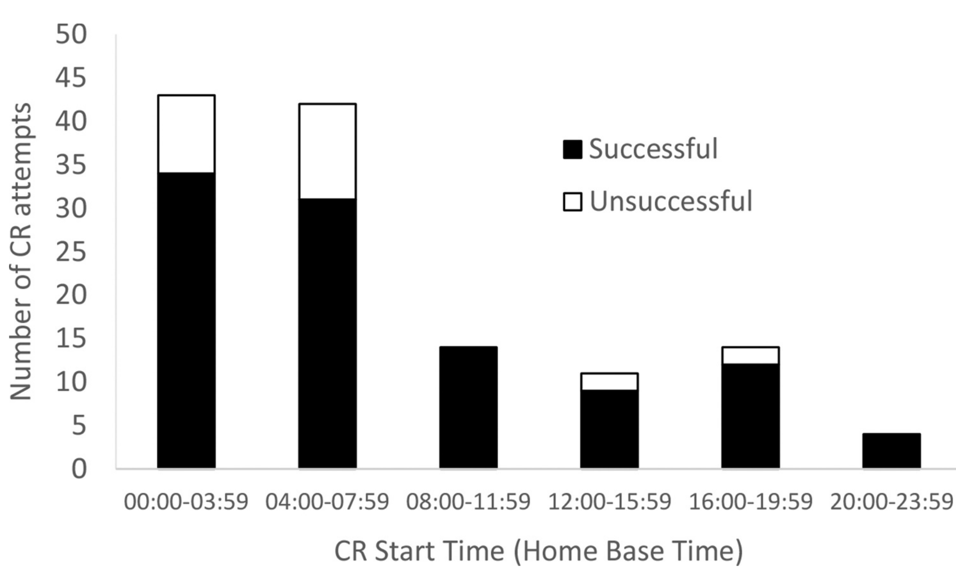

Figure 1. Number of successful (with sleep; black bars) and unsuccessful (without sleep; white bars) Controlled Rest (CR) attempts by time-of-day relative to the participants' home-base time.

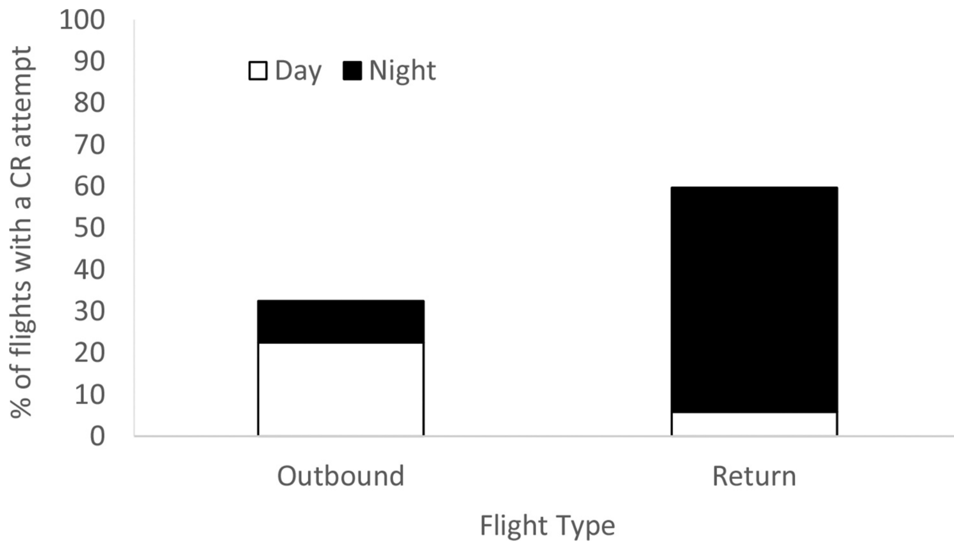

Figure 2. Percentage of flights with a Controlled Rest (CR) attempt by direction (Outbound vs. Return) and time (Night, black bars vs. Day, white bars) of flight.

1994b) and Valk and Simons (15 min; Valk and Simons 1997), and less than Spencer and Robertson (47 min; Spencer and Robertson 1999). Further, the success rate of CR in our study fell between Rosekind et al. (93%; Rosekind et al. 1994a) and Valk and Simons (41–48%; Valk and Simons 1997). Spencer and Robertson (1999) did not report the success rate of CR. Our results are likely to differ due to a number of factors. First, our study was conducted under naturalistic settings, allowing pilots to take CR if and when they needed to, rather than pre-planning CR as an intervention. This should increase the success of CR periods as we assume pilots in this cohort were taking them when they were sleepy. Second, although the average CR period duration was 43 min, rather than having a fixed 40-min rest period, pilots reported taking rest periods between 15 to over 60 min long, allowing for a greater range, and greater potential for longer sleep durations. Finally, we assessed sleep using actigraphy, which has been shown to overestimate in-flight sleep relative to EEG (Signal et al. 2005). Our observations show that taking CR in normal operations is an effective strategy for obtaining sleep in-flight.

Our analysis revealed that CR was most commonly used at night. These findings are in line with previous observations of napping on the flight deck (European Commission 2018; Sallinen et al. 2017; Spencer and Robertson 1999). For example, in a recent large-scale study of European airline pilots, 27% of all night flights >10 h duration contained CR (European Commission 2018), comparable to 35% of the same flights in our sample. It is not surprising that crew might experience unexpected fatigue during the biological night. The circadian drive for sleep is at its highest during the biological night (Borbély 1982). Studies of night shifts across multiple industries show higher levels of sleepiness, fatigue, performance impairment, and work-related injuries compared to day shifts or days off (Dorrian et al. 2011; Folkard et al. 2005; Härmä et al. 2002). These effects can persist even if minimum rest requirements are met before the shift, as the sleep opportunity is often at a time when it is difficult to sleep due to the circadian drive for wakefulness (Borbély 1982; Ferguson et al. 2010; Silva Borges and Fischer 2003). Therefore, even if pilots have used their off-duty period responsibly and reported fit for duty at the start of a night shift, they may still encounter unanticipated fatigue during a night flight.

Our study also shows that fatigue can occur on any length flight that operates at times when the pilots would normally be sleeping. Indeed, as we see in our sample, CR was taken on 76% of night flights *less than* 10 h in duration. Moreover, a recent study by Sallinen et al. (2017) reported that 29% of nighttime short-haul flights (≤6 h flight duty period) contained CR. Our secondary analysis showed that the use of CR on short night flights is likely due to the limited crew size on these flights (2-pilot) which does not allow for bunk rest. The greater frequency of CR periods taken in these conditions may indicate a high prevalence of fatigue due to sleepiness on these flights. Further research is needed in this area to disentangle the factors driving the use of CR on night flights <10 h. In addition, this finding highlights the value of collecting information on CR use to help focus fatigue risk management efforts within an operation. Our results suggest that there is a need for careful fatigue management on night flights, regardless of their length, and that CR is currently being used by pilots to manage this fatigue risk.

Despite the strong effect of crew size on CR likelihood, a surprising finding from this study was the use of CR on augmented flights, that is, flights on which pilots also had a bunk rest opportunity. In these cases, we hypothesized that CR would be most useful when the bunk rest was allocated at an adverse time for sleep (i.e., during the biological day), or when the bunk rest opportunity did not result in sleep (e.g., due to other disturbances such as turbulence or cabin noise). In previous studies, pilots have reported multiple disturbances to bunk rest (Amann et al. 2014; Marqueze et al. 2017; Rosekind et al. 2000) or simply not feeling tired enough to sleep (Holmes et al. 2012). Marqueze et al. (2017) found that 52% of pilots surveyed rated their in-flight bunk rest environment as below average, which was associated with a 34% increased risk of falling asleep unintentionally on the flight deck. When looking at our data, we found that while there were more observations of CR being taken before bunk rest within a flight, when CR was taken after bunk rest, it was following a bunk rest opportunity outside of the home-base night (00:00–08:00 h). The length of sleep obtained during bunk rest, however, was comparable for bunk rest taken with or without CR. Interestingly, two-thirds of bunk rest opportunities for Captains were during the home-base night, compared to less than 50% for First Officers. This may explain the non-significant trend toward more frequent use of CR in First Officers versus Captains. Together, these findings demonstrate that unexpected fatigue due to sleepiness may occur even on flights in which a rest opportunity in a designated facility is provided, suggesting that CR is a valuable countermeasure to unexpected fatigue due to sleepiness on both un-augmented and augmented flights.

Just as sleep in a designated rest facility may be disturbed in-flight, so too might the sleep on the flight deck (Spencer and Robertson 1999; Valk and Simons 1997). In addition to the disturbances noted for bunks above, the angle of seat recline is directly related to the ability to sleep, with sleep quantity and quality increasing in a dose-dependent manner as the angle approaches 90° to vertical (i.e., flat) (Roach et al. 2018). Therefore, it is important to consider the flight deck environment when determining the ability to sleep during CR. Pilots are encouraged to recline the seat as far as possible and to use ear plugs and eye masks to reduce the risk of being disturbed during CR. We did not collect data on the strategies used to prepare for successful CR in this study. A future survey asking pilots about the strategies used to prepare for CR and the perceived barriers to successful CR would help to identify ways to improve the success of CR attempts. While the majority of CR attempts were deemed successful in this study, the ability to sleep during a CR attempt – or the ability to take CR at all (e.g., cruise phase too short, nonstandard operations, etc.) – is not guaranteed. Therefore, CR, as a tool to manage unexpected fatigue, should not be relied upon as a mitigation strategy in lieu of arriving fit for duty, nor to justify flight time limit extensions. All other fatigue mitigation strategies should still be employed, including optimized scheduling and protection of minimum rest, with CR used as a last resort, in-flight alertness tool when required and available.

It is important to note that while there are considerable benefits to CR, there are also potential risks. The most recognized risk is sleep inertia. Regulations recommend that 20 min of recovery time is planned following a napping period to allow for the dissipation of any potential sleep inertia ([ICAO] International Civil Aviation Organisation 2015; Fatigue Countermeasures Working Group 2018). Further, CR periods are often limited to 40 min to allow sufficient time for sleep to be achieved, while reducing the risk of going into deep (slow wave) sleep, which is often correlated with more severe sleep inertia (Dinges et al. 1985). It is important to note, however, that the relationship between slow wave sleep (SWS) and sleep inertia is inconsistent in short naps (Hilditch et al. 2017a). In addition, the relationship between nap length and SWS presence is based on several factors including prior sleep-wake history, such that limiting nap duration does not always prevent SWS onset (Brooks and Lack 2006; Hilditch et al. 2016, 2017b). Thus, a sleep inertia recovery period is needed regardless of nap length. Another risk relates to the alertness of the wakeful pilot during the CR period. Prior sleep-wake history of the wakeful pilot is important to consider as less sleep before a flight is associated with higher fatigue levels in-flight, potentially increasing the risk of unintentional sleep during the CR period (Sallinen et al. 2018). Therefore, best practice guidelines recommend that the ability of the wakeful pilot to maintain alertness during the CR period is discussed during the briefing for CR and that an alarm system, usually involving cabin crew, is in place (Fatigue Countermeasures Working Group 2018). Establishing evidence-based best practice to manage the risks associated with CR can improve the cost-benefit analysis of implementing CR as a fatigue countermeasure tool.

While these guidelines and policies for reducing the risks associated with CR are evidence-based and supported by both laboratory and experimental field-based studies, it is important to assess the implementation of, and compliance with, these policies in regular flight operations. Although our report demonstrates that most pilots appeared to follow the CR procedure at the airline, a few individuals reported taking a longer CR than their carrier's policy. It is difficult to determine whether such deviations resulted from lack of understanding about the appropriate procedures or from excessive fatigue. However, these findings highlight the need for operators to assess how FRM policies are used in practice. Comparing actual CR use against CR policy allows for the assessment of the effectiveness of specific procedures and potentially the need for re-training of pilots, or re-drafting of guidance documents.

Identifying the routes that CR is most commonly used on also provides the airline with data to feed into their FRM program. For example, an un-augmented flight pairing on which pilots consistently take CR may point to the need for augmentation or additional rest opportunity before the flight. CR, therefore, has the potential to provide continuous, system-wide feedback on the fatigue profile of an operation. It should be noted, however, that we have assumed CR was taken according to the policy guidelines with respect to the intention for CR to be taken as a countermeasure to unexpected fatigue due to sleepiness on the flight deck. In this way, we assume the use of CR to be a proxy for fatigue arising from sleepiness. We cannot, however, be sure that CR was used exclusively for this purpose. Conversely, the absence of CR does not necessarily indicate an absence of fatigue. There are many reasons why CR may or may not have been taken, including personal fatigue management strategies, access to bunk rest, airline culture, and local regulations. Therefore, any conclusions regarding the potential need for fatigue controls on flights which show higher levels of CR use must be interpreted with this caveat in mind. More direct measures of fatigue are needed in addition to the current data in order to determine the most effective use of fatigue controls.

While it is important to assess the implementation and effectiveness of CR policies and to manage the risks associated with CR, in regions in which CR is not currently allowed by the aviation regulator (e.g., United States, Brazil), napping on the flight deck occurs in the absence of a formalized policy or risk management controls. Surveys indicate that 39–58% of pilots admit to taking an intentional nap (Co et al. 1999; Rosekind et al. 2000) or unintentionally falling asleep on the flight deck (Marqueze et al. 2017) during flight. Hence, the prevalence of "uncontrolled" flight deck napping, either unintentionally or intentionally without a CR policy, strengthens the argument for CR as a useful tool to minimize the occurrence of these uncontrolled sleep episodes on the flight deck.

Just as aviation faces challenges in implementing napping strategies to combat fatigue, other industries such as healthcare, emergency services, and road transport have also identified and addressed unique barriers. Those industries that have recognized the potential of napping in the workplace have developed and trialed strategies to improve napping environments both physically and culturally (Baxter and Kroll-Smith 2005; Darwent et al. 2012; Fallis et al. 2011). Sharing the lessons learned from one industry or workplace can help others to think of novel ways to incorporate on-site napping as a countermeasure to fatigue in diverse environments. When barriers and challenges are overcome, napping opportunities have often been shown to translate into improvements for sleep, alertness, performance, and safety (Martin-Gill et al. 2018; Ruggiero and Redeker 2014; Shea et al. 2014).

While some of the lessons learned from this study can be shared within aviation and across industries, the specific results are limited to the participating airline. Replica studies across multiple airlines are needed in order to determine the generalizability of these results to other airline cultures, operations, and regions. To increase the scope of data collection, a global, comprehensive survey of CR use and other in-flight fatigue countermeasures could be conducted. There is the potential that the participants in the study, in volunteering, created a selection bias toward pilots who use CR regularly and were therefore more interested in the study. That said, we did not mention CR in our recruiting strategy and 11% of the cohort did not report any CR periods, suggesting that pilots who never, or infrequently use CR were not excluded from the sample. Further, the profile of flights captured in the study was representative of the airline's normal flight operations.

Conclusion

Controlled Rest (CR) is a commonly used countermeasure to fatigue due to sleepiness on the flight deck in the observed airline. Flight crew were more likely to take CR on flights: crewed by 2-pilots (mostly under 10 h duration), flown at night, and returning to their home-base. CR was also taken, however, on augmented flights on which a bunk rest opportunity was available. The results of this study highlight the usefulness of CR as a tool available to flight crew to manage fatigue experienced in-flight. Further research is needed to determine the generalizability of these results to other operations and to assess the efficacy of CR to maintain crew alertness during critical phases of flight.

Acknowledgements

We would like to thank the pilots who collected data for this study and the airline's flight safety department for all their hard work in coordinating equipment and recruitment. Thanks also to Kenji Kato for his work in developing the application used in the data collection, and Nicholas Bathurst for his help in formatting the manuscript. This work was supported by the NASA Airspace Operations and Safety Program, System-Wide Safety Project.

Disclosure statement

The authors report no conflict of interest.

Funding

This work was supported by the NASA Airspace Operations and Safety Program, System-Wide Safety Project.

References

Amann U, Holmes A, Caldwell J, Hilditch C. 2014. Sleep and sleepiness of pilots operating long-range airplane emergency medical missions. Aviat Space Envir Med. 85 (9):954–959. doi:10.3357/ASEM.3986.2014

Baxter V, Kroll-Smith S. 2005. Normalizing the workplace nap: blurring the boundaries between public and private space and time. Curr Sociol. 53(1):33–55. doi:10.1177/0011392105048287

Borbély AA. 1982. A two process model of sleep regulation. Hum Neurobiol. 1(3):195–204.

Brooks A, Lack L. 2006. A brief afternoon nap following nocturnal sleep restriction: which nap duration is most recuperative? Sleep. 29(6):831–840. doi:10.1093/sleep/29.6.831

Caldwell J, Mallis M, Caldwell J, Paul M, Miller J, Neri D. 2009. Fatigue countermeasures in aviation. Aviat Space Envir Med. 80:29–59. doi:10.3357/ASEM.2435.2009

Caldwell JA. 2012. Crew schedules, sleep deprivation, and aviation performance. Curr Dir Psychol Sci. 21(2):85–89. doi:10.1177/0963721411435842

Co EL, Gregory KB, Johnson JM, Rosekind MR. 1999. Crew factors in flight operations XI: a survey of fatigue factors in regional airline operations. Moffett Field (CA): NASA. Technical Memorandum; p. 1999–208799.

Darwent D, Roach GD, Drew D. 2012. How well do truck drivers sleep in cabin sleeper berths? Ergonomics. 43 (2):442–446.

Dawson D, Chapman J, Thomas MJ. 2012. Fatigue-proofing: a new approach to reducing fatigue-related risk using the principles of error management. Sleep Med Rev. 16 (2):167–175. doi:10.1016/j.smrv.2011.05.004

Dinges DF, Orne MT, Orne EC. 1985. Assessing performance upon abrupt awakening from naps during quasi-continuous operations. Behav Res Meth Ins C. 17 (1):37–45. doi:10.3758/BF03200895

Dorrian J, Baulk SD, Dawson D. 2011. Work hours, workload, sleep and fatigue in Australian rail industry employees. Appl Ergon. 42(2):202–209. doi:10.1016/j.apergo.2010.06.009

[EASA] European Aviation Safety Agency. 2018. Acceptable means of compliance (AMC) and guidance material (GM) to annex IV commercial air transport operations [part-CAT]. Cologne (Germany): European Aviation Safety Agency.

European Commission. 2018. Effectiveness of flight time limitation (FTL) final report. Brussels (Belgium): European Commission. Report No. MOVE/C2/2016-360.

Fallis WM, McMillan DE, Edwards MP. 2011. Napping during night shift: practices, preferences, and perceptions of critical care and emergency department nurses. Crit Care Nurse. 31 (2):e1–e11. doi:10.4037/ccn2011710

Fatigue Countermeasures Working Group. 2018. Controlled rest on the flight deck: a resource for operators. Alexandria (VA): Flight Safety Foundation.

Ferguson SA, Thomas MJ, Dorrian J, Jay SM, Weissenfeld A, Dawson D. 2010. Work hours and sleep/wake behavior of Australian hospital doctors. Chronobiol Int. 27 (5):997–1012. doi:10.3109/07420528.2010.489439

Folkard S, Lombardi DA, Tucker PT. 2005. Shiftwork: safety, sleepiness and sleep. Ind Health. 43(1):20–23. doi:10.2486/indhealth.43.20

Gander PH. 2015. Evolving regulatory approaches for managing fatigue risk in transport operations. Rev Hum Factor Ergon. 10(1):253–271. doi:10.1177/1557234X15576510

Gander PH, Gregory KB, Graeber RC, Connell LJ. 1991. Crew factors in flight operations VIII: factors influencing sleep timing and subjective sleep quality in commercial long-haul flight crews. Moffett Field (CA): NASA. Technical Memorandum; p. 103852.

Härmä M, Sallinen M, Ranta R, Mutanen P, Müller K. 2002. The effect of an irregular shift system on sleepiness at work in train drivers and railway traffic controllers. J Sleep Res. 11 (2):141–151. doi:10.1046/j.1365-2869.2002.00294.x

Hartzler BM. 2014. Fatigue on the flight deck: the consequences of sleep loss and the benefits of napping. Accid Anal Prev. 62:309–318. doi:10.1016/j.aap.2013.10.010

Hilditch CJ, Centofanti SA, Dorrian J, Banks S. 2016. A 30-minute, but not a 10-minute nighttime nap is associated with sleep inertia. Sleep. 39(3):675–685. doi:10.5665/sleep.5550

Hilditch CJ, Dorrian J, Banks S. 2017a. A review of short naps and sleep inertia: do naps of 30 min or less really avoid sleep inertia and slow-wave sleep? Sleep Med. 32:176–190. doi:10.1016/j.sleep.2016.12.016

Hilditch CJ, Dorrian J, Centofanti SA, Van Dongen HP, Banks S. 2017b. Sleep inertia associated with a 10-min nap before the commute home following a night shift: a laboratory simulation study. Accid Anal Prev. 99:411–415. doi:10.1016/j.aap.2015.11.010

Holmes A, Al-Bayat S, Hilditch C, Bourgeois-Bougrine S. 2012. Sleep and sleepiness during an ultra long-range flight operation between the Middle East and United States. Accid Anal Prev. 45:27–31. doi:10.1016/j.aap.2011.09.021

[ICAO] International Civil Aviation Organisation. 2015. Fatigue management guide for airline operators. Montreal (Canada): International Civil Aviation Organisation.

Marqueze EC, Nicola ACB, Diniz DH, Fischer FM. 2017. Working hours associated with unintentional sleep at work among airline pilots. Rev Saúde Públ. 51:61–70. doi:10.1590/s1518-8787.2017051006329

Martin-Gill C, Barger LK, Moore CG, Higgins JS, Teasley EM, Weiss PM, Condle JP, Flickinger KL, Coppler PJ, Sequeira DJ, et al. 2018. Effects of napping during shift work on sleepiness and performance in emergency medical services personnel and similar shift workers: a systematic review and meta-analysis. Prehosp Emerg Care. 22 (sup1):47–57. doi:10.1080/10903127.2017.1376136

[NTSB] National Transportation Safety Board. 2019. Reduce fatigue-related accidents – aviation. Washington (DC): National Transportation Safety Board. accessed 2020 Jan 15. https://www.ntsb.gov/safety/mwl/Pages/mwlfs-19-20/mwl2-fsa.aspx.

Petrie KJ, Powell D, Broadbent E. 2004. Fatigue self-management strategies and reported fatigue in international pilots. Ergonomics. 47(5):461–468. doi:10.1080/00140130310001585653

Roach GD, Matthews R, Naweed A, Kontou TG, Sargent C. 2018. Flat-out napping: the quantity and quality of sleep obtained in a seat during the daytime increase as the angle of recline of the seat increases. Chronobiol Int. 35(6):872–883. doi:10.1080/07420528.2018.1466801

Rosekind MR, Gander PH, Miller DL, Gregory KB, Smith RM, Weldon KJ, Co EL, Mcnally KL, Lebacqz JV. 1994a. Fatigue in operational settings: examples from the aviation environment. Hum Factors. 36(2):327–338. doi:10.1177/001872089403600212

Rosekind MR, Graeber RC, Dinges DF, Connell LJ, Rountree MS, Spinweber CL, Gillen KA. 1994b. Crew factors in flight operations IX: effects of planned cockpit rest on crew performance and alertness in long-haul operations. Moffett Field (CA): NASA. Technical Memorandum; p. 108839.

Rosekind MR, Gregory KB, Co EL, Miller DL, Dinges DF. 2000. Crew factors in flight operations XII: a survey of sleep quantity and quality in on-board crew rest facilities. Moffett Field (CA): NASA. Technical Memorandum; p. 2000–209611.

Ruggiero JS, Redeker NS. 2014. Effects of napping on sleepiness and sleep-related performance deficits in night-shift workers: a systematic review. Biol Res Nurs. 16(2):134–142. doi:10.1177/1099800413476571

Sallinen M, Åkerstedt T, Härmä M, Henelius A, Ketola K, Leinikka M, Kecklund G, Sihvola M, Tuori A, Virkkala J, et al. 2018. Recurrent on-duty sleepiness and alertness management strategies in long-haul airline pilots. Aerosp Med Hum Perf. 89(7):601–608. doi:10.3357/AMHP.5092.2018

Sallinen M, Härmä M, Åkerstedt T, Rosa R, Lillqvist O. 1998. Promoting alertness with a short nap during a night shift. J Sleep Res. 7(4):240–247. doi:10.1046/j.1365-2869.1998.00121.x

Sallinen M, Sihvola M, Puttonen S, Ketola K, Tuori A, Härmä M, Kecklund G, Åkerstedt T. 2017. Sleep, alertness and alertness management among commercial airline pilots on short-haul and long-haul flights. Accid Anal Prev. 98:320–329.doi:10.1016/j.aap.2016.10.029

Shea JA, Dinges DF, Small DS, Basner M, Zhu J, Norton L, Ecker AJ, Novak C, Bellini LM, Dine CJ. 2014. A randomized trial of a three-hour protected nap period in a medicine training program: sleep, alertness, and patient outcomes. Acad Med. 89(3):452–459. doi:10.1097/ACM.0000000000000144

Signal TL, Gale J, Gander PH. 2005. Sleep measurement in flight crew: comparing actigraphic and subjective estimates to polysomnography. Aviat Space Envir Med. 76 (11):1058–1063.

Silva Borges FN, Fischer FM. 2003. Twelve-hour night shifts of healthcare workers: a risk to the patients? Chronobiol Int. 20(2):351–360. doi:10.1081/CBI-120019341

Spencer M, Robertson K 1999. The Haj operation: alertness of aircrew on return flights between Indonesia and Saudi Arabia. Farnborough (UK): DERA. Report No. CR980207.

Valk P, Simons M 1997. Pros and cons of strategic napping on long haul flights. Pros and cons of strategic napping on long haul flights. Neuilly-sur-Seine (France): NATO. Report No. AGARD-CP-599.