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Australian and EASA based pilots' duty schedules, stress, sleep difficulties, fatigue, wellbeing, symptoms of depression and anxiety

Marion Venus [a,b,*], Martin grosse Holtforth [b,c]

[a] Venus Aviation Research, Training & Pilot Support, Zurich, Switzerland
[b] Department of Psychology, University of Bern, Fabrikstrasse 8, 3012 Bern, Switzerland
[c] Psychosomatic Competence Center, Inselspital, c/o Martin grosse Holtforth, 3010 Bern, Switzerland

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ABSTRACT

Introduction: Recent research has reported widespread high levels of fatigue among pilots. Pilot fatigue can affect their performance and has become a threat to flight safety.
Objective: This study examines whether different flight time limitations (FTL) and rosters of EASA-based and Australian pilots were associated with different levels of stress, sleep difficulties, fatigue levels, symptoms of depression or anxiety and wellbeing.
Method: 192 EASA-based and 180 Australian pilots completed a cross-sectional online survey, which asked for their schedules, stress, sleep problems, fatigue, wellbeing, and symptoms of depression and anxiety. These variables were compared for the groups of EASA-based and Australian pilots.
Findings: Although EASA based and Australian pilots were scheduled for only 57–62% of maximum duty and flight hours, 71.8% EASA-based vs. 77% Australian pilots reported severe or high fatigue. Significant depression symptoms were reported by 17.2% Australian and 18% EASA-based pilots, 7% pilots reported significant symptoms of depression *and* anxiety. Australian pilots reported more demanding rosters, significantly more sleep problems and significantly lower wellbeing.
Conclusions: Present regulations and FTL likely could not prevent high fatigue levels among EASA based and Australian pilots. Both groups were equally fatigued, although Australian pilots reported more demanding rosters. Pilots of both groups reported the same levels of stress, depression, and anxiety symptoms, while Australian pilots' sleep and wellbeing were significantly more impaired. These results suggest that fatigue should not be regarded as an isolated problem for flight-safety. Fatigue is closely related to pilots' physical and mental health, which may be at risk in the long run.

Introduction

Airline pilots spend most of their working hours in their "front office" around 10 km above ground ground in a hostile environment. In the cockpit, pilots operate complex avionics and interacting automated systems in the high-risk high-reliability system aviation. Despite the cutting edge technology, reduced pilot performance due to fatigue has been identified as a threat to modern flight safety (Bandeira et al., 2018; Bendak and Rashid, 2020; Bourgeois-Bougrine, 2020; Coombes et al., 2020; Goode, 2003). In the 1980s, pilots reported on average 46 flight hours every month (Sloan and Cooper, 1986), while present flight time limitations (FTL, e.g., CASA FTL, 2013; EASA FTL, 2014) allow up to 100 flight hours and 1000 flight hours per year (examples Table 1).

Severe fatigue contributed to several crashes and severe incidents like China Airlines 006 (NTSB, 1987), Korean Air 801 (NTSB, 2000), American Airlines 1420 (NTSB, 2001) and the TransAsia crashes (ASC, 2015, 2016), while fatigue and precarious working conditions contributed to the crash of Colgan Air 3407 (NTSB, 2010). These accidents or crashes caused 380 fatalities; additional 170 persons were injured. Fatigue has become a significant threat to flight safety (Bandeira et al., 2018; Bendak and Rashid, 2020; Bourgeois-Bougrine, 2020; Caldwell et al., 2009; Goode, 2003). So far, mental health problems or negative life events played a substantial role in seventeen commercial aviation accidents and incidents, which caused 576 fatalities (Mulder and de

Abbreviations: FRM, Fatigue Risk Management; FTL, Flight Tme Limitations; EASA, European Aviation Safety Agency; CASA, Civil Aviation Safety Authority.

* Corresponding author at: Venus Aviation Research Training and Pilot Support, Wassbergstasse 37, 8127 Forch, Zürich, Switzerland.
E-mail address: marion.venus@sunrise.ch (M. Venus).

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Table 1
Examples of basic flight time limitations (FTL) rules of the European Aviation Safety Agency (EASA), Civil Aviation Safety Authority (CASA) and the US Federal Aviation Administration (FAA). These EASA and CASA FTL were in force for the investigated 192 EASA-based and 180 Australian pilots, at the time of data collection from June 2018 until March 2019 (Venus and grosse Holtforth, 2021a).

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

Note. All definitions from EASA FTL (2014).
**) "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."*
§) "augmented flight crew means a flight crew which comprises more than the minimum number required to operate the aircraft, allowing each flight crew member to leave the assigned post, for the purpose of in-flight rest, and to be replaced by another appropriately qualified flight crew member."
†) "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.
FDP: flight duty period."

Rooy, 2018). Nevertheless, the mental health of pilots only received more attention after the Germanwings crash (BEA, 2016). This research compares professional pilots from two continents with different regulations regarding their actual schedules, work-related and psychosocial stress, sleep problems, fatigue levels, pilots' associated wellbeing, symptoms of depression and anxiety. In this study, we are referring to professional or airline pilots as opposed to private pilots. In accordance with Shahid et al. (2010) we differentiate between *alertness/sleepiness* and more accumulated *fatigue*, similar to previous studies (Aljurf et al., 2018; Cabon et al., 2012; Reis et al., 2013; Reis et al., 2016a; Shahid et al., 2010).

Definitions of sleepiness and fatigue

The International Civil Aviation Authority (ICAO) has defined 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." (ICAO, 2015). The sleepiness described is an increased tendency to fall asleep after long hours of wakefulness or sleep deprivation; sleepiness is associated with low psychophysiological arousal (Shahid et al., 2010). "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). The International Classification of Diseases (ICD-11) defines fatigue as strain, tiredness, or exhaustion, which indicate that a person's functioning in different areas of life (e.g., work and/or family life) is impaired. Sleepiness is a key symptom of fatigue, whereby fatigue represents allostatic (over)load, which is often associated with long-term impairment of performance and health, as explained by the theory of allostasis (McEwen, 2004; McEwen, 2006; McEwen and Karatsoreos, 2015; McEwen and Stellar, 1993).

Previous research has shown, that the theory of allostasis is also applicable to pilots, who are confronted with considerable work-related and psychosocial stressors (Venus and grosse Holtforth, 2021a). Table 2 displays different acute and chronic stressors that pilots face in everyday work.

Pilots can lose up to 40% of their regular sleep time (Cabon et al., 2012; Coombes et al., 2020), due to legal but competitive rosters, often

Table 2
Overview over different types of stressors and examples as described by Venus and grosse Holtforth (2021a).

Type of Stressor	Examples
Physiological stressors	• "exertion, heat, cold, trauma, infection, and inflammation" (McEwen & Stellar, 1993). • sleep problems, insomnia (McEwen & Karatsoreos, 2015) • flight-duty related sleep restrictions (Chen et al., 2014; McEwen, 2006; McEwen & Karatsoreos, 2015; Sapolsky, 2004) o due to irregular shift work o due to frequently crossing time zones
Psychological Stressors	• "fear and anxiety, social defeat and humiliation, disappointment" (McEwen & Stellar, 1993, p
Psychosocial stressors	• health concerns, • relationship problems, • childcare stress, • financial problems, • having no one to talk, etc.. (Spitzer & Williams, 2005)
Work-related stressors	• less experience in a cutting-edge work place like the flight deck • conflicts at the workplace such as examination of pilots' private lives after they filed a fatigue report, e.g., blaming pilots that they caused their fatigue themselves • Frequently changing irregular shifts • frequent time pressure due to o economic pressure, o minimum rest and o minimum turnaround times o long flight duties in heavily frequented airspace, start and finish at congested airports (Fanjoy et al., 2010; Sapolsky, 2004; Venus & grosse Holtforth, 2021b)
Existential or chronic work-related stressors	• operators' impending bankruptcy or mergers (in the last years, e.g., Flybe, SunExpress, LATAM, South African Airways, Thomas Cook, Air Berlin, Condor, etc.) • job insecurity due to non-traditional work arrangements (Brannigan et al., 2019; Little et al., 1990; Young, 2008). • "Pilot Pushing" (Fanjoy et al., 2010) • responsibility for hundreds of passengers and crew on every flight
Immediate threats to life and flight safety	• blinding pilots with laser pointers • unexpected drone encounters on short final near airports (Venus & grosse Holtforth, 2021b) • Flying overhead active war zones (e.g., Ukraine, Syria, ...)

created with biomathematical modeling software (Dawson et al., 2017; Dorrian et al., 2012).

Stress, sleep and health

Some studies examined, how pilots' work-related and psychosocial stress relate to their wellbeing and mental health issues (Cahill et al., 2021; Cullen et al., 2020; O'Hagan et al., 2017; Omholt et al., 2017; Widyahening, 2007). More stress at work was significantly linked to more health ailments, particularly sleep difficulties and fatigue (Cullen et al., 2020; Omholt et al., 2017), in line with the wear and tear processes described by the theory of allostasis (McEwen, 2008; McEwen and Karatsoreos, 2015; McEwen and Stellar, 1993; Venus and grosse Holtforth; 2021a). Sleep problems and fatigue have previously been viewed as related but isolated issues. The role of stress for sleep and fatigue (Ekstedt et al., 2006; Kalmbach et al., 2020; McEwen and Karatsoreos, 2015; Omholt et al., 2017; Venus, 2020) and burnout (Demerouti et al., 2019; Fanjoy et al., 2010) was mostly neglected, as well as how stress and fatigue can affect physical and mental health (McEwen, 2006; McEwen and Karatsoreos, 2015).

Exposure to different acute and chronic stressors (Table 2) represent high allostatic load or even overload. Therefore, the stressed individual's physiology must work hard to re-establish homeostasis through allostasis. Allostatic (over)load can lead to impaired mood, fatigue, higher levels of cortisol in the evening, which was reported to be associated with longer sleep latency, shorter sleep and generally more sleep difficulties (Chen et al., 2014; McEwen, 2006; Venus and grosse Holtforth; 2021a). In the pathogenesis of depressive and other mental disorders, stress hormones like cortisol play an important role, suggesting emotional arousal, allostatic struggle and deviance from homeostasis (McEwen, 2004). This interplay of psychophysiological processes can explain, why stress is not only unpleasant, but also unhealthy. Allostatic overload can become detrimental for physical and mental health and was associated with fatigue, impaired immune systems, depressive and anxiety disorders (McEwen, 2006; McEwen and Stellar, 1993). While causalities between stress, sleep, fatigue and mental health are difficult to investigate, depressive disorders were reported to affect many physiological systems, like the immune system, and of course the brain itself (Hannibal and Bishop, 2014; McEwen, 2004; Sapolsky, 2004).

Sleep is essential for human life, regeneration and regaining homeostasis (McEwen and Karatsoreos, 2015; Sapolsky, 2004). Roster related sleep deprivation or circadian disruptions (jetlag) are acute or chronic stressors, which can negatively affect the brain and many psychological functions (McEwen, 2006; McEwen and Karatsoreos, 2015; Sapolsky, 2004). Regardless of the reasons why sleep is restricted – circadian disruptions, anxiety (e.g., unstoppable worries, unspecific fears), depressive disorders, jetlag, shift work, or other aspects of the modern 24-hours society – there are consequences for allostatic (over) load throughout the body. "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 and Karatsoreos, 2015). Over time, sleep restrictions and sleep disorders are associated with physical health impairment, e.g., cardiovascular vulnerability and diabetes. Sykes et al. (2012) reported an almost six-fold higher risk of kidney disease in pilots, and an almost 50-fold higher risk of skin cancer. As a result of chronic stress, psychophysiological changes in the brain and body are associated with altered reactions to stressors, impaired mood and deteriorated cognitive function (McClung, 2013; McEwen, 2004; McEwen and Karatsoreos, 2015; O'Hagan et al., 2018; O'Hagan et al., 2019).

Cortisol secretion was associated with chronic, uncontrollable stress (Dahm et al., 2017; Hannibal and Bishop, 2014; Lundberg and Frankenhaeuser, 1999; Mariotti, 2015; McEwen, 2008; Sapolsky, 2004). Cortisol causes wear and tear on the human body, but it is also vital (McEwen, 2006; Sapolsky, 2004). In healthy individuals, Cortisol is usually excreted one hour before wake-up-time, so that we can get up without fainting (Sapolsky, 2004). One symptom of allostatic (over)load after acute or chronic stress are higher cortisol levels in the evening, which were also reported for patients with major depression (McEwen and Karatsoreos, 2015; Sapolsky, 2004). High cortisol levels in the evening often prevent long and good sleep, due to longer sleep latency and shorter total sleep time (Chen et al., 2014; Kalmbach et al., 2018, 2020).

Bostock and Steptoe (2013) investigated how early and late flight duties of short-haul pilots are related to perceived stress, cortisol levels, mood, and fatigue. Early flight duty start was associated with higher cortisol levels after waking up and during the entire following flight duty period (day). The total secretion of cortisol was significantly higher when flight duty started early, compared with later starting flight duties or on rest days. In line with other studies, like Roach et al. (2012) and Vejvoda et al. (2014), early starting flight duties were associated with shorter sleep duration. Flight duties were associated with more stress, more fatigue and worse mood (Bostock and Steptoe, 2013). These results suggest that roster-related sleep-restrictions represent significant acute stress, and if repeated on a regular basis, in the long run chronic stress. In addition to that, pilots must deal with many different stressors every day. Shorter recovery time between flight duties implies that pilots must use their time off duty efficiently, to be fit to fly for the next flight duty period. Less time for children, spouse/partner and friends can increase psychosocial stress when the family suffers and family problems arise, which can often lead to a separation or divorce. With less social and family support, vital resources for coping with stress can disappear (Cullen et al., 2020; Sloan and Cooper, 1986; Widyahening, 2007).

„Stress begins in the brain and affects the brain, as well as the rest of the body. Acute stress responses promote adaptation and survival via responses of neural, cardiovascular, autonomic, immune, and metabolic systems." (McEwen, 2008). Thus, fatigue might not be the pilots' only problem. Other physical and mental health complaints related to acute and chronic stress seem to come with the wear and tear. Beyond fatigue, headache and other physical pain, impaired health and fatigue-related cognitive performance deficits were associated with long term allostatic overload (Chen et al., 2014; McEwen, 2008; McEwen and Karatsoreos, 2015; Sapolsky, 2004). Human brain structures can be damaged by long term stress and high allostatic load, affecting brain areas relevant for learning, the working (or short term) memory and executive functions (McEwen, 2004). These performance decrements were also reported in sleep deprivation and fatigue studies of pilots (Coombes et al., 2020; Hartzler, 2014). Brain tissue damages due to stress can be transient, if chronic stress only lasts several weeks (McEwen, 2006; McEwen, 2008). "However, it is not clear whether prolonged stress for many months or years may have irreversible effects on the brain." (McEwen, 2008).

High fatigue and micro-sleep despite fatigue risk management (FRM) and FTL

Despite various measures to prevent fatigue, several studies have consistently reported high levels of fatigue in active commercial pilots (Aljurf et al., 2018; Reis et al., 2013, 2016a, 2016b). Severe fatigue was reported by 68.3% to 93% pilots (Aljurf et al., 2018; Reis et al., 2013, 2016a, 2016b; Venus and grosse Holtforth, 2021a), although pilots' high on-duty sleepiness and fatigue represents an operational safety risk (Aljurf et al., 2018; Coombes et al., 2020; Goode, 2003; Reis et al., 2013, 2016a; Williamson & Friswell, 2017). Validation studies of the Fatigue Severity Scale (Krupp et al., 1989) showed less fatigue for healthy individuals (non-pilots) and some patient groups (Lerdal et al., 2005; Valko et al., 2008).

Although it is difficult to assess fatigue and sleepiness on the flight deck, micro-sleep represents a valid and reliable manifestation of high sleepiness and fatigue in the cockpit. Sudden incapacitation caused by fatigue – especially during micro-sleep episodes – can be as serious as sudden incapacitation because of medical reasons like stroke or heart attack (Coombes et al., 2020). The APA dictionary describes micro-sleep 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, monitoring flight parameters during uneventful flights etc.]. Micro-sleep episodes can be noticed when the head literally drops forward and can last from <1 s to minutes" (APA, 2021). "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). Situation awareness (SA) is vital for flight safety. SA disappears if a pilot accidentally nods off or falls asleep: The pilot will need some time to reorientate himself and to regain situational awareness. Redundancy in the multi-pilot cockpit - which is still absolutely necessary for the benefit of flight safety - is gone, if both pilots are 'micro-sleeping' at the same time (Coombes et al., 2020; ICAO, 2018). A recent study reported 1.1 cases per 2000 flight hours, where both pilots nodded off without coordination, and 7.3 cases of one pilot's micro-sleep on the flight-deck within 1000 flight hours (Coombes et al., 2020). In previous research, 45% to 76% pilots reported microsleeps in the cockpit (Aljurf et al., 2018; Venus and grosse Holtforth, 2021a; Williamson and Friswell, 2017).

1.4. Research questions

Fatigue, fatigue related performance decrements and flight safety

Several studies reported high levels of fatigue among pilots during the last years (Aljurf et al., 2018; Bourgeois-Bougrine et al., 2003; Reis et al., 2013, 2016b; Venus & grosse Holtforth, 2021a). Restricted rest periods, long and irregular shifts with multiple sectors on short haul (Jackson and Earl, 2006; Roach et al., 2012; Vejvoda et al., 2014; Venus and grosse Holtforth; 2021b), circadian disruptions, night flights and inconsistent roster patterns on trans-meridian long haul flights (Bendak and Rashid, 2020; Bourgeois-Bougrine et al., 2003; Reis et al., 2016a; Venus and grosse Holtforth; 2021b) often increase pilot fatigue. Minimum legal rest on ground (CASA FTL, 2013; EASA FTL, 2014) and insufficient on-board rest can enhance high fatigue levels (Williamson and Friswell, 2017).

Fatigue and on-duty sleepiness threaten flight safety by impairment of cognitive functions, decision making, perception, motivation and situational awareness (Bandeira et al., 2018; Bendak and Rashid, 2020; Coombes et al., 2020; Goode, 2003; Hartzler, 2014). Two of three Australian pilots reported fatigue-related errors, 20% having fallen asleep on the flight-deck without prior coordination (Williamson and Friswell, 2017). Every second pilot (48.8%) reported not feeling comfortable to leave their fellow pilot alone in the cockpit (Aljurf et al., 2018; Cullen et al., 2020). Fatigue Risk Management (FRM) should prevent fatigue and is mandatory in Australia (CASA FTL, 2013) and in EASA member states (EASA FTL, 2014), when operators want to deviate from FTL because of operational or economic reasons. FRM is generally recommended by ICAO, but may be less successful than expected (Bendak and Rashid, 2020; Bourgeois-Bougrine, 2020; Coombes et al., 2020).

Severe fatigue in the cockpit at flight-level 330 represents a considerable threat to passengers' and aircrews' safety. Nevertheless, problematic fatigue was reported for Australian and EASA based pilots (Aljurf et al., 2018; Reis et al., 2013, 2016b, 2016a; Williamson & Friswell, 2017). More liberal FTL in Australia (Table 1) allow, e.g., maximum flight duty periods of 14 h and 200 duty hours per month. These FTL could result in more demanding rosters for Australian pilots. This study was set out to investigate, if different FTL (CASA FTL, 2013; EASA FTL, 2014) are associated with significantly different duty schedules for pilots. The following hypothesis shall be tested:

H.1 Australian pilots report significantly more demanding rosters in terms of

a) more duty hours, and/or
b) flight hours, and/or
c) more sectors (take-offs and landings) and/or
d) early starts, and/or
e) night flights, and/or
f) standby days, and/or
g) fatigue risks associated with flight duties, and/or
h) fewer rest days, and/or
i) fewer vacation days, compared with EASA-based pilots.

More demanding rosters of Australian pilots could be associated with higher fatigue levels of pilots. In addition to more liberal FTL in Australia, regulators' different attitudes towards pilot fatigue could have an effect: EASA does not accept fatigue in active airline pilots (Commission Regulation (EU) 2018/1042), but in an email communication, the Australian regulator's fatigue specialist accepts fatigue-levels of the general population for active professional pilots, referring to Lerdal et al. (2005). Based on different FTL in EASA member states and Australia and regulators' different attitudes towards fatigue, the following hypothesis shall be tested:

H.2 Compared to EASA-based pilots, a greater proportion of Australian pilots report severe or high fatigue.

Stress, sleep, fatigue and mental health

So far, pilots' fatigue has been treated as stand-alone phenomenon, only associated with sleep deprivation, time on task, duty hours, and circadian disruptions as pilots crossed time zones. The terms fatigue and sleepiness were used as synonyms (e.g., Cosgrave et al., 2018; Gander et al., 2015; Holmes et al., 2012; Sallinen et al., 2017; van den Berg et al., 2016), ignoring the fact that drowsiness is just one symptom of more accumulated fatigue. Stress and the links between fatigue, physical and mental health were generally not addressed in these studies. We recently investigated, if the theory of allostasis and allostatic processes is applicable to pilots (Venus and grosse Holtforth, 2021a). This study reported highly significant intercorrelations between stress, sleep difficulties and fatigue, in line with several other studies (Hannibal and Bishop, 2014; Mariotti, 2015; McEwen, 2006; McEwen and Karatsoreos, 2015; McEwen and Stellar, 1993; Sapolsky, 2004).

Wu et al. (2016) reported positive depression-screening results for 13.5% international pilots, while only 8.6% of the general population reported PHQ9 $\geq$ 10 (Kroenke et al., 2009). Sleep deprivation was associated with impaired mood and performance (McClung, 2013; O'Hagan et al., 2019). More flight hours were associated with higher levels of depression and anxiety (O'Hagan et al., 2017) and common mental disorders (Feijo et al., 2012). Aljurf et al. (2018) used the Hospital Anxiety and Depression Scale (HADS) and reported abnormal depression symptoms for 34.5%, abnormal anxiety scores for 40.2% pilots (Aljurf et al., 2018). A higher proportion of severely fatigued pilots reported abnormal depression and anxiety symptoms.

Pilots' mental health and wellbeing has received more attention in the aftermath of the Germanwings crash (BEA, 2016; Cahill et al., 2021; Pasha and Stokes, 2018; Sloan and Cooper, 1986; Widyahening, 2007). Recent studies suggest that sleep problems and fatigue relate to impaired mental health (Aljurf et al., 2018; O'Hagan et al., 2017; Sloan and Cooper, 1986) and burnout (Demerouti et al., 2019; Fanjoy et al., 2010). High burnout levels were reported by 32.6% US-based regional pilots (Fanjoy et al., 2010) and 40% EASA-based pilots (Demerouti et al., 2019). 'Inappropriate' presenteesm (Johansson and Melin, 2018) was reported by 63% EASA-based pilots, who went on duty while actually unfit to fly due to fatigue, mental health issues or after stressful life events. 'Sickness presenteeism' was reported by 54% of the investigated active pilots, who went on flight duty unfit to fly, instead of taking sick leave (Johansson and Melin, 2018).

Only superficial and hardly comparable data is available regarding prevalence of depressive and anxiety disorders of the Australian or European general population. In Australia, anxiety disorders were more common than depressive disorders (AIHW, 2019), while depressive disorders were slightly more common in Europe (WHO, 2018). To our knowledge, no comparable data of EASA-based and Australian pilots' stress, sleep problems, fatigue, mental health, and wellbeing has been published or compared so far. Therefore, the following hypothesis shall be tested:

H.3 Australian pilots report significantly

a) more stress, and/or
b) more sleep problems, and/or
c) higher fatigue levels, and/or
d) more depression symptoms, and/or
e) more generalized anxiety symptoms, and/or
f) lower wellbeing, compared with EASA-based pilots.

Method

Procedure

This study was conducted as part an external PhD of the first author. So far, the authors have already examined how pilots' rosters, stress, sleep problems and fatigue are related to one another (Venus and grosse Holtforth, 2021a). Differences between short and long haul pilots were also analyzed (Venus and grosse Holtforth, 2021b). Going further than previous studies, we have not only looked at sleep problems and fatigue levels (Bourgeois-Bougrine et al., 2003; Caldwell, 2005; Honn et al., 2016; Jackson and Earl, 2006; Reis et al., 2013; 2016a), we also examined differences in stress levels, duty rosters, wellbeing, symptoms of depression and anxiety. The present study serves as the first exploratory pilot study to examine differences between actual schedules, stress, sleep difficulties, fatigue, well-being, symptoms of depression and anxiety of EASA-based and Australian pilots.

Before the start of this study, Ethical Approval No. 20180500008 was granted by the Ethics Commission of the Philosophisch Humanwissenschaftlichen Fakultaet of the University of Bern, Switzerland. Written consent was not necessary, because we guaranteed and protected confidentiality of the data collected with the anonymous online survey. The pilots were not compensated for their participation.

This study analyzed data of a cross-sectional online survey, which was used to assess directly comparable data of pilots from two continents with different FTL and regulations. In phase one, EASA-based pilots completed the cross-sectional online survey during peak flight season from June until October 2018 before the Covid-19 pandemic. In phase two, Australian pilots completed the survey from December 2018 until March 2019, during the Australian peak flight season. Participation was open to all commercial pilots who had flown for a commercial air operator in the past 12 months. The online survey was programmed with Lemon Survey®. European and Australian pilot unions emailed the link to the online survey to their members, embedded in newsletters, along with other news and links to other surveys. The aim of this complex study and the protection of anonymity was explained on the start page of the survey. Participants were informed that they would need their rosters of the past two months, and that they could stop and delete their data at any time.

Participants

Pilots should complete the survey on a rest day, off duty. Finally, 192 EASA-based and 180 Australian pilots completed the online-survey within M = 38 ± 18 min (M ± SD). 49.2% captains and 50.8% first officers participated in this research, with no significant rank differences on both continents (Chi-Square (1) = 0.259; p = 0.611). 8% of the EASA-based and 9% of the Australian pilots were female. 52% of the pilots in this study were flying for EASA based operators: 31% for network carriers (NWC), 13% for low-cost carriers (LCC), 5% reported cargo, 3% charter operations. Of the Australia based pilots, 23% reported flying for NWC, 18% for LCC, 1% cargo and 6% charter operations with significant differences in type of operator between the continents (Chi-Square (3) = 17.912; p < 0.001).

86% of the Australian pilots in this study were flying short and medium haul (sectors < 6 h, multiple sectors/day), 14% were operating long haul flights. 39% EASA-based pilots reported flying long haul, 61% short haul. Significantly more EASA-based pilots reported long haul operations, while the majority of EASA based and Australian pilots were flying short and medium haul (Chi-Square (1) = 29.953; p < 0.001).

Description of the cross-sectional online survey

Duty rosters and operational data

The online survey was based on previous studies (Aljurf et al., 2018; Reis et al., 2016a; Williamson and Friswell, 2017), to obtain comparable data. Pilots' maximum duty hours were assessed with*, "How long was your longest duty time in the last three years?"* and the *"Longest time awake, when you had to go on duty during your standby, from waking up until check out from flight duty"*. Pilots should also report their days of sick leave and days off because of fatigue in the past 12 months. Pilots total flight experience and flight hours on their latest aircraft type were assessed. Pilots rated 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 was called 'operator-stability and job-security', higher values indicate higher job security (range 0–10). Pilots should also rate on a 5-point Likert scale from 0 (never) to 4 (always) if they had experienced sleep restrictions or other fatigue risks on flight duties (Fig. 1). Pilots were also asked to rate the frequency of micro-sleeps on the flight deck, mistakes and incidents caused by fatigue on a 6-point Likert scale from never (0) to more than once/month (5). Finally, pilots were asked to rate their perceived fatigue protection (Fig. 2) and concerns about perceived fatigue threats associated with the present FTL on a 6-point Likert scale from 0 (no concern) to 5 (severe concern, Fig. 3). Pilots should report their duty schedules of the last two months. We expected that these rosters could affect pilots' perceived stress, sleep difficulties, fatigue, and mental health. We used the limits and definitions of the EASA FTL (2014) for early starts, night flights, etc. To investigate eventual beneficial effects of physical exercise, pilots were asked for their hours of

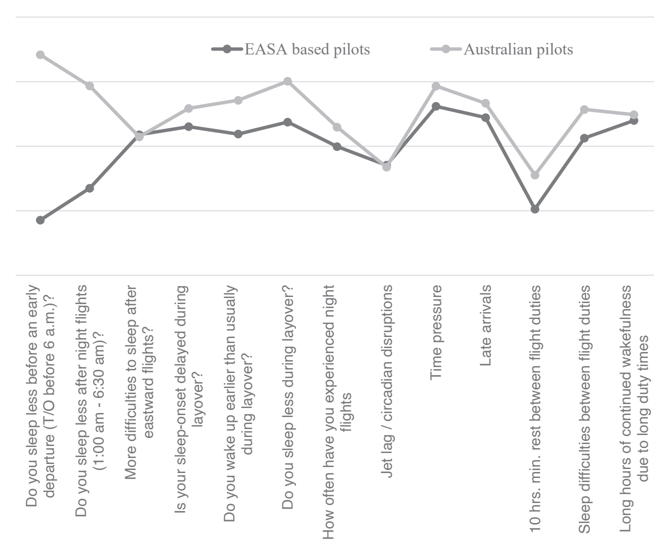

Fig. 1. Sleep restrictions and other fatigue risks associated with flight duties, reported by Australian and EASA-based professional pilots (N = 372). "When you were on flight duty, how often did you experience …" 0 = never, 1 = rarely, 2 = sometimes, 3 = often, 4 = always.

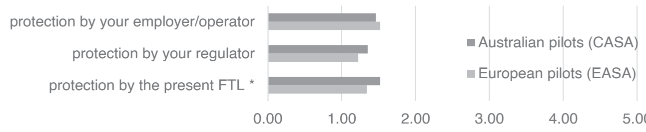

Fig. 2. Perceived protection from fatigue as perceived by EASA-based and Australian pilots: "According to your personal opinion: How good is the protection of flight crew against fatigue by …" 0 = no protection at all, 5 = high level of protection. Independent-Samples Mann-Whitney U Tests for significant differences between Australian and EASA-based pilots (* $p < 0.05$).

physical exercise.

Standardized questionnaires

Pilots' fatigue was self-assessed with the nine items of the Fatigue Severity Scale (Krupp et al., 1989). FSS example items are, *"I am easily fatigued. Fatigue causes frequent problems for me. Fatigue interferes with carrying out certain duties and responsibilities."* FSS had good internal consistency in healthy subjects, clinical patients, and in the general population, while FSS reliability was lower for pilots in this research. Scale means (M), standard deviations (SD), Cronbach's Alpha in this and in previous studies are displayed in Table 3.

Psychosocial stress was self-assessed with the ten stress related items of the Brief Patient Health Questionnaire (PHQ Stress) (Spitzer and Williams, 2005), which had acceptable internal consistency and referred to, *"Worries about your health, your weight or how you look; difficulties with your spouse, partner or friend; burden of caring for children, parents or other relatives; financial problems or worries, to have nobody to talk about problems"*.

Sleep problems were self-assessed with the Jenkins Sleep Scale (JSS, Table 3) (Jenkins et al., 1988). The four items are, *"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? 4) wake up after your usual amount of sleep feeling tired and worn out?"*

To measure pilots' mental health, screening instruments recommended by the World Health Organization (WHO) were used: Professional pilots' wellbeing was assessed with the WHO5 (Krieger et al., 2014; Winther Topp et al., 2015), with these 5 items; *"I have felt cheerful and in good spirits; I have felt calm and relaxed; I have felt active and vigorous; I woke up feeling fresh and rested; My daily life has been filled with things that interest me"*.

To obtain comparable data with Wu et al. (2016) or Cahill et al. (2021) the Patient Health Questionnaire 8 (PHQ8) was used for the self-assessment of depression symptoms (Kroenke et al., 2009; Razykov et al., 2012), asking for the key depression symptoms according to DSM IV (Kroenke et al., 2009), like *"Little interest or pleasure in doing things; Feeling down, depressed, or hopeless; Trouble falling or staying asleep or sleeping too much; Feeling tired or having little energy; Trouble concentrating on things"*.

The Generalized Anxiety Disorder Questionnaire (GAD7, Löwe et al., 2008; Spitzer et al., 2006; Spitzer and Williams, 2005) was used for the self-assessment of symptoms of generalized anxiety (Table 3). GAD7 asks for the key symptoms of generalized anxiety according to DSM IV (Spitzer et al., 2006), like *"Feeling nervous, anxious or on edge; Not being able to stop or control worrying; Trouble relaxing; Becoming easily annoyed or irritable"*.

Statistical analyses

SPSS Version 27.0 (Statistical Package for Windows by SPSS Inc., Chicago, IL, US) was used for statistical analyses, $p < 0.05$ was considered statistically significant. Chi-Square-tests were used to compare categorical data. Complex parametric procedures could be calculated due to metric or interval-scaled variables. For psychosocial stress, sleep problems, fatigue-severity, wellbeing, symptoms of depression and generalized anxiety the scale scores were used.

To test H.1 and H.3, a multivariate General Linear Model (GLM) with the group-variable EASA-based vs. Australian pilots was calculated, to compare all dependent roster variables, stress, sleep, fatigue, and mental health variables in one analysis, to minimize the α-error compared with 23 bivariate independent t-tests. To test H.2, the traditionally used cut-off values were referred to (Kroenke et al., 2009; Lerdal et al., 2005; Spitzer et al., 2006; Valko et al., 2008). Additional Chi-Square-tests were calculated to test significant group differences.

Table 3
Scale means (M), standard deviations (SD) and Cronbach's Alpha for reliability/internal consistency in this research (N = 372 Australian and EASA based professional pilots) and in previous studies.

Scale	Scale Range	Cut-Off Values	Cronbach's Alpha (this study)	Cronbach's Alpha (former research)
Well-being WHO5	1–100	< 50 < 29	0.89	0.83 to 0.95 (Krieger et al., 2014)
Depression Screening PHQ8	0–24	≥ 10	0.90	0.82 (Kroenke et al., 2009)
Anxiety Screening GAD7	0–21	≥ 10	0.90	0.92 (Spitzer et al., 2006)
Fatigue Severity Scale FSS	1–7	≥ 4 ≥ 5	0.82	0.93 (Valko et al., 2008) 0.88 (Lerdal et al., 2005)
Jenkins Sleep Scale JSS	0–5	≥ 3 ≥ 4	0.85	0.84 (Jenkins et al., 1988)
PHQ-Stress (psychosocial stress)	0–20		0.81	

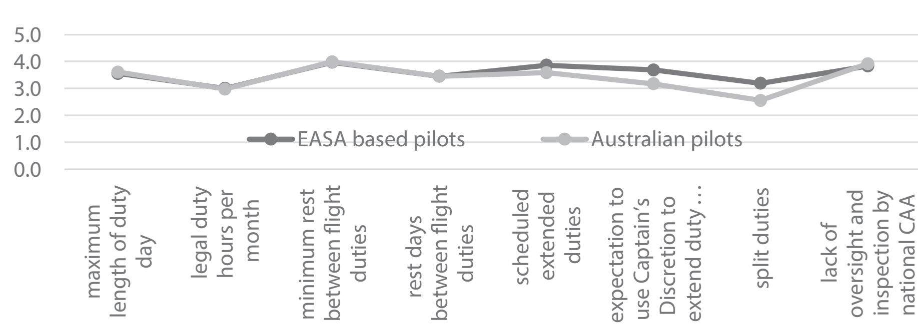

Fig. 3. Mean ratings of Australian and EASA-based pilots' concerns: "What worries you most about the current Flight Time Limitations?" 0 = no concern, 5 = severe concern.

Findings

Descriptive results

Australian pilots reported significantly more sleep restrictions associated with flight duties (16.80 ± 3.90) than EASA-based pilots (11.25 ± 2.83; F (1,137) = 83.153, p < 0.001), with significantly different profiles (Fig. 1). In addition to various flight duty related sleep restrictions, 18.3% Australian and 9.4% EASA-based pilots reported considerable sleep problems in 8 to 14 nights per month. 10% European and 8.3% Australian pilots reported significant sleep problems in 15 or more nights/month.

Australian pilots also reported significantly more other fatigue risks on flight duties (e.g., time pressure, late arrivals, night flights, sleep problems between flight duties, Fig. 1) than EASA-based pilots, with different fatigue risk profiles (F(1,357) = 21,486, p < 0.001).

Both pilot groups perceived protection from fatigue by their employers, FTL and the responsible regulators equally low (F(1,356) = 1.169, p = 0.280, Fig. 2).

Of the EASA-based pilots, 76% had experienced microsleeps in the cockpit or had accidentally fallen asleep at the controls once or more often on active duty, vs. 72.6% Australian pilots. While only 10.2% EASA-based and 5.6% Australian pilots reported no fatigue related errors or mistakes in the cockpit, 21.2% EASA-based and 26.2% Australian pilots reported fatigue related errors once/month or more often. Involvement in fatigue related incidents or accidents on flight duty were reported by 23.2% of the EASA-based and 43.7% of the Australian pilots. EASA-based and Australian pilots perceived threats associated with their FTL equally.

Hypothesis testing

Fatigue and mental health of EASA based and Australian pilots

H.2 stated that significantly more Australian pilots would report severe or high fatigue and was not confirmed. Although EASA based and Australian pilots were scheduled for only 57–62% of maximum duty and flight hours, 33% EASA-based and 31.7% of the Australian pilots reported high fatigue levels (FSS ≥ 5), in addition to that, 38.8% EASA-based vs. 45.3% Australian pilots reported severe fatigue (FSS 4 to 4.9), with no significant differences between the continents (Chi Square (2) = 2.092, p = 0.351). 71.8% EASA-based vs. 77% Australian pilots reported severe or high fatigue. FSS means of EASA-based and Australian pilots were exactly equal with M = 4.46 (Table 4), they were more than one SD higher than FSS scores of healthy subjects (FSS 3.00 ± 1.08) and almost 1 SD higher than FSS means of the general population (3.67 ± 1.35).

Significant differences between EASA-based and Australian pilots

To test H.1 and H.3, a multivariate GLM was calculated. The fixed group variable was EASA-based vs. Australian pilots, the dependent variables were all interval scaled or metric. The multivariate effect of the group variable was significant (F(28;247) = 5.278, p < 0.001, ε^2 = 0,374), tests of between-subjects-effects showed significant differences in several variables (Tables 4 and 5).

H.1 a) to i) stated that Australian pilots would report significantly more demanding rosters with significantly more duty and flight hours, more early starts, more sectors/month etc. H.1c) to i) were confirmed (Tables 4 and 5): Australian pilots reported significantly more sectors per month, significantly more standby days, significantly fewer rest and vacation days, significantly more early starts, more hours of physical exercise and more fatigue risks associated with flight duties. EASA-based pilots reported more flight hours and less duty hours/month than Australian pilots (Tables 4 and 5), in line with more short haul pilots in Australia.

H.3 stated that Australian pilots would report a) significantly more stress, and/or b) more sleep problems, and/or c) higher fatigue levels, and/or d) more symptoms of depression, and/or e) more symptoms of generalized anxiety, and/or f) lower wellbeing, compared with EASA-based pilots. H.5b) and f) were confirmed. In line with more demanding rosters, Australian pilots' wellbeing was significantly more impaired. Australian pilots also reported significantly more sleep problems (Tables 4 and 5).

Australian pilots' felt significantly worse than European pilots. 51.8% of the Australian pilots reported feeling equally good or better than the general population, while 57.6% EASA based pilots did so. Positive depression screenings (PHQ8 ≥ 10) were reported by 17.2% Australian and 18% EASA-based pilots, with no significant group differences (Chi Square (1) = 0,037, p = 0,847). 8.5% EASA-based and 7.8% Australian pilots reported positive anxiety screenings (GAD7 ≥ 10), with no significant group differences (Chi Square (1) = 0.058; p = 0.809). Overall, 6.7% Australian pilots and 6.9% EASA-based pilots reported positive depression *and* anxiety screening results.

When the PHQ8 Algorithm (Kroenke et al., 2009) was used, 7.8% EASA-based vs. 6.7% Australian pilots screened positive for suspected major depression, another 8.3% EASA-based vs. 6.7% Australian pilots screened positive for other depressive disorders, with no significant group differences (Chi Square (2) = 0,597, p = 0.742).

Table 4
Scale means (M) and Standard Deviations (SD) of the roster data, sleep problems, fatigue-severity, mental health, and wellbeing of EASA based and Australian pilots (N = 372) in this research.

Dependent Variables	EASA-based Pilots M ± SD	Australian Pilots M ± SD
Age	40.31 ± 10.19	41.15 ± 10.99
Flight hours on your present type of aircraft	4411 ± 3'626	3'972 ± 105
commuting time (one way in minutes)	61.17 ± 64.18	52.85 ± 73.83
flight hours/month[‡]	62.03 ± 19.62	60.80 ± 21.02
duty hours/month[‡]	109.02 ± 39.69	116.20 ± 34.42
no. of sectors flown/month[‡,**]	63.34 ± 44.81	91.06 ± 61.20
standby days/month[‡,**]	1.93 ± 1.99	2.66 ± 2.73
rest days/month[‡,**]	11.00 ± 3.22	9.68 ± 2.84
vacation days/month[‡,**]	2.79 ± 3.43	1.89 ± 3.82
no. of early starts/month[‡,**]	4.10 ± 3.92	5.20 ± 4.07
no. of night flights/month[‡]	3.86 ± 3.96	4.22 ± 6.07
hours of physical exercise/month[‡,**]	12.01 ± 8.46	16.36 ± 11.64
operator stability & job security	7.32 ± 2.22	7.23 ± 2.51
fatigue risks associated with flight duties[**]	12.44 ± 3.81	14.84 ± 3.71
days off "unfit to fly" due to fatigue (last year)	1.04 ± 1.87	1.42 ± 2.23
days off "unfit to fly" (sick leave last year)	6.37 ± 9.94	7.05 ± 14.28
Longest duty time (last 3 years)[**]	15.39 ± 2.30	14.22 ± 2.34
Longest time awake (flight duty during standby)	19.70 ± 5.92	18.58 ± 6.32
Psychosocial stress (PHQ-Stress)	4.74 ± 3.57	4.93 ± 3.30
Fatigue Severity Scale (FSS)	4.46 ± 1.06	4.46 ± 0.91
Sleep problems (JSS)[**]	1.80 ± 1.20	2.17 ± 1.09
Wellbeing PR (WHO5)[**]	57.56 ± 20.24	51.80 ± 19.32
Depression screening (PHQ8)	5.54 ± 4.74	5.72 ± 4.04
Generalized anxiety screening (GAD7)	3.76 ± 3.76	3.94 ± 3.63

Note: M = Mean, SD = Standard Deviation.
[‡] *Means of the last two months were used.*
[**] *Significant group difference (p < 0.05).*

Discussion

Although the pilots were only rostered for 57% to 62% of the legally permitted monthly duty and flight hours (CASA FTL, 2013; EASA FTL, 2014), 71.8% EASA-based vs. 77% Australian pilots reported severe or high fatigue. Australian pilots reported more demanding rosters, significantly more sleep problems and lower wellbeing. Australian and EASA based pilots reported similar stress levels, symptoms of depression

Table 5
Multivariate GLM, Tests of Between Subjects Effects Differences between EASA based and Australian pilots incl. effect size (Partial Eta Square).

	Tests of between Subjects Effects	F (df = 1)	Sig.	Partial Eta Square
Groups: EASA based vs. Australian pilots	flight hours	0,251	0,616	0,001
	duty hours	2,588	0,109	0,009
	no. of sectors flown	17,874	0,000	0,061
	standby days	6,267	0,013	0,022
	rest days	12,981	0,000	0,045
	vacation days	4,144	0,043	0,015
	no. of early starts	5,226	0,023	0,019
	no. of night flights	0,326	0,568	0,001
	hours of phys. exercise	12,256	0,001	0,043
	commuting time (one way in minutes)	0,982	0322	0004
	monthly net income €	0,454	0,501	0,002
	flight hours on present aircraft	0,871	0,351	0,003
	Age	0,435	0,510	0,002
	job security	0,091	0,764	0,000
	Fatigue risks experienced on flight duty	28,064	0,000	0,093
	days of sick leave	0,028	0,866	0,000
	days off due to fatigue	1,154	0,284	0,004
	days "unfit to fly" due to fatigue (last year)	2,342	0,127	0,008
	days "unfit to fly" due to sickness (last year)	0,202	0,654	0,001
	Longest duty time	17,269	0,000	0,059
	Longest time awake when flight duty during standby	2,267	0,133	0,008
	WHO5	5,764	0,017	0,021
	PHQ8	0,128	07,20	0,000
	GAD7	0,169	0,681	0,001
	PHQ Stress	0,217	0,642	0,001
	FSS	0,002	0,961	0,000
	JSS	7,059	0,008	0,025

Note: Partial Eta Square: Effect Size.

and anxiety.

These high levels of fatigue are concerning because the investigated pilots were scheduled for 38% to 43% fewer duty and flight hours than the legal maximum (CASA FTL, 2013; EASA FTL, 2014). Consistent with the theory of allostasis and allostatic (over)load (McEwen, 2006; McEwen and Karatsoreos, 2015; Sapolsky, 2004), far more pilots, compared with the general or healthy population, reported severe or high fatigue, positive depression and anxiety screening results (Kroenke et al., 2009; Spitzer et al., 2006). The significant role of psychosocial stress was mostly neglected in previous fatigue studies, although stress was stongly associated with sleep problems, fatigue (Venus and grosse Holtforth, 2021a). Frequent sleep deprivation due to flight duties, and other fatigue risks can promote fatigue, prevent sufficient good quality sleep and impair health, while acute and chronic stress can themselves impair sleep and recovery (Jansson and Linton, 2006; Kalmbach et al., 2020; McEwen, 2006; McEwen and Karatsoreos, 2015; Sapolsky, 2004). Pilots must cope with time pressure and other stressors, even traumatic events like near miss with drones or being blinded by laser pointers on short final, the most safety critical phase of flight. High levels of cortisol after a stressful flight, long sleep latency or long times awake after sleep onset aggravate the problem, in addition to other life events like divorce, change of home-base or job-loss: "During high stress, individuals having difficulty falling or staying asleep may be vulnerable to cognitive intrusions after stressful events, given that the inability to sleep creates a period of unstructured and socially isolated time in bed" (Kalmbach et al., 2018). Insomnia and cognitive intrusions significantly predicted depression severity over three years (Kalmbach et al., 2018). Consistent with recent research, stress was strongly related to sleep problems or insomnia (Kalmbach et al., 2018; Sapolsky, 2004). Sleep problems and sleep deprivation were related to impaired mood or symptoms of depression (McClung, 2013; O'Hagan et al., 2019). Recent, still unpublished research reported that stress, sleep problems, fatigue-levels, wellbeing, depression and anxiety symptoms were significantly intercorrelated (Venus and grosse Holtforth, n.d.). Considerable evidence has shown, that chronic stress promotes burnout and insomnia (Armon et al., 2008; Demerouti et al., 2019; Ekstedt et al., 2006; Jansson and Linton, 2006; McEwen, 2006; McEwen and Karatsoreos, 2015; Sapolsky, 2004).

Pilots' mental health & wellbeing

Australian pilots' wellbeing was significantly more impaired, while both groups were on average above the WHO5 cut-off value 50 (Krieger et al., 2014). Individuals with WHO5 < 50 should undergo the clinical-psychological diagnostic process, so that the diagnosis of a depressive disorder can be excluded or confirmed (Krieger et al., 2014). Referring to the WHO5 screening results in this study, a more detailed diagnostic evaluation would be recommended for 48.2% Australian and 42.4% EASA-based pilots.

Pilots' depression and anxiety screening results

Compared with the general population (Kroenke et al., 2009), almost twice as many pilots reported positive screening results for major depression and other depressive disorders. More pilots reported significant symptoms of depression when the cut-off value PHQ8 $\geq$ 10 was used (17.6%), compared with the diagnostic algorithm (14.8%), probably because of considerable sleep problems and exhaustion among pilots. These results are comparable with the PHQ9 results of Wu et al. (2016) and Cahill et al. (2021), who reported positive depression screenings for 13.5% and 16% international pilots respectively. Aljurf et al. (2018) used the Hospital Anxiety and Depression Scale (HADS) and reported 34.5% pilots with abnormal depression symptoms.

In this study, overall 8.1% pilots reported significant anxiety symptoms (GAD7 $\geq$ 10), in contrast to 40.2% pilots, when assessed with HADS (Aljurf et al., 2018), and compared with 5% of the general population (Löwe et al., 2008). Almost 7% pilots reported positive depression *and* anxiety screening results. These results could be explained with considerable sleep problems, resulting impaired mood and high levels of fatigue. In FRM trainings pilots learn that fatigue in the cockpit is a severe threat to flight safety. Most pilots are aware of these risks and fear accidentally falling asleep at the controls on the flight deck, which is nevertheless quite common (Coombes et al., 2020).

Pilots' anxiety levels were on average low, and more symptoms of generalized anxiety are likely not pathologic anxiety. According to ICD-10 6B00 'generalised anxiety disorder' represents excessive *unreasonable* fears, worries and rumination without real life-threatening imminent stressors. Today pilots must cope with real existential threats and fears due to fatigue, sleep problems or beginning burnout, realistically fearing to lose their career and livelihood. In addition to that, pilots must generally cope with all risks associated with flying airplanes and having their front office 10 km above ground. Air travel has become very safe, but engine shut-downs, system failures, etc. still occur. Wind shears, thunderstorms, congested airspace, and busy airports are more frequent risks. Our self-assessed GAD7 results cannot distinguish between pathological "generalized anxiety" and realistic worries, existential stressors, and threats pilots may encounter on a daily basis.

Pilots with significant symptoms of accumulated fatigue, sleep problems, burnout, depression or anxiety should inform their aeromedical examiner about their problems. Most pilots are reluctant to do so, fearing to lose their medical certification or even their job. Many pilots may not even know that they should inform their aeromedical examiner about their impaired health, because they simply adapted to feeling worse and worse due to more duty and flight hours, longer shifts, more stress, constant time pressure and detrimental economic competition over the last decades. Just like their colleagues.

High fatigue plus depression symptoms = burnout?

Demerouti et al. (2019) reported high burnout scores for 40% of their investigated pilot sample, 20% had burnout scores as high as in-patients treated for burnout. Almost 18% pilots in this research reported significant symptoms of depression and/or anxiety. Bianchi et al. (2015) reported vast overlap of burnout and depression. All mental health issues – depression, anxiety and burnout – are disqualifying for pilots, according to e.g. MED.B.055 and MED.B.060 of Part-MED. Any mental health issue can lead to long term grounding, often followed by final withdrawal of the medical certification and layoff. Commission Regulation (EU) 2018/1042 states, that pilots are not allowed to fly when fatigued or when their physical or mental health is impaired. Coombes et al. (2020) concluded that fatigue related performance impairment and pilots' micro-sleep events at the controls are comparable with medically driven incapacitation. Consequently; the question arises, when fatigue, sleep problems and beginning burnout might render pilots legally unfit to fly. Pilots' mental and physical health is crucial for flight safety in single pilot and multi crew operations, to prevent *sudden in-flight incapacitation'* (ICAO, 2012) or another Germanwings (BEA, 2016) or LAM crash (MWT, 2016), where the mentally sick pilot in the cockpit intentionally crashed a fully functional passenger jet into the ground.

Differences between Australian and European Pilots

Our results suggest that Australian pilots might to be more resilient than European pilots. Despite more demanding rosters with more duty hours, more early starts, more flown sectors, more fatigue risks associated with flight duties, Australian pilots reported significantly more hours of physical exercise, while their reported stress, symptoms of depression and anxiety were on average low and like EASA based pilots. Significantly more sleep problems and lower wellbeing of pilots seem to be owed to more demanding schedules. It is also possible that Australian pilots tend to downplay their symptoms of depression and anxiety.

Fatigue risks, FTL and flight safety

Pilots' high concerns regarding the present FTL and the perceived lack of protection against fatigue suggest, the present FTL may be dysfunctional for EASA-based and Australian pilots. Mandatory FRM, the use of Biomathematical Models (BMM) for legal and safe rosters and mandatory fatigue reporting seem to fail. The International Labor Organization ILO recommends, work time arrangements must be designed to prevent occupational accidents and impairment of health (ILO, 2019). Nonetheless, present FTL likely do not prevent fatigue, sleep problems (Aljurf et al., 2018; Reis et al., 2013, 2016b, 2016a; Venus and grosse Holtforth, 2021a), burnout (Demerouti et al., 2019; Fanjoy et al., 2010) and mental health issues (Aljurf et al., 2018; Cahill et al., 2021; Wu et al., 2016), as replicated in our results. EASA's evaluation of shortcomings of the present FTL is ongoing (European Commission, 2019). The Australian regulator (CASA) published a report on Australian pilots' fatigue (Williamson and Friswell, 2017). In the comments section of the presented study, many pilots reported that their duty rosters and restricted rest times were often obstacles for long and good quality sleep. A pilot wrote: *"[Operators] scheduling crew up to maximum FDP [flight duty periods], associated high workload (multiple sectors, slot delays, pax [passenger] issues, weather, complex airports, busy skies, tech issues, early starts, late finishes) followed by minimum rest is now more than ever taking its toll on crew wellbeing and cumulative fatigue levels."* Despite on average low anxiety screening scores, pilots reported to be frightened by the lack of protection against fatigue. A pilot uttered his concerns: *"Fatigue levels going through the roof and more absence due to fatigue than ever before. It's the crew and the crew alone that have to deal with the burden of ruined sleep, destructed social and family lives and eventually – shattered careers."*

Pilots are legally allowed to rest, nap or sleep according to CAT.OP.MPA.210 (3) (EASA FTL, 2014). ICAO recommends: *"During all phases of flight each flight crew member required to be on duty in the flight crew compartment shall remain alert. If a lack of alertness is encountered, appropriate countermeasures shall be used. If unexpected fatigue is experienced, a controlled rest procedure, organized by the commander, may be used if workload permits."* (ICAO, 2015). ICAO (2011) additionally states: *"During controlled rest; the non-resting pilot must perform the duties of the pilot flying and the pilot monitoring, be able to exercise control of the aircraft at all times and maintain situational awareness. The non-resting pilot cannot leave his/her seat for any reason, including physiological breaks."* When both pilots nod off or fall asleep unintentionally, as previous studies reported (Aljurf et al., 2018; Coombes et al., 2020; Venus and grosse Holtforth, 2021a; Williamson and Friswell, 2017), nobody on the flight deck can maintain situation awareness as legally required (ICAO, 2011). Situation awareness is still crucial for flight safety, despite sophisticated avionics and high levels of automation in large modern aircrafts.

Fatigue related errors can quickly become fatal, when one or more systems fail in flight. Over thousands of flight hours, pilots acquire excellent coping abilities to overcome severe sleepiness in the cockpit, and to stay sufficiently alert to manage the flight deck. Nevertheless, thiscoping-effort seems to take its psychophysiological toll, impairing mood, physical and mental health, further enhancing accumulated fatigue. This could explain the high prevalence of burnout of professional pilots (Demerouti et al., 2019; Fanjoy et al., 2010), and the high rates of significant depression symptoms or impaired mood (Aljurf et al., 2018; Cahill et al., 2021; McClung, 2013; O'Hagan et al., 2019; Wu et al., 2016).

The safety relevance of accumulated fatigue is underpinned by the reported high incidence of microsleeps on the flight deck, fatigue related errors and incidents or accidents, similar to previous research (Aljurf et al., 2018; Coombes et al., 2020; Venus and grosse Holtforth, 2021a; Williamson and Friswell, 2017). Three of four pilots reported severe accumulated fatigue, associated were more symptoms of depression in terms of exhaustion and impaired mood, as consequence of chronic sleep deprivation and accumulated fatigue (McClung, 2013; Venus and grosse Holtforth, 2021a, 2021b). The reported depression symptoms represent less likely clinical depression.

Limitations

Representativity of the sample

This study is a first exploratory pilot study. Finally, 192 EASA-based and 180 Australian pilots answered all questions of the comprehensive online-survey. The potential target group were members of pilot unions in Europe and Australia. The survey link was sent out in newsletters, along with other news for pilots and links to other surveys.

Participation was probably more difficult due to various hurdles: Pilots usually get grounded for months or forever, when they are dealing with mental health issues. Therefore, reporting mental health problems in an online survey may have deterred pilots from participating.

The survey was long, and pilots had to have their own rosters of the last two months at hand, which was an additional hurdle for many pilots who dropped out. The aim of this study was to assess commercial pilots in their peak flying season, when most duty and flight hours were expected: EASA-based pilots completed the online survey during the summer months, Australian pilots in the period after Christmas. In the off-season, more pilots would probably have participated.

The representativity of the sample is difficult to check. Pilots from EASA Member States and Australia participated in this research, short and long-haul pilots of different operators. Without any funds, we could not address a representative random sample and compare the groups.

We collected lots of data to describe the sample as accurately as possible. The pilots in this research were rostered for on average 57% to 62% of the maximum monthly duty and flight hours. Pilots with the maximum legally allowed 190 to 200 duty hours and 100 flight hours per month did not participate in this study. This could explain, why fewer pilots were severely fatigued compared with other studies (Reis et al., 2013, 2016a), and similarly fatigued but with fewer symptoms of depression (Aljurf et al., 2018).

Cahill et al. (2021) investigated 1059 pilots, of whom 16% reported significant symptoms of depression (PHQ9 $\geq$ 10). Wu et al. (2015) investigated 1848 international pilots and reported PHQ9 $\geq$ 10 for 13.5% pilots. In this study, 17.5% pilots reported PHQ8 $\geq$ 10, comparable with the referenced studies.

Self-Assessed screening results are no diagnoses

Screening instruments tend to overestimate the prevalence of mental health issues (Razykov et al., 2012; Thombs et al., 2018). Sum scores of self-assessed screening instruments obtained through online surveys cannot be considered diagnoses of mental disorders. Screening results only indicate a likely diagnosis of, e.g., a depressive or anxiety disorder and requires confirmation by standardized clinical psychological diagnosis. Artefacts must be avoided: for example, what looks like a positive depression screening (PHQ8 $\geq$ 10) might be an exhausted, severely fatigued pilot, whose mood is impaired due to roster related sleep deprivation.

Results of psychological questionnaires can generally be questioned; questionnaire results can be biased on purpose or by chance. Therefore, psychophysiological measurement of fatigue and recovery would be needed, supported by in-depth data regarding living conditions, work-related and psychosocial stress, mental health, prescribed and over the counter medication, potential causalities, everything collected in the diagnostic process.

Strengths

While some studies have compared short and long haul pilots regarding sleepiness and fatigue (Bourgeois-Bougrine et al., 2003; Caldwell, 2005; Honn et al., 2016; Jackson and Earl, 2006; Reis et al., 2013, 2016a; Venus and grosse Holtforth, 2021b), to our knowledge no study has compared pilots of different continents with different FTL regarding fatigue, and no previous study examined stress, sleep problems, fatigue and mental health of pilots from two continents. This study investigated, if different flight time limitations would be associated with significantly different duty rosters for pilots and found several significant differences. The next research question was to investigate, if different rosters would be associated with different levels of psychosocial stress, sleep difficulties, fatigue, impaired wellbeing, and depression and/or anxiety symptoms, and gave interesting insights.

This research asked for individual pilots' rosters, not the general impact of different FTL, rules and regulations. Furthermore, our cross-sectional online survey measured more variables in terms of working conditions, work-related and psychosocial stress, sleep problems, fatigue, wellbeing, symptoms of depression and anxiety. PHQ8 and GAD7 are based on the DSM IV, therefore their validity and reliability is undisputed (Krieger et al., 2014; Kroenke et al., 2009; Razykov et al., 2012; Spitzer et al., 2006).

We used approved, standardized screening instruments, whose results can be compared with previous studies (Aljurf et al., 2018; Reis et al., 2013; Reis et al., 2016a; Reis et al., 2016b; Wu et al., 2016) and with the general population (Kroenke et al., 2009; Lerdal et al., 2005; Spitzer et al., 2006; Valko et al., 2008). This may also be the first endeavor to collect comparable data on fatigue, sleep problems, mental health, and wellbeing of European and Australian pilots. Our multi-level approach made it possible to differentiate between symptoms of mental disorders like depression, generalized anxiety and well-being, as well as to measure stress and separately sleep problems and fatigue.

Given the guaranteed anonymity of this online survey, pilots were expected to answer honestly. Some pilots may inadvertently downplay their mental health issues because they adapted to consequently deteriorating working conditions, shorter rest, longer flight duties etc. over the years, and slowly got used to fatigue and impaired mood, worrying more and more to lose their job or their life in a crash.

Research implications

Future research should investigate, why EASA-based and Australian professional pilots consistently reported concerning high levels of fatigue, despite FTL, FRM and the use of Biomathematical Models to prevent fatigue. More research is needed to investigate, if accumulated fatigue is more often the reason or the consequence of impaired mental fitness, especially in context with sleep restrictions, sleep problems, depression, and burnout.

More research is needed to investigate why Australian pilots reported more demanding duty rosters but the same levels of stress and fatigue and not significantly more symptoms of depression and anxiety. Australian pilots only reported significantly more impaired well-being and significantly more sleep problems, while their mental fitness was not more impaired. More research is needed to find out whether Australian pilots are actually more resilient than EASA-based pilots: Despite more strenuous schedules, Australian pilots reported significantly more physical exercise, while their sleep quality and well-being suffers. More knowledge is needed to investigate, whether it is only a matter of time before pilots' physical and mental health is ultimately compromised to the point where pilots are actually unfit to fly.

Almost twice as many EASA-based and Australian pilots reported positive depression and anxiety screening results and high fatigue levels, compared to the general population. Future research should also focus on the prevention of fatigue and mental health issues of pilots. Appropriate, effective treatment methods for pilots should be developed, how pilots' fitness to fly can be maintained or regained. AMEs along with clinical and aviation psychologists should cooperate regarding qualified, evidence-based decisions regarding mental health assessment in context with renewal of Medical Class 1. In FRM training according to ORO. FTL.250 (EASA FTL, 2014; Hartzler, 2014; ICAO, 2015) pilots should learn about the close relationships between stress, sleep, fatigue and mental health, and how stress cannot only impair sleep (Bostock and Steptoe, 2013; Kalmbach et al., 2018, 2020), but can also cause mental health issues and cardiovascular disorders (Sapolsky, 2004).

Conclusions

Australian pilots may be more resilient than European pilots: They reported significantly more demanding duty rosters, but also significantly more hours of physical exercise. Australian pilots reported the same levels of stress, depression, and anxiety symptoms and equal, concerningly high fatigue levels as EASA based pilots. Australian pilots reported significantly more sleep problems and more impaired well-being. The high fatigue levels are concerning because the investigated pilots were scheduled for far less duty and flight hours than legally allowed, according to the applicable flight time limitations.

The traditional fragmented view of pilot fatigue may not be appropriate when stress and health are closely related to fatigue and sleep, according to the theory of allostasis. Fatigue is not an isolated problem for pilots' performance and flight safety, but is closely related to the pilots' health and well-being. Compared to the general population, more EASA based and Australian pilots reported significant symptoms of depression and anxiety. Future research and regulations development should consider the complex relationships between flight duty schedules, stress, sleep disturbances, fatigue, and pilots' flight safety relevant physical and mental health. New measures are necessary to better protect pilots' health and flight safety.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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