European Commission

Effectiveness of Flight Time Limitation (FTL)

D3.3 Conclusions and Recommendations

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Classification: Restricted

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Chapter 1: Introduction to the research study

Main objective and scope of the research study

The European Aviation Safety Agency (EASA) was mandated to perform a continuous review of the effectiveness of the rules concerning flight and duty time limitations and rest requirements contained in Annexes II and III of Commission Regulation (EU) No. 965/2012[1].

The review commenced in 2017 with the commission of a research study.

The research study was broken down into smaller phases; each focused on specific flight duty periods (FDPs). The first and current research phase studied the following two FDPs:

- FDP1: Duties of more than 10 hours at the less favourable time of day.
  This focuses on operations that encroach (fully or partially) any portion of the period between 02:00h and 04:59h; and
- FDP2: Disruptive schedules.
  This focuses on consecutive early duty starts, late duty finishes, night duties, and combinations thereof.

Scope of the current deliverable

This Deliverable D3.3 (Conclusions and Recommendations) reports the overall research conclusions and includes recommendations regarding required follow-up actions.

[1] Commission Regulation (EU) No. 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No. 216/2008 of the European Parliament and of the Council.

Chapter 2: Final conclusions and recommendations

The final conclusions and recommendations derive directly from the results presented in D2.3 (Performance of the Data Collection and Data Analysis), D3.1 (Analysis of the Fitness for Purpose of the Current Safety Management Controls), and D3.2 (Benchmark of this Analysis with Other Relevant Sources).

Summary of the results

The summary tables below provide an overview of the main results for high fatigue at top of descent (TOD) at the end of the FDPs of interest.

Summary of the results on high fatigue at TOD during ***non-consecutive*** *FDPs*

FDP of interest	***Main results on high fatigue[1] at TOD and its predictors***
Night duties (> 10h)	All night FDPs were associated with a high probability of high fatigue at TOD. Similar probability percentages were reported for short (≤ 10h) and long nights (> 10h).
Nights	The probability of high fatigue at TOD during night FDPs was higher than during daytime FDPs. Encroachment of the FDP on the WOCL and shorter prior sleep were the significant predictors. When night FDPs were analysed alone, shorter prior sleep explained the occurrence of high fatigue at TOD.
	To cover the continuum from evening to night, late finish plus night (start time before 00:00h) FDPs were combined. A higher probability of high fatigue at TOD during these FDPs than during daytime FDPs was predicted by encroachment on the WOCL, shorter prior sleep, later FDP start time, and longer FDP duration. When late finish plus night FDPs were analysed alone, encroachment on the WOCL, earlier FDP end time, and shorter prior sleep explained the occurrence of high fatigue at TOD.
	To cover the continuum from late night to early morning, very early (03:00h – 04:59h) and early (05:00h – 06:59h) starting FDPs were combined[2]. A higher probability of high fatigue at TOD during these FDPs than in daytime FDPs was explained by earlier FDP start time and shorter prior sleep. When these FDPs were analysed alone, shorter prior sleep was the only factor that explained the occurrence of high fatigue at TOD.
	An alternative way of classifying FDPs was suggested. When applying this classification, deep early (start time 02:00h – 04:59h) and early (start time 05:00h – 06:59h) start FDPs[3] returned a similar probability of high fatigue at TOD. The highest probability of high fatigue at TOD was recorded for deep night FDPs that covered the entire night (start time 01:59h or earlier, end time 06:00h or later).
Early starts	The probability of high fatigue at TOD during early start FDPs was higher than during daytime FDPs. An earlier FDP start time was the only statistically significant predictor. When early start FDPs were analysed alone, none of the FDP-related characteristics explained the occurrence of high fatigue at TOD.
Late finishes	The probability of high fatigue at TOD was higher during late finish FDPs than during daytime FDPs. A longer FDP duration was the only significant predictor. When late finish FDPs were analysed alone, a longer FDP duration, an earlier FDP start time, and an earlier FDP end time explained the occurrence of high fatigue at TOD.

[1] A high level of fatigue was defined as Karolinska Sleepiness Scale (KSS) scores equal to or greater than 7 (= sleepy, but no effort to keep awake).
[2] FDPs starting between 03:00h and 04:59h are considered night FDPs in the current FTL, whereas those starting between 05:00h and 06:59h are not.
[3] The deep early FDPs are considered night FDPs in the current FTL, whereas early FDPs are not.

Summary of the results on high fatigue at TOD during ***two consecutive*** *FDPs*

FDP of interest	*Main results on high fatigue[1] at TOD*
Consecutive early starts	Fatigue levels at TOD were similar for the first and second consecutive early start FDPs.
Consecutive late finishes	The probability of high fatigue at TOD appeared to be similar for the first and second consecutive late start FDPs.
Consecutive nights	Fatigue levels at TOD were similar for the first and second consecutive night FDPs.
Mix	The probability of high fatigue at TOD during mixes of disruptive schedule FDPs appeared to be greater than the corresponding probability in the baseline data set, containing all FDPs collected.

[1] A high level of fatigue was defined as KSS scores equal to or greater than 7 (= sleepy, but no effort to keep awake).

Conclusions

All night FDPs, both those longer and shorter than 10 hours, were associated with a high probability of fatigue at TOD. This is not fully reflected in the current FTL regulation and guidance materials. The regulation and guidelines explicitly note the need for appropriate fatigue risk management and the importance of obtaining sufficient sleep in relation to night duties *longer* than 10 hours, but not for those *shorter* than 10 hours.

Within the FDPs defined as 'night' FDPs in the current regulations, three subgroups can be distinguished based on the occurrence probability of high fatigue at TOD:

1. FDPs with a start time window between 02:00h and 04:59h;
2. FDPs with an end time between 02:00h and 05:59h and a start at 01:59h or earlier; and
3. FDPs with an end time of 06:00h or later and a start at 01:59h or earlier.

The existence of these subgroups is not recognised in the current FTL. Distinguishing these subtypes could help operators tailor fatigue risk management strategies for increased effectivity.

The factors that best predicted increased odds of high fatigue at TOD varied by FDP type. This suggests that further adjustment of a single FDP characteristic would be ineffective in mitigating fatigue. Instead, fatigue mitigation measures should be based on various fatigue management strategies and tailored to FDP type and operator context.

Recommendations

The following recommendations are made in no particular order.

Recommendation 1

Within the FDPs that are defined as 'night' FDPs in the current regulation, three subgroups can be distinguished based on the probability of occurrence of high fatigue at TOD:

- FDPs starting between 02:00h and 04:59h;
- FDPs ending between 02:00h and 05:59h and starting at 01:59h or earlier; and
- FDPs ending at 06:00h or later and starting at 01:59h or earlier.

It is recommended to include these subgroups in the definition of night FDPs to help operators to design effective fatigue risk management strategies.

Recommendation 2

The analysis provides evidence of high fatigue at TOD during late finish FDPs. It is recommended to require operators to apply appropriate fatigue risk management to mitigate the fatiguing effect of late finish FDPs, regardless of FDP duration.

Recommendation 3

The analysis provides evidence of high fatigue at TOD during both long duration (> 10h) and shorter duration (≤10h) night FDPs. It is recommended to require operators to apply appropriate fatigue risk management to mitigate the fatiguing effect of *all* night FDPs, regardless of FDP duration.

Recommendation 4

Within night FDPs, duty periods that end at 06:00h or later, combined with a start at 01:59h or earlier, show the greatest probability of high fatigue at TOD. It is recommended that the regulation define this category of FDP and require operators to pay specific attention to these FDPs when applying fatigue risk management for *all* night FDPs, as proposed in recommendation 3.

Recommendation 5

The analysis found shorter prior sleep to be a predictor of high fatigue at TOD for all night FDPs. The current guidance material for night duties (GM1 CS FTL.1.205) stipulates that it is 'critical for the crew member to obtain sufficient sleep' for night duties of more than 10 hours. It is recommended to amend the GM to state that it is critical for the crew member to obtain sufficient sleep before *all* night duties, regardless of FDP duration.

Recommendation 6

The analysis provides evidence of high fatigue at TOD during night FDPs. This phenomenon seems to be fairly independent of FDP characteristics (e.g. start and end times, duration), as long as the FDP in question meets the criteria for a night FDP. Prior sleep is the main predictor of eventual fatigue. We therefore recommend that for night FDPs, operators should be required to promote optimum use of sleep opportunities (i.e. before reporting and during the FDP).

How to implement recommendations 5 and 6?

Our research found that shorter sleep in the 24 hours prior to TOD is a predictor of high fatigue at TOD for all night FDPs. Recommendation 6 states that for night FDPs operators should be required to promote optimum use of sleep opportunities before flight. To implement this recommendation, we suggest addressing the practicalities of attaining sleep prior to reporting or during the FDP. Providing rest facilities for crew members at or near the airport would improve the probability of obtaining sleep as close as possible to the start of the night duty (as referred to in GM1 CS FTL.1.205 (a)(2) FDP on appropriate fatigue risk management for night duties). That might imply providing suitable accommodation (as defined in ORO.FTL.105 Definitions) at the reporting point for napping in the afternoon prior to a night duty, e.g., for commuting crew members and during the FDP when the crew member is on the ground, such as during a long turnaround.

A way of improving opportunities for *in-flight* sleep is the use of an augmented crew (only applicable for longer flights). An augmented crew enables crew members to take in-flight rest breaks, during which they have the opportunity to sleep in a separate rest facility. Van den Berg et al. (2016) and Gander et al. (2013) showed that additional in-flight sleep effectively mitigated fatigue on longer flights.

As fatigue can sometimes occur unexpectedly the use of controlled rest could be considered. 'Controlled rest' means a period of time 'off task' that may include actual sleep. Research has shown that short, controlled rest is an effective in-flight fatigue-mitigation strategy (Rosekind et al. 1994). It can enhance alertness and performance. Our data show that napping is quite frequent during night duties. According to GM1 CAT.OP.MPA.201, controlled rest is not pro-active fatigue management (i.e., which is planned before the flight) and may be performed only to manage unexpected fatigue and to reduce the risk of fatigue during higher workload periods later in the flight (see also the ICAO Fatigue Management Guide for Operators, 2015).

We suggest promoting the development and use of controlled rest procedures to enable pilots and cabin crew to take a nap during night FDPs to manage unexpected fatigue and to reduce the risk of fatigue during higher workload periods later in the flight. Pilots can take their controlled rest on the flight deck, whereas for the cabin crew the operator would have to provide suitable bunks or seats. We also suggest operators to track the use of controlled rest as it is a very useful indication of where additional more effective controls may be necessary.

Chapter 3: Follow-on actions

Areas for improvement of the current FTL study and requirements for additional research to be carried out are listed below.

Increase the number of participants and resulting FDPs for consecutive disruptive schedules

We did not achieve the required sample sizes[2] to evaluate more than two consecutive disruptive FDPs of any type. In addition, for two consecutive late duties and mixes, it was not clear whether fatigue increased from one duty to the next. This limited our analyses.

The sample size for consecutive disruptive (i.e., more than two and mixes of disruptive schedules) FDPs could be improved by performing 'more controlled' data collection, compared to the crowdsourcing-like data collection method we used to recruit volunteers. This could work, for example, by requesting the schedules from the airlines beforehand and specifically recruiting crew members operating the consecutive disruptive patterns of interest.

Study the remaining four FDPs of interest

The overall FTL review was broken down into smaller research phases, each focusing on specific FDPs. The first and current research phase studied the two top-ranked FDPs [3]: i.e., night duties of more than 10 hours and disruptive schedules.

Still to be studied are the FDPs ranked from third to sixth based on their expected level of fatigue risk:

- Ranked 3: Duties of more than 11 hours for crew members in an unknown state of acclimatisation;
- Ranked 4: Duties including a high level of sectors (more than six);
- Ranked 5: Duties of more than 13 hours at the most favourable time of the day; and
- Ranked 6: On-call duties such as standby or reserve, followed by flight duties.

The specific FTLs that apply to these six types of duty periods are mostly intertwined with one another. It would therefore be preferable to have available the recommendations resulting from studies on all six FDPs of interest and use these together to update – if needed – the FTL rules.

Study the effectiveness of the fatigue management training programme

Training and education are a fundamental requirement for fatigue risk management. However, few studies have evaluated the short- and long-term effects of such programmes. A recent study by Pylkkönen et al. (in press) failed to find evidence that a non-recurrent alertness-management training was an effective remedy for driver sleepiness in occupational settings. These findings conflict with previous studies reporting positive effects of training on alertness management (Gander et al. 2005; Rosekind et al. 2006), sleep quality (Nishinoue et al. 2012), and on-duty sleepiness (Kakinuma et al. 2010; Van Drongelen et al. 2014). Contrary to Pylkkönen et al. (in press), these studies evaluated intervention effects using retrospective self-report questionnaires on sleep and on-duty alertness, before and after an intervention, without actual field measurements.

[2] As established in D2.2 (Definition of the Data Collection Process).
[3] As ranked in D1 Addendum using bio-mathematical modelling and an online survey.

The AMC1 ORO.FTL.250 Fatigue Management Training provides details on content to be covered in initial and recurrent fatigue management training for crew members, for personnel responsible for preparation and maintenance of crew rosters, and for the management personnel concerned. It would be worthwhile to study further the effectiveness of this fatigue management training content and frequency.

Look further into fatigue mitigation measures focusing specifically on more sleep (opportunity)

As prior sleep (opportunity) is such a strong determinant of fatigue we suggest studying effective ways of achieving more sleep. A few potentially interesting directions of research are discussed below. All of these warrant further investigation to better assess their operational feasibility and effectiveness.

The first area concerns the effectiveness of in-flight sleep, in the cabin or bunk. Previous studies suggest that in-flight sleep obtained in crew rest facilities (horizontal sleeping position) is lighter and more fragmented than sleep in a layover hotel (Ho et al. 2005; Signal et al. 2005, 2013). Other studies have found that pilots have difficulty converting time in on-board rest facilities into a reasonable amount of sleep (Signal et al. 2005; Roach et al. 2011). In addition, sleep inertia is a factor to be reckoned with when designing in-flight sleep strategies, and thus also deserves research attention.

'Best practices' is another area of academic work that could yield measures for improving sleep opportunities. Best practices to improve sleep should focus specifically on ways to optimise opportunities to sleep prior to a night FDP. A good example of such a set of best practices is that provided by O'Keeffe and Gander (2012) for resident doctors. A similar set of best practices focused on airline rostering still appears to be lacking. General scheduling principles based on fatigue science are already provided in GM1 CS FTL.1.205 (a) (2) FDP and the Manual for the Oversight of Fatigue Management Approaches (ICAO Doc 9966), which ORO.FTL refers to for further guidance on fatigue risk management. These should be taken into account when designing duty rosters. However, we expect that adding best practice examples from different types of operations would help operators and schedulers assure adequate sleep for crews prior to a night FDP.

A particular aspect of rostering that came out in our survey and could be of interest examined further is roster changes. Some 14% of respondents in our survey[4] indicated 'roster changes' as affecting their level of fatigue in the upcoming duty. This is likely because changes, which may well come at the last minute, make it more difficult for crew members to achieve sufficient sleep before their duty commences.

In the context of fatigue management training, a promising option to achieve more sleep prior to night flights is personalised and context-specific interventions. For instance, tailored advice regarding exposure to daylight, sleep, physical activity, and nutrition could be provided, perhaps using mobile health technology (Van Drongelen et al. 2014; Lentferink et al. 2017).

Look for an alternative beside PVT as an objective performance measure

The use of PVT as an objective performance measure was unsuccessful in the current field study set-up. Pilots were asked to perform the PVT 15 minutes prior to TOD in their final sector. Note that cabin crew were *not* asked to perform the PVT, as we expected that it would be difficult for them to do so undisturbed. Pilots stated numerous times that the PVT was too burdensome and disturbing to perform on the

[4] As presented in D2.1 (Identification of Potential Fatigue Hotspots).

flight deck. Also, the pilots did not always perform the PVT in line with the protocol, which stated that the test should be done 15 minutes prior to the TOD of the final sector of that day. This resulted in inadequate data points for inclusion of PVT data in the final dataset.

Many studies have successfully collected PVT data in flight operations under *controlled* conditions.[5] The reason for being our lack of success now could be that no researcher was present to make sure the test was performed in line with the study protocol and without disturbances. Or perhaps it was because we did not offer crew *individual* training on the PVT. Nonetheless, as fatigue risk management processes also sometimes require collecting data, operators would benefit from an alternative to PVT to objectively measure performance (i.e., alertness). Alternatives should be less burdensome and intrusive and less sensitive to disturbances. Additionally, it would be valuable if future objective performance measurement methods could record fatigue-related data in a rather continuous manner. This would allow assessment of the length of time that crew actually are fatigued and thus improve the identification and assessment of fatigue hazard.

Study diet and physical exercise as countermeasures to fatigue

ORO.FRL.240 on nutrition describes regulatory requirements on opportunities to eat and drink to avoid dips in crew members' performance. Indeed, prior research has found reduced meal frequency among shift workers, but snacking is more common on the night shift (Atkinson et al. 2008). Night work has also been found to reduce opportunities for physical activity and participation in sports (Waterhouse et al. 2007). Optimal timing of physical activity and intake of specific nutrients can enhance sleep duration and quality, thus stimulating alertness or relaxation (Waterhouse et al. 2007; Atkinson et al. 2008; Fischer et al. 2002). Access to suitable catering facilities that provide nutritional food and beverages, the consistent availability of advice on diet, and performance of physical exercise are areas perhaps insufficiently promoted as effective countermeasures to fatigue. Some 5-7% of respondents in our survey[6] indicated 'poor nutrition' as a condition that worsened their level of fatigue. It might be worthwhile to review the state of the art on diet and physical exercise and extend the work that has been done to come up with best practices for this.

[5] As listed in D1 (Definition of the Baseline).
[6] As presented in D2.1 (Identification of Potential Fatigue Hotspots).

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List of abbreviations

Abbreviations	***Description***
AMC	Acceptable Means of Compliance
CS	Certification Specification
D	Deliverable
EASA	European Aviation Safety Agency
EC	European Commission
EU	European Union
FDP	Flight Duty Period
FTL	Flight Time Limitation
GM	Guidance Material
ICAO	International Civil Aviation Organization
MPA	Motor-Powered Aircraft
OP	Operating Procedures
PVT	Psychomotor Vigilance Task
TOD	Top Of Descent
WOCL	Window Of Circadian Low

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