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How Duty Rosters and Stress Relate to Sleep Problems and Fatigue of International Pilots

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Cover Page Footnote

We would like to thank Alvarez IT Solutions for programming the online survey, IT-security and webhosting and my informal network of experienced pilots for their professional support, check-reading and valuable background information for this research.

Commercial pilots spend most of their working hours in their 'front office' at an average altitude of 10 km above ground in a hostile environment. Pilots manage complex, sophisticated flight management systems and are responsible for safe and punctual air transport in the high risk, high reliability system of aviation. In the 1980s, pilots reported flying on average 45.7 flight hours per month (Sloan & Cooper, 1986), while the current flight time limitations (FTL, Appendix 1) allow up to 100 flight hours per month (CASA FTL, 2013; EASA FTL, 2014; 14 CFR Part 117, 2014). In this paper, we typically refer to *professional pilots*, in contrast to private or glider pilots.

Flight Time Limitations and Fatigue Prevention

FTL were originally developed to prevent fatigue in long-haul operations, where pilots must cope with circadian disruptions, layovers in other time zones, frequent night flights, and generally long flight duties. Nonetheless, more short-haul pilots have consistently reported high levels of fatigue, more sleep restrictions, and on-duty sleepiness because of long duty days and generally higher workload with more take-offs and landings within flight duty periods (FDP) (Bourgeois-Bougrine et al., 2003; Honn et al., 2016; Jackson & Earl, 2006; Reis et al., 2013, 2016a; Roach, Sargent, et al., 2012; Vejvoda et al., 2014). ICAO (2015) defines fatigue as:

> A physiological state of reduced mental or physical performance 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.

To understand, how pilots' working conditions and chronic stress can affect their sleep, fatigue, mental and physical health, some basics of the allostasis theory are described below.

Homeostasis, Stress, Allostasis and Allostatic Load

The human body strives for homeostasis to function and to be healthy and productive. The term homeostasis describes the ideal condition when physiological systems interact successfully to achieve the necessary balance to maintain life. To maintain homeostasis and keep us alive, the human brain monitors changes in the external and internal environment, controls interactive physiological processes, and adjusts physiological processes accordingly. All body functions (including adequate regeneration, good sleep, regulation of body temperature, pH, glucose levels, oxygen levels, etc.) interact, they are controlled by the brain. This interactive process is called 'allostasis', where stability is obtained through interactive adaptation (McEwen, 2006, 2008; McEwen & Karatsoreos, 2015).

Types of Stressors

Stress is often described as threat to homeostasis, real or perceived, requiring physical action or physiological allostatic processes to regain homeostasis (McEwen & Stellar, 1993). Physiological stressors are e.g., "exertion, heat, cold, trauma, infection, and inflammation; psychologic stressors such as fear and anxiety, social defeat and humiliation, disappointment" (McEwen & Stellar, 1993, p. 2093). Sleep deprivation or insufficient good recovery sleep are also classified as physiological stressors (Chen et al., 2014; McEwen, 2006; McEwen & Karatsoreos, 2015; Sapolsky, 2004).

Psychosocial stressors are e.g., worries about health, weight or appearance, difficulties with spouse or partner, burden of caring for children, parents, or other relatives, stress at work or at school, financial problems or worries, having nobody to talk about problems, recent trauma, etc. (Spitzer & Williams, 2005).

Pilots' Acute and Chronic Work-Related Stressors and Allostatic Load

"Allostatic load/overload refers to the cumulative wear and tear on body systems caused by too much stress and/or inefficient management of the systems that promote adaptation through allostasis" (McEwen & Karatsoreos, 2015, p. 1). Work related stressors are e.g., little experience in a complex and sophisticated technical environment like the cockpit, conflicts at the workplace like investigations into pilots' private life after fatigue reports (like blaming pilots for causing their own fatigue), financial instability of the employer/operator (Little et al., 1990; Mohr, 2000; Young, 2008), or frequent time pressure (Lundberg & Frankenhaeuser, 1999; Sapolsky, 2004).

Pilots' time pressure arises from minimum turnaround times, minimum rest, long flight duties in crowded airspace, starting and ending on congested airports (restricting available leisure time and recovery). Other work related chronic stressors are operators in financial trouble in terms of looming imminent bankruptcy (e.g., of Flybe, Thomas Cook, Air Berlin, Germanwings, Condor, etc.), or mergers (Young, 2008), low job security due to atypical contracts (Brannigan et al., 2019; Little et al., 1990) and classic 'Pilot Pushing' (Fanjoy et al., 2010). Responsibility for many lives on board, fewer hours on a new type of a modern, complex aircraft, immediate threats to flight safety due to being blinded by laser pointers or unexpected encounter of drones on short final near airports are traditional and new work-related stressors and threats for pilots.

Previous research investigated how work related stress relates to pilots' wellbeing (Cahill et al., 2021; Cullen et al., 2020) and mental health issues (O'Hagan et al., 2017; Widyahening, 2007). Omholt et al. (2017) reported that pilots' work-related stress was associated with more subjective health complaints like sleep problems and fatigue.

Short-haul pilots' shifts are associated with high workload (Honn et al.,

2016) and frequent sleep restrictions (Roach, Sargent, et al., 2012; Vejvoda et al., 2014). Long-haul pilots must cope with frequent circadian disruptions (Cosgrave et al., 2018; Gander et al., 2015; Holmes et al., 2012). Pilots' difficulties to sleep include (1) having to sleep during their wake maintenance zone (Zeeuw et al., 2018), (2) having to work during the 'window of circadian low' (WOCL), i.e., when body temperature is lowest between 02:00–06:00 a.m., when homeostatic sleep drive is strongest and maintaining acceptable performance levels is most difficult (Lamp et al., 2019), and (3) operational necessity to sleep during the day (times of circadian high). The result is considerable allostatic load, while pilots must cope with a wide variety of other stressors on a regular basis. These wear and tear processes due to allostatic load could explain, why pilots experienced higher stress and strain across four consecutive duty days, although their objective workload was decreasing (Goffeng et al., 2019).

Sleep problems and fatigue are not isolated problems, but closely related to stress (Ekstedt et al., 2006; Kalmbach et al., 2020; Lundberg & Frankenhaeuser, 1999; Omholt et al., 2017; Sapolsky, 2004; Sloan & Cooper, 1986; Venus, 2020) and burnout (Demerouti et al., 2019; Fanjoy et al., 2010). Despite fatigue prevention measures like fatigue risk management (FRM) and FTL, several studies reported high levels of fatigue among active professional pilots (Aljurf et al., 2018; Reis et al., 2013, 2016a, 2016b). These studies measured fatigue with the Fatigue Severity Scale (FSS, Krupp et al., 1989). Severe fatigue (FSS≥4) was reported by 68.5% (Aljurf et al., 2018) up to 93% pilots (Reis et al., 2013, 2016a, 2016b; Venus & grosse Holtforth, 2021), although pilots' high levels of fatigue are associated with high operational safety risks (Aljurf et al., 2018; Coombes et al., 2020; Goode, 2003; Reis et al., 2013, 2016a; Williamson & Friswell, 2017). FSS Validation studies reported lower fatigue levels in the general or healthy population (Lerdal et al., 2005; Valko et al., 2008). Therefore, we want to explore, how many pilots report severe (FSS≥4) or high fatigue (FSS≥5), compared with the healthy or general population.

Stress and Allostatic Load Associated with Sleep Deprivation

Sleep has important functions for regeneration and maintaining homeostasis. Sleep deprivation or other forms of circadian disruptions like jetlag are stressors, which have consequences for the brain and many body systems. Circadian disruptions due to sleep restrictions, sleep problems, insomnia, shift work or frequently crossing time zones impact allostasis and result in the elevation of allostatic load, with multiple adverse health effects (Chen et al., 2014; McEwen, 2006; McEwen & Karatsoreos, 2015; Sapolsky, 2004). It is less important, why sleep is restricted. "Long-term consequences of sleep deprivation and circadian disruptions constitute a form of allostatic load, with consequences involving hypertension, reduced parasympathetic tone, increased pro-inflammatory cytokines, increased oxidative stress, and increased evening cortisol and insulin" (McEwen & Karatsoreos, 2015, p. 7) In the long run, sleep restrictions and circadian disruptions are associated higher risks for cardiovascular diseases and diabetes.

Stress, Cortisol & Sleep

Bostock and Steptoe (2013) investigated how early and late starting flight duties of British short-haul pilots were related to perceived stress, salivary cortisol levels, mood, and fatigue. Early starting flight duties were associated with shorter sleep duration and significantly higher cortisol levels throughout. Early and late flight duties were associated with more perceived stress, more tiredness and more impaired mood, compared with rest days (Bostock & Steptoe, 2013).

Considering allostatic load, fatigue is not the only problem for pilots. Other considerable health impairments like cardiovascular diseases, accumulated fatigue, pain, declines in health and fatigue related cognition, higher mortality (Chen et al., 2014), and impaired immune systems (McEwen, 2008; McEwen & Karatsoreos, 2015) were confirmed as long-term consequences of repeated high or chronic stress. Moreover, Sykes et al. (2012) reported, their investigated pilots had a 5,5 times higher prevalence of kidney diseases, and a 47.5 times higher prevalence of melanoma skin cancer.

Sleep Drives and Sleep Restrictions

The main causes of sleepiness and fatigue of healthy individuals are (1) circadian phase, (2) time awake, and (3) amount of prior sleep (Ingre et al., 2014). The 'homeostatic process' describes that pressure for sleep or homeostatic sleep drive builds up, as time awake increases. This pressure to sleep gets stronger the longer we stay awake and decreases during sleep, reaching a low after a full night of good quality sleep (Hartzler, 2014). The 'circadian process' refers to the diurnal variation of alertness, essentially to be able to sleep at night (WOCL) and be alert during the day (circadian high). Prophylactic or recuperative naps or sleeps can reduce the homeostatic sleep drive, especially effective during the WOCL (Hartzler, 2014).

Fatigue & Circadian Disruptions (Jet-Lag)

Long-haul pilots often experience disruptions of their sleep/wake cycles when they cross several time zones on a long-haul flight. This 'jet-lag' can lead to sleep problems and prevent sufficient recovery sleep during layovers in different time zones due to often fragmented sleep and naps (Cosgrave et al., 2018; Roach, Petrilli, et al., 2012; Sallinen et al., 2018). Insufficient sleep due to sleep restrictions or sleep problems and associated sleepiness can be recovered with more compensatory sleep (Hartzler, 2014). If the sleep deficit or accumulated sleep debt

(ICAO, 2015b) cannot be recovered, sleep deprivation related incapacitations can affect sensory, cognitive, physical and behavioral functioning of aircrews (Chen et al., 2014; McEwen, 2006; McEwen & Karatsoreos, 2015).

These fatigue related incapacitations especially during micro-sleep can be functionally similar to medically driven incapacitations (Coombes et al., 2020). "Neurobehavioural performance effects of sleepiness reported by pilots include increasing pressure to fall asleep, degraded alertness, errors of omission and commission, deterioration in judgement and decision making, worsened mood, and deteriorating flying skills" (Coombes et al., 2020, p. 3).

Micro-Sleeps as Manifestations of High Fatigue

Micro-sleep is defined as "momentary loss of awareness when a person is fatigued or sleep-deprived, especially during monotonous tasks [for pilots e.g., cruise phase of flights, looking at monitors in the cockpit (PFD), monitoring flight parameters during uneventful flights etc.]. Micro-sleep episodes can be noticed when the head literally drops forward and can last from less than 1 second to minutes" (APA, 2021). Safety-essential situational awareness is of course vanished when a pilot accidentally nods off or falls asleep: The pilot will be 'behind his plane' and most probably not know, how much flight time he has missed, where he is, what has happened, and what the next steps are. Although sleep inertia may be low after short sleep duration (Hartzler, 2014), the pilot will need some time for re-orientation. Redundancy for the benefit of flight safety has completely disappeared, when both pilots accidentally nod off at the same time (Coombes et al., 2020; ICAO, 2018). Per 2000 flight hours, 1.1 cases of both pilots so fatigued that they nodded off or fell asleep simultaneously and without coordination were reported (Coombes et al., 2020).

Problem and Purpose

Biomathematical Models (BMM), Fatigue Risk Management (FRM) & Resulting Rosters

Today most operators use scheduling software and biomathematical models (BMM) (Cabon et al., 2012; Dawson et al., 2017; Dorrian et al., 2012) to produce legal, competitive rosters. Several regulators like the European Aviation Safety Agency (EASA) and the Australian Civil Aviation Safety Authority (CASA) made Fatigue Risk Management (FRM) mandatory to manage pilots' fatigue and fatigue risks on flight duty, if operators wanted to deviate from FTL because of operational or competitive necessities (Bendak & Rashid, 2020; Bourgeois-Bougrine, 2020).

BMM automatically imply certain amounts of sleep during scheduled rest time, despite circadian disruptions (Dawson et al., 2017; Dorrian et al., 2012), and although pilots' effective amount of obtained sleep can hardly be predicted (Dorrian et al., 2012). During the 'window of circadian low' (WOCL) (EASA FTL, 2014; ICAO, 2015b), when sleep pressure is highest, the effort to maintain acceptable levels of performance is high, and performance can deteriorate significantly (Hartzler, 2014). Overall performance declines as a function of time spent awake, and this decline in performance is modulated by the circadian rhythm (Coombes et al., 2020). Safety relevant performance impairment due to fatigue includes impairment of cognitive abilities, e.g., short-term memory, problem solving and decision making are impaired, as well as reasoning abilities, divergent thinking, spatial processing, with generally lower processing speed (Bandeira et al., 2018; Hartzler, 2014).

For one in four FDPs, the used BMM predicted a main sleeping opportunity shorter than six hours, and 10% of all flight hours were associated with high fatigue risk (Coombes et al., 2020). In their study, pilots reported 7.3 events of accidental sleep in the cockpit per 1000 flight hours. This rate is far greater than what was reported to regulators. For comparison, micro-sleep events or fatigue related incapacitations exceeded by far "the target rate of medical incapacitation permissible under the medical incapacitation safety standard for commercial aviation of less than one occurrence per 1,000,000 h." (Coombes et al., 2020, p. 1).

Fatigue & Safety

EASA links pilots' fatigue explicitly with flight safety (EASA FTL, 2014; Commission Regulation (EU) 2018/1042, 2018). Several studies support the relevance of fatigue for flight safety and pilot performance (Bandeira et al., 2018; Bendak & Rashid, 2020; Bourgeois-Bougrine, 2020; Cabon et al., 2012; Goode, 2003; Hartzler, 2014). Therefore, further research seems necessary to improve flight safety, which may save aircrews' and passengers' lives. High fatigue on the flight deck, 10 km above ground, represents a significant risk for passengers' and aircrews' safety (Bendak & Rashid, 2020; Bourgeois-Bougrine, 2020; Goode, 2003). Pilots should be alert and less fatigued than the general population (Lerdal et al., 2005) or patients with chronic diseases (Valko et al., 2008).

Differentiation Between Sleepiness and Fatigue

Fatigue studies for FRM usually measure alertness/sleepiness with the Karolinska Sleepiness Scale (KSS) by Åkerstedt and Gillberg (1990) or the Epworth Sleepiness Scale (Johns, 1991). In contrast to these studies and in line with Shahid et al. (2010), we differentiate between alertness/sleepiness and fatigue. "Sleepiness means an increased propensity to doze off or fall asleep; it may be related to a low arousal level" (Shahid et al., 2010, p. 81). On the other hand, "Fatigue is a feeling of strain or exhaustion; it includes physiological fatigue and pathological fatigue. Physiological fatigue, or 'normal fatigue', is induced by daily activities it lasts a short period and is usually relived by rest" (Shahid et al., 2010, p. 85) We typically refer to fatigue as physiological fatigue (Shahid et al., 2010), or *accumulated fatigue* (Cabon et al., 2012), which is also reflected in the fatigue definition of the International Classification of Diseases (ICD 11).

While most fatigue related performance impairments are difficult to measure during flight operations in the cockpit, micro-sleeps are valid manifestations of high sleepiness and/or fatigue. When sleepiness is high (e.g. KSS>7), unvoluntary sleep intrusions occur, and the risk of unintended micro-sleeps is high (Akerstedt, 2009), and even motivated individuals have difficulties to stay alert or even awake (Coombes et al., 2020).

Therefore, we want to explore: How many active professional pilots report having experienced sleep restrictions (like sleeping less before early starts or after night flights, restricted sleep on layovers) and other fatigue risks associated with flight duties (e.g., frequent time pressure, early starts before 6 a.m., late ending flight duties). Moreover, fatigue related errors, micro-sleeps in the cockpit, perceived fatigue protection, longest flight duty periods (FDP) and longest time awake on flight duty shall be assessed.

Stress, Sleep & Fatigue

Regulators develop rule sets to prevent fatigue. Operators comply and often use sophisticated Biomathematical Models (BMM) to schedule their pilots for legal, but competitive flight operations. The gap between the goal of fatigue prevention and consistently reported high fatigue of active pilots could be explained by not correctly identified and tackled fatigue risks, like psychosocial and work-related stress. Long lasting stress and burnout research has shown that stress and allostatic load is often associated with sleep problems (Chen et al., 2014; Jansson & Linton, 2006; Kalmbach et al., 2018, 2020; McEwen, 2006; McEwen & Karatsoreos, 2015; Sapolsky, 2004; Zoccola et al., 2009). Sleep problems or restricted sleep (<6 hours) were associated with burnout (Ekstedt et al., 2006; Söderström et al., 2012), while exhaustion in terms of severe accumulated fatigue is an important component of burnout (Demerouti et al., 2019; Ekstedt et al., 2006; Metlaine et al., 2018; Söderström et al., 2012).

Economic pressure, minimum margins and harsh competition motivate commercial air operators to maximize their productivity by using FTL as productivity goals and FRM to justify even more demanding rosters (Aljurf et al., 2018; Bourgeois-Bougrine, 2020; Coombes et al., 2020; Reis et al., 2016b). Resulting stress and allostatic (over)load was usually neglected so far. Therefore, the main aim of this research is to explore the following hypothesis, based on the variables described in Methods/Online Survey, Tables 2-3, Figures 1-4, and scale scores for psychosocial stress (PHQ-Stress), sleep problems (JSS), fatigue (FSS):

H.1: More psychosocial stress is associated with significantly more sleep problems and significantly higher fatigue.

Furthermore, it should be analyzed, if psychosocial stress and/or fatigue risks experienced on flight duty were significant predictors for sleep problems and/or fatigue, in addition to roster-related data, similar to Reis et al. (2016b).

H.2: More demanding rosters, and/or longer commuting times, and/or fewer hours of physical exercise, and/or more psychosocial stress, and/or more work-related stress (fewer flight hours on the present type of aircraft, lower job security) and/or higher age significantly predict more sleep problems.

H.3: More sleep problems, and/or more demanding rosters, and/or longer commuting times, and/or fewer hours of physical exercise, and/or more psychosocial stress, and/or more work-related stress (fewer flight hours on the present type of aircraft, lower job security) and/or higher age significantly predict higher fatigue levels.

Method

Design and Procedure

This study was part of an external PhD project at the Department of Psychology of the University of Bern, Switzerland. The second author is also supervisor of this PhD. Before project start, ethical approval no. 2018-05-00008 was granted by the Ethics Commission of the Philosophisch-Human-wissenschaftlichen Fakultät of the University of Bern. Written informed consent was not required because the data was collected with an anonymous online survey, where anonymity and confidentiality were guaranteed to all participants. The participating pilots did not receive any compensation.

This research analyzed data of active international pilots flying for commercial air operators. The data was collected with a cross-sectional online survey, which was programmed with Lemon Survey®. The survey included some time-bound questions and referred to the last three years or less. Pilot unions emailed the link to the online survey to their members included in newsletters. EASA based and Middle East based pilots answered the online survey from June 2018 to Oct. 2018, Australian pilots from Dec. 2018 until March 2019, during their peak flying seasons, and before the Covid-19 pandemic started.

The purpose of this independent research, data security, and protection of anonymity was explained at the beginning of the survey. Participants were informed they would need their duty rosters of the last two months to complete the survey, and that they could have a break any time or delete all data without consequences.

Subjects

1097 professional pilots started the online survey, 406 completed it within 38±18 minutes (M±SD). The inclusion criterion was being an active professional pilot working for a commercial air operator. The final sample consisted of 192 pilots from EASA based operators, 180 Australian, and 34 pilots flying for operators in other regions (e.g., Middle East, Turkey, Asia Pacific). Pilots' mean age was 40.93±10.62 years (M±SD), pilots reported on average 9'051±6'059 total flight hours (Table 1).

Table 1

Descriptive Statistics (Means (M) and Standard Deviations (SD) of the N=406 International Professional Pilots in this Research)

Category of Variable	Variable	M±SD
Roster-data	mean flight hours*	61,32±20,74
	mean duty hours*	112,05±37,41
	mean no. of sectors flown*	73,95±53,15
	mean standby days*	2,30±2,43
	mean rest days*	10,57±4,15
	mean vacation days*	2,49±4,09
	mean no. of early starts*	4,48±4,01
	mean no. of night flights*	4,31±5,60
Work related stress	flight hours on present type of aircraft	4005±3641
	Operator-stability & job-security	7,26±2,33
Psychosocial stress	PHQ-Stress	5,05±3,67
Commuting	Commuting time (one way, min.)	64,84±161,15
Recreation	mean hours of phys. Exercise*	13,91±10,82
Demographics: age,	Age	41,03±10,51
flight experience	total number of flight hours	9051±6059
Fatigue	**Fatigue severity (FSS)**	**4,50±1,00**
Sleep Problems	**Sleep problems (JSS)**	**2,05±1,19**

*Note: * Means of the last two months were used*
M=mean; SD=Standard Deviation

50.5% captains and 49.5% first officers participated, with no significant gender differences in rank between the 8% female and 92% male pilots [(df=2)=0.269, p=0.874]. Most pilots (55%) reported flying for network carriers, 30% for low-cost-carriers (LCC), 6% for cargo, and 9% for charter operators. 70% were flying short-and medium-haul (sectors up to 6 hours, multiple legs per FDP), 12.6% medium- and long-haul, 15.3% only long-haul (more than 6 hours per sector), and 1.2% ultra-long-range. 90.6% had an employment contract with their operator, the rest was employed by an intermediary manning-agency, was 'self-employed' or had a 'Pay-to-Fly' arrangement or no employment contract. 88% were full-time pilots with on average 4'005±3'641 flight hours experience on their present type of aircraft.

Description of the Online Survey

Pilots were asked to complete the survey on a rest day. Pilots reported sociodemographic information such as their age, gender, etc., which was not evaluated in this study. The survey was based on previous research (Aljurf et al., 2018; Reis et al., 2016a; Williamson & Friswell, 2017), to obtain comparable data. Pilots were asked for their commuting time, their longest duty time in the last three years. They were also asked for the longest time awake, when they had to go on flight duty during standby, from waking up until check-out from flight duty. Pilots should also report their days 'unfit to fly' due to fatigue and sickness of the last year. To estimate pilots' work-related stressors, they were asked for the following: (1) pilots' experience (flight hours) on their present type of aircraft, (2) perceived financial stability of their operator/employer, (3) perceived job security. Pilots should rate their agreement on a 6-point Likert-scale, *"I am flying for a financially stable operator."* and *"I feel high job-security for my present job/position."* The sum of both items was called 'job-security.' Pilots were also asked for sleep difficulties, sleep restrictions associated with flight duties, and fatigue risks experienced on flight duty (Figure 1). Furthermore, pilots were asked for micro-sleeps in the cockpit, fatigue related errors, incidents and accidents and pressure to use "Commander's Discretion" (Figure 2). Professional pilots' concerns regarding present FTL (Figure 3) and protection from fatigue (Figure 4) were also assessed. Pilots' psychosocial stress was measured with PHQ-Stress (Spitzer & Williams, 2005, items Appendix 2).

As recommended by Shahid et al. (2010), and in order to obtain results comparable to previous studies (Aljurf et al., 2018; Reis et al., 2013, 2016a), the Fatigue Severity Scale (FSS, Krupp et al., 1989) was used to measure fatigue (items of all used standard questionnaires in Appendix 2). Means (M), standard deviations (SD), published cut-off values, Cronbach's Alpha for reliability/internal consistency are presented in Table 2. Sleep problems were self-assessed with Jenkins Sleep Scale (JSS, Jenkins et al., 1988). All used scales had very good to satisfactory reliability in terms of internal consistency.

Table 2

Means (M), Standard Deviations (SD), Published Cut-off-values, Cronbach's Alpha for Reliability/Internal Consistency in This Research and in Previous Studies

Scale	**Cut-Off**	**M ±SD**	**Cronbach's Alpha** (this study)	**Cronbach's Alpha, Cut-Off Values** (previous research)
Fatigue severity Scale (FSS)	≥ 4 ≥ 5	4.57 ±1.00	0.82	0.93 (Valko et al., 2008) 0.88 (Lerdal et al., 2005)
Jenkins Sleep Scale (JSS)	≥ 3	2.19 ±1.24	0.85	0.84 (Reis et al., 2014)
Psychosocial stress (PHQ-Stress)		5.29 ±3.72	0.81	(Spitzer & Williams, 2005)

Pilots should report their roster-data of the last two months. We used the same limits and definitions (EASA FTL, 2014; Reis et al., 2016b) for early starts (05:00 a.m. to 06:59 a.m.), night-flights (including flight time from 11:00 p.m. to 06:29 a.m.), duty and flight hours, number of sectors, standby, rest and holidays, and hours of physical exercise (Table 1).

Statistical Evaluation

SPSS Version 27.0 (Statistical Package for Windows by SPSS Inc., Chicago, IL, USA) was used for the statistical analyses. Results with p-values < 0.05 were considered statistically significant. For sample description, χ^2-tests were used to compare categorical data. To explore the frequency of safety critical events in the cockpit or pilots' attitudes or perceptions, percentages of pilots' ratings were used (Figure 1-4). To compare results regarding sleep problems and fatigue severity, the published cut-off values were used, proportions of pilots with severe (FSS≥4) or high fatigue (FSS≥5) or considerable sleep problems (JSS≥3 or 4) were compared with previous studies.

To test H.1, one sided Pearson-Correlations were calculated. To test H.2 and H.3, Linear Multiple Regression Analysis with forward inclusion were calculated, because all entered variables were metric or interval scaled.

To test H.2., the dependent or criterion variable was sleep problems (JSS), potential predictors were numbers of duty and flight hours, number of flown sectors, standby, rest and vacation days, number of early starts, night flights, commuting times, hours of physical exercise, fatigue risks experienced on flight duty, psychosocial stress, and work-related stress in terms of flight hours on the present type of aircraft, job security and age.

To test H.3., the dependent or criterion variable was fatigue severity (FSS), potential predictors were sleep problems and all predictors used for the first Regression Analysis. It was of particular interest, if psychosocial or work-related stress and/or pilots' estimated fatigue risks experienced on flight duty would be significant predictors.

Collinearity Statistics for the predictors were calculated to check and exclude artefacts due to high intercorrelations of the independent variables. Instead of using the group variable short vs. long-haul, the number of sectors flown was used. For roster data and hours of physical exercise, the means of the last two months were used.

Results

Roster Data

The investigated pilots reported on average 61.32±20.74 flight hours and 112.05±37.41 duty hours per month (Table 1). Compared with legal FTL (Appendix 1), the pilots in this sample were rostered for on average 61.32% of the legally allowed flight hours per month and 56.25% to 60% of the allowed duty hours per month.

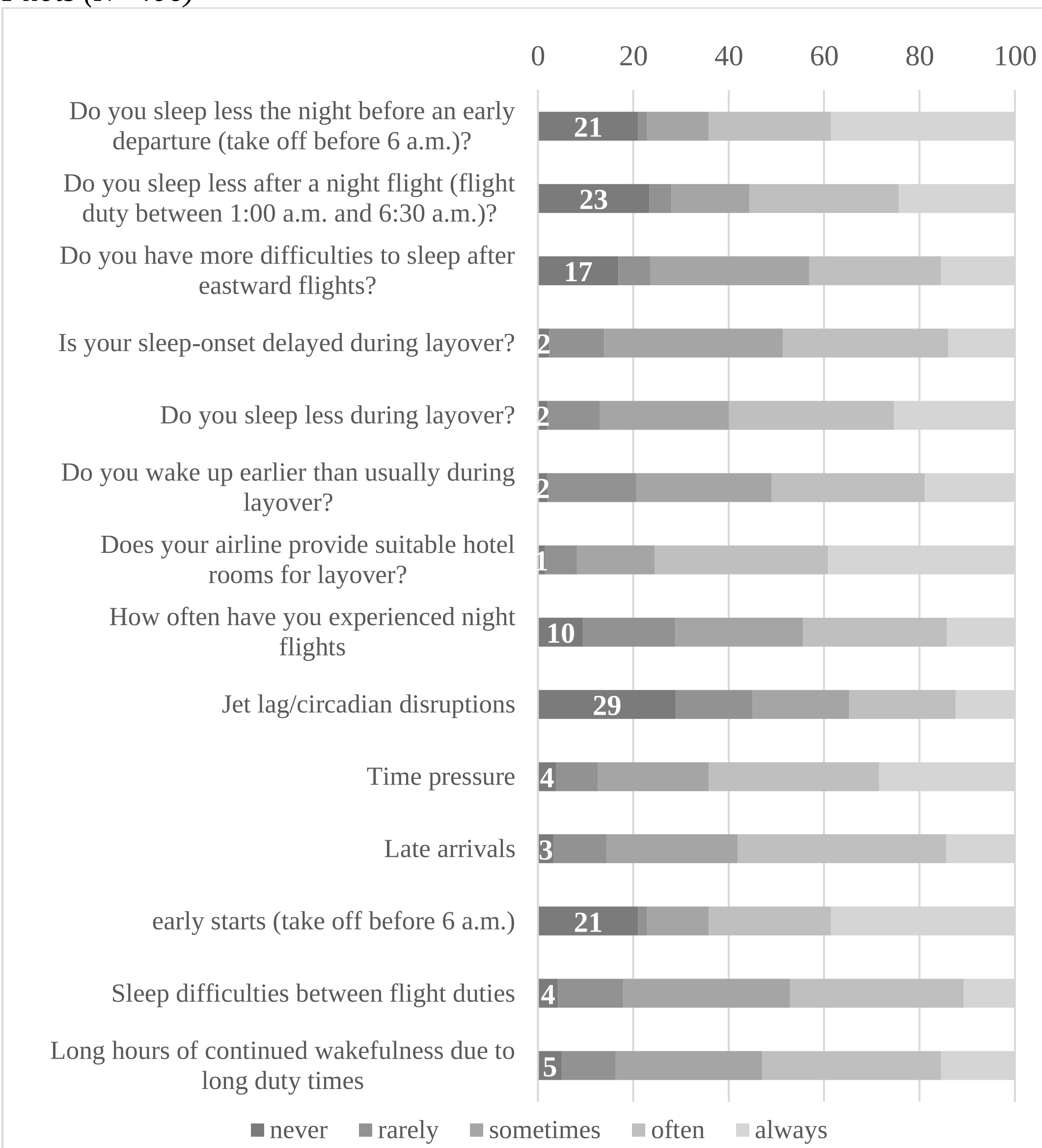
Fatigue Risks Associated with Flight Duties, Micro-Sleep in the Cockpit and Concerns regarding FTL

Most pilots reported considerable sleep restrictions and fatigue risks associated with flight duties (Figure 1). Pilots' longest flight duties lasted on average 14.78±2.48 hours, while their longest time awake until check-out from flight duty was 19.12±6.20 hours, when pilots had to go on duty on a standby day.

Nine out of ten pilots (90%) reported they had once or more often felt too tired to be on active duty (Figure 2). Three out of four (76%) pilots reported micro-sleeps in the cockpit or having fallen asleep without prior coordination. Involvement in fatigue related incidents or accidents was less frequent (Figure 2), while 92% reported fatigue related mistakes on flight duty in the last two years. Almost all pilots reported considerable concerns regarding the legal FTL (Figure 3). Most pilots (91%) reported they were concerned about the lack of regulatory oversight and in-depth inspection by regulators. Most of the pilots also reported considerable worries about minimum rest, maximum length of flight duties, legal duty hours per month, extended flight duties and the use of Commander's Discretion (Figure 3).

Figure 1

Fatigue Risks Associated with Flight Duties, Reported by Percentage (%) of Pilots (N=406)

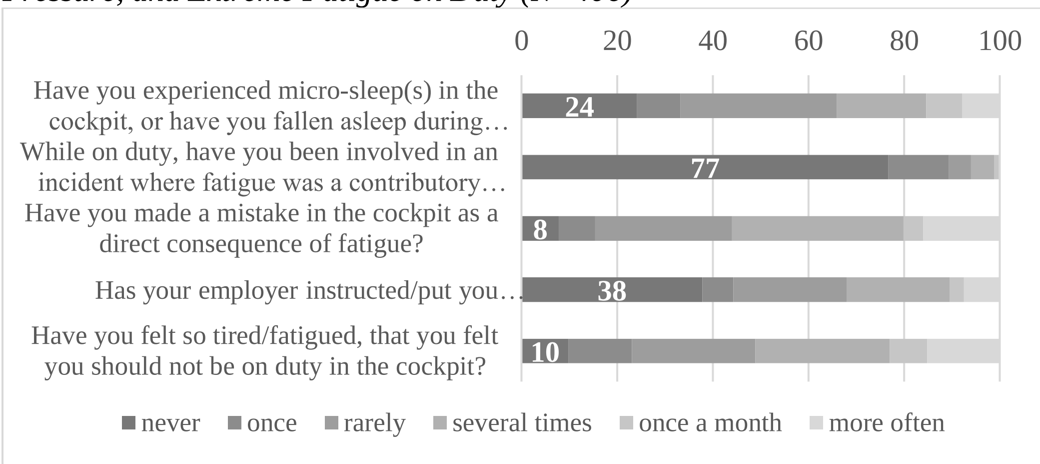


Note. Answer to the question: "Over the last two months, when you were on duty: How often did you experience …?" Percent of pilots answering 0=never, 1=rarely, 2=sometimes, 3=often, 4=always.

We asked pilots to indicate how good they would rate their protection against fatigue. Most pilots perceived minimum or no protection against fatigue by their employer/operator, regulator and FTL (Figure 4).

Figure 2

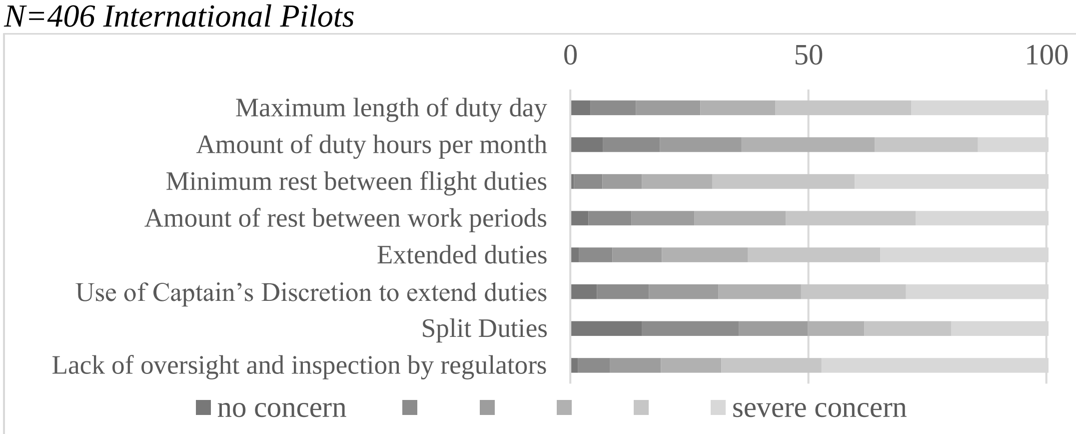
Frequency of Fatigue-Related Errors and Incidents, Micro Sleeps in the Cockpit, Pressure, and Extreme Fatigue on Duty (N=406)



Note. Answer to the question: "Over the last two years: How often have you experienced..." Percent of pilots answering 0 = never to 5 = more often.

Figure 3

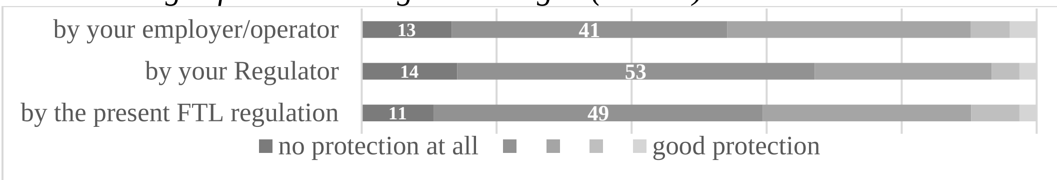
Professional Pilots Concerns and Worries Regarding FTL, Mean Ratings of N=406 International Pilots



Note. Answer to the question: "What worries you most about the current Flight Time Limitations?" 0=no concern, 5=severe concern.

Figure 4

Pilots' Ratings of Protection Against Fatigue (N=406)



Note. Answer to the question: "According to your personal opinion: How good is the protection of flight crew against fatigue …"

Pilots' Fatigue Levels and Sleep Problems

In this study, 42.6% pilots reported severe fatigue (FSS 4-4.9), 33.4% even high fatigue (FSS≥5), although these pilots were scheduled for only 56.2% to 61.25% of the legally allowed duty and flight hours per month (Appendix 1). Considerable sleep problems (JSS≥4) in 15 or more nights per month were reported by 9.4% pilots, 24.2% reported significant sleep problems in eight or more nights per month.

Intercorrelations of Stress, Fatigue and Sleep Problems

H.1 stated that more psychosocial stress would be associated with significantly more sleep problems and higher fatigue and was confirmed (Table 3). More sleep problems were associated with significantly higher fatigue levels.

Table 3

Pearson Correlations of Psychosocial Stress, Fatigue Risks Experienced on Flight Duty, Commuting Time, Fatigue, and Sleep Problems of International Pilots (N=406)

	Pearson Correlations				
	PHQ-Stress	FSS	JSS	Commute	Fatigue risks
Fatigue FSS	.311**				
Sleep problems JSS	.530**	.363**			
Commuting time	.088*	-.059	.100*		
Fatigue risks on flight duty	.361**	.341**	.460**	.087*	
Sleep restrictions	.286**	.221**	.436**	-.014	.406**

Note. **. Correlation is significant at the 0.01 level (1-tailed).
*. Correlation is significant at the 0.05 level (1-tailed).

Predictors of Sleep Problems

To test H.2, a Multiple Linear Regression Analysis with forward inclusion was calculated to investigate, which factors mentioned above would significantly predict the criterion (JSS). More psychosocial stress and more fatigue risks associated with flight duties significantly predicted more sleep problems and explained 37.3% of the variance (Table 4). H.2 was confirmed for psychosocial stress and fatigue risks on flight duty.

Table 4

Results of the Multiple Linear Regression Analysis for Sleep Problems (JSS)

Model Summary

R	R^2	**Adj. R^2**	Std. Err.
.614	,377	**0.373**	0.9391

Predictors: (Constant), PHQ-Stress, fatigue risks on flight duty

Coefficients

Model	Unstandardized Coefficients		Stand. Coeff.	**Sig.**	Collinearity Stat.	
		Std. Err.	**Beta**		Tolerance	VIF
(Const.)	0.101	0.184		**0.584**		
Stress	0.148	0.016	**0.444**	**0.000**	0.881	.13
Fatigue risks	0.088	0.014	**0.297**	**0.000**	0.881	1.13

Note. *Dependent variable: sleep problems (JSS). Independent variables: duty and flight hours, number of flown sectors, standby, vacation days, number of early starts, night-flights, fatigue risks on flight duty, commuting time, psychosocial and work-related stressors like less experience on the latest type of aircraft, monthly income and job security, age, and hours of physical exercise.*

Predictors of Fatigue

To test H.3, a second Multiple Linear Regression Analysis with forward inclusion was calculated to analyze, which independent variables significantly predicted fatigue severity (FSS, Table 5). More sleep problems, more fatigue risks associated with flight duties, more psychosocial stress, shorter commuting times, and fewer hours of physical exercise significantly predicted higher fatigue (FSS). H.3 was confirmed for the mentioned five significant predictors (Table 5).

Table 5

Results of the Multiple Linear Regression Analysis, Criterion Fatigue Severity (FSS)

Model Summary			
Model	R	R Square	**Adjusted R Square**
5	.451	0.204	**0.191**
Predictors: JSS, Fatigue Risks, Stress, commuting time, hours of phys. Exercise			

Coefficients						
Model	Unstandardized Coefficients		Stand. Coeff.	**Sig.**	Collinearity Statistics	
	B	Std. Error	**Beta**		Tolerance	VIF
(Constant)	.518	,196		**.000**		
Sleep problems	0.145	0,053	**0.173**	**.007**	.622	,608
Fatigue Risks	0.045	0,014	**0.182**	**.001**	.772	,295
Stress	0.049	0,017	**0.175**	**.004**	.686	,457
Commute	-0.001	0,001	**-0.103**	**.040**	.989	,011
phys. exercise	-0.009	0,005	**-0.102**	**.044**	.982	,018

Note. Dependent Variable: fatigue severity (FSS). Independent variables: duty and flight hours, number of flown sectors, standby, vacation days, number of early starts, night-flights, fatigue risks on flight duty, commuting time, psychosocial and work-related stressors like less experience on the latest type of aircraft, monthly income and job security, age, and hours of physical exercise.

Discussion

Fatigue and Sleep Problems

Severe fatigue was reported by 76% pilots, one out of three pilots (33.4%) even reported high fatigue (FSS≥5), although pilots were only rostered for 56.25% to 61.32% of the legally allowed flight and duty hours per month. Considerable sleep problems were less frequent than in previous research (Aljurf et al., 2018; Reis et al., 2016b). Most pilots reported sleep restrictions and other fatigue risks associated with flight duties, despite FTL, FRM, the use of BMM for safe and legal crew planning (Dawson et al., 2017; Dorrian et al., 2012), and mandatory fatigue reporting systems linked to FRM and SMS. Pilots' high fatigue levels were in line with previous research, which reported severe fatigue of 68.5% to 93% pilots (Aljurf et al., 2018; Reis et al., 2016a, 2016b).

Comparison of our Results with Previous Research

Reis et al. (2016b) conducted a similar study, analyzing how roster related data was related to fatigue (FSS) and sleep problems (JSS). In their regression analysis, significant predictors for sleep complaints were sleepiness, flight hours, and early starts (Reis et al., 2016b). These variables explained 15.5% of the variance of sleep problems (JSS). They did not measure psychosocial stress or perceived fatigue risks associated with flight duties, although both variables were highly significant in this research and explained 37.3% of the variance of the JSS score, as far as we could control, without artefacts (e.g., collinearity of predictors, Tolerance, VIF).

In line with previous research, psychosocial stress was associated with impaired sleep (Chen et al., 2014; Ekstedt et al., 2006; Kalmbach et al., 2020; McEwen, 2006; McEwen & Karatsoreos, 2015; Omholt et al., 2017; Sapolsky, 2004). Roster data like duty and flight hours, early starts, night flights, standby days etc., were not significant for sleep problems in this study when psychosocial stress and fatigue risks were analyzed simultaneously. Therefore, psychosocial stress, fatigue risks associated with flight duties should be integrated in future studies of pilots’ fatigue.

Reis et al. (2016b) also analyzed if roster-data, sleepiness, or sleep problems significantly predicted fatigue (FSS). Type of flight operations (short haul), night flights, sleepiness and sleep complaints were significant and explained 18% of the variance of FSS. In this study, five significant predictors explained 19.1% of the variance of fatigue (FSS): More sleep problems, more fatigue risks associated with flight duties, more psychosocial stress, shorter commuting times and fewer hours of physical exercise predicted higher fatigue (FSS).

Stress, Allostatic Load, Sleep Problems and Fatigue

Acute and chronic stress as well as prolonged sleep deprivation represent allostatic load, which is associated with complex psychophysiological adaptation processes, including higher levels of cortisol and shorter sleep (Bostock & Steptoe, 2013; McEwen, 2004, 2006; McEwen & Karatsoreos, 2015; Sapolsky, 2004). Insomnia is often triggered by major or existential stressors (Jansson & Linton, 2006; Kalmbach et al., 2020; Little et al., 1990; Sapolsky, 2004; Young, 2008; Zoccola et al., 2009), while pilots must cope with flight duty related sleep restrictions, economic uncertainty, time pressure and stressful high workload during descent and landing at the end of each flight. After arrival, aircrews must use their rest periods efficiently, while unwinding may be difficult and can also reduce available effective sleep time (Ekstedt et al., 2006; Zoccola et al., 2009).

Pilots' Stress, Health and Wellbeing

Work related stress can impair the biopsychosocial wellbeing of pilots (Cullen et al., 2020), while today the 'pilot's job itself' can be an inherent risk to pilots' health (Cahill et al., 2021). Early starting and late ending flight duties were associated with more stress, tiredness and lower happiness ratings (Bostock & Steptoe, 2013), in line with previous research (McClung, 2013; McEwen & Karatsoreos, 2015). Due to more psychophysiological stress and less sleep, early starts of flight duties were also associated with higher levels of cortisol, during waking hours, compared with late shifts or rest days (Bostock & Steptoe, 2013). While pilots' rosters and working conditions are associated with stress, sleep restrictions and sleep problems, these stressors represent a heavy burden or allostatic overload for humans. Even though most pilots reported regular hours of physical exercise, negative effects on pilots' health cannot be ruled out (Feijo et al., 2012; Venus & grosse Holtforth, 2021). Other studies reported high burnout levels among 32% (Fanjoy et al., 2010) to 40% active pilots (Demerouti et al., 2019).

Pilot Specific Stressors, 'Pilot Pushing' and Burnout

Regarding psychosocial stress, pilots were most worried about their health. Being healthy and having a valid Medical Class 1 certification is one precondition to work as a pilot (e.g. Part-MED, 2019), the other is having successfully passed the recurring skill checks in a Flight Simulator. When their Medical Class 1 is suspended, pilots are grounded until the responsible AME recertifies their health. In case of mental health issues like burnout, EASA based pilots often lose their Medical Class 1 for good.

In this study, 60% pilots felt under pressure to fly when they were fatigued, thus 'Pilot Pushing,' as described by Fanjoy et al. (2010), still exists: "In addition to actual exposure to stressors, a perception of risk may also increase burnout." (Fanjoy et al., 2010, p. 19). Pilots can make a subjective assessment of the risk of injury, accompanied by the emotional, affective reaction, which can be expressed as well-founded concerns:

> Pilot pushing' is the pressure that pilots face from management to keep airplanes in the air as much as possible by agreeing to fly legs with critical equipment problems, in severe weather, with reduced fuel requirements, or in a state of fatigue. Pilot pushing may result in chronic stress that has a significant impact on many health outcomes. (Fanjoy et al., 2010, p. 19)

Fatigue and Micro-Sleep in the Cockpit

High fatigue in the cockpit represents a significant risk for passengers' and aircrews' safety (Bandeira et al., 2018; Bendak & Rashid, 2020; Bourgeois-Bougrine, 2020; Goode, 2003; Hartzler, 2014). More pilots reported severe or high fatigue compared with the general population (Lerdal et al., 2005), healthy individuals or patients with chronic diseases (Valko et al., 2008). The high fatigue levels correspond with previous research (Aljurf et al., 2018; Reis et al., 2016a; Venus & grosse Holtforth, 2021), while no peer-reviewed studies have found lower levels of fatigue.

Involuntary, uncoordinated micro-sleeps in the cockpit are visible, valid manifestations of high sleepiness or fatigue on the flight deck. In this study, 76% pilots reported micro-sleep events, compared with lower rates in previous research (Aljurf et al., 2018; Williamson & Friswell, 2017). Coombes et al. (2020) reported frequent micro-sleep events in the cockpit. Pilots affected by accumulated fatigue may still experience low levels of fatigue when rested. They can also tire more quickly and report higher levels of fatigue and sleepiness on duty, although they may not be fully aware of their actual fatigue level (Hartzler, 2014; Oken et al., 2006). In line with allostasis theory, fatigue related health impairment must also be considered in times when most pilots report severe or even high fatigue.

Limitations

Representativity of the Sample

1097 international pilots participated in this research, 406 answered all questions, while an unknown number started the survey and deleted all answers. The link to the online survey was disseminated by pilot unions, included in newsletters, therefore we do not know how many pilots saw the link and answered. This way, confidentiality could be guaranteed.

Some obstacles likely made participation difficult: Pilots' sleep problems, fatigue, exhaustion, and burnout are often disqualifying for pilots, jeopardizing their Medical Class 1, and career. We know that the participating pilots were scheduled for on average only 56.25% to 61.32% of the legally allowed duty and flight hours per month. From this data we can conclude that pilots scheduled for the maximum legal 100 flight hours and 190 to 200 duty hours per month did not participate in this research.

Pilots had to have their own duty rosters of the last two months at hand, which may have been another potential hurdle. We intended to cover pilots' peak season with maximum rostered duty and flight hours, while more pilots would likely have participated off season.

The representativity of this sample can hardly be checked. International pilots of different operators and diverse types of operation participated. Since this research was not funded, it was impossible to select a random sample and compare the demographics and results of both pilot samples.

Methodical Limitations

Results of questionnaires can be questioned due to bias on purpose or by chance. Ultra-high resolution 24-hour HRV measurement with an integrated actimeter would be a more reliable, valid, and user-friendly method to measure quality and quantity of obtained sleep, stress and arousal during night and day, as well as fatigue and recovery over several days and nights, completed by activity protocols and psychological assessments.

Results of regression analyses indicate significant correlations between predictors and criterion variables, while causality cannot be determined.

Strengths

This cross-sectional research assessed more variables than previous research: Actual individual rosters, psychosocial and work-related stressors like experience on the present type of aircraft, perceived financial operator stability and job security, commuting time, hours of physical exercise, etc. were measured. Pilots' sleep restrictions and other fatigue risks experienced on flight duty were assessed, in addition to their individual schedules.

Pilots' concerns about FTL and perceived protection against fatigue were measured in this study. Going further than most previous research, psychosocial and work-related stress was measured and integrated in complex analyses. Fatigue levels and sleep problems were assessed with established screening instruments to obtain data comparable with previous research.

The results of this study correspond very closely with known effects of acute and chronic stress, theory of allostatic load and overload, and how these mechanisms relate to sleep problems and fatigue. It could be pointed out, that not only sleep problems and roster variables related to fatigue, but that stress and perceived fatigue risks associated with flight duties were strong predictors for sleep problems, and also relevant for fatigue, in line with the theory of allostatic load (McEwen, 2004, 2006; McEwen & Karatsoreos, 2015; McEwen & Stellar, 1993; Sapolsky, 2004).

Research Implications

Future research should investigate why previous research consistently reported high levels of fatigue among pilots, despite flight time limitations, Fatigue Risk Management, and Biomathematical Models.

More valid and reliable psychophysiological measures for fatigue vs. alertness/sleepiness should be evaluated.

We need to know more about the development of accumulated fatigue, underlying sleep restrictions and/or sleep problems, and lack of recovery to provide a solid psychophysiological model for the complex interactions of the mentioned variables and other individual factors like type of operation and operator, route-specifics like direction of flight, circadian type etc.

In addition, stress, and allostatic load of short-haul operations due to frequent early starts should be considered as particular fatigue risks, which should be mitigated like long-haul pilots' fatigue risks, which are more obvious (crossing time zones, layovers in different time zones causing circadian disruptions, etc.). Mitigation could mean fewer early starts per month and even shorter maximum duty hours after early starts than are legal now. Additional availability of rest facilities close to airports, not only at home-base, would be recommended.

Future research should differentiate between alertness/sleepiness and accumulated fatigue. Fatigue in terms of strain, tiredness or exhaustion is neither a physical nor a mental disorder, but a psychophysiological indicator that a person's functioning in different areas of life might be impaired (Shahid et al., 2010). Shahid et al. (2010) define sleepiness and fatigue as different constructs, requiring different methods for assessment and treatment. Sleepiness is one symptom of fatigue, while the term 'fatigue' describes significant exhaustion as middle and long-term effect of long legal working hours, irregular shift work, lack of sleep and exhaustion, which can result in burnout (Demerouti et al., 2019; Ekstedt et al., 2006; Fanjoy et al., 2010). Fatigue is more than acute sleepiness and refers to impairment of workability, everyday life and motivation to accomplish private and professional obligations (Shahid et al., 2010). Homeostatic sleep-drive due to long time awake, sleep problems, restricted sleep, and circadian sleep-drive (Zeeuw et al., 2018) especially during the WOCL usually lead to sleepiness and reduced alertness on flight duty or other types of shift work (Hartzler, 2014; Shahid et al., 2010).

Even if only 'on duty sleepiness' is of interest to regulators and airlines, the underlying accumulated fatigue must be considered as a relevant 'pre-existing condition' for critical to extreme on-duty sleepiness. Accumulated fatigue can contribute to the fact that aircrews tire more quickly, experience greater sleepiness, and start work with a basic level of significant fatigue, comparable with widespread burnout among pilots (Demerouti et al., 2019; Fanjoy et al., 2010). Accumulated sleep debt (lack of sleep for a longer period) and accumulated fatigue usually cannot be recovered over normal rest times (ICAO, 2015a), but may be less severe than burnout.

Causal relationships must be investigated, for example which working conditions cause an allostatic overload and cannot be remedied in the short term. Future research should investigate, if legal rosters, psychosocial stress, sleep problems and fatigue can affect professional pilots' mental health and well-being. Furthermore, effective burnout prevention and burnout treatment for professional pilots should be developed. Future research should also find ways, how Fitness to Fly can be maintained or regained.

For this purpose, new and especially objective measures and tests should be developed for healthy subjects like pilots. In reliable and valid measures of fatigue, sleepiness is one symptom, but does not represent the complex construct of (accumulated) fatigue. In addition to fatigue related performance decrements, potential medium and long-term health impairment like burnout must be considered.

Sleepiness and fatigue should be defined and treated as different constructs, relations of accumulated fatigue and burnout should be investigated. Distinct definitions and differential diagnostic criterions should be defined to advance research on pilots' fatigue and burnout, and how pilots' sleep and fatigue relates to pilots' mental health and wellbeing.

Conclusions

Severe fatigue was reported by 76% of the investigated pilots, 33.4% reported high fatigue, although pilots were only scheduled for 56% to 62 % of the maximum legal duty and flight hours. Every fourth pilot (24.2%) reported considerable sleep problems. Psychosocial stress and fatigue risks associated with flight duties were significant predictors for sleep problems and fatigue. Higher fatigue levels were predicted by more sleep problems, more psychosocial stress, more fatigue risks, and less physical exercise. The accumulation of sleep restrictions and other fatigue risks were strongly associated with pilots' individual rosters. More duty and flight hours were related to less available leisure time for recovery and are likely to enhance psychosocial stress.

Previous research and this study consistently reported unwelcome high levels of fatigue in most pilots, and no studies reported otherwise. Acute and chronic work related and psychosocial stress, allostatic load and associated significant health risks must be included in future fatigue research. Pilots' fatigue and associated health and safety risks must be taken seriously. Improvement of FTL, critical review of Fatigue Risk Management and Biomathematical Models should be the most promising approaches to prevent high levels of fatigue and associated health impairment of professional pilots.

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Appendices

Appendix 1

Overview over the most basic FTL rules of EASA and CASA, relevant for 91% of the investigated pilots in this research, in effect at the time of data collection from June 2018 until March 2019. All definitions from EASA FTL (2014, p. 21 f.). For comparison FAA FTL.

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
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 consec. months	1000 flight hours	1000 flight hours	
Minimum rest‡	Before flight duty	10 hours (exceptions)	10 hours (exceptions)	10 hours

FDP: flight duty period

* *"Duty period" [duty hours] means a period which starts when a crew member is required by an operator to report for or to commence a duty and ends when that person is free of all duties, including post-flight duty;*

† *"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 crew member is free of all duties, standby and reserve;*

Appendix 2:

Items of all used standard questionnaires: PHQ-Stress (Spitzer & Williams, 2005), Jenkins Sleep Scale (Jenkins et al., 1988), Fatigue severity Scale (Krupp et al., 1989)

Patient Health Questionnaire (PHQ) Stress to measure psychosocial 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 about problems 9. Something bad that happened recently 10. Thoughts of scary events of the past or dreams about them *0=not at all; 1=A little affected; 2=Severely impaired*	**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. *1=I strongly disagree; 7=I strongly agree*
JSS Jenkins Sleep Scale (Quality of Sleep) 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? *0=never; 1=1 to 3 days, 2=4 to 7 days; 3=8 to 14 days; 4=15 to 21 days; 5=22 to 31 days*	