Fatigue Among Student Pilots

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INTRODUCTION: Fatigue is an important phenomenon in modern aviation. Despite the progress in research concerning fatigue among civil aviation and military pilots, fatigue in student pilots has remained unexamined. The aim of this study was to examine fatigue among ab-initio pilots. In this study, the fatigue model previously proposed and used in the literature is redesigned for ab-initio pilots.

METHOD: A 48-item questionnaire was applied. Factor analysis was performed using SPSS. The data were collected from 114 ab-initio pilots.

RESULTS: It was determined that 23% ($N = 26$) of the participants included in the study were women and 77% ($N = 88$) were men. When the license types of the participants were analyzed, it was seen that 11% ($N = 13$) had commercial pilot licenses (CPL; $N = 80$), 70% had private pilot licenses (PPL), and 18% ($N = 21$) had student pilot licenses (SPL). Results showed that seven performance factors (types of flight, training scheduling, crew composition, environment of the aircraft, types of accommodation, flight training-related issues, and biological issues) affect ab-initio pilots' fatigue on various levels.

DISCUSSION: The findings may help flight training organizations and ab-initio pilots take assertive preventive measures against fatigue.

KEYWORDS: fatigue, ab-initio pilots, civil aviation, human factors, pilot training.

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Civil aviation growth has increased dramatically over the past two decades, and this growth and a corresponding increase in the fleets of airlines have resulted in the demand for pilots, cabin crew, technicians, and dispatchers all over the world. To meet this demand, airline companies, flight training academies, universities, and small regional flight schools are striving to mitigate crew shortages.[1] During ab-initio flight training, cadets are trained according to regulations of the respective civil aviation authorities, e.g., the Federal Aviation Administration (FAA), Civil Aviation Authority (CAA), or European Aviation Safety Agency (EASA). All cadets need to complete a number of training phases such as a ground training course and a flying course with single engine aircraft and multiengine aircraft to obtain an airman certificate.[7] During training flights, cadets are likely to be exposed to various challenges, including fatigue, spatial disorientation, stress, personal readiness, and lack of theoretical knowledge.[18] Among these risk factors, fatigue is one of the most widely challenging factors for student pilots.[14]

Fatigue is a common problem in the aviation industry, as well as in other industries. It gives rise to increased discomfort, loss of capacity, feeling of tiredness and weariness, and significant impairment in individuals' ability to perform tasks.[8,16] Fatigue may give rise to lowered response times and impaired attention and alertness among aviators.[10] Furthermore, it may result in impairment of cognitive skills (e.g., decision-making and situational awareness), which are vital for a safe flight operation.[13]

Fatigue-related impairment is one of the most common causal factors of accidents and incidents in aviation.[4] Previous studies have reported that fatigue (as a human factor) is one of the contributing factors of more than 70% of accidents in aviation.[28] Since the 1970s, fatigue has become a central issue for the National Transportation Safety Board (NTSB).[9] In 1994, NASA's Aviation Safety Reporting System demonstrated that fatigue gave rise to 21% of the reported aviation incidents.[23] It was reported that fatigue was a contributing factor to 7 air carrier accidents (250 fatalities and 52 serious injuries) within the

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United States over the past two decades.[6] In another study, it was stated that 25% of the U.S. Air Force accidents that occurred in the period of 1974–1992 were attributed to fatigue. In 2019, Havle and Kilic demonstrated that fatigue in flight crew is one of the major contributing factors to gross navigation errors during transatlantic flights.[12] In a more recent study, fatigue was identified as the major contributing factor for many (15%) hot-air balloon accidents.[15]

Ab-initio pilots need to perform various types of flights (e.g., solo flight, cross-country flight, takeoff and landing practices, instrument flights, and training flights for emergencies) to get pilot licenses such as a private pilot license (PPL), commercial pilot license (CPL), and air transportation pilot license (ATPL). The first training flight of ab-initio pilots might be the first flight experience for most of them, and they may feel stressed due to lack of experience.[18] Therefore, they are prone to feeling exhausted and fatigued. The possibility of fatigue related to jet-lag (or circadian misalignment) was not considered in the present investigation since student pilots generally are not subjected to time-zone changes.

Scheduling is a big concern in various industries, including aviation, medicine, manufacturing, and education, and it plays an important role in the performance of students as well as in employees. Most airlines publish monthly rosters for their flight crew and cabin crew. However, it is completely different for flight schools. Rosters for ab-initio pilots are published by flight training organizations (FTOs) daily. Mostly, the students receive e-mail regarding daily rosters in the late evening. The combination of the late notification of the training flight and early morning starts is very likely a cause for sleep disruption and performance degradation. Another important effect contributing to fatigue is early morning flights on successive days.

The effects of communication among crewmembers during a flight on aviation accidents are undeniable.[17] Considering accidents in recent years, between 2006 and 2015, due to crew resource management (CRM) and communication, there have been 3083 incidents, 17 serious incidents, and 5 accidents.[5] In another study which investigated accidents that take place during training flights, it was seen that CRM had an effect on 4% of 70 accidents.[14] This is why communication between the instructor assigned to a training flight and the student pilot is very important. There are multiple factors that affect the communication between the two individuals. A flight instructor with a dominant character who is inconsiderate and disrespectful causes stress in the student pilot by disrupting the environment in the cockpit and, therefore, leads to fatigue, loss of concentration, and mistakes.[18] A flight instructor with insufficient level of knowledge and inadequate capabilities may also show sudden reactions to situations that develop during the flight, get angry, and, therefore, affect the setting in the cockpit negatively. Moreover, in the case that the student pilot and the instructor are from different countries or cultures, the information exchange between the individuals may be affected. This may lead to errors and fatigue that could potentially jeopardize safety.[20]

The physical environment was found as a contributing factor in 60% of accidents involving training aircraft in the United States.[14] As opposed to the case in passenger aircraft, noise levels are higher in piston-powered single-engine and double-engine aircraft that are used for training.[25] Likewise, onboard temperature control also works differently. As training planes often do not have air conditioning systems, hot air operations may lead to distractions associated with heat stress. Smaller aircraft are more susceptible to turbulence than larger aircraft. Student pilots are prone to experiencing failures under turbulent weather because bumpy weather may give rise to fatigue among pilots.[27]

The type of living accommodation is a potential concern in higher education generally, and thus may also be a concern for students undergoing flight training. The influence of accommodation (e.g., dormitory, shared apartment, low-cost hotels) should not be underestimated. It was reported that living conditions (e.g., cleanliness and overpopulation) and room size affect academic performance.[21] Improper living conditions may give rise to physical fatigue. There might be a difference between living in a dormitory and owning a house. Students should make sure that all amenities are available when they decide to stay in a dormitory or rent an apartment. Sleep quality and sleep duration may affect fatigue among pilots, and fatigue may affect sleep quality, as well.[26]

Intensive ground training courses between training flights and extensive amounts of verbal briefings and debriefings may give rise to fatigue among ab-initio pilots.[19] Furthermore, old-fashioned aircraft and inconvenient airfield locations (commuting from home to the airport) are other factors contributing to fatigue among pilots.[24] Improper nutrition also may be an issue of concern among student pilots. Diets that are nutritionally insufficient and lack provisions for adequate hydration may lead to fatigue and a reduction in cognitive capacity.[3]

Flight timing is an important determinant of pilot fatigue.[22] Recent regulatory approaches have determined the limitation of flight and duty times.[2] Fatigue in long-haul and short-haul airline pilots has been relatively well studied.[11] Even if fatigue among airline pilots (long-haul and short-haul flying flight crew) and general aviation pilots has been well-examined, fatigue in student pilots has been neglected.[20] The aim of this study is to identify and examine the factors contributing to fatigue among ab-initio pilots from all perspectives.

Based on the interview with ab-initio pilots and the literature review, it was concluded that there are several contributing factors (performance factors) to fatigue among ab-initio pilots. Based on the findings from the literature review and the interviews, we derived three performance effects (physical fatigue, mental fatigue, and lack of rest). Based on the issues mentioned above, the following hypotheses were proposed.

- Hypothesis 1. There is a positive correlation between student pilot's physical fatigue and performance factors.
- Hypothesis 2. There is a positive correlation between student pilot's mental fatigue and performance factors.
- Hypothesis 3**.** There is a positive correlation between the lack of rest and performance factors.

Table I. Reliability and Validity Tests for Performance Factors.

DIMENSION	EIGENVALUE	EXPLAINED VARIANCE	RELIABILITY	KMO
Types of flight (TF)	2.44	11%	0.77	0.88
Training scheduling (TS)	2.25	10%	0.78	
Crew composition (CC)	2.06	9%	0.78	
Environment of the aircraft (EA)	2.22	10%	0.78	
Types of accommodation (TA)	2.12	9%	0.76	
Flight training (FT)	2.01	9%	0.75	
Biological issues (BI)	1.93	8%	0.74	

METHODS

Subjects

The survey was sent online to 480 students who were receiving flight training around Turkey and 114 students returned their responses. Of the intended population, 23.8% were reached. The Turkish Airline Pilots Association (TALPA) assisted in reaching students at flight schools regarding the survey. Among the participants, there were 26 (23%) female student pilots. Of the respondents, 11% ($N = 13$) had CPL, 70% ($N = 80$) had PPL, and 18% ($N = 21$) had student pilot (SPL) licenses. The majority (47%, $N = 53$) of the participants were between the ages of 17 and 23. Ethical approval for this study was obtained from the Özyeğin University's Human Research Ethics Board (2020/1).

Questionnaire

Based on a review of the relevant literature on fatigue, 48 questions were developed and organized into six subscales: 1) demographic items (e.g., age, gender, ranking, and type of pilot license, 3 questions); 2) performance factors (33 questions); and 3) performance effects (12 questions). Questions regarding performance factors and performance effects were to be answered on a 5-point Likert-type scale (1. Strongly Disagree–5. Strongly Agree; **Appendix A**, which can be found at https://drive.google.com/file/d/1tSR9V-waUkXCrNfAq5MJ5oN_hWnyoelI/view?usp=sharing).

Procedure

We notified the subjects about the survey and asked them to complete it, and once the survey data were collected, we analyzed the data via factor analysis and correlations. The analysis was carried out with the SPSS 22.0 package program.

Statistical Analysis

In order to test the reliability of 33 expressions designed to determine the opinions of the participants about flight training in the survey study, Cronbach's alpha analysis was applied. At the end of the analysis, the Cronbach's alpha coefficient was found to be 0.90. The coefficients that were obtained showed that the scale was quite reliable. As a result, it was seen that there was no need to remove any questions from the study. Following the reliability analysis, factor analysis (PFA) was applied to the scale in order to test the scale's construct validity.

Furthermore, another Cronbach's alpha analysis was applied to test the reliability of 12 expressions designed to determine the fatigue levels of the employees during the flight training in the survey study. At the end of the analysis, Cronbach's alpha coefficient was found to be 0.92. The obtained coefficients showed that the scale is quite reliable. As a result, it was found that there was no need to remove any questions from the study. Following the reliability analysis, PFA was applied to the scale to test the construct validity.

RESULTS

In the study, seven performance factors with an eigenvalue of one and above were determined after the PFA. These performance factors were defined as Types of Flight (TF), Training Scheduling (TS), Crew Composition (CC), Types of Accommodation (TA), Environment of the Aircraft (EA), Flight Training (FT), and Biological Issues (BI). In the PFA, the varimax rotation was used. It was observed that the factor loads of the expressions in the performance factors were 0.50 and above. The sampling adequacy coefficient (KMO) that was calculated in the factor analysis was found to be 0.88. It was an indication that the sample size ($N = 114$) was quite sufficient to reveal the factorial structure of the scale. Additionally, according to the Bartlett's test result ($\chi^2 = 1456.29$, $P = 0.01$, $P < 0.05$) in which the significance of factor structures is tested, the dimensions obtained were structurally significant. The internal consistency and the explained variance of the performance factors are presented in **Table I**.

Three performance effects with an eigenvalue of one and above were determined after the factor analysis. These performance effects were defined as the Physical Fatigue (PF), Mental Fatigue (MF), and Lack of Rest (LR) dimensions. In PFA, the varimax rotation was used.

The factor loads of the performance effects were found to be 0.50 and above. The KMO calculated in the factor analysis was found to be 0.89. It was an indication that the sample size ($N = 114$) was quite sufficient to reveal the complete factorial structure of the scale. Additionally, the performance effects obtained according to the Bartlett's test ($\chi^2 = 1523.37$, $P = 0.01$, $P < 0.05$), in which the significance of the factor structures was tested, were structurally significant. The internal consistency and the explained variance of performance effects are shown in **Table II**.

Table II. Reliability and Validity Tests for Performance Effects.

DIMENSION	EIGENVALUE	EXPLAINED VARIANCE	RELIABILITY	KMO
Physical fatigue (PF)	3.81	23%	0.82	0.89
Mental fatigue (MF)	3.74	22%	0.81	
Lack of rest (LR)	3.53	21%	0.79	

Table III. Examination of the Dimensions Affecting Fatigue Levels.

DIMENSION		TYPES OF FLIGHT (TF)	TRAINING SCHEDULING (TS)	CREW COMPOSITION (CC)	TYPES OF ACCOMMODATION (TA)	ENVIRONMENT OF THE AIRCRAFT (EA)	FLIGHT TRAINING (FT)	BIOLOGICAL ISSUES (BI)
Physical fatigue (PF)	r	0.44**	0.37**	0.33**	0.14	0.27**	0.39**	0.43**
	p	0.01	0.01	0.01	0.15	0.01	0.01	0.01
Mental fatigue (MF)	r	0.42**	0.43**	0.43**	0.19*	0.28**	0.29**	0.38**
	p	0.01	0.01	0.01	0.04	0.01	0.01	0.01
Lack of rest (LR)	r	0.51**	0.37**	0.33**	0.09	0.17	0.16	0.39**
	p	0.01	0.01	0.01	0.35	0.05	0.06	0.01

Correlation analysis: **significant on the level of 0.01; *significant on the level of 0.05.

The participants' PF levels had positive relationships with all performance factors, with the exception of TA. Therefore, Hypothesis 1 is confirmed (**Table III**).

There were positive relationships between the MF levels of the participants and performance factors (TF, TS, CC, TA, EA, FT, and BI levels). Therefore, Hypothesis 2 is confirmed (Table III).

There were positive relationships between the participants' LR levels and all performance factors (TF, TS, CC, EA, FT, and BI) with the exception of TA. Therefore, Hypothesis 3 is confirmed (Table III).

DISCUSSION

In short, the findings of this study showed that the seven performance factors were related to the ab-initio pilots' physical and mental fatigue as well as to lack of rest among them. One unanticipated finding was that there was no significant relationship between the participants' LR and TA levels. This was not in line with previous findings.[20] Another unanticipated finding was that the participants' PF levels had no positive relationships with TA. This was not consistent with previous results.[20] It was also shown that crew composition (i.e., Partnership between Flight Instructor and Student Pilot) was strongly associated with the ab-initio pilots' physical and mental fatigue. This result was well in line with previous findings.[20]

We conclude that this study shows a clear mandate for the use of individual preventive measures against flight-related fatigue among ab-initio pilots. The findings suggested that seven major contributing factors increased ab-initio pilots' fatigue, which may result in reduction of individuals' performance and consequently unsafe conditions during flight. These seven factors (types of flight, training scheduling, crew composition, environment of the aircraft, types of accommodation, flight training-related issues, and biological issues) affect the fatigue of ab-initio pilots on various levels. The ab-initio pilots' fatigue was divided into three groups as the performance effects. These were physical fatigue, mental fatigue, and lack of rest resulting in fatigue.

The findings in this study are subject to several limitations. First of all, the low response rate limits the statistical results. Further efforts (e.g., phone survey or face-to-face interview) may be performed to increase the participation rate. The second limitation is that the ab-initio pilots participating in the survey were attending an aviation university or flight school to earn an ATPL. The proposed survey and study are valid only for students attending civil flight schools. Further research should be carried out to investigate fatigue among ab-initio pilots attending military flight schools.

The findings of this study have significant implications for ab-initio pilot training and fatigue risk management among ab-initio pilots. Flight training organizations should implement strategies by using the findings of this study to make improvements in factors contributing to fatigue.

The ab-initio pilots' fatigue from various perspectives that we have identified therefore assists in our understanding of the role of fatigue in pilot training as well as in accidents that occur during flight training. Flight training organizations should educate student pilots on the effects of fatigue and fatigue countermeasures, and they should develop and implement a Fatigue Education and Awareness Program.

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