Short and Long Haul Pilots' Rosters, Stress, Sleep Problems, Fatigue, Mental Health, and Well-Being

Marion Venus; Martin grosse Holtforth

OBJECTIVE: This research was conducted to compare short haul (SH) and long haul (LH) pilots regarding sleep restrictions and fatigue risks on flight duty, stress, sleep problems, fatigue severity, well-being, and mental health.

METHOD: There were 406 international SH and LH pilots who completed the cross-sectional online survey. Pilots' sleep restrictions and fatigue-risk profiles (e.g., time pressure, late arrivals, minimum rest), sleep problems, fatigue severity, well-being, and symptoms of depression, anxiety, and common mental disorders (CMD) were measured and compared for SH and LH pilots.

RESULTS: Although SH and LH pilots were scheduled for only 51.4–65.4% of the legally allowed duty and flight hours, 44.8% of SH pilots reported severe fatigue (FSS ≥ 4 to 4.9), and an additional 31.7% high fatigue (FSS ≥ 5), compared with 34.7% and 37.3% LH pilots. Considerable sleep problems in ≥8 nights/mo were reported by 24.6% SH vs. 23.5% LH pilots. Positive depression screenings were reported by 18.1% SH and 19.3% LH pilots. Positive anxiety screenings were reported by 9.6% SH and 5% LH pilots. Of all investigated pilots, 20% reported significant symptoms of depression or anxiety, and 7.23% had positive depression and anxiety screenings. LH pilots reported significantly better well-being than SH pilots.

CONCLUSIONS: Our results show that even far less duty and flight hours than legally allowed according to flight time limitations lead to high levels of fatigue, sleep problems, and significant mental health issues among pilots. SH pilots were even more affected than LH pilots. Pilots' fatigue should be considered an immediate threat to aviation safety and pilots' fitness to fly by promoting fatigue and burnout.

KEYWORDS: fatigue severity, sleep problems, short haul and long haul pilots, work-related and psychosocial stress, common mental disorders, fatigue risks, sleep restrictions, mental health.

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Pilots enjoy a unique work environment, spending most of their work time in their 'front office' about 33,000 ft or 10,058 m above ground at the upper end of the atmosphere. On the flight deck, pilots manage complex, interacting, sophisticated technologies with high degrees of automation, contributing to safe and smooth commercial air transport in the high-risk, high-reliability aviation system. In the 1980s, pilots were flying on average 45.7 ± 30 (mean ± SD) flight h/mo,[32] while today flight time limitations (FTL, see examples in **Table I**) allow up to 100 flight hours.[9]

FTL were originally developed to prevent fatigue of long haul (LH) pilots, who must cope with frequent circadian disruptions, layovers in different time zones, night flights, and generally long, often monotonous flight duties. Nevertheless, short haul (SH) pilots have consistently reported higher levels of fatigue, more sleep restrictions, and on duty sleepiness[6,18,37] due to long duty days, many sectors and successive early starts, and generally higher workload due to more starts and landings within flight duty periods. ICAO defines fatigue as "A physiological state of reduced mental or physical performance

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Table I. Short Overview Over the Most Basic FTL Rules of EASA and CASA in Effect at the Time of Data Collection from June 2018 Until March 2019.

	FLIGHT TIME LIMITATIONS IN EFFECT UNTIL MARCH 2019		
	EASA FTL: ORO.FTL.210	**CASA FTL 48.1**	**FAA PART 121**
Duty period or duty hours*/pilot (multi-pilot operation)			
Max. duty hours	13 duty hours	14 duty hours	14 duty hours
Max. duty hours/month	190 duty hours	200 duty hours	--
Commander's Discretion (Extension of max. duty hours)	max. 13 duty hours plus max. 2 duty hours	max. 14 duty hours plus max. 1 duty hour	max. 14 duty hours plus max. 2 duty hours
Augmented Crews§			
depending on time of day	FDP > 9 to 13 duty hours	FDP > 8 to 14 duty hours	FDP > 9 to 14 duty hours
Flight hours†/pilot (multi pilot operation)			
In any 28 consecutive days	100 flight hours	100 flight hours	100 flight hours
In any calendar year	900 flight hours	--	1000 flight hours
In any 12 consecutive months	1000 flight hours	1000 flight hours	--
Minimum rest‡			
Before flight duty	10 hours (exceptions)	10 hours (exceptions)	10 hours

All definitions from EASA FTL (2014) p. 21.[9]

FTL: flight time limitations; FDP: flight duty period.

*"Duty period" (duty hours) means a period which starts when a crewmember is required by an operator to report for or to commence a duty and ends when that person is free of all duties, including postflight duty; §"augmented flight crew" means a flight crew which comprises more than the minimum number required to operate the aircraft, allowing each flight crewmember to leave the assigned post for the purpose of in-flight rest, and to be replaced by another appropriately qualified flight crewmember; †"Flight time" (flight hours) means the time between an aircraft first moving from its parking place for the purpose of taking off until it comes to rest on the designated parking position and all engines or propellers are shut down; ‡"Rest period" means a continuous, uninterrupted, and defined period of time, following duty or prior to duty, during which a crewmember is free of all duties, standby, and reserve.

capability resulting from sleep loss, extended wakefulness, circadian phase, and/or workload (mental and/or physical activity) that can impair a person's alertness and ability to adequately perform safety-related operational duties." The European Aviation Safety Agency (EASA) explicitly links fatigue and pilots' physical and mental health with flight safety, stating that pilots must not execute flight duties when influenced by psychoactive substances or unfit to fly due to injury, fatigue, medication, sickness, etc. (Commission Regulation (EU) 2018/1042). Throughout the last decades, pilot fatigue has been considered to be a major threat to pilot performance and aviation safety.[1,13] The latest research has shown that sleep problems and fatigue are not isolated problems, but strongly related to stress,[32,38] common mental disorders (CMD),[11] impaired mood,[27] symptoms of depression,[1,38] and burnout.[7,10] This research goes further than previous research, investigating and comparing SH and LH pilots' actual rosters, sleep restrictions, fatigue risks on flight duty, sleep problems, fatigue severity, and mental health in terms of well-being, symptoms of CMD, depression, and anxiety. In this paper, we typically refer to professional pilots, in contrast to private or glider pilots.

CMD are less severe impairments, usually related to difficult living conditions or occupational stress, can be transitory or long lasting, and more or less frequent. CMD can include psychosomatic symptoms like headache, problems with concentration and decision-making, irritability, exhaustion, or sleep problems.[11] Of the investigated pilots, 6.3% reported ≥ eight symptoms of CMD.[11]

Before the Germanwings crash,[3] pilots' mental health was a scarce research topic. Sloan and Cooper[32] reported the mental health of airline pilots was associated with fatigue and psychosocial stress. Pilots' heavy workload was associated with more CMD.[11] Positive depression screening results were reported by 13.5%[39] to 34.5%[1] of pilots, with 4.1% of pilots even reporting suicidal thoughts.[39] Severe fatigue was reported by 68.3% of Middle Eastern pilots; 34.1% also reported excessive daytime sleepiness, and 29.3% sleep problems.[1] Among pilots flying for EASA-based operators, 34.9% reported sleep problems, 59.3% daytime sleepiness, and 84.4% LH vs. 93% SH pilots reported severe fatigue.[28]

Pilots' sleep deprivation was associated with impaired mood and performance decrements.[27] High burnout levels were reported by 32.6% of U.S.-based SH pilots[10] and 40% of European pilots.[7] Work-related and psychosocial stress were often associated with cognitive arousal and sleep problems.[12,21,31] Significant associations and interactions of sleep problems, insomnia, fatigue, and burnout were reported in several studies.[2,19,33] Health risks associated with shift work and lack of sleep also pertain to flight operations,[1] with higher stress and cortisol levels after early or late flight duties.

Several regulators, e.g., EASA and the Australian Civil Aviation Authority (CASA), made Fatigue Risk Management (FRM) mandatory to manage pilots' fatigue and fatigue risks on flight duty when operators wanted to deviate from FTL because of operational or economic reasons.[5] Some regulators like EASA, CASA, and the General Civil Aviation Authority of the UAE (GCAA) have allowed controlled, coordinated onboard rest or naps to reduce 'unexpected fatigue' and restore alertness for critical flight phases like descent and landing,[14] while the FAA does not allow rest or naps in the cockpit (SH). Microsleeps in the cockpit were reported by 45% of pilots,[1] two of three pilots reported fatigue-related errors in the cockpit, and 20% had fallen asleep on the flight deck without prior coordination.[38]

Previous studies have investigated fatigue and sleep problems in pilots of different operators, countries, or types of operation.[1,28,30] SH and LH pilots have been investigated regarding sleepiness, levels of fatigue severity, and sleep problems.[6,18,28] Other research focused on pilots' fatigue, depression, and anxiety,[1] pilots' burnout,[7,10] CMD,[11] and work related[32] and existential stress,[40] while differences between SH and LH pilots' well-being, symptoms of depression, anxiety, and CMD have not been analyzed so far.

High levels of fatigue on the flight deck 33,000 ft (10,058 m) above ground represents a significant risk for passengers' and aircrews' safety. Pilots should be more alert and less fatigued than the general population or patients with chronic diseases,[25,36] even though previous research suggests otherwise.[1,28,38] In context with legal rosters, FTL, and FRM, we tested the following hypotheses:

H.1: The majority (≥50%) of both SH and LH pilots report severe or high levels of fatigue, i.e., a higher proportion of active pilots report severe or high fatigue compared with the general population or with healthy subjects.

H.2: Pilots' mean fatigue severity score is more than 1 SD higher than the Fatigue Severity Scale (FSS) score of healthy subjects, and more similar to the FSS scores of patients with chronic diseases.

Although LH operations were originally expected to be associated with more fatigue risks, SH pilots consistently reported higher fatigue levels.[18,6,28] This research was conducted to test the following further hypotheses:

H.3: SH pilots report the same levels of fatigue risks on flight duty, but significantly different fatigue risk profiles compared with LH pilots.

H.4: SH pilots report significantly:

a) more sleep restrictions;
b) less micro sleeps in the cockpit;
c) more common involvement in incidents where fatigue was a contributory factor;
d) less protection from fatigue by legal FTL, regulators, and their employer; and
e) more concerns and worries regarding FTL and lack of fatigue prevention compared with LH pilots.

Feijo et al. reported significant symptoms of CMD (Self-Reporting Questionnaire 20; SRQ20 ≥ 8) in 6.7% of their investigated pilots.[11] Wu et al. reported positive depression screening results (Patient Health Questionnaire 9; PHQ9 ≥ 10) for 13.5% of pilots, while 9.1% of the general population reported PHQ8 scores ≥ 10. According to Aljurf et al.,[1] 34.5% of pilots reported significant symptoms of depression, assessed with the Hospital Anxiety and Depression Scale (HADS).

H.5: More pilots compared with the general population report significant symptoms of depression in terms of positive depression screening results.

The mean General Anxiety Disorder-7 (GAD7) scores for women were 6.1 and for men 4.6,[34] while no comparable values are available for pilots. This research also tested the following hypothesis:

H.6: Pilots report fewer symptoms of anxiety than the general population.

Considering the high levels of fatigue and sleep problems reported in previous research,[1,6,28] and even higher levels of fatigue reported by SH pilots, we additionally tested the following hypothesis:

H.7: The well-being of SH pilots is significantly lower than the well-being of LH pilots.

METHODS

Procedure

Ethical approval no. 2018 05 00008 for this research was granted by the Ethik Kommission der Philosophisch Humanwissenschaftlichen Fakultät of the University of Bern, Switzerland. Written informed consent was not required because we guaranteed and protected confidentiality of the data collected with the anonymous online survey. This research analyzed data from a

Table II. Descriptive Statistics of the SH and LH pilots.

	SHORT HAUL	LONG HAUL
	M* ± SD†	M* ± SD†
Age**	39.98 ± 10.40	43.63 ± 10.36
Flight hours‡	60.54 ± 20.59	65.38 ± 20.17
Duty hours‡**	118.35 ± 37.24	97.80 ± 32.23
No. of sectors flown‡**	94.48 ± 47.63	25.61 ± 18.62
Standby days‡**	2.65 ± 2.56	1.36 ± 1.88
Rest days‡**	9.82 ± 2.81	11.48 ± 3.45
Vacation days‡	2.36 ± 3.81	2.51 ± 4.10
No. of early starts‡**	5.39 ± 3.89	2.32 ± 3.25
No. of night flights‡	3.89 ± 5.39	4.65 ± 4.20
Hours of physical exercise‡	13.90 ± 10.48	16.28 ± 12.87
Experienced Fatigue Risks	13.90 ± 3.97	13.43 ± 3.970
Longest duty time (FDP)**	14.10 ± 1.84	16.57 ± 2.67
Longest time awake with flight duty during standby**	18.40 ± 4.77	20.94 ± 8.68
End of last flight duty**	42.28 ± 66.15	70.07 ± 93.61
Flight hours on the present type of aircraft	3999.27 ± 3725.00	4705.11 ± 4095.28
Commuting time**	52.17 ± 69.27	72.16 ± 74.20
Days "unfit to fly" due to fatigue (last year)	1.30 ± 2.11	4.40 ± 3.33
Days "unfit to fly" due to sickness (last year)	6.05 ± 7.73	8.79 ± 20.27
PHQ Stress	5.19 ± 3.53	4.40 ± 3.33
WHO5 PR (Wellbeing)**	52.61 ± 19.32	60.60 ± 20.33
PHQ-8 (Depression Screening)	5.98 ± 4.43	5.01 ± 4.50
GAD-7 (Anxiety Screening)	4.18 ± 3.92	3.30 ± 3.43
SRQ-20 (Common Mental Disorders)**	4.34 ± 4.20	3.04 ± 3.49
Fatigue Severity Scale	4.48 ± 0.97	4.38 ± 1.05
Jenkins Sleep Scale**	2.11 ± 1.14	1.76 ± 1.17

SH: short haul; LH: long haul; FDP: flight duty period; PHQ: Patient Health Questionnaire; WHO5 PR: World Health Organization Well-Being Index; GAD: Generalized Anxiety Disorder scale; SRQ: Self-Reporting Questionnaire.
*M = means; †SD = standard deviation of the dependent variables for SH and LH pilots; ‡means of the last 2 mo were used; **Generalized Linear Modeling: significant differences between means of SH and LH pilots ($P < 0.05$).

cross sectional online survey of SH and LH pilots flying for international commercial air operators. The online survey was programmed with Lemon Survey® and included some time-bound questions referring to the last 3 yr. Pilot unions emailed the link to the online survey as part of their newsletters to their members from June 2018 until March 2019. The purpose of this independent research and protection of anonymity was explained on the starting page of the survey. Participants were informed that they would need their duty rosters of the last 2 mo to complete the survey, and that they could delete all data without consequences.

Subjects

There were 1097 pilots who started the online survey, 192 EASA based, 180 Australian, and 34 pilots from UAE, Turkey, and Asia Pacific who completed it within M = 38 ± 18 min (mean ± SD). The inclusion criterion was being an active ATPL pilot. Pilots' age and other sociodemographic and roster related data are displayed in **Table II**. Regarding type of operation, 75 pilots reported only flying SH (sectors < 2 h), 185 short and medium-haul (sectors < 6 h, multiple sectors per flight duty), 46 medium and LH, 56 only LH (sectors > 6 h, usually one sector per flight duty), and 5 pilots ultra-long range operations (ULR, sectors > 16 h). These five types of operation were reduced to two categories: Short and medium haul, hereinafter referred to as 'short haul = SH', vs. medium, LH, and ULR, hereinafter referred to as 'long haul = LH', to obtain comparable data with previous studies.[9,28] Finally, 70% of the pilots in this research reported SH and 30% LH operations.

There were no significant differences between SH and LH pilots regarding rank [$\chi^2(1) = 1331$; $P = 0.249$] or gender [$\chi^2(1) = 0.025$; $P = 0.874$]. Of the short and LH pilots, 50% were captains and 50% first officers. Of the pilots in this research, 8% were women. We found significant differences between types of operation and type of operator [$\chi^2(3) = 29.160$; $P < 0.01$]. Of the pilots in this research, 55% reported flying for network carriers, 30% for low-cost carriers (LCC), 6% reported cargo, and 9% charter operations. One of three SH pilots (34%) was employed by a network carrier, one of four SH pilots (25%) was flying for a LCC, and the remaining SH pilots operated cargo or charter flights. LH pilots (21%) primarily worked for network carriers, with only 5% working for LCC. There were 91% of all SH pilots and 92% of the LH pilots who had an employment contract directly with their airline/employer, while the rest had contracts via intermediary manning agencies, or were 'self-employed', which implied low job security.

Cross Sectional Online Survey

The online survey was based on previous research[1,28,39] so that results of different samples and years could be compared. Pilots reported their age, gender, and other sociodemographic data, which was not evaluated in this study. Pilots rated their fatigue risks on flight duty (**Fig. 1**) on a 5-point Likert scale from never (0) to always (4). The sum score of these seven ordinal scaled items was called 'fatigue risks experienced on flight duty'. Pilots also rated on a 5-point Likert scale from never (0) to always (4) if they had experienced sleep restrictions associated with flight duties (**Fig. 2**). The sum score of these six ordinal scaled items was called 'sleep restrictions'. Pilots were also asked to rate the frequency of microsleeps in the cockpit, fatigue-related incidents, fatigue, and sick leave (**Fig. 3**) on a 6-point Likert scale from never (0) to more than once/month (5). Finally, pilots were asked to rate their concerns and worries associated with FTL (**Fig. 4**) on a 6-point Likert scale from "no concern" (0) to "severe concern" (5).

Pilots' fatigue was self-assessed with the nine-item Fatigue Severity Scale[24] (**Table III** and **Table IV**). FSS showed very good reliability in healthy subjects and clinical patients[36] and in the general population,[25] while reliability was lower for pilots in this research (Table IV). Psychosocial stress was measured with the 10 stress-related items of the Brief Patient Health Questionnaire,[35] hereinafter referred to as PHQ-Stress,

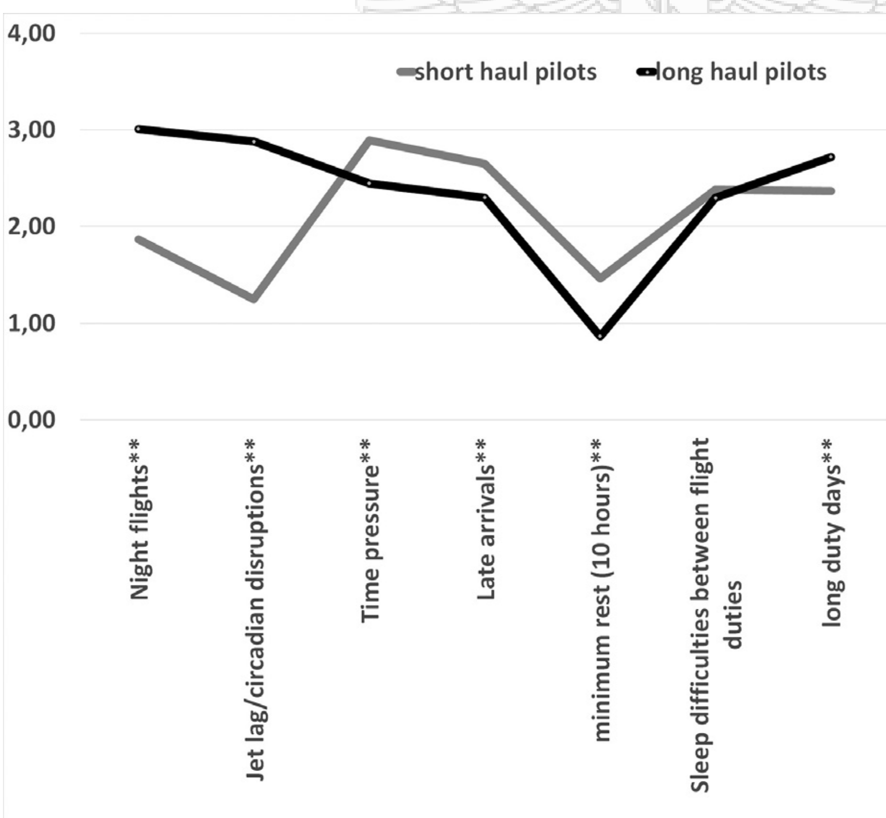

Fig. 1. Fatigue risks experienced on flight duty reported by SH and LH pilots. "Over the last 2 months, when you were on duty: How often did you experience ...": 0 = never, 1 = rarely, 2 = sometimes, 3 = often, 4 = always. **Independent-samples Mann-Whitney U test: significant difference between groups ($P < 0.01$).

which had acceptable internal consistency in this research. Sleep problems were self-assessed with the Jenkins Sleep Scale[20] (JSS), Cronbach's alpha, range, and means and SDs in Table IV; all JSS items are listed in Table III. To measure pilots' mental fitness, screening instruments recommended by the World Health Organization (WHO) were used: pilots' wellbeing was assessed with WHO5,[22] symptoms of CMD were assessed with the Self-Reporting Questionnaire-20 (SRQ20). To obtain comparable data,[39] PHQ8 was used for the self-assessment of depression symptoms,[35] and GAD7[34,35] was used for self-assessment of symptoms of generalized anxiety. Some pilots' original, authentic comments on this online survey were cited to illustrate our results and relate them to previous research in the discussion section.

Statistical Analyses

SPSS Version 27.0 was used for statistical analyses; results with $P < 0.05$ were considered statistically significant. For sample description, Chi-squared tests were used to compare categorical data. For psychosocial stress, sleep problems, fatigue, wellbeing, symptoms of depression, generalized anxiety, and CMD, the ordinal scaled item scores were added to compute scale scores; for JSS and FSS the mean scale scores were used. To test H.1, H.5, and H.6, the published cutoff scores, means, and SD were used. To test H.2, H.3, H.4, and H.7, median tests or independent samples Mann-Whitney U tests were calculated.

RESULTS

SH pilots reported on average 60.5 ± 20.6 flight hours (M ± SD) in the last 2 mo, and LH pilots 65.4 ± 20.2 flight hours. SH pilots reported 118.4 ± 37.2 duty hours, while LH pilots reported significantly less flight hours (97.8 ± 32.2). Compared with, e.g., the EASA FTL (Table I), SH pilots reported on average 60.5% and LH pilots 65.4% of the legally allowed 100 flight h/mo. Pilots on SH reported on average 62.3% and on LH 51.4% of the legally allowed 190 duty h/mo. Nevertheless, 44.8% of the SH pilots reported severe fatigue (FSS 4–4.99), an additional 31.7% reported high fatigue (FSS ≥ 5). Of the LH pilots, 34.7% reported severe fatigue and 37.3% high fatigue. H.1 stated that the majority (≥50%) of SH and LH pilots would report severe or high levels of fatigue, more pilots than the healthy or general population, and was confirmed. H.2 stated that pilots' mean fatigue severity score would be 1 SD higher than the FSS of healthy subjects and more similar to FSS of patients with chronic diseases and was confirmed. FSS means of SH and LH pilots were almost equal (Table II).

Of the SH pilots, 24.6% reported considerable sleep problems in ≥8 nights/mo and 9.5% in ≥15 nights/mo, compared with 23.5% and 9.2% of the LH pilots. Pilots' sleep problems were associated with sleep restrictions and fatigue risks (Fig. 2 and Fig. 3).

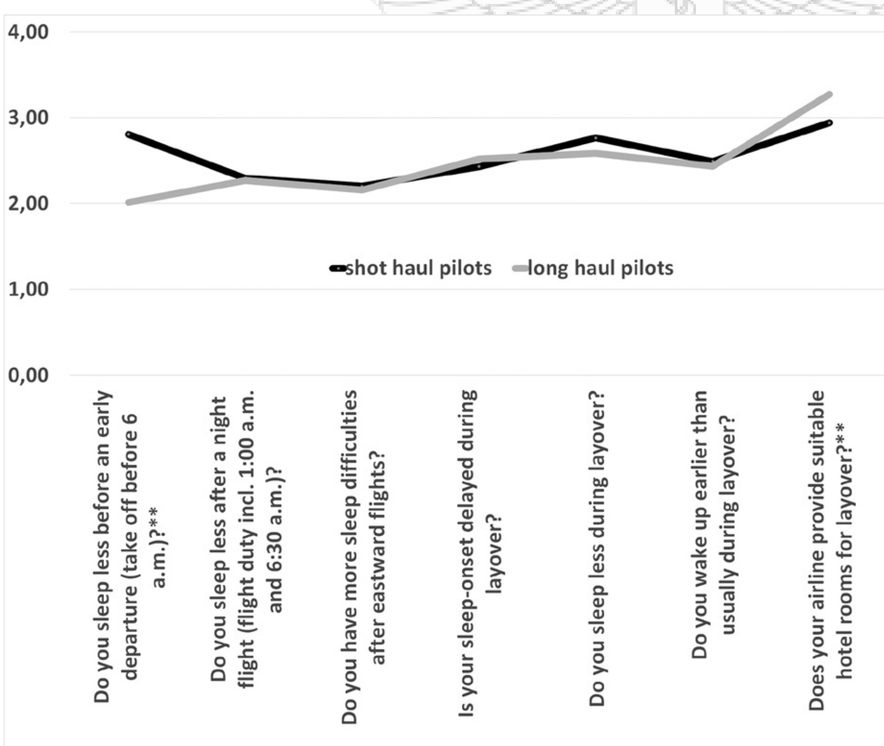

Fig. 2. Sleep restrictions associated with flight duties of SH and LH pilots. "When you were on flight duty, how often did you experience …": 0 = never, 1 = rarely, 2 = sometimes, 3 = often, 4 = always. **Independent-samples Mann-Whitney U test: significant difference between groups ($P < 0.01$, $N = 406$).

H.3 stated that SH pilots would report the same levels of fatigue risks on flight duty, but significantly different fatigue risk profiles compared with LH pilots and was confirmed: SH and LH pilots reported the same quantitative extent of fatigue risks (Mann-Whitney U Test = 15,256,00; $P = 0.677$), but SH and LH pilots had significantly different fatigue risk profiles (Fig. 1). LH pilots reported significantly more night flights, more long duty days, and circadian disruptions, while SH pilots reported more late arrivals, more time pressure, and 'back-to-back' rostering with minimum rest between late and early flight duties.

H.4.a) stated that SH pilots would report significantly more sleep restrictions and was confirmed (Mann-Whitney U = 2357,000, $P = 0.007$, Fig. 2). SH pilots reported significantly more restricted sleep before early starts, but the same sleep restrictions as LH pilots on layover.

H.4.b) stated that SH pilots would report significantly less microsleeps in

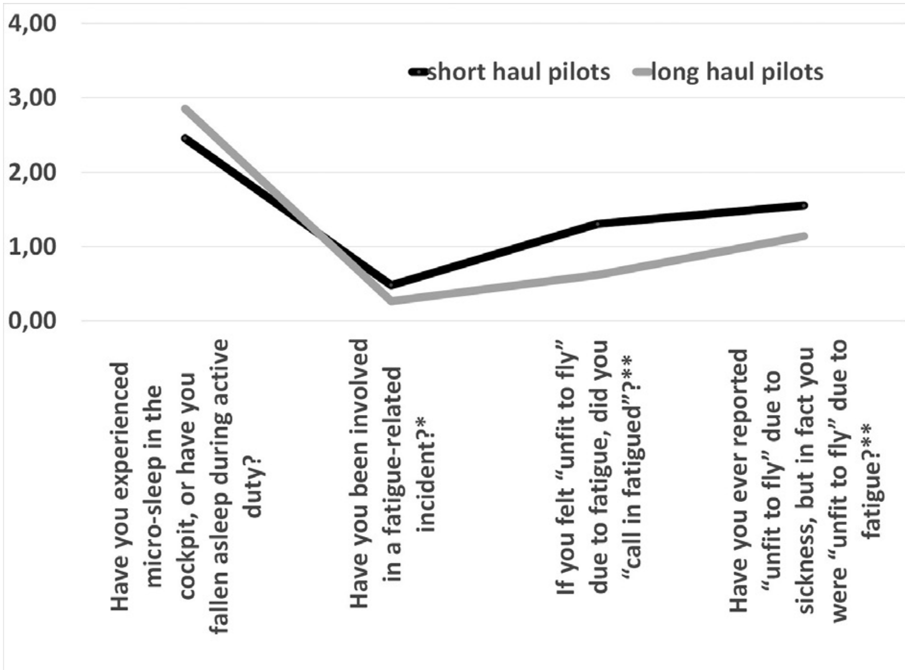

Fig. 3. Frequency of microsleeps in the cockpit, fatigue-related incidents, fatigue, and sick leave of SH vs. LH pilots in the last 2 yr. "Over the last years: How often have you experienced …": 0 = never, 1 = once/year, 2 = twice/year, 3 = almost every month, 4 = every month, 5 = more often. **Independent-samples Mann-Whitney U test: significant difference between groups (P < 0.05).

the cockpit, mostly due to more starts and landings and shorter cruise phases, and was not confirmed [median test(1) = 1172, P = 0333, Fig. 3]. H.4.c) stated that SH pilots would report significantly more involvement in incidents where fatigue was a contributory factor and was confirmed [median test(1) = 4.868, P = 0038, Fig. 3].

H.4.d) stated that SH pilots would report significantly less protection against fatigue by legal FTL, regulators, and their employer, and was not confirmed: both pilot groups perceived the same lack of protection against fatigue from FTL, their employers, and the responsible regulators [F(1384) = 0508, P = 0.476]. H.4.e) stated that SH pilots would report significantly more concerns and worries regarding FTL and failing fatigue prevention compared with LH pilots, and was not confirmed [F(1325) = 0115, P = 0.735, Fig. 4].

H.5 stated that more pilots compared with the general population would report significant symptoms of depression in terms of positive depression screening results and was confirmed. Twice as many pilots reported positive depression screenings compared with the general population.[23] Of the SH pilots' sample, 18.1% reported PHQ8 scores ≥10, compared with 19.3% of the LH pilots, with no significant differences between the groups [$\chi^2(1)$ = 0077, P = 0781]. SH pilots' PHQ8 mean was 5.93 ± 4.5 (M ± SD), LH pilots' mean PHQ8 was 5.29 ± 4.6. SH pilots also reported significantly more symptoms of CMD (Table II).

H.6 stated that pilots would report lower mean anxiety scores than the general population and was confirmed: SH pilots' GAD7 mean was 4.1 ± 3.9 (M ± SD), LH mean GAD7 score was 3.4 ± 3.5 (Table II), lower than the GAD7 scores of the general population.[34] GAD7 ≥ 10 was reported by 9.6% of SH pilots and 5% of the LH pilots, with no significant group differences [$\chi^2(1)$ = 2303; P = 0129]. Overall, 20% of all investigated pilots had positive depression and/or anxiety screening results. Out of all the pilots, 18.7% reported a PHQ8 ≥ 10 and 7.23% also reported a GAD7 ≥ 10, while 1.25% reported only GAD7 ≥ 10 with PHQ8 < 10.

H.7 stated that the well-being of SH pilots would be significantly lower than the well-being of LH pilots and was confirmed (Mann-Whitney U = 20,301,000, P = 0001). LH pilots on average reported feeling equally good or better than 60.6% of the general population, and SH pilots equally good or better than 52.6% (Table II). Both groups were on average above the WHO5 cut-off value of 50.[22]

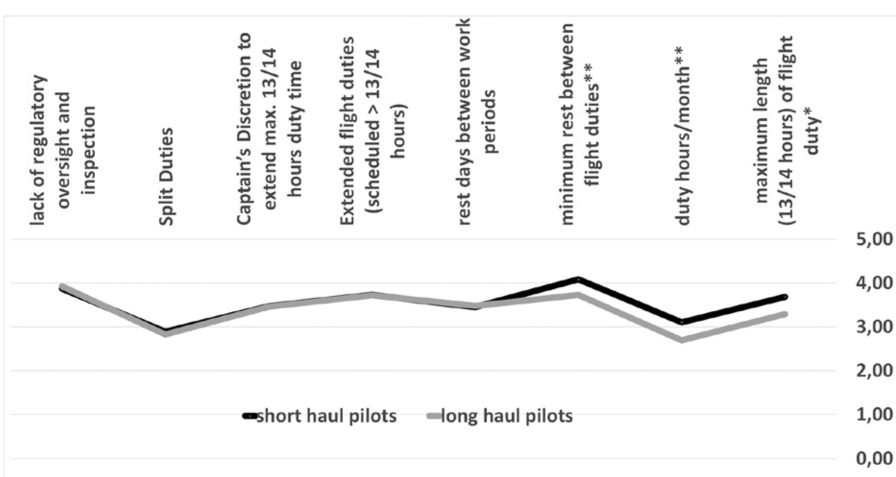

Fig. 4. Mean ratings of SH and LH pilots: "What worries you most about the current Flight Time Limitations?" 0 = no concern, 5 = severe concern. Independent-samples Mann-Whitney U test significant differences between groups: **P < 0.01, *P < 0.05.

Table III. Overview of Standard Questionnaires Used and Their Items.

QUESTIONNAIRES AND ITEMS
WHO5 Well-Being Index
1. I have felt cheerful and in good spirits.
2. I have felt calm and relaxed.
3. I have felt active and vigorous.
4. I woke up feeling fresh and rested.
5. My daily life has been filled with things that interest me.
SRQ 20
1. Do you often have headaches?
2. Is your appetite poor?
3. Do you sleep badly?
4. Are you easily frightened?
5. Do your hands shake?
6. Do you feel nervous, tense, or worried?
7. Is your digestion poor?
8. Do you have trouble thinking clearly?
9. Do you feel unhappy?
10. Do you cry more than usual?
11. Do you find it difficult to enjoy your daily activities?
12. Do you find it difficult to make decisions?
13. Is your daily work suffering?
14. Are you unable to play a useful part in life?
15. Have you lost interest in things?
16. Do you feel that you are a worthless person?
17. Has the thought of ending your life been on your mind?
18. Do you feel tired all the time?
19. Are you easily tired?
20. Do you have uncomfortable feelings in your stomach?
PHQ8: Depression Screening
1. Little interest or pleasure in doing things.
2. Feeling down, depressed, or hopeless.
3. Trouble falling or staying asleep or sleeping too much.
4. Feeling tired or having little energy.
5. Poor appetite or overeating.
6. Feeling bad about yourself or that you are a failure or have let yourself or your family down.
7. Trouble concentrating on things, such as reading the newspaper or watching television.
8. Moving or speaking so slowly that other people could have noticed? Or the opposite: being so fidgety or restless that you have been moving around a lot more than usual.
GAD 7: Anxiety Screening
1. Feeling nervous, anxious or on edge.
2. Not being able to stop or control worrying.
3. Worrying too much about different things.
4. Trouble relaxing.
5. Being so restless that it is hard to sit still.
6. Becoming easily annoyed or irritable.
7. Feeling afraid as if something awful might happen.
JSS: Jenkins Sleep Scale
How often in the past four weeks did you …
1. have trouble falling asleep?
2. wake up several times per night?
3. have trouble staying asleep (including waking far too early)?
4. wake up after your usual amount of sleep feeling tired and worn out?
FSS: Fatigue Severity Scale
1. My motivation is lower when I am fatigued.
2. Exercise brings on my fatigue.
3. I am easily fatigued.
4. Fatigue interferes with my physical functioning.
5. Fatigue causes frequent problems for me.
6. My fatigue prevents sustained physical functioning.
7. Fatigue interferes with carrying out certain duties and responsibilities.
8. Fatigue is among my three most disabling symptoms.
9. Fatigue interferes with my work, family, or social life.
PHQ Stress
1. Worries about your health.
2. Your weight or your look/appearance.
3. Little or no sexual desire or pleasure in sexual intercourse.
4. Difficulties with your spouse, partner, or friend.
5. Burden of caring for children, parents, or other relatives.
6. Stress at work or at school.
7. Financial problems or worries.
8. To have nobody to talk to about problems.
9. Something bad that happened recently.
10. Thoughts of scary events of the past or dreams about them.

WHO5: World Health Organization Well-Being Index; SRQ: Self-Reporting Questionnaire; PHQ: Patient Health Questionnaire; GAD: Generalized Anxiety Disorder scale.

DISCUSSION

In line with previous research,[6,18,28] more SH pilots (76.5% vs. 72%) reported severe fatigue. Other research reported severe fatigue (FSS ≥ 4) in 68.5%[1] or up to 93%[28] of their investigated pilots despite FTL and FRM. More LH pilots (37.3%) reported high fatigue (FSS ≥ 5) compared with 31.7% SH pilots. Compared with the general population, 30% more pilots reported severe and 10% more high fatigue.[25] Compared with the healthy population,[36] 58% more pilots reported severe fatigue, although pilots spend most of their duty hours 33,000 ft (10,058 m) above ground in a high-risk high-reliability system, where alertness, situation awareness, and performance are vital. FSS means of SH and LH pilots were almost equal, but more than one SD higher than FSS scores of healthy subjects[25,36] and even higher than those of most patient groups.[36]

According to pilots, LH flights with augmented crews help to reduce on-duty sleepiness and fatigue significantly. The question arises, why LH pilots' fatigue is overall equal with SH pilots' fatigue levels, while more LH pilots reported high fatigue. A possible explanation may be that only a very small proportion of all flights is rostered with fatigue reducing augmented aircrews, and that circadian disruptions on transmeridian LH flights, often short layovers, and frequent night flights enhance fatigue on LH flights.

The present sample of active pilots represents a healthy population whose health must be certified at least once/yr according to medical requirements for flight crew licensing. Three of four pilots reported severe or high fatigue, although they were on average only scheduled for 51.4–65.4% of the legally allowed 100 flight and 190 duty h/mo.[9] Several questions arise from these results: which levels of fatigue render professional pilots unfit to fly, according to, e.g., Commission Regulation (EU) 2018/1042 or international medical requirements for flight crew licensing? Which levels of fatigue are still safe for aircrews and passengers? The International Labor Organization recommends that work time arrangements including shift work should be designed to prevent occupational accidents and impairment of health. Present FTL likely do not protect SH and LH pilots from high levels of fatigue, fatigue risks on flight duty, or sleep restrictions and sleep problems,[37,29] potentially

Table IV. Scale Means (M), Standard Deviations (SD), Scale Range, Cronbach's Alpha in This Research and in Previous Studies, and Cut-Off Values Published in Previous Research.

SCALE	RANGE	CUT-OFF	MEAN	SD	CRONBACH'S α	CRONBACH'S α (PREVIOUS RESEARCH)
WHO5	0–100	< 50	54.44	19.92	0.89	0.83 to 0.95[32]
PHQ8	0–24	≥10	5.64	4.37	0.90	0.82[33]
GAD7	0–21	≥10	3.86	3.68	0.90	0.92[28]
SRQ20	0–20	≥ 8	3.91	3.99	0.87	0.81[9]
FSS	1–7	≥ 4/5	4.46	0.98	0.82	0.93[26]
JSS	0–5	≥ 3/4	2.00	1.16	0.85	0.79[31]
PHQ-Stress	0–20		4.84	3.42	0.81	--

promoting burnout and impairing pilots' mental fitness,[7,10] which also threatens aviation safety.[5,6]

Our results suggest that the present FTL and FRM may be dysfunctional, while SH pilots' health in terms of well-being, CMD symptoms, and sleep problems was significantly more impaired. SH pilots reported significantly more sleep restrictions and sleep problems, in line with previous research.[28,29,37] In this research 24.6% of the SH pilots reported considerable sleep problems ≥8 nights/mo and 9.5% ≥15 nights/mo, compared with 23.5% and 9.2% of the LH pilots. These results are comparable with sleep problems reported by 34% of European pilots[28] and 29.3% of Middle Eastern pilots.[1] Early starts were the most frequently mentioned sleep restrictions for SH pilots. Restricted sleep time due to, e.g., the 'wake maintenance zone',[8] when falling asleep 1 or 2 h earlier than the normal bed-time is physiologically almost impossible and having to get up during the window of circadian low[9,16] are well known fatigue risks. SH operations are often associated with minimum rest due to 'back-to-back rostering'. SH operations have been proven to be more demanding, due to multiple takeoffs, landings, and turnarounds per flight duty. LH pilots pointed at the fatigue risks associated with 24-h layovers when they had to fly back during home-base night. SH pilots' health was significantly more impaired. While pilots tend to ignore or suppress mental health issues, they are aware of physical health threats, because pilots must "sit in a chair buckled in for 13 hours […] it's bad for my health, thin dry air, radiation, no place to move around. Eating bad nutrition without possibility to change food. Also, very noisy cockpit. This combined with long days and bad weather is a challenge and sometimes I wish I had called NFF [Not Fit to Fly] when decisions are to be made."

SH pilots' well-being was significantly impaired. SH pilots reported feeling equally good or better than 52.6% of the general population, while the WHO5 cut-off is 50. If a person's WHO5 score is below 50, diagnosis or exclusion of a depressive disorder is recommended.[22] Positive depression screening results were reported by 18.1% of the SH vs. 19.3% of LH pilots, similar to 13.5%[39] and 34.5%[1] of pilots in previous research. Pilots reported lower anxiety scores than reported for the general population.[34]

Pressure to fly despite feeling fatigued was reported by 60–63% of pilots[38] and two of three pilots reported pressure to use 'Commander's Discretion',[9,38] in line with previous research. 'Pilot Pushing' was introduced for this implicit pressure on pilots to use airplanes as effectively as possible for maximum productivity, to fly as many sectors as possible despite technical issues with the aircraft, threatening weather conditions, or high levels of fatigue on flight duty.[5,10] 'Pilot Pushing' likely contributed to pilots' high levels of fatigue and burnout. Nevertheless, pilots are still responsible for all aspects of flight safety on every flight.[15] Pilots are legally obliged to report themselves unfit to fly due to fatigue, physical, or mental health issues, according to the medical requirements for flight crew licensing, e.g., MED.B.055 and MED.B.060. Many pilots are reluctant to do so because they fear to lose their Medical Class 1 and their jobs after long-term grounding and final layoff. Consequently, the question arises, which levels of work-related and psychosocial stress, sleep problems, fatigue, exhaustion, and burnout render pilots legally not fit to fly? Many pilots have adapted to consequently deteriorating working conditions, shorter rest, longer flight duties, and more duty and flight hours per year, especially during the last 15 yr. Most pilots step by step got used to fatigue, constant exhaustion, feeling worse and worse, impaired mood and symptoms of depression, and worrying more and more about their health and safety.

Psychophysiological stress reactions are related to higher physiological and/or cognitive arousal,[12] which can in turn reduce sleep[21,31] or trigger insomnia. Insomnia can also cause or worsen burnout.[2,19] Rumination and worries are key symptoms of sleep disturbances and insomnia; both are implicated in the etiology and maintenance of sleep problems. Cognitive arousal is also associated with anxiety and depression.[21] Long duty days packed with time pressure, busy airspace, unexpected drones near congested airports, or weather-related threats like thunderstorms or wind shear can enhance pilots' stress levels and cognitive arousal on every flight duty.[38] Lack of experience on the present type of aircraft after, e.g., changing from Airbus to Boeing, also implies more cognitive effort to manage a new, different type of complex aircraft. That can enhance cognitive arousal, which can foster sleep problems[21] and finally enhance fatigue. Our results suggest that sleep problems of pilots are associated with industry friendly FTL and resulting legal rosters. All that seems to impair pilots' mood in terms of symptoms of depression, realistic fears for flight safety, life and livelihood, psychosomatic health issues,[12,31] and burnout.[7,10,33] GAD7 asks for symptoms of generalized anxiety. According to the International Classification of Diseases (ICD-11), 6B00 'generalized anxiety disorder' represents excessive unreasonable fears, worries, and rumination without real life-threatening imminent stressors. In this research GAD7 scores were on average low and cannot differentiate between pathological 'generalized anxiety' and pilots' realistic worries and existential threats. Today pilots must cope with the fear of losing their Medical Class 1 due to fatigue, sleep problems, or beginning burnout, with consecutive loss of career and livelihood and real risks associated with working 33,000 ft (10,058 m) above ground. Engine and system failures are rare, but still happen.

Inefficient FRM may have affected safety culture. Pilots have become reluctant to file fatigue reports because of repercussions and no improvement afterwards.[5,38] Yet fatigue is considered to be a risk for pilot performance and flight safety.[1,13,14] Results of this research underpin the safety relevance of high levels of fatigue in pilots: "[…] feeling slow and tired, I am getting afraid of mistakes due to fatigue. I get irritated on the system at work". The safety relevance of fatigue was supported by our descriptive results: 23% of pilots reported involvement in a fatigue-related incident or accident. In this research, 76% of pilots reported microsleeps in the cockpit or having fallen asleep at the controls without prior coordination, compared with 45% in 2018.[1] Pilots are legally allowed to rest, nap, or sleep according to CAT.OP.MPA.210(3).[9] "During all phases of flight, each flight crewmember required to be on duty in the flight crew compartment shall remain alert. If a lack of alertness is encountered, appropriate countermeasures shall be used. If unexpected fatigue is experienced, a controlled rest procedure, organized by the commander, may be used if workload permits." ICAO (2011, p. 150) also states, "During controlled rest, the non-resting pilot must perform the duties of the pilot flying and the pilot monitoring, be able to exercise control of the aircraft at all times, and maintain situational awareness. The non-resting pilot cannot leave his/her seat for any reason, including physiological breaks."[17] When both pilots nod off or sleep, no pilot maintains situation awareness, which is still crucial for flight safety despite sophisticated avionics and high levels of automation in modern aircrafts. The legal FTL allow long shifts up to 13/14 duty hours in, e.g., EASA Member States or Australia, while LH pilots reported almost 17 and SH pilots on average 14 h maximum duty hours. When LH pilots had to go on flight duty during standby, at the end of their "on-call flight duty," they were awake 21 h and SH pilots on average 18.4 h.

Previous fatigue studies were often conducted to satisfy Fatigue Risk Management. They often considered pilots' fatigue, sleepiness, and sleep as immediate reactions to stimuli like check-in and check-out times from flight duties, rest, and 'rostered' assigned sleep time.[30] Our results, long lasting research in work psychology and on burnout,[7,10,33] suggest that there are strong interactions between high work demands, psychophysiological stress reactions, sleep problems, and burnout. Many pilots reported restricted sleep and additional sleep problems due to maximum legal flight and minimum rest times. Burnout either predicted insomnia over time or could intensify insomnia.[2] Severe sleep problems or insomnia predicted the development of burnout over time.[2]

The vast overlap of burnout and depression,[4] high levels of fatigue,[1,28] psychosocial and work related stress,[32,40] sleep problems or insomnia associated with work-related stress,[19,21,31] sleep restrictions associated with irregular shift work,[30] and additional sleep problems[1,28] suggest that many pilots suffer from beginning up to high levels of burnout.[7,10] Interactions of insufficient sleep (< 6 h), high work demands, work-related stress, inability to unwind, and clinical burnout were reported.[33] Our multidimensional results suggest that is also the case for active pilots. Sleep problems of pilots may not only be associated with obstructive sleep apnea,[1] but also with burnout, while causality should be investigated. ICD-11 describes 'Burnout' as "resulting from chronic workplace stress […] characterized by three dimensions: feelings of energy depletion or exhaustion; increased mental distance from one's job, or feelings of negativism or cynicism related to one's job and reduced professional efficacy." Of pilots, 40% reported high burnout scores and 20% reported the same burnout levels as inpatients treated for burnout.[7] Both depression and burnout are disqualifying for pilots. According to, e.g., MED.B.055 and MED.B.060 of Part-MED, any mental health issue can lead to long-term withdrawal of pilots' Medical Class 1 and final layoff. Looking at the high levels of fatigue and mental health issues of our pilots, the question arises, which levels of stress, sleep problems, fatigue, exhaustion, and burnout might render pilots legally unfit to fly?

Beyond high levels of fatigue, pilots represent a healthy population. All pilots need a valid Medical Class 1 to be allowed to work as pilot. Pilots must renew their medical at least once per year to fly huge passenger or cargo jets. Pilots' mental and physical health is crucial for flight safety, to prevent sudden incapacitation in flight or another Germanwings[3] or LAM crash.[26] International aviation regulations state that pilots' health is an integral part of aviation safety in single-pilot and multi-crew cockpits.

Looking at the screening results for well-being, depression, anxiety, and CMD, pilots reported the highest scores on items relating to fatigue, exhaustion, and sleep problems. The highest GAD7 scores were "Becoming easily annoyed or irritable" and "Trouble relaxing". These results imply pilots' exhaustion, impaired mood, and burnout, not a 'sudden outbreak' of depressive and anxiety disorders among pilots. "High workload (multiple sectors, slot delays, pax issues, weather, complex airports, busy skies, tech issues, early starts, late finishes) followed by minimum rest is now more than ever taking its toll on crew well-being and cumulative fatigue levels. It frightens me […] it's the crew and the crew alone that have to deal with the burden of ruined sleep, destructed social and family lives, and eventually—shattered careers."

In this study, 1097 mainly EASA-based and Australian pilots participated; 406 pilots completed the comprehensive online survey. The target groups were members of the

European and Australian pilot unions. Some obstacles may have made participation difficult: the focus of this research, i.e., mental health issues, fatigue, and burnout, are disqualifying for pilots according to medical requirements for flight crew licensing. Pilots had to have their own rosters of the last 2 mo at hand, so many pilots dropped out right before these questions. We intended to cover pilots' peak season, summer flight plan in Europe and the time after Christmas in Australia, because we wanted to investigate operators' crew planning and pilots' fatigue, sleep, and mental health issues when maximum duty and flight hours were expected.

This research was based on individual pilots' actual rosters of the last 2 mo. We expected that the current rosters might affect sleep, fatigue, and mental health. Pilots were expected to answer honestly because we guaranteed confidentiality.

The representativity of this sample can hardly be checked in detail. Most demographic data in this research corresponds with former studies, e.g., age, gender, proportion of LH/SH pilots, etc. International pilots participated in this research, pilots of different types of operators and flight operations. The sample of this study could be biased, i.e., pilots in this research were scheduled for only 51.4–65.4% of the legally allowed duty and flight hours. Pilots rostered for the legally possible maximum duty and flight hours might have been either too busy or too fatigued to participate in this research. The results of this research show that our pilots were significantly less fatigued than pilots in previous studies,[28] and similarly fatigued but with fewer symptoms of depression.[1]

Screening results obtained through self-assessment in online surveys cannot be considered diagnoses of mental disorders. Positive depression or anxiety screenings only indicate that a likely diagnosis of, e.g., a depressive or anxiety disorder should be confirmed or rejected by standardized clinical psychological diagnosis without short cuts, not based on 'gut feeling'. Artifacts must be avoided, e.g., what looks like a positive depression screening (PHQ8 $\geq$ 10) might be an exhausted, severely fatigued pilot, whose mood is impaired due to exhaustion and roster-related sleep deprivation over months or years. It would be a wrong conclusion that only pilots with a depressive disorder have sleep problems and high fatigue levels. More probably, sleep restrictions, fatigue risks experienced on flight duty, with or without sleep problems on top, often result in impaired mood,[27] more symptoms of depression,[1] exhaustion, and burnout.[7,10]

Results of psychological questionnaires can be questioned. They can be biased on purpose or by chance. Pilots could exaggerate or downplay fatigue, sleep problems, or mental health issues in FRM studies. Valid and reliable psychophysiological measurement of fatigue and recovery is needed, in combination with in-depth data regarding mental health acquired through the diagnostic process. These psychophysiological measures would also deliver valuable information about the validity and reliability of biomathematical models and the effectiveness of FRM.

In contrast to former studies, this research investigated more dimensions simultaneously for each pilot (i.e., psychosocial stress, fatigue severity, sleep problems, well-being, symptoms of depression, anxiety, and CMD), relating these dimensions to their rosters, fatigue risks experienced on flight duty, etc. This research also used reliable, valid, and standardized screening instruments and questionnaires (i.e., PHQ-Stress, WHO5, SRQ20, PHQ8, GAD7, FSS, JSS), whose results can be compared with previous research.[1,11,39]

Future research should investigate if fatigue is more often the reason or the consequence of impaired mental fitness, especially in context with sleep restrictions, sleep problems, depression, and burnout. The prevalence of depression and burnout in a representative sample of pilots should be determined, and which prevention and treatment methods are effective to maintain or regain fitness to fly. AMEs along with clinical aviation psychologists should cooperate regarding qualified evidence-based decisions in case of health issues like accumulated fatigue, burnout, and depression.

Future research should also investigate the effect of longer commuting times for SH and LH pilots. Many pilots reported living far from home base due to the high costs of living next to airports. LH pilots reported significantly more rest, fewer standby days, and longer commuting times, on average 20 min longer commutes than SH pilots. In still unpublished research, we found that longer commuting times of LH pilots were associated with significantly lower fatigue, while interactions of commuting time, recreational value of more distant domiciles, and microsleeps on the way home after flight duties deserve a closer look in future research.

Considering the fatigue levels of most pilots, sleeping quarters close to or at airports should be encouraged for aircrews. Instant rest and recovery before, between, and after flight duties would help prevent microsleeps on the way home after long or night flight duties. Maximum flight duty periods per day, month, and year should be significantly reduced to prevent burnout among pilots. Consequently, more LH flights should be rostered with augmented crews, because a third pilot on board makes it possible that one of three pilots can rest and restore flight safety-relevant alertness throughout flight duties. Operators must solve the problem that many SH pilots build up high fatigue and sleepiness during a long flight duty, especially after sleep restrictions due to early starts. Coordinated rest in the cockpit on SH should be allowed, otherwise pilots are at risk to fall asleep without coordination.

SH pilots reported significantly more demanding rosters and significantly more sleep problems, symptoms of CMD, and lower well-being, although they were significantly younger than LH pilots. Severe fatigue was reported by 44.8% of SH pilots, with an additional 31.7% indicating high fatigue, compared with 34.7% and 37.3% of LH pilots, while flying on average 51.4–65.4% of the legally allowed duty and flight hours, despite FTL and FRM. Future research and regulations development should improve FTL and schedules for SH pilots, whose sleep, physical, and mental health was significantly impaired. The consistently measured and published high levels of accumulated fatigue should not only be considered as an immediate threat to aviation safety, but also as significant threat for pilots' fitness to fly by promoting burnout and mental disorders.

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REFERENCES

1. Aljurf TM, Olaish AH, BaHammam AS. Assessment of sleepiness, fatigue, and depression among Gulf Cooperation Council commercial airline pilots. Sleep Breath. 2018; 22(2):411–419.
2. Armon G, Shirom A, Shapira I, Melamed S. On the nature of burnout-insomnia relationships: a prospective study of employed adults. J Psychosom Res. 2008; 65(1):5–12.
3. BEA. Accident to the Airbus A320-211, registered D-AIPX and operated by Germanwings, flight GWI18G, on 03/24/15 at Prads-Haute-Bléone. 2016. [Accessed 3 August 2021]. Available from https://www.bea.aero/uploads/tx_elydbrapports/BEA2015-0125.en-LR.pdf.
4. Bianchi R, Schonfeld IS, Laurent E. Burnout-depression overlap: a review. Clin Psychol Rev. 2015; 36:28–41.
5. Bourgeois-Bougrine S. The illusion of aircrews' fatigue risk control. Transportation Research Interdisciplinary Perspectives. 2020; 4:100104.
6. Bourgeois-Bougrine S, Carbon P, Gounelle C, Mollard R, Coblentz A. Perceived fatigue for short- and long-haul flights: a survey of 739 airline pilots. Aviat Space Environ Med. 2003; 74(10):1072–1077.
7. Demerouti E, Veldhuis W, Coombes C, Hunter R. Burnout among pilots: psychosocial factors related to happiness and performance at simulator training. Ergonomics. 2019; 62(2):233–245.
8. de Zeeuw J, Wisniewski S, Papakonstantinou A, Bes F, Wahnschaffe A, et al. The alerting effect of the wake maintenance zone during 40 hours of sleep deprivation. Sci Rep. 2018; 8(1):11012.
9. EASA. Commission Regulation (EU) No. 83/2014. 2014:1–34. [Accessed 3 August 2021]. Available from https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ%3AL%3A2014%3A028%3A0017%3A0029%3AEN%3APDF.
10. Fanjoy RO, Harriman SL, DeMik RJ. Individual and environmental predictors of burnout among regional airline pilots. Int J Appl Aviat Stud. 2010; 10(1):15–30.
11. Feijó D, Luiz RR, Camara VM. Common mental disorders among civil aviation pilots. Aviat Space Environ Med. 2012; 83(5):509–513.
12. Goffeng EM, Nordby KC, Tarvainen M, Järvelin-Pasanen S, Wagstaff A, et al. Cardiac autonomic activity in commercial aircrew during an actual flight duty period. Aerosp Med Hum Perform. 2019; 90(11): 945–952.
13. Goode JH. Are pilots at risk of accidents due to fatigue? J Safety Res. 2003; 34(3):309–313.
14. Hartzler BM. Fatigue on the flight deck: the consequences of sleep loss and the benefits of napping. Accid Anal Prev. 2014; 62:309–318.
15. ICAO. Annex 6 - operation of aircraft - Part I - international commercial air transport - aeroplanes. 2018. [Accessed 3 August 2021]. Available from https://www.verifavia.com/bases/ressource_pdf/299/icao-annex-6-part-i.pdf.
16. ICAO. Fatigue management guide for air operators. 2015. [Accessed 3 August 2021]. Available from https://www.icao.int/safety/fatiguemanagement/FRMS Tools/FMG for Airline Operators 2nd Ed (Final) EN.pdf.
17. ICAO. Fatigue risk management systems. 2011. [Accessed 3 August 2021]. Available from https://www.icao.int/safety/fatiguemanagement/FRMS Tools/FRMS Implementation Guide for Operators July 2011.pdf.
18. Jackson CA, Earl L. Prevalence of fatigue among commercial pilots. Occup Med (Lond). 2006; 56(4):263–268.
19. Jansson M, Linton SJ. Psychosocial work stressors in the development and maintenance of insomnia: a prospective study. J Occup Health Psychol. 2006; 11(3):241–248.
20. Jenkins CD, Stanton BA, Niemcryk SJ, Rose RM. A scale for the estimation of sleep problems in clinical research. J Clin Epidemiol. 1988; 41(4):313–321.
21. Kalmbach DA, Buysse DJ, Cheng P, Roth T, Yang A, Drake CL. Nocturnal cognitive arousal is associated with objective sleep disturbance and indicators of physiologic hyperarousal in good sleepers and individuals with insomnia disorder. Sleep Med. 2020; 71(7):151–160.
22. Krieger T, Zimmermann J, Huffziger S, Ubl B, Diener C, et al. Measuring depression with a well-being index: Further evidence for the validity of the WHO Well-Being Index (WHO-5) as a measure of the severity of depression. J Affect Disord. 2014; 156:240–244.
23. Kroenke K, Strine TW, Spitzer RL, Williams JBW, Berry JT, Mokdad AH. The PHQ-8 as a measure of current depression in the general population. J Affect Disord. 2009; 114(1-3):163–173.
24. Krupp LB, LaRocca NG, Muir-Nash J, Steinberg AD. The Fatigue Severity Scale. Application to patients with multiple sclerosis and systemic lupus erythematosus. Arch Neurol. 1989; 46(10):1121–1123.
25. Lerdal A, Moum T, Wahl AK, Rustøen T, Hanestad BR. Fatigue in the general population: a translation and test of the psychometric properties of the Norwegian version of the fatigue severity scale. Scand J Public Health. 2005; 33(2):123–130.
26. MWT. Civil aircraft accident report ACCID/112913/1-12. 2016. [Accessed 3 August 2021]. Available from http://reports.aviation-safety.net/2013/20131129-0_E190_C9-EMC.pdf.
27. O'Hagan AD, Issartel J, Wall A, Dunne F, Boylan P, et al. "Flying on empty"–effects of sleep deprivation on pilot performance. Biol Rhythm Res. 2020; 51(7):1133–1154.
28. Reis C, Mestre C, Canhão H, Gradwell D, Paiva T. Sleep and fatigue differences in the two most common types of commercial flight operations. Aerosp Med Hum Perform. 2016; 87(9):811–815.
29. Roach GD, Sargent C, Darwent D, Dawson D. Duty periods with early start times restrict the amount of sleep obtained by short-haul airline pilots. Accid Anal Prev. 2012; 45(Suppl.):22–26.
30. Sallinen M, Åkerstedt T, Härmä M, Henelius A, Ketola K, et al. Recurrent on-duty sleepiness and alertness management strategies in long-haul airline pilots. Aerosp Med Hum Perform. 2018; 89(7):601–608.
31. Sapolsky RM. Why zebras don't get ulcers. New York: St. Martin's Press; 2004.
32. Sloan S, Cooper CL. Pilots under stress [Book Review]. Stress & Health. 1987; 3(4):318.
33. Söderström M, Jeding K, Ekstedt M, Perski A, Åkerstedt T. Insufficient sleep predicts clinical burnout. J Occup Health Psychol. 2012; 17(2):175–183.
34. Spitzer RL, Kroenke K, Williams JBW, Löwe B. A brief measure for assessing generalized anxiety disorder: The GAD-7. Arch Intern Med. 2006; 166(10):1092–1097.
35. Spitzer RL, Williams JBW. Brief Patient Health Questionnaire. [Database record]. APA PsycTests. Washington (DC): American Psychological Association; 1999.

36. Valko PO, Bassetti CL, Bloch KE, Held U, Baumann CR. Validation of the fatigue severity scale in a Swiss cohort. Sleep. 2008; 31(11): 1601–1607.
37. Vejvoda M, Elmenhorst EM, Pennig S, Plath G, Maass H, et al. Significance of time awake for predicting pilots' fatigue on short-haul flights: implications for flight duty time regulations. J Sleep Res. 2014; 23(5):564–567.
38. Venus M. A survey of professional pilots' health and wellbeing. Hindsight/Skybrary. 2020; 2020(30):38–41. [Accessed 3 August 2021]. Available from https://www.skybrary.aero/bookshelf/books/5672.pdf.
39. Wu A, Donnelly-McLay D, Weisskopf MG, McNeely E, Betancourt TS, Allen JG. Airplane pilot mental health and suicidal thoughts: a cross-sectional descriptive study via anonymous web-based survey. Environmental Health. 2016; 15(1):121. Correction in: Environmental Health. 2017; 16:129.
40. Young JA.The effects of life-stress on pilot performance. Moffett Field (CA): NASA Ames Research Center; 2008. NASA Tech Memo. [Accessed 3 August 2021]. Available from https://humanfactors.arc.nasa.gov/flightcognition/Publications/Young_TM2008_215375_final.pdf.