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Interactions of International Pilots' Stress, Fatigue, Symptoms of Depression, Anxiety, Common Mental Disorders and Wellbeing

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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 pilot network who supported this research with valuable insights, explanations, check reading and professional support.

Professional pilots' workplace is most of the time several kilometers above ground in an environment, which is hostile to life. On the flight deck pilots manage complex, cutting-edge technology in the high-risk, high-reliability system called aviation. In the 1980s, professional pilots were rostered for on average 46 flight hours/month (Sloan & Cooper, 1986). Today, flight time limitations (FTL) allow up to 100 flight hours/month (examples Table A.1, Appendix), and pilots' fatigue has become a problem for flight safety. In this study, we generally refer to *professional* pilots, not private or glider pilots. Consistent with Shahid et. al (2010) and the International Classification of Diseases (ICD-10) we differentiate between *sleepiness* and *fatigue,* and typically refer to more accumulated fatigue.

FTLs and Fatigue Risk Management should prevent severe fatigue in aircrews, and originally focused on long-haul operations with frequent circadian disruptions and night flights. ICAO 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. (2015)

Commission Regulation (EU) 2018/1042 states that pilots must not be on flight duty when not fit to fly because of injury, fatigue, sickness, etc., and explicitly links fatigue, health, and flight safety (Part-MED, 2019). In the past decades, pilots' fatigue was recognized as a relevant risk for flight safety and the pilots' performance (Bandeira et al., 2018; Bendak & Rashid, 2020; Bourgeois-Bougrine, 2020; Coombes et al., 2020; Goode, 2003; Hartzler, 2014).

Short haul pilots' sleep and rest-times are often restricted by irregular, long shifts, multiple sectors (i.e. take-offs and landings) per flight duty, early starts, and minimum rest times (Honn et al., 2016; Jackson & Earl, 2006; Roach et al., 2012; Vejvoda et al., 2014; Venus & grosse Holtforth, 2021b). Long-haul pilots have to deal with circadian disruptions, more night flights and inconsistent roster patterns on trans-meridian flights (Bourgeois-Bougrine et al., 2003; Reis et al., 2016a; Venus & grosse Holtforth, 2021b). Long flight duty periods (FDPs), short recovery times and insufficient on-board rest significantly increased problematic fatigue (Bendak & Rashid, 2020; Williamson & Friswell, 2017).

Workload, Stress, Fatigue, Mental Health and Wellbeing

A recent study reported highly significant correlations between psychosocial stress, sleep problems and fatigue, in line with the theory of allostasis. Fatigue risks caused by flight duties exacerbated stress, sleep problems and fatigue (Venus & grosse Holtforth, 2021a). Other studies have investigated work-related stress and pilots' wellbeing (Cahill et al., 2021; Cullen et al., 2020) or mental health (O'Hagan et al., 2017; Venus & grosse Holtforth, 2021b, 2022; Widyahening, 2007). Pilots' work-related stress was linked to more subjective health ailments such as difficulty sleeping and fatigue (Omholt et al., 2017; Venus & grosse Holtforth, 2021a). McClung (2013) reported how the circadian rhythms can affect or impair mood. Other studies reported that excessive flight times and fatigue could impair pilots' mental health and mood (Feijo et al., 2012; O'Hagan et al., 2017, 2019; Sloan & Cooper, 1986). High burnout levels were reported by 32.6% US-based regional pilots (Fanjoy et al., 2010) and 40% of the investigated European pilots, 20% of whom had similar values as inpatients in treatment for burnout (Demerouti et al., 2019). Burnout was strongly associated with sleep problems, insomnia and fatigue (Armon et al., 2008; Ekstedt et al., 2006; Söderström et al., 2012).

For a better understanding of the empirically supported relationships and interactions between chronic stress, sleep, fatigue, physical, and mental health, the theory of allostasis is briefly explained in the next section.

Homeostasis, Stress, Allostasis and Allostatic Load

The human body generally strives for homeostasis to be healthy and productive. Homeostasis is an ideal, life-sustaining balance, achieved through the successful interaction of physiological systems (McEwen, 2004; McEwen & Karatsoreos, 2015). The brain monitors the external and internal environment and controls physiological processes to regain homeostasis and keep us alive. All body functions (like regenerative sleep, body temperature, oxygen levels, etc.) are controlled by the brain. When stability is obtained through interactive adaptation, this interactive process is called ‘allostasis’ (McEwen, 2006, 2008; McEwen & Karatsoreos, 2015). Stressors constitute a real or perceived threat to homeostasis, and require physical activity or physiological processes to restore homeostasis (McEwen & Stellar, 1993). Table 1 below presents a short overview over different types of stressors, as described in previous research (Chen et al., 2014; McEwen, 2004, 2006; McEwen & Karatsoreos, 2015; Sapolsky, 2004; Venus & grosse Holtforth, 2021a).

Stress and Sleep

High acute and chronic stress can impair quality and quantity of sleep, and thus affect fatigue levels of pilots (Chen et al., 2014; McEwen, 2006; McEwen & Karatsoreos, 2015; Sapolsky, 2004; Venus & grosse Holtforth, 2021a). “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).

Sleep is essential for performance, health, and homeostasis. “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). Pilots' sleep difficulties are due to the fact that they have to sleep irregularly during the day, and/or in their “wake maintenance zone” before early starts (Zeeuw et al., 2018). Having to work during the ‘window of circadian low’ (WOCL) seems to significantly enhance fatigue (Åkerstedt et al., 2021; Coombes et al., 2020; Lamp et al., 2019).

Stress Hormones, Allostatic (Over)Load, Sleep and Health

Cortisol is a stress hormone, triggered by chronic and/or perceived uncontrollable stress. To get their organism going, healthy people have the highest cortisol level on average one hour before awakening, so that they can get up without fainting (Sapolsky, 2004). One symptom of allostatic (over)load after chronic stress are higher cortisol levels in the evening, which were also reported for patients with major depression (McEwen & Karatsoreos, 2015). Significant acute or chronic stressors can trigger high cortisol levels in the evening, which often prevent long and good sleep due to long sleep latency and short total sleep time (Chen et al., 2014).

Table 1
Overview Over Different Types of Stressors and Examples of Stressors Especially Relevant for Pilots (Venus & grosse Holtforth, 2022)

Type of Stressor	**Psychophysiological Stress Reactions**

Physiological stressors	• physical or mental effort, exertion
	• extreme temperatures
	• hunger, thirst
	• accident, trauma,
	• infection, inflammation”
	• sleep problems, insomnia
	• sleep restrictions
	  ○ roster-related
	  ○ due to irregular shift work
	  ○ due to frequently crossing time zones

Psychological Stressors	• realistic fear of a plane crash due to high fatigue • anxiety • (fear of) social defeat, humiliation • disappointment
Psychosocial stressors	• health concerns (burnout, mental health issues) • partnership problems • childcare stress • financial problems • having no one to talk, etc.

Work-related stressors	• little experience in a cutting-edge cockpit (e.g., after type-rating)
	• workplace conflicts (like investigation into pilots’ private lives after fatigue reports, blaming pilots for their own fatigue)
	• time pressure due to
	  ○ economic pressure,
	  ○ minimum rest and minimum turnaround times
	  ○ long flight duties in busy airspace, starting and ending at congested airports

Existential or chronic work-related stressors	• operators’ impending bankruptcy or mergers (in the last years, e.g., Flybe, SunExpress, LATAM, Thomas Cook, Air Berlin, etc.) • job insecurity due to atypical contracts (e.g., pay to fly, fake self-employment) • ‘Pilot Pushing’ • responsibility for hundreds of passengers and crew during flight operations
Immediate threats to life/flight safety	• pilot blinded by laser pointer on short final • drone encounters minutes or seconds before touch-down • both pilots nodding off at the controls / in the cockpit • flying overhead active war zones (e.g., Syria, Ukraine, …)

Stress and allostatic (over)load can also impair human immune reactions on various levels. Some immune reactions are suppressed, others overshoot, leading to a higher risk for cancer or weak defense against viral infections (McEwen & Stellar, 1993; Sapolsky, 2004). It is noteworthy in this context that pilots are almost six times more likely to develop kidney disease and almost 50 times more likely to develop melanoma skin cancer (Sykes et al., 2012). Other manifestations of allostatic (over)load are “atherosclerosis, obesity, bone demineralization, and atrophy of nerve cells in the brain. Many of these processes are seen in major depressive illness and may be expressed also in other chronic anxiety disorders” (McEwen, 2004, p. 1). Depression and anxiety symptoms have been associated with chronic stress and allostatic overload, frequent and severe sleep problems and fatigue are inherent symptoms of depression and other mental health problems (McClung, 2013; McEwen, 2006, 2008; McEwen & Karatsoreos, 2015; Sapolsky, 2004). “Nearly all people suffering from mood disorders have significant disruptions in circadian rhythms and the sleep/wake cycle. In fact, altered sleep patterns are one of the major diagnostic criteria for these disorders” (McClung, 2013, p. 242). Bostock and Steptoe (2013) investigated how flight duties of short-haul pilots starting early and/or late were related to perceived stress, salivary cortisol levels, mood, and fatigue. Early starts were associated with less sleep. In context with early and late flight duties, pilots reported more stress, more fatigue and more impaired mood (Bostock & Steptoe, 2013). Also, Aljurf et al. (2018) reported more abnormal depression and anxiety symptoms for severely fatigued pilots.

Lack of sleep, sleep problems and the associated drowsiness can be compensated for by getting more sleep (Hartzler, 2014). Cumulative sleep debt (EASA FTL, 2014; ICAO, 2015) following total or partial sleep deprivation over a longer period of time and accumulated fatigue usually cannot be compensated by normal rest periods (Hartzler, 2014), but are usually less severe than burnout (Demerouti et al., 2019; Fanjoy et al., 2010).

High Fatigue Levels and Micro-Sleeps in the Cockpit

If accumulated sleep debts (ICAO, 2015) are not offset by adequate sleep, sleep deprivation can impair cognitive, sensory abilities and behavior of pilots (Chen et al., 2014; Hartzler, 2014; McEwen, 2006; McEwen & Karatsoreos, 2015). “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).

Hartzler (2014) also reported fatigue-related performance impairments of divided attention, short term memory, concentration, deteriorated psychomotor and visual performance. While these multimodal performance impairments are not easy to measure on flight duty, micro-sleeps in the cockpit could be considered as valid manifestations of very high sleepiness and fatigue at the controls. Incapacitations due to fatigue can be equally severe as sudden medical incapacitations (like heart attack, cardiac arrhythmias or stroke), especially during micro-sleep events (Coombes et al., 2020). 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)

Situational awareness (SA) is essential for flight safety (Bendak & Rashid, 2020; O'Hagan et al., 2019), but SA immediately disappears when a pilot nods off or falls asleep. As soon as the pilot wakes up again, he will probably startle and need some time for re-orientation at the controls, being 'behind the plane' for some minutes (Venus & grosse Holtforth, 2021a, 2021b). If both pilots accidentally nod off at the same time, redundancy in favor of flight safety is vanished (Coombes et al., 2020; ICAO, 2018). Coombes et al. (2020) reported 1.1 cases per 2,000 flight hours in which both pilots had fallen asleep because of extreme sleepiness. Almost every second pilot (45%) reported unintentional microsleeps in the cockpit (Aljurf et al., 2018; Williamson & Friswell, 2017). Two of three pilots had reported fatigue-related errors, and 20% had fallen asleep on the flight deck without prior coordination (Williamson & Friswell, 2017).

Flight Time Limitations and Economic Pressure

Due to the risks associated with flight operations, complex rules and regulations were developed to ensure the highest possible levels of aviation safety . Regulators like EASA, FAA or CASA define safety standards and regulations for their member states. Pilots' objective workload has increased significantly in the last decades. Long duty hours, more responsibilities (e.g. fuel saving, commander's discretion) can lead to more stress, fatigue and burnout of pilots (Demerouti et al., 2019; Fanjoy et al., 2010) and can impair flight safety and safety culture (Bandeira et al., 2018; Bendak & Rashid, 2020; Bourgeois-Bougrine, 2020; Goode, 2003). Nevertheless, the 'Chicago-Convention' is still in force and defines the universal responsibilities of pilots for flight safety on every flight (ICAO, 2018). 'Pilot Pushing' refers to the implicit pressure on pilots to use airplanes as effectively as possible for maximum productivity. Examples for 'Pilot Pushing' are, e.g., the pressure to fly as many sectors as possible despite technical issues with the aircraft, threatening weather conditions, or high levels of pilot fatigue on flight duty. 'Pilot Pushing' could play an important role for accumulated fatigue and burnout (Demerouti et al., 2019; Fanjoy et al., 2010), as well as for flight safety (Bandeira et al., 2018; Bendak & Rashid, 2020; Bourgeois-Bougrine, 2020; Goode, 2003).

Research Questions

Several authors argue that fatigue prevention through FTL and Fatigue Risk Management (FRM) could probably not avoid high fatigue levels in active pilots (e.g., Aljurf et al., 2018; Reis et al., 2013, 2016a, 2016b). Although high levels of pilots' fatigue represent a significant safety risk during flight operations (Aljurf et al., 2018; Coombes et al., 2020; Goode, 2003; Reis et al., 2013, 2016a; Williamson & Friswell, 2017), severe fatigue (FSS $\geq$4) was reported by 68.3% up to 93% of the investigated pilots (Aljurf et al., 2018; Reis et al., 2016b; Venus & grosse Holtforth, 2021a, 2021b). In comparison, smaller proportions of the general or healthy population reported severe fatigue in FSS validation studies (Krupp et al., 1989; Lerdal et al., 2005; Valko et al., 2008).

Pilots' Fatigue and Mental Health

High qualification requirements for pilots, high cognitive and social demands associated with everyday work in the cockpit (Bourgeois-Bougrine, 2020; Demerouti et al., 2019; Fanjoy et al., 2010), and the medical requirements for flight crew licensing (Part-MED, 2011; Part-MED, 2019) could be associated with particular resilience of pilots, fewer mental health issues, as well as less comorbidities of mental and physical disorders (Krieger et al., 2014; Kroenke et al., 2009; Spitzer et al., 2006). Nevertheless, due to high workload (Feijo et al., 2012; Honn et al., 2016) and high levels of fatigue (Aljurf et al., 2018; Reis et al., 2016a; Venus & grosse Holtforth, 2021a, 2021b), it is likely that there are some mental-health issues to be observed among pilots. Feijo et al. (2012) examined the effects of workload and physical activity on pilots' symptoms of common mental disorders (CMD), without measuring fatigue. Common mental disorders CMD represent often stress related symptoms of physical impairment, which are not yet pathologic (e.g., headache, feeling nervous, and impaired mood) and can pertain to difficulties in concentration, decision-making, irritability, etc. Symptoms of CMD can be influenced by living conditions and occupational stress, and they can be transitory or long lasting (Beusenberg et al., 1994; Feijo et al., 2012). While 23.7% pilots with heavy workload reported eight or more symptoms of CMD, only 6.3% pilots with moderate and 3.3% pilots with light workload did so (Feijo et al., 2012).

Pilots' high workload and more duty hours were associated with more depression and anxiety symptoms (O'Hagan et al., 2017, 2019). . Other studies reported high levels of burnout among active pilots (Demerouti et al., 2019; Fanjoy et al., 2010). Recent research reported positive depression screening results for 13.4% (Wu et al., 2016), 16% (Cahill et al., 2021) to 34.5% (Aljurf et al., 2018) of the active pilots, while the general population reported lower rates (8.6%) of positive depression screenings (Kroenke et al., 2009).

This study examines, which percentage of pilots reports impaired well-being (WHO5<50), and/or significant symptoms of depression (PHQ8≥10) and/or anxiety (GAD7≥10), and/or common mental disorders (SRQ20≥8) according to the published cut-off values (Aljurf et al., 2018; Beusenberg et al., 1994; Feijo et al., 2012; Krieger et al., 2014; Kroenke et al., 2009; Reis et al., 2016b; Spitzer et al., 2006). Significant anxiety symptoms, measured with the Hospital Depression and Anxiety Scale (HADS), were reported by 40.2% of Middle East based professional pilots (Aljurf et al., 2018), while only 1.6% to 5% of the general populations reported GAD7≥10 (Spitzer et al., 2006). According to Gao et al. (2014) approximately 35% of employees reported low well-being (WHO5<50). Cahill et al. (2021) showed that the well-being of most pilots was significantly impaired. Population-based studies in industrialized countries have reported significant symptoms of CMD for on average 17% of the general population (Goldberg & P., 1992). Therefore, the following hypothesis shall be tested:

H.1 Compared with the general population, more pilots report
a) impaired well-being and/or
b) positive depression screening results and/or
c) positive anxiety screening results and/or
d) more symptoms of common mental disorders (CMD).

Is the Theory of Allostasis Applicable to Pilots ?

In line with the theory of allostasis, previous research found that pilots' higher fatigue levels were associated with more psychosocial stress, more sleep problems and fatigue risks like circadian disruptions or sleep restrictions due to early or late flight duties (Reis et al., 2016b; Venus & grosse Holtforth, 2021a, 2021b). Also corresponding with the allostasis theory (Chen et al., 2014; McEwen, 2006; McEwen & Karatsoreos, 2015), severely fatigued pilots reported more abnormal depression and anxiety symptoms compared with not fatigued pilots (Aljurf et al., 2018), in line with similar studies (O'Hagan et al., 2017, 2018, 2019).

Over the past few years, several studies have reported high levels of pilot fatigue (Aljurf et al., 2018; Bourgeois-Bougrine et al., 2003; Reis et al., 2013, 2016a; Venus & grosse Holtforth, 2021a, 2021b, 2022). Deteriorating working conditions of airline pilots were associated with more stress and impaired wellbeing (Cahill et al., 2021; Cullen et al., 2020; Sloan & Cooper, 1986; Widyahening, 2007). Pilots' heavy workload in terms of flight hours was associated with more symptoms of CMD (Feijo et al., 2012). .

This study investigates, whether the theory of allostasis (as described above) can also be applied to pilots. By this, this study will extend previous research and investigate, if allostatic (over)load in terms of acute and chronic stress, sleep problems (as a consequence of stress and as stressor or allostatic load itself), and fatigue (as reaction to allostatic overload and form of wear and tear) will be associated with significantly more symptoms of CMD, depression, anxiety, and more impaired wellbeing (other wear and tear symptoms or consequences of allostatic overload) (Chen et al., 2014; McEwen, 2004, 2006; McEwen & Karatsoreos, 2015; McEwen & Stellar, 1993; Sapolsky, 2004). The following hypothesis will be tested:

H.2 Higher levels of psychosocial stress are significantly associated with
a) more sleep problems, and higher fatigue, and/or
b) more impaired wellbeing, and/or
c) more depression symptoms and/or
d) more anxiety symptoms, and/or
e) more symptoms of CMD.

Method

Design and Procedure

This study was carried out as part of an external dissertation at the Institute for Psychology of the University of Bern. The second author is supervisor of this PhD. Before starting this investigation, the Ethical Approval No. 2018-05-00008 was granted by the Ethics Commission of the Philosophisch Human-wissenschaftlichen Fakultaet of the University of Bern, Switzerland. The online survey used similar questionnaires like previous studies, to obtain comparable data (Aljurf et al., 2018; Reis et al., 2016a; Wu et al., 2016). Pilots reported their age, gender, and other sociodemographic data. Pilots were instructed not to complete the survey on a day with flight duties, and to have their roster data of the last two months at hand. We expected that the rosters of the last two month would affect pilots’ perceived stress, sleep problems, fatigue, mental health, and wellbeing. We used established limits and definitions for duty and flight hours, early starts and night flights (EASA FTL, 2014). The reported rosters are described in Table 4.

Pilots’ fatigue was self-assessed with the nine items of the Fatigue Severity Scale (Krupp et al., 1989). FSS had good internal consistency in validation studies (Lerdal et al., 2005; Valko et al., 2008). Its reliability was lower for the sample of international pilots in this research (Table 2, Figure 1).

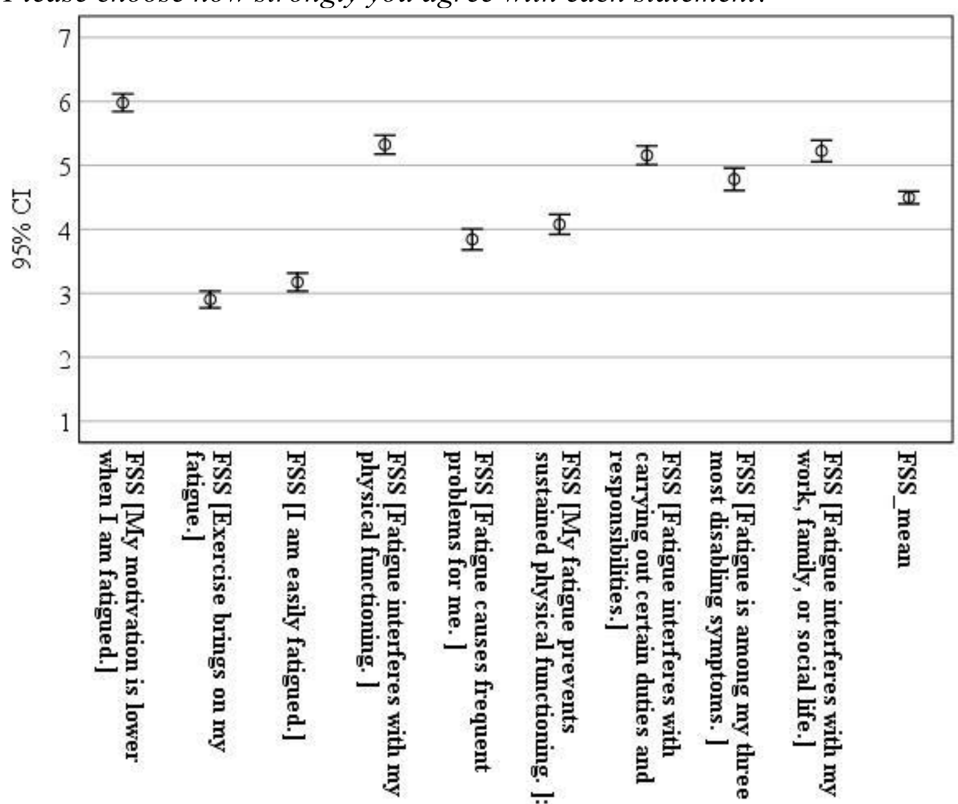
Table 2

Scale Means (M), Standard Deviations (SD) and Cronbach's Alpha for Internal Consistency in this Research (N=406 International Pilots) and in Former Studies

Scale	Mean±SD*	Cron-bach's Alpha	Cronbach's Alpha (previous research)
Wellbeing Index WHO5	54.4 ± 20	0.89	0.83 to 0.95 (Krieger et al., 2014)
Common mental disorders SRQ20	4 ± 4.1	0.87	0.81 (Beusenberg et al., 1994)
Depression-Screening PHQ8	5.9 ± 4.7	0.90	0.82 (Kroenke et al., 2009)
Anxiety screening GAD7	4 ± 4	0.90	0.92 (Spitzer et al., 2006)
Fatigue Severity Scale FSS	4.5 ± 1	0.82	0.93 (Valko et al., 2008); 0.88 (Lerdal et al., 2005)
Jenkins Sleep Scale JSS	2±1.2	0.85	0.84 (Reis, 2014)
PHQ-Stress	5±3.7	0.81	

Figure 1

Item Mean Scores and Confidence Intervals (CI) 95% for All Nine Items of the Fatigue Severity Scale FSS (Krupp et al., 1989) of N=406 International Pilots. "Please choose how strongly you agree with each statement?"

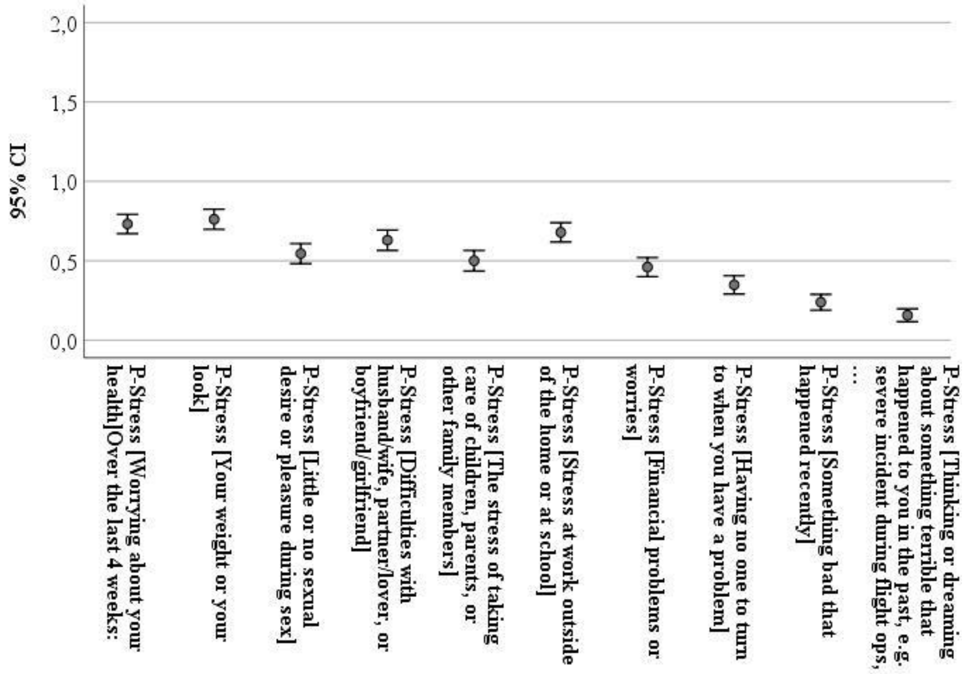


Note: 1 = I strongly disagree, 7 = I strongly agree.

Psychosocial stress was measured with the 10 stress related items of the Brief Patient-Health-Questionnaire, PHQ Stress (Spitzer & Williams, 2005), which had acceptable internal consistency in this study (Table 3, Figure 2). To assess sleep problems, the Jenkins Sleep Scale JSS (Jenkins et al., 1988) was used and had satisfactory internal consistency.

Figure 2

Mean Items Scores and Confidence Intervals (95%) of the 10 Items of the PHQ-Stress (Spitzer & Williams, 2005) of N=406 International Pilots

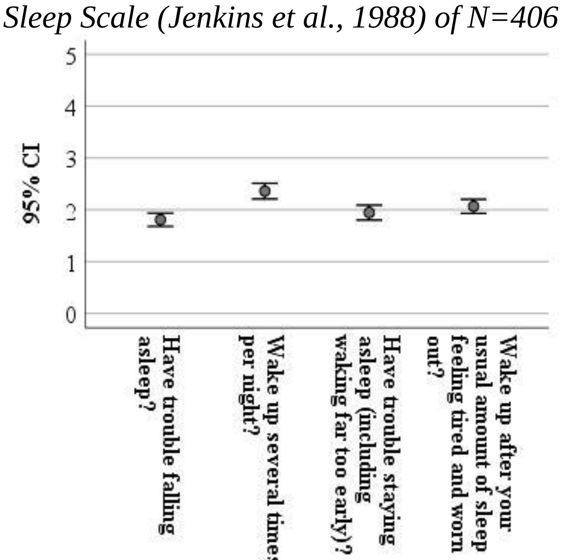


Note. 0 = not at all, 1 = a little affected, 2 = severely impaired.

To assess pilots' mental health, standardized screening instruments recommended by the World Health Organization (WHO) were used: Pilots' well-being (Figure 4) was assessed with the WHO5 (Krieger et al., 2014; Winther Topp et al., 2015), symptoms of common mental disorders (CMD, Figure 5) with the Self-Reporting-Questionnaire SRQ20 (Beusenberg et al., 1994; de Paula et al., 2017).

Figure 3

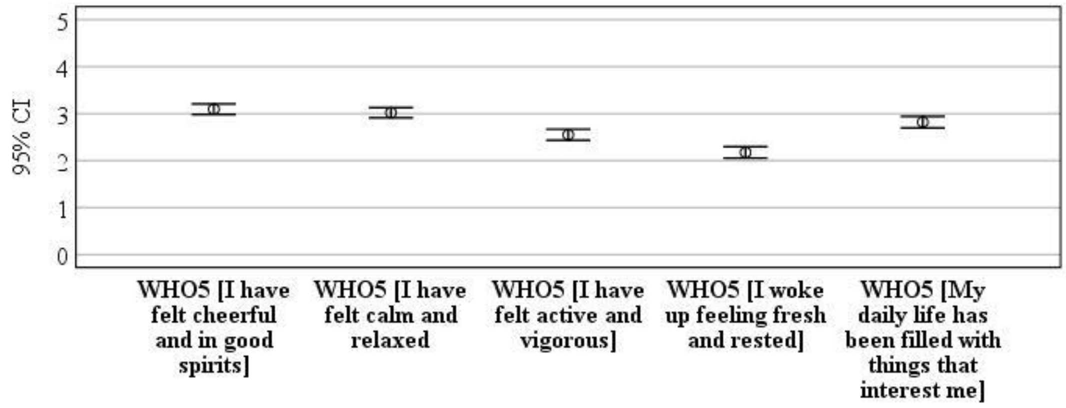
Mean Items Scores and Confidence Intervals (95%) of the 4 Items of the Jenkins Sleep Scale (Jenkins et al., 1988) of N=406 International Pilots



Note: 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

Figure 4

Mean Items Scores and Confidence Intervals (95%) of the WHO5 Wellbeing Index (Krieger et al., 2014; Winther Topp et al., 2015) of N=406 International Pilots



Note: 0 = at no time, 1 = some of the time, 2 = less than half of the time, 3 = more than half of the time, 4 = most of the time, 5 = all the time

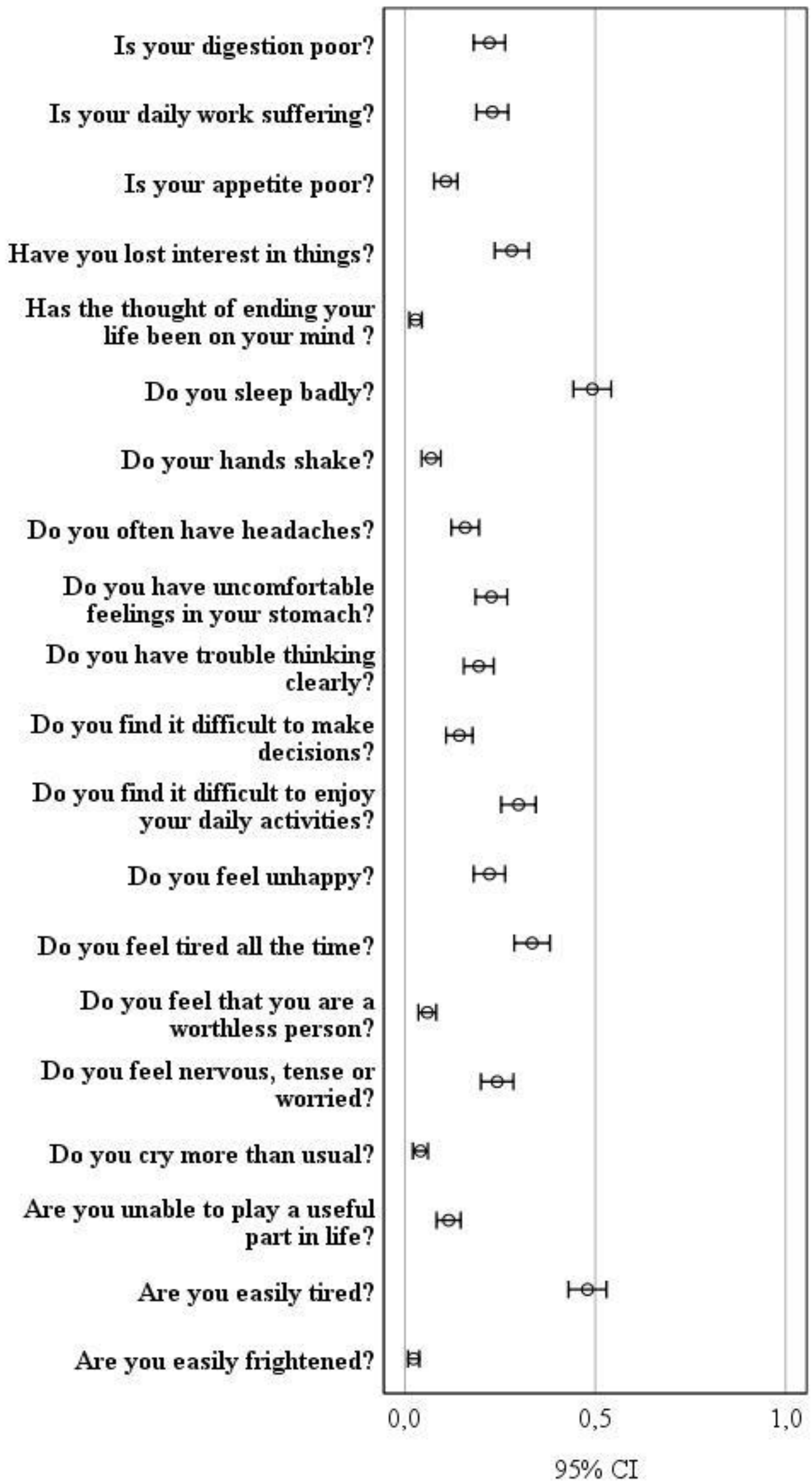
To obtain comparable data with previous research (Cahill et al., 2021; Wu et al., 2016), the Patient-Health-Questionnaire-8 (PHQ8, Figure 6) was used for the self-assessment of depression symptoms (Kroenke et al., 2009; Spitzer & Williams, 2005). The Generalized Anxiety Disorder Screener GAD7 (Spitzer et al., 2006; Spitzer & Williams, 2005) was used to measure symptoms of generalized anxiety (Figure 7, Table 3).

Procedure

This study was executed as a first explorative pilot study. In this context, a cross-sectional online survey was programmed with Lime Survey®, and the collected data were analyzed. Pilot unions emailed the link to the online survey to their members during peak flying season: To EASA based pilots from June 2018 to October 2018, to Australian pilots from December 2018 to March 2019, several months before the Covid-19 pandemic started. The link was sent embedded into newsletters, along with other news and surveys. Study purpose and confidentiality were explained, and participants were asked to have their flight duty schedules for the last two months on hand. Participants could stop and delete all data without any consequences.

Figure 5

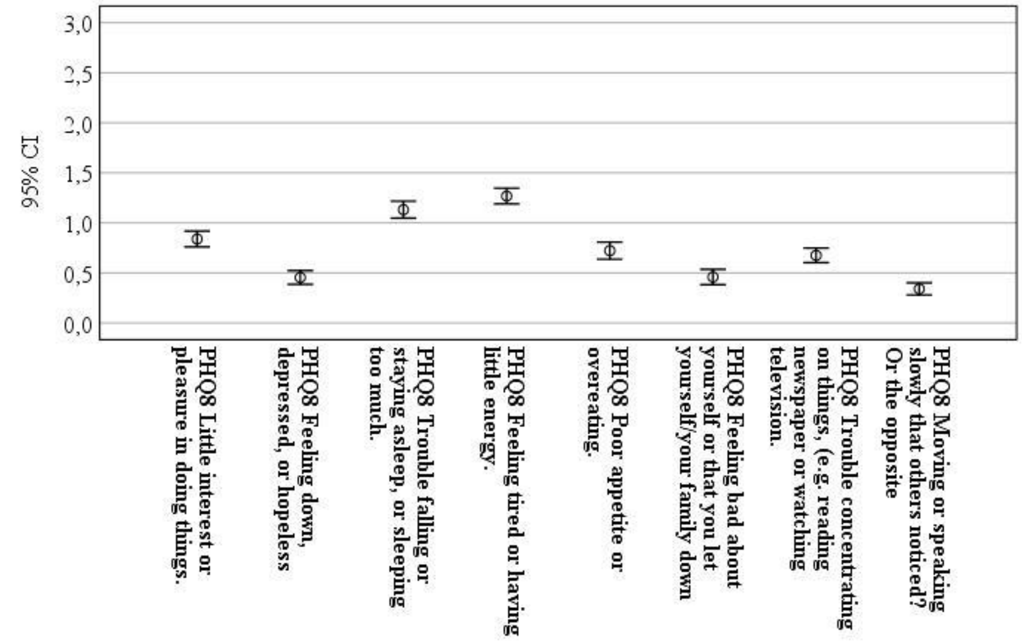
Mean Items Scores and Confidence Intervals (95%) of the Self Report Questionnaire 20 (SRQ20) for the Screening of Common Mental Disorders of N=406 International Pilots.



Note. 0 = no, 1 = yes

Figure 6

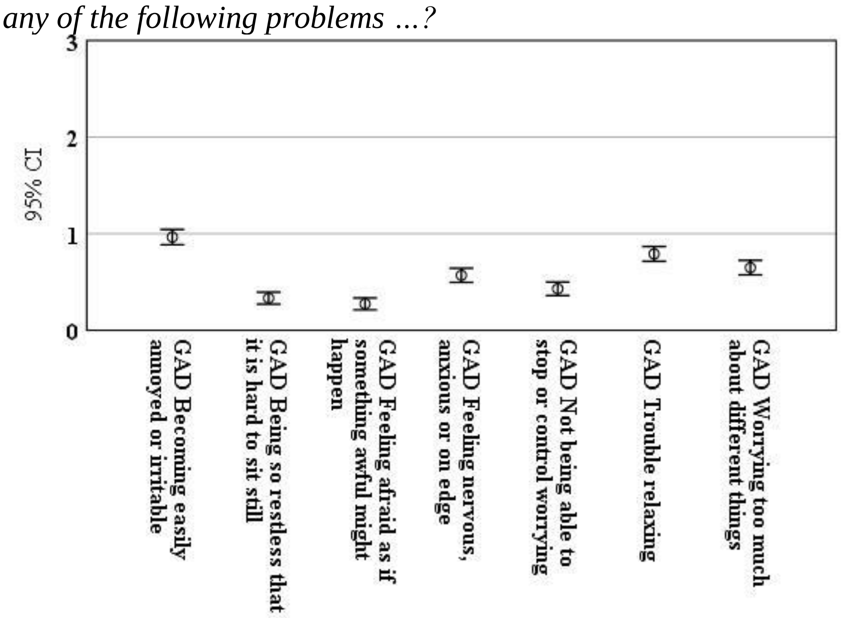
Item Mean Scores and CI 95% for Depression-Screening Results (PHQ8 Scores) of N=406 International Pilots. "Over the last two weeks, how often have you been bothered by any of the following problems?"



Note: 0=not at all, 1=several days, 2=more than half the days, 3=nearly every day

Figure 7

Item Mean Scores and CI 95% for Symptoms of Generalized Anxiety (GAD7) of N=406 Pilots. "Over the last two weeks, how often have you been bothered by any of the following problems …?



Note: " 0=not at all, 1=several days, 2=more than half the days, 3=nearly every day

Subjects

The current study is part of a larger external PhD research project. This first exploratory study was intended to provide deeper insight into the psycho-physiological complexity of pilot fatigue, which has long been known in work psychology and burnout research (Demerouti et al., 2003, 2019; Maslach & Jackson, 1984; Ulich, 2001). Relationships between pilots' actual duty rosters, their perceived psychosocial stress, sleep problems, fatigue, mental health, and well-being are examined. All questions of the comprehensive cross-sectional online survey were completed by 406 international pilots. Of these pilots, 192 were flying for EASA-based, 180 for Australia based and 34 for commercial air operators based in the UAE, Turkey, and Asia Pacific. Written informed consent was not required, because we guaranteed confidentiality of the data, which were collected with the anonymous online survey. The participating pilots received no remuneration.

In this research, 55% pilots reported flying for network carriers (NWC), 30% for low-cost carriers (LCC), 6% for cargo, 9% for charter operators. 70% of the pilots reported flying short haul (sectors up to 6 hours, multiple legs/flight duty), 30% were flying long haul (sectors > 6 hours). Pilots' age, roster-data, experience, etc. are displayed in Table 3.

Of the participating pilots 50.5% were commander, 49.5% were first officers, 8% of the international airline pilots were female. Ninety point six percent (90.6%) of our investigated pilots had a work contract directly with their employer, the remaining pilots had a contract with intermediary manning agency or were 'self-employed'.

Table 3

Descriptive Data of the Participating International Pilots

	Mean	**± SD***
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

Note:

** Standard Deviation*

[+] *the mean values of the last two months were used.*

Statistical Analysis

For the statistical analyses, SPSS Version 27.0 (Statistical Package for Windows by SPSS Inc., Chicago, IL, US) was used. Results with $p < 0.05$ were considered as statistically significant. Means of the last two months were used for analyses of schedule-related data. To compare categorical data, χ^2-tests were used. For psychosocial stress, sleep problems, fatigue the mean of the scale scores were used. For symptoms of depression, generalized anxiety and CMD, the sums of the item scores were used. For wellbeing, the sum of the item scores was multiplied with 4 to obtain the WHO5 wellbeing percent range (PR) (Winther Topp et al., 2015).

To test H.1 a) to d) the published cut-off values were used. Of the general population, 35% reported impaired wellbeing (WHO5<50) (Winther Topp et al., 2015). Positive depression screening results (PHQ8≥10) were reported by 8.6% (Kroenke et al., 2009), positive anxiety screening results (GAD7≥10) by 7% (Spitzer et al., 2006) of the general population. Eight or more CMD were reported by on average 17% employees in industrialized countries. This study investigates, if more pilots than in the general population report values above the mentioned published cut off values.

To test H.2 a) to e), one-tailed Pearson intercorrelations between stress, sleep problems, fatigue, wellbeing, symptoms of CMD, depression and anxiety were calculated.

Results

During the pilots' main flight season 2018 to 2019 (before the Covid-19 pandemic), the pilots surveyed stated an average of 61.3 ± 20.7 flight hours and 112.1 ± 37.4 duty hours (M ± SD). Compared to the EASA FTL, pilots were deployed on average for 61.3% of the permitted flight hours and for 59% of the statutory maximum duty hours/month.

Pilots' Mental Health and Wellbeing

In this research, pilots reported the highest item-scores for items that indicate accumulated fatigue, psychophysiological exhaustion, irritability, trouble relaxing and sleep problems (Figures 1-7), while pilots' scores on the key depression symptoms "Little interest or pleasure in doing things" and "Feeling down, depressed, or hopeless" were lower. Pilots' mean PHQ8 and GAD7 scores were below the cutoff value ten. One out of four pilots (24.2%) reported considerable sleep problems in 8 or more nights/month.

H.1 a) stated that more pilots would report impaired well-being (WHO5<50), compared with the general population, and was confirmed. Very low wellbeing (WHO5 scores of 28 or lower) was reported by 16.4%, impaired wellbeing (WHO5<50) by 44.7% pilots. Pilots indicated feeling on average equally good or better than 54% of the general population (Figure 5). Compared with a sample of working individuals (Winther Topp et al., 2015), more pilots reported impaired wellbeing.

H.1 b) stated that a greater proportion of pilots would report positive depression screening results compared to the general population and was confirmed. Of the investigated pilots 18.7% reported PHQ8≥10, compared with only 8.6% of the general population (Kroenke et al., 2009).

H.1 c) stated that a greater proportion of pilots would report positive anxiety screening results compared to the general population and was also confirmed. 8.5% pilots reported GAD7≥10, more than the reported 1.6% to 5% of the general population measured in previous studies. Overall, 20% pilots had positive depression or anxiety screenings, 7.23% reported *GAD7 and PHQ 8≥10*. Only positive anxiety screenings were reported by 1.25%.

H.1 d) stated that a higher proportion of pilots would report eight or more symptoms of CMD, compared with the general population (17%) and was confirmed. Of our investigated pilots, 19.6% reported eight or more symptoms of CMD, and on average four CMD symptoms (Table 2). The five most frequent symptoms of CMD were "Do you sleep badly?" "Are you easily tired?" "Do you feel tired all the time?" "Do you feel nervous, tense, or worried?" "Is your daily work suffering?", corresponding with the depression and anxiety screening results (Figures 5, 6, 7).

Intercorrelations between Stress, Sleep, Fatigue, Mental Health and Wellbeing

H.2 a) to e) stated that more psychosocial stress would be significantly associated with more sleep disturbances (JSS), higher fatigue levels (FSS), more depression symptoms (PHQ8), more anxiety symptoms (GAD7), more symptoms of CMD (SRQ20), and more impaired well-being (WHO5). To test H.2, one-tailed Pearson correlations between the mentioned variables were calculated. H.2 a) to e) were confirmed. All these correlations were highly significant to high (Table 4), in line with Venus & grosse Holtforth (2021a), the correlation between psychosocial stress and fatigue was lowest (r=.311, p<.001), yet significant. The correlation between stress and sleep problems was higher (r=.499, p<.001).

More stress was associated with more sleep problems, higher fatigue, more symptoms of depression, anxiety and CMD, and lower wellbeing. Higher wellbeing was significantly associated with fewer depression symptoms (r=-646; p<.001). Higher scores of the depression screening were significantly associated with higher anxiety scores (r=.773; p <0.001), and this was the highest intercorrelation of the investigated variables. More symptoms of CMD were significantly associated with more depression and anxiety symptoms and lower wellbeing (Table 4).

Table 4

One Tailed Pearson Correlations for the Intercorrelations of Psychosocial Stress, Sleep Problems (JSS), Fatigue (FSS), Psychosocial Stress (PHQ-Stress), Depression Screening (PHQ8), Generalized Anxiety Screening (GAD7), Symptoms of Common Mental Disorders (SRQ20) and Wellbeing (WHO5) of N=406 International Pilots in this Study.

	Stress	**JSS**	**FSS**	**PHQ 8**	**GAD 7**	**SRQ 20**	**WHO5**
Psychosocial. stress (PHQ-Stress)	-	,530**	,311**	,704**	,701**	,684**	-,499**
Sleep problems (JSS)		-	,363**	,631**	,527**	,622**	-,533**
Fatigue (FSS)			-	,396**	,261**	,364**	-,404**
Depression Screening PHQ8				-	,773**	,731**	-,646**
Anxiety Screening GAD7					-	,679**	-,546**
Common mental disorders (SRQ20)						-	-,626**
Wellbeing (WHO5)							-

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

Higher fatigue levels were significantly associated with more sleep problems, more symptoms of depression and lower wellbeing (Table 4), although these correlations were low to moderate. Higher levels of fatigue were associated with more psychosocial stress, more sleep problems, lower wellbeing, more symptoms of depression, anxiety, and CMD. The correlation between mental-health-dimensions and wellbeing was significant and high, better wellbeing was associated with fewer depression and anxiety symptoms, lower fatigue, and fewer sleep problems.

Discussion

Pilots' Rosters and Fatigue

Although pilots were on average scheduled for 59% to 61% of the legally allowed duty and flight hours/month, three of four pilots (76%) reported high levels of fatigue, similar to previous studies (Aljurf et al., 2018; Reis et al., 2013, 2016b, 2016a; Venus & grosse Holtforth, 2021b, 2022). Every third pilot (33.4%) reported even very high fatigue (FSS≥5) (Venus & grosse Holtforth, 2021a). For comparison: In a yet unpublished study of the authors, a working sample with and without regular shift-work, 31.6% reported FSS≥4, their FSS mean was 3.38±1 (M±SD), similar to previous research (Lerdal et al., 2005; Valko et al., 2008). The question arises, which level of fatigue is generally acceptable for pilots in terms of flight safety.

Pilots' Sleep Problems and Mental Health

One out of four pilots (24.2%) reported considerable sleep problems in 8 or more nights/month (Venus & grosse Holtforth, 2021a), other studies reported comparable results (Aljurf et al., 2018; Reis et al., 2016a). One out of five pilots (20%) reported significant mental health issues. In line with previous research, sleep problems were strongly associated with more depression symptoms in terms of exhaustion and impaired mood (McClung, 2013; O'Hagan et al., 2019; Venus & grosse Holtforth, 2021b, 2022), as consequence of chronic sleep deprivation and accumulated fatigue. Nonetheless, some cases of depressive disorders cannot be excluded. Pilots scored highest on symptoms of CMD, depression and anxiety suggesting accumulated fatigue (Aljurf et al., 2018; Reis et al., 2016a), exhaustion, beginning or high burnout (Demerouti et al., 2019; Fanjoy et al., 2010) and severely impaired mood (Aljurf et al., 2018).

Pilots' Mental Health and Wellbeing

Compared to the general population (Kroenke et al., 2009), more than twice as many pilots (18.7%) reported significant symptoms of depression (PHQ8≥10). Compared to the general population (Spitzer et al., 2006), significant more pilots (8.5%) reported considerable worries and fears (GAD7≥10). In still unpublished research of the authors, 11.6% of the working population sample reported PHQ8≥10, 5.7% reported positive anxiety screening results (GAD7≥10).

Pilots' average wellbeing was marginally above the cut-off value 50. With WHO5 scores below 50, a depressive disorder should be confirmed or dismissed diagnostically (Krieger et al., 2014). Almost every second pilot (44.7%) reported WHO5 scores below 50, 16.4% even reported very low wellbeing (WHO5 ≤ 28). The wellbeing of pilots was on average low, compared with the general population (Winther Topp et al., 2015). Slightly more pilots (20%) reported eight or more symptoms of CMD, compared with the general population (Goldberg & P., 1992).

Differentiation of Sleepiness and Fatigue and Medical Certification (Medical Class 1)

Regarding pilots, it is vital to differentiate between accumulated fatigue, chronic sleep deprivation by dysfunctional rosters (early starts, night flights, minimum legal rest between flight duties, etc.), acute on-duty sleepiness, impaired wellbeing and mental disorders. Sufficient recovery with some days off (with no flight duties) before the Medical Class 1 certification with the included Mental Health Assessment, could help pilots recover accumulated fatigue until a certain degree. This way, artefacts could be avoided: Not every severely fatigued pilot is suffering a depressive disorder. Pilots' fatigue is usually not caused by depressive disorders, but associated with dysfunctional FTL and competitive, yet legal rosters (Venus & grosse Holtforth, 2021b, 2021a, 2022).

The Mental Health Assessment should be generally conducted by or in cooperation with a clinical and aviation psychologist, to avoid diagnostic artefacts. Accumulated fatigue and impaired mood could falsely be interpreted as a depressive disorder. Sleep problems and realistic worries for life and livelihood could falsely be interpreted as generalized anxiety disorder. Long-term withdrawal of their 'Medical' would place even more existential stress on pilots who struggle to relax and recover amid fears of losing their technical skills and certifications during a long-term grounding. Many pilots reported that the return to the cockpit after months, retraining and skill check in the simulator was an extremely stressful experience and woud require a lot more organizational and peer support.

Stress, Sleep and Burnout

Often reported psychophysiological stress reactions are associated with higher arousal, which can impair sleep and enhance fatigue in multiple ways or even trigger insomnia (Jansson & Linton, 2006; Kalmbach et al., 2020; McEwen & Karatsoreos, 2015; Sapolsky, 2004). Insomnia or less than six hours of sleep can also lead into burnout over time (Armon et al., 2008; Ekstedt et al., 2006; Söderström et al., 2012). Higher cognitive arousal with e.g. rumination and worries are key symptoms of sleep disturbance and insomnia, they are involved in the development and maintenance of sleep problems (Kalmbach et al., 2020; McEwen, 2006; McEwen & Karatsoreos, 2015). Psychosocial stress and cognitive arousal are also associated with frequent insomnia comorbidities, e.g. anxiety, depression and cardiovascular diseases (Kalmbach et al., 2020; McEwen & Karatsoreos, 2015; Sapolsky, 2004).

Long stressful duty days packed with time pressure due to minimum turnaround times, delays due to adverse weather conditions, crowded airspace and unruly passengers, unexpected drones near congested airports can enhance professional pilots' stress levels and cognitive arousal on every flight duty, especially at the end of long flight duty days or nights (Venus & grosse Holtforth, 2021b, 2022).

Research Implications

Future research should investigate, why the majority of pilots reported severe or high levels of fatigue, although Fatigue Risk Management and flight time limitations should prevent sleepiness and fatigue on flight duties (EASA FTL, 2014; ICAO, 2015).

Future research should better focus on the differences between the symptom sleepiness and the more complex construct fatigue, and not use sleepiness and fatigue as synonyms. Moreover, interactions of modern pilots' stress, sleep, high levels of unwelcome fatigue and health should be a new focus of fatigue research.

Limitations

Representativity of the Sample

Potential limitations of this first exploratory research concern the representativity of the sample. The potential target group were members of European and Australian pilot unions, who emailed the link to the online survey embedded in newsletters, along with other surveys. 406 pilots answered all questions of the cross-sectional online survey.

Data collection started in June 2018 and ended in March 2019, several months before the Covid-19 pandemic. Pilots had to enter their roster data of the last two months, which may have been a hurdle. We had considered the effective workload, reflected in their actual individual rosters, as relevant for the development of fatigue, sleep problems, mental health, and wellbeing.

Some more obstacles likely made participation difficult: Pilot mental health issues, fatigue and burnout are disqualifying for pilots, they all jeopardize pilots' Medical Class 1 and career. The survey was quite long due to the complexity of the topic, which was covered. Our intention was to collect data during pilots' peak flying season with the most rostered duty and flight hours, i.e., pilots' summer flight plan in Europe and the time from Christmas until March in Australia. More pilots might have participated in less busy flight seasons.

It is difficult to check the representativity of this sample in more detail. Pilots from several EASA Member States, Australia, UAE, and other regions participated in this research. Pilots of different types of operators (NWC, LCC, cargo, charter) and diverse types of operation (short haul and long-haul pilots). The participating pilots were scheduled, on average, for 59% to 61.3% of the legal duty and flight hours/month according to EASA's and similar FTL. Maybe extremely exhausted and fatigued pilots – scheduled for the 190-200 duty hours and 100 flight hours – were too tired to complete the online survey.

Sample selection biases in previous research were never discussed or even mentioned, although – according to study purposes – eligible pilots generally participated on a voluntary basis (Cosgrave et al., 2018; Gander et al., 2015; Holmes et al., 2012; Sallinen et al., 2018), in line with ethical research standards. Thus, representativity can generally not be guaranteed for available fatigue studies.

Self-Assessed Screening Results are not Diagnoses

Positive screening results are not diagnoses. Individuals with positive screening results should be examined psychologically and diagnostically for a possible existing mental illness. With our results we do not imply a 'sudden outbreak' of depressive or anxiety disorders among pilots, but that many pilots are exhausted and – associated with high levels of fatigue, sleep problems and sleep restrictions – suffer from impaired mood, irritability, and worries. Knowing about fatigue risks associated with fatigue in the cockpit, many pilots are worried about flight safety, their jobs and livelihood.

Artefacts must be avoided. E.g., what looks like a positive depression screening (PHQ8≥10) might be an exhausted, severely fatigued pilot, whose mood is impaired due to exhaustion and roster related sleep deprivation. Along with aeromedical examiners, clinical and aviation psychologists should cooperate regarding qualified evidence-based decisions in case of mental health issues, fitness to fly and the medical recertification of pilots.

Correlation vs. Causality

Significant correlations between variables do not imply causality. Nonetheless, allostasis theory suggests potential causalities and interactions between stress, sleep, fatigue, wellbeing, physical and mental health, as described above. Higher scores in GAD7 may represent realistic fears about health, job, and livelihood, due to high fatigue levels, sleep disturbances and sleep restrictions associated with flight duties, not pathological generalized anxiety.

Psychometric Questionnaires vs. Psychophysiological Data

Results of psychological questionnaires can be questioned, and they may be biased on purpose or by chance. Pilots could exaggerate or downplay fatigue, sleep problems or mental health issues. Therefore, psychophysiological measurement of fatigue and recovery is needed, in combination with in-depth data regarding mental health acquired through the diagnostic process and with objective psychophysiological measures, e.g., 24 hours high resolution measurement of heart-rate-variability.

Strengths

Key Findings from this First Exploratory Study

The results of this exploratory study provide important insights into previously unexplored correlations and interactions in the complex topic of pilot fatigue. This study examined whether the theory of allostasis and allostatic (over)load may be applicable to pilots. In line with a sound body of scientific evidence we could confirm, that stress plays a significant role regarding sleep, fatigue, and health. In addition to accumulated fatigue, physical and mental health can be impaired by chronic stress and allostatic wear and tear.

Use of Standardized Questionnaires

This study used approved, standardized screening instruments to assess sleep problems, as well as symptoms of depression, generalized anxiety and CMD with good validity and reliability. Objectivity was also granted by the online survey. Our results can be directly compared with former research (Aljurf et al., 2018; Cahill et al., 2021; Feijo et al., 2012; Reis et al., 2016a; Wu et al., 2016), while the comparability of the results of national and international pilot samples must be investigated in future research.

Comparability with Previous Research

Our results regarding fatigue and sleep problems (Aljurf et al., 2018; Reis et al., 2016a) and pilots' mental health and wellbeing (Aljurf et al., 2018; Cahill et al., 2021; Wu et al., 2016) are comparable with previous research. Considerable mental health issues were reported for 13% to 42% pilots (Aljurf et al., 2018; Cahill et al., 2021; Widyahening, 2007; Wu et al., 2016).

To our best knowledge, only one other peer reviewed study has reported better results. Sykes et al. (2012) described the potential selection biases in their study, where only 1.9% pilots reported mental health issues. Sykes' study was not anonymous, conducted in context with the Medical Class 1 certification at the airline's own aeromedical center. Among other potential selection biases, predominantly younger, healthier pilots participated (Sykes et al., 2012).

Our pilot sample's sociodemographic data is comparable with previous research (Aljurf et al., 2018; Cahill et al., 2021; Reis et al., 2016a). No other peer reviewed publications reported lower levels of fatigue (not alertness/sleepiness). Considering the guaranteed anonymity in this online survey, pilots should have answered honestly.

Conclusions

Although pilots were scheduled for on average 60% of the legal duty and flight hours, most pilots reported severe or very high fatigue, in line with previous research. 20% of the pilots reported positive depression and/or anxiety screening results, 7.2% reported significant symptoms of depression *and* anxiety. Based on the theory of allostasis, this study examined the hypothesis that in pilots higher levels of psychosocial stress are significantly associated with sleep problems, fatigue, impaired wellbeing, symptoms of depression, anxiety and CMD. The hypothesis was confirmed. Our results suggest that fatigue and sleep problems are not isolated problems, but strongly related to stress, mental health, and wellbeing. Stress can affect the sleep and recovery of commercial pilots, promoting fatigue and burnout. Mental and physical health of pilots can be negatively affected by chronic stress and allostatic wear and tear processes. This study could show that the previously very fragmentary view of fatigue needs to be revisited. Other considerable health impairments like cardiovascular diseases, sleep problems, pain, higher mortality, impaired immune systems and mental health issues were confirmed as long-term consequences of repeated high or chronic stress.

Although only flight-safety related aspects of acute on-duty sleepiness have been of interest to aviation authorities and operators, accumulated fatigue and how it affects physical and mental health needs better investigation. The theory of allostasis also appears to be applicable to pilots and most likely to other transport professions, where time pressure, stress and fatigue occur regularly.

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Appendix

Table A.1

Examples of Basic Flight Time Limitations of the European Aviation Safety Agency (EASA) and the Civil Aviation Safety Authority (CASA), Quoted from Venus & grosse Holtforth, (2021a, p.33)

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

"Flight time 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" (EASA FTL, 2014, p. 21)

"Duty period 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" (EASA FTL, 2014, p. 21.

"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" (EASA FTL, 2014, p. 22)