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Fatigue in Collegiate Flight Training

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Fatigue-related problems are not new in the aviation industry and have been a contributing factor to more than one-fifth of all aviation accidents. Using an online survey instrument, this exploratory study investigated how 138 collegiate flight students interact with fatigue during their flight training. Overall, students recognize they are fatigued and that it has a negative impact on their flight training. Many of the students identify the proper strategic adjustments that they need to make to manage fatigue, such as reducing workload, getting more sleep, and keeping a regular sleep schedule. However, they do not seem to be making those adjustments. They indicate that they lack enough quality sleep, have high workloads, and do not keep a regular sleep schedule. Findings from this study are consistent with recent flight training studies and can assist the collegiate flight training community in the management of student fatigue.

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Everyone experiences fatigue from time to time, but fatigue in high-risk industries such as transportation is an especially-dangerous risk factor. Fatigue-related problems are not new in the aviation industry. Fatigue contributed to a substantial number of aviation accidents from the mid-1970s to the early-1990s (Caldwell, 2005), and the National Transportation Safety Board (NTSB) made over 50 fatigue-related recommendations between 1972 and 2018 (NSTB, 2018). Fatigue was a contributing factor to 20.3% of all investigations by the NTSB conducted between 2001 and 2012; and of those, fatigue was a contributing factor in 23% of aviation-related transportation accidents during the same period (Marcus & Rosekind, 2017).

The effects of fatigue can manifest in subtler ways than aircraft accidents or incidents. Fatigue insidiously infiltrates the lives of pilots long before they become the subject of NTSB investigations, and the long-term effects of fatigue can have lasting impacts on pilots. Fatigue is a precursor that may be uncovered during accident investigations; and, it has been established that the long-term effects of fatigue on pilot performance is a critical safety issue that warrants mitigations (International Air Transport Association [IATA], International Civil Aviation Organization [ICAO], & International Federation of Air Line Pilots' Associations [IFALPA], 2011). Human factors training introduces new pilots to fatigue, its effects, and methods to avoid fatigue. This study provides educators a chance to see the prevalence of fatigue within a collegiate flight training environment.

Purpose of the Research

There has been very little research conducted regarding fatigue in flight training (Levin, Mendonca, Keller, & Teo, 2019) This research aims to expand our understanding of the impact fatigue has on students in a collegiate flight training environment. McDale and Ma (2008) investigated the effects fatigue had on a group of flight instructors at part 141 flight schools. This research investigates the same issues related to flight students at a collegiate Part 141 flight school.

The role of the university within a person's life is debatable, but behavioral changes are often the result of education. The behavioral changes that occur can be positive or negative, depending on social and structural determinants of health. The social determinants of health "consist of policies and environments that support access to education, provide relevant resources for health (e.g., contraception), and create opportunities to enhance young people's autonomy, decision-making capacities, employment, and human rights" (U.S. Department of Transportation, 2012, p. 1634). Collegiate flight programs act as a structural means to provide opportunities for young adults to interact with positive social determinants of health by educating them about how their behaviors affect their flight performance and long-term well-being. This research will help clarify how flight students interact with fatigue to help shape human factors training into a relevant curriculum that incorporates the needs of students.

Collegiate aviation students will be members of the professional pilot workforce and play a vital role in fatigue risk management systems. Collegiate flight programs have the opportunity to shape students' attitudes and knowledge about fatigue, which will help inexperienced pilots effectively managing their own fatigue.

Aside from educating new pilots about professional standards and norms, flight schools certified under Part 141 also operate full flight schedules that carry their own inherent safety risks. We can also improve operational safety in collegiate flight training courses by teaching college student-pilots to manage their own fatigue during flight training. Improving fatigue-related human factors training also has the added benefit of improving the safety within collegiate flight training environments.

Three primary research questions provided the focus for this research:

1. How do students evaluate their fatigue and how do they believe it impacts their flight training?
2. What do students perceive to be the causes of their fatigue?
3. What lifestyle adjustments do the students believe are necessary to manage their fatigue?

Literature Review

An industry-wide strategy has been developed to combat the risks associated with fatigue in aviation. Fatigue management (FM) “generally refers to the identification of fatigue risk and the implementation of strategic controls” (Avers, Hauck, Blackwell, & Nesthus, 2010, p. 52). Avers, Hauck, Blackwell, and Nesthus (2010) describe three distinct stakeholder groups that are necessary for effective FM: (1) regulatory agencies; (2) operating organizations; and (3) the pilots. A fourth stakeholder group--the research community--also contributes to FM strategies.

The regulator mandates maximum duty time and rest requirements for flight crews in operational environments. The operator, or airline, influences the fatigue culture in two ways. First, the airline schedules its pilots and must, at a minimum, follow duty limitations regulations. Second, airlines may implement Fatigue Risk Management Systems (FRMS) to identify and mitigate risks associated with fatigue. The pilot is responsible for managing their own fatigue and for being *fit for duty* (U.S. Department of Transportation, 2012). Fitness for duty means a pilot is “physiologically and mentally prepared and capable of performing duties assigned” (U.S. Department of Transportation, 2012, 2012, p.1). The research community is the fourth stakeholder group involved in FM. The research community should inform and educate other FM stakeholders to find ways to reduce the risks associated with operating aircraft in fatigued states. Their research also contributes to the body of literature used by other stakeholder groups to address fatigue-related issues.

Definition of Fatigue

In their thorough review of FAA fatigue research, Avers and Johnson (2011) correctly describe fatigue as a “complex state” (p. 88). Understanding fatigue requires a definition that reflects the complex nature of the construct of fatigue. Literature provides many definitions of fatigue that lack comprehensiveness and consistency (Avers & Johnson, 2011; Lee & Kim, 2018; Noy et al., 2011; Phillips, 2015). Using a common definition for fatigue will help the aviation research community develop comprehensive research agendas covering all aspects of fatigue.

A complete definition of fatigue adequately describes the complex nature of the condition of fatigue, the causes of fatigue, and the consequences of fatigue (Phillips, 2015). A multi-dimensional construct with such immediate safety risks deserves a definition that reflects the complex nature of fatigue, its antecedents, and its outcomes (Avers & Johnson, 2011; Noy et al., 2011). A consistent, comprehensive definition of fatigue will allow the research community to strategically investigate these different aspects.

A unified definition of fatigue provides transportation researchers with a theoretical framework to guide future fatigue-related research. Because previous definitions of fatigue in transportation research are too divergent to be useful, Phillips (2015) proposes a new definition of fatigue and “claims that by delimiting the origins, state, and consequences of fatigue, a ‘whole’ definition would help make explicit for different transport researchers, aspects of fatigue that different studies do not measure, as well as those that they do measure” (p. 49). A common, unified definition of fatigue in transportation research allows the research community to monitor and categorize fatigue research into different aspects of the complex construct of fatigue. According to Phillips (2015):

Fatigue is a suboptimal psychophysiological condition caused by exertion. The degree and dimensional character of the condition depends on the form, dynamics, and context of exertion. The context of exertion is described by the value and meaning of performance to the individual; rest and sleep history; circadian effects; psychosocial factors spanning work and home life; individual traits; diet; health, fitness and other individual states; and environmental conditions. The fatigue condition results in changes in strategies or resource use such that original levels of mental processing or physical activity are maintained or reduced (p. 53).

This definition of fatigue has three basic parts: origin, state, and consequences. First, *origins* refer to the sources of fatigue, which can be mental or physical exertion and varies along with working conditions. Next, *state* refers to the psycho-physiological condition, characterized by objective and subjective measures of fatigue. The fatigued condition is directly dependent on the type and degree of exertion (physical or mental effort). Lastly, *consequences* refer to the behavioral changes that result from fatigue (Phillips, 2015). The results of this research follow this three-part framework.

College Students in Aviation

College students engaged in flight training are different than other members of the piloting workforce because they are typically younger and less experienced than counterparts. Persons of all ages need quality sleep to maintain their physical and psychological health, but college-age students who are in their late adolescence are more susceptible to the effect of fatigue and face greater safety risks when operating airplanes for flight training because their physiological needs differ (Pink, 2018).

Collegiate aviation is a rare intersection in the aviation industry because its members are young college students, a unique population in the industry. Pilots in this age group interact with fatigue differently than older pilots. Aside from their novice status among the piloting

community, collegiate aviation students are unique because most are still in the developmental process of adolescence, albeit in the latter stages (American Psychological Association, 2002; Curtis, 2015; Sawyer et al., 2012). They are known for impulsivity and peer pressure (Sawyer et al., 2012). As adolescents, they possess different behavioral characteristics, such as staying up late, sleeping in on weekends, and have different sleep needs than fully-developed adults.

The sleep patterns of college students are notorious, and their lack of sleep creates conditions conducive to chronic and acute fatigue and their related symptoms (Lund, Reider, Whiting, & Prichard, 2010). College is a “a time of minimal adult supervision, erratic schedules, and easy access to over-the-counter (OTC), prescription, and recreational drugs” (Lund, et al., 2010, p. 125). The academic demands of school and the social demands of college life relegate sleep to a tertiary status. According to Lund et al. (2010), only 29.4% of college students report getting enough sleep. They noted that average sleep time for college student ($N=5,401$) was 7.02 hours ($SD=1.15$) (Lund et al., 2010, p. 125).

Levin, Mendonca, Keller, and Teo (2019) through a mixed methods exploratory study investigated how pilots in the collegiate flight training environment mitigate fatigue through lifestyle factors and how they rank those solutions for fatigue management. The most effective solutions that the participants identified for fatigue mitigation were obtaining more sleep, reduced workload, and time management of their flight and class workloads. Several themes through qualitative inquiry were found, including; socializing and late night electronic use delayed student’s bed times, excessive noise and light in the dorm environment led to sleep disturbances, and school workload time spent working frequently left participants sleepless.

Research Methodology

This study used a survey methodology to understand how students at Part 141 pilot schools feel they were impacted by fatigue. This study replicates the questionnaire of McDale and Ma (2008) who assessed the impacts of fatigue on flight instructors at Part 141 pilot schools in the U.S. The instrument used was not validated and some questions were altered to suit the new population. The internet-based questionnaire, data collection methodology, and the informed consent notification were approved by the university institutional review board to ensure high ethical standards in the research process. All participation in the study was voluntary.

Sampling

This study used a convenient, non-probability sample to identify participants for the survey. A department student listserv was used to email a survey link to all students enrolled in the flight program. The researchers acknowledge that the convenient sampling technique limits the generalizability of the results (Cohen, Manion, & Morrison, 2011). This exploratory study shows the prevalence of fatigue-related issues within the study sample and possibly other flight training environments.

Participants

The participants in the study were undergraduate students engaged in flight training at a certified Part 141 pilot school at a state university in the U.S. The students were enrolled in a two-year flight degree and a four-year aviation management degree. All participation in the study was anonymous and voluntary.

Data Collection and Analysis

Data were collected over two different periods. The first data collection period was from November 9, 2017 until December 8, 2017, and the second data collection period was from April 8, 2019 until April 17, 2019. Both of these time periods had a high number of operational activities.

The researchers added an additional question to the second questionnaire to ensure that each participant only contributed one set of responses. The first question on the second questionnaire asked respondents if they had taken the survey during the first data collection period. Respondents who indicated they previously participated in the first survey were removed from the second group of respondents. The nature of the variables used in the survey limit the analysis for the current project to descriptive statistics.

Results

The results are divided into three major section based on the different elements of Phillips' (2015) definition of fatigue: (1) the psychophysiological state; (2) the exertion expended and the context in which it occurred; and (3) the strategic behavioral adjustments that are made as a result of fatigue. A demographics section provides a general picture of the respondent population.

Response Rate

The number of students enrolled at the time the of data collection determined the population for this study. A total of 132 students were enrolled in the flight program, and a total of 60 students responded to the questionnaire, yielding a 45% response rate for the first data collection period. The enrollment during the second data collection period was 153 students, with 68 students responding, resulting in a 44% response rate during the second data collection period (Institutional Research and Studies, 2019).

Demographics

The respondents were students enrolled in a collegiate flight training program at a flight school certified under 14 C.F.R. §141. A large majority (80.47%) of the 128 respondents were between the ages of 18-24, and the remaining respondents were older. Survey respondents reported enrollment in the range of aviation flight-related courses offered in the curriculum, with the largest concentration of students training for instrument rating (26.78%). The curriculum at the institution where the data were collected offers private pilot, instrument rating, commercial

pilot, multi-engine, and flight instructor courses. Nearly two-thirds (66.33%) of the 98 respondents had only a private pilot certificate while the remaining one-third of respondents had an instrument rating, or other flight certifications and ratings. Most of the respondents (60.71%) had less than 200 hours of total flight time

A Sub-optimal Psychophysiological State

Phillips (2015) explains that fatigue is both a subjective (psychological) and objective (physiological) condition. This research does not address the objective, physiological state of fatigue. Rather, the survey questions asked the respondents for their perceptions of fatigue, a subjective rating.

Respondents indicated awareness of their fatigue and believed it impacted their flight training. Using a ten-point Likert-type scale, respondents rated the degree to which they were aware of their own fatigue, with 1 being the least aware and 10 being the most aware of their own fatigue. A weighted average of the responses was 7.40, with a median and mode of 7 (30% of respondents). In addition, 95% of respondents ($n = 121$) indicated that fatigue effects the quality of their flight training.

The respondents provided information indicating how they experience fatigue during flight operations. Using a five-point, Likert-type scale, the respondents indicated their levels of agreement to the six statements contained within Figure 1.

Responses to these statements are listed in Figure 1. Those respondents who claim they *strongly disagree* with the previous statements potentially do a good job managing their fatigue, whereas those responding as *neutral*, *strongly agree*, or *strongly disagree* may need more guidance on effective fatigue management strategies.

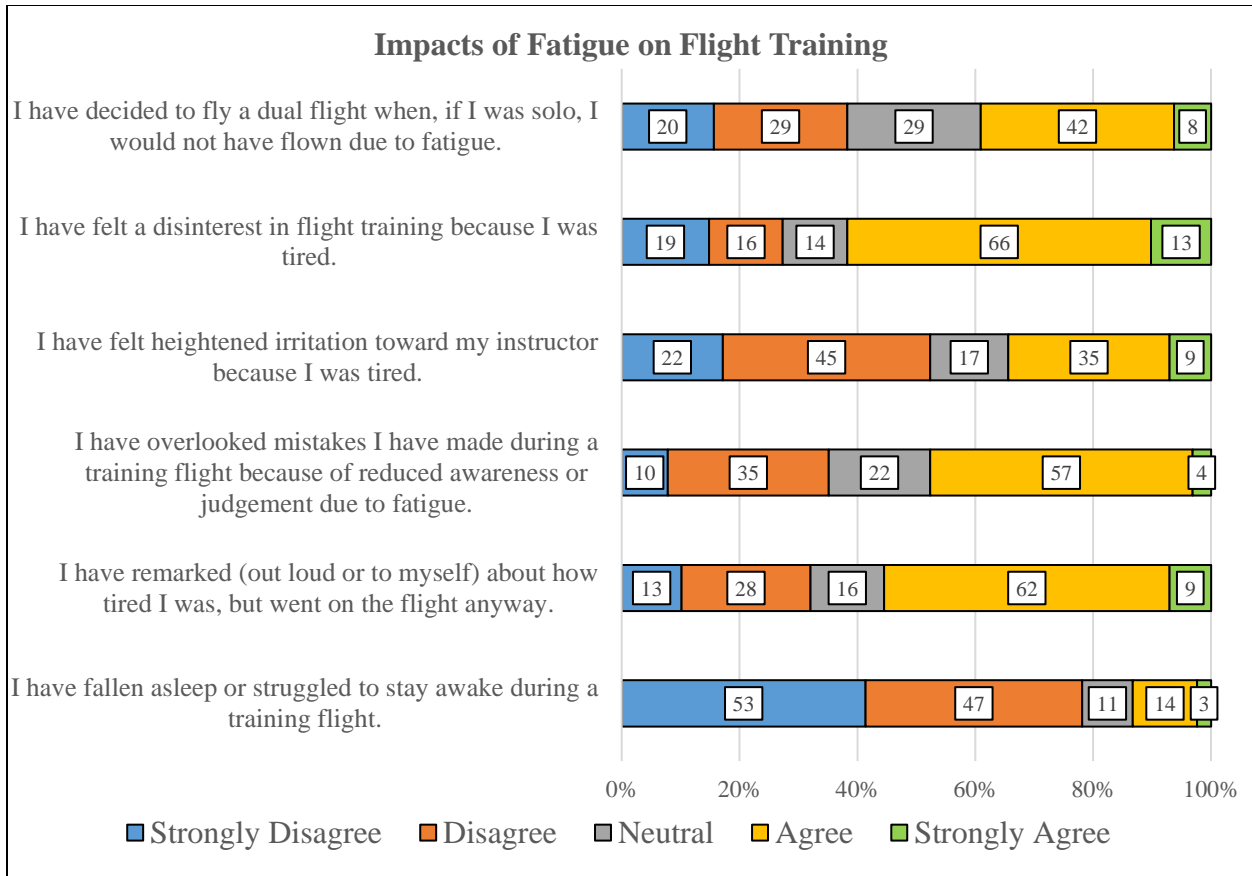


Figure 1. Impacts of Fatigue on Flight Training.

Exertion

Fatigue is caused by exertion, which occurs in different contexts. This section provides information on the context of fatigue like weekly workloads, sleep habits, and other lifestyle factors. Respondents also ranked factors that contributed to their fatigue.

Academic workload. The primary workload of a student enrolled in a collegiate flight program is the effort related to the university’s core curriculum and courses required by for the aviation-related major, including flight courses. Respondents reported being in school for most of the week. Nearly 66% of the 128 respondents answering this question indicated that they attend class five days a week. Three-quarters of respondents ($n = 96$) indicated they attend class between 3-5 hours each day. Most of the respondents (76.56%) reported a full-time academic schedule, of 12 or more credit-hours per semester. Respondents most commonly reported being enrolled in 15-18 credit hours, which is 1-2 courses over the standard, full-time workload.

Sleep habits. Respondents reported information about their sleep habits. This section reports results of the respondents’ quantity and quality of their sleep. Quantity of sleep refers to the number of hours respondents slept per day, either through regular, nightly sleep or by napping. Quality of sleep refers to the number of times respondents’ sleep was interrupted per night and whether their sleep made them feel rested.

Quantity of sleep. Respondents showed different sleeping habits on the weekdays than on the weekends. Overall, the respondents reported an average of 7.89 hours of sleep per night during the week and an average of 9.04 hours of sleep per night during the weekend. Respondent sleep and rise times also differed from weekday to weekend.

Respondents reported sleep patterns on *school nights* and *non-school nights*. Half of respondents ($n = 64$) reported going to bed between 11:00 pm and 12:00 am on nights when they have school the next day. An additional 29 respondents (22.66%) go to bed sometime after midnight on school nights. The remaining results are displayed in Figure 2 which shows a pattern that shifts toward later bedtimes on non-school.

Similar to the manner bed times shifted to later times on non-school nights, wake times also shifted later on non-school mornings. Wake times on school days were distributed normally, with the highest concentration of respondents waking between 7:00 am and 8:00 am (see Figure 3). Wake times on non-school days show a distinctly different reporting pattern. The majority of respondents (57.81%) indicate that they wake sometime after 9:00 am on non-school days.

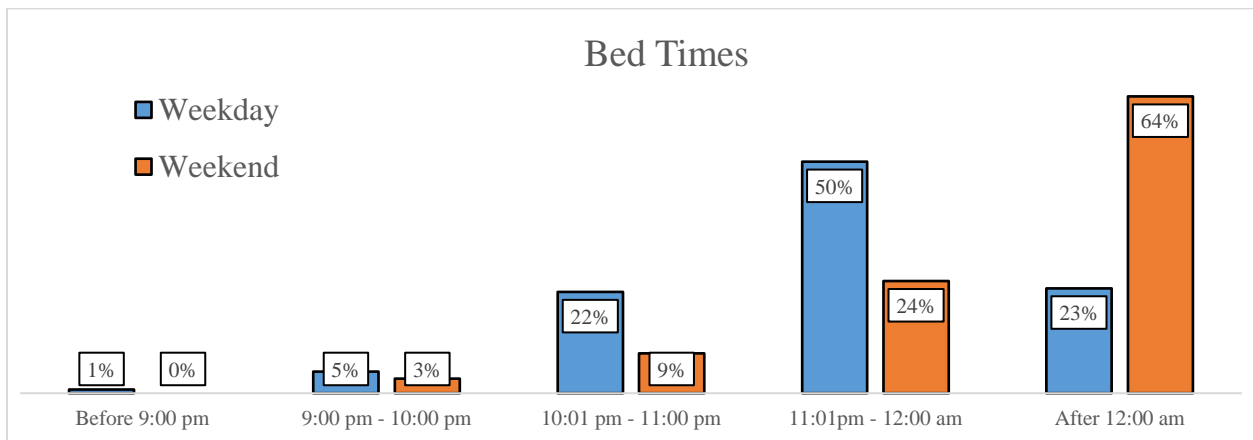


Figure 2. Responses to this question indicate the degree to which fatigue-related symptoms impact flight training activities.

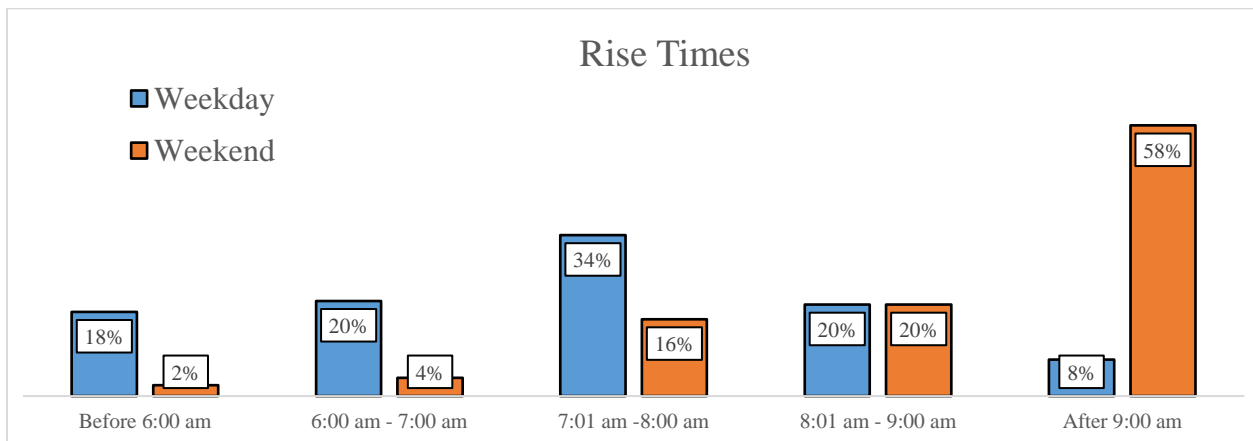


Figure 3: Bed Times and Rise Times on Weekdays and Weekends

Quality of sleep. Respondents reported how often their nightly sleep was interrupted and whether or not they were refreshed after a night’s sleep. Figure 4 displays the number of times the respondents’ sleep was interrupted each night. More than half (57%) of the 128 respondents claimed their sleep was interrupted one or fewer times each night, almost a quarter (23%) had sleep interrupted twice each night, and the remaining 20% had their sleep interrupted three or more times each night. Additionally, 38% respondents reported feeling dissatisfied with the quality of their sleep, a proportion that closely mirrors the number of respondents who reported two or more interruptions every night.

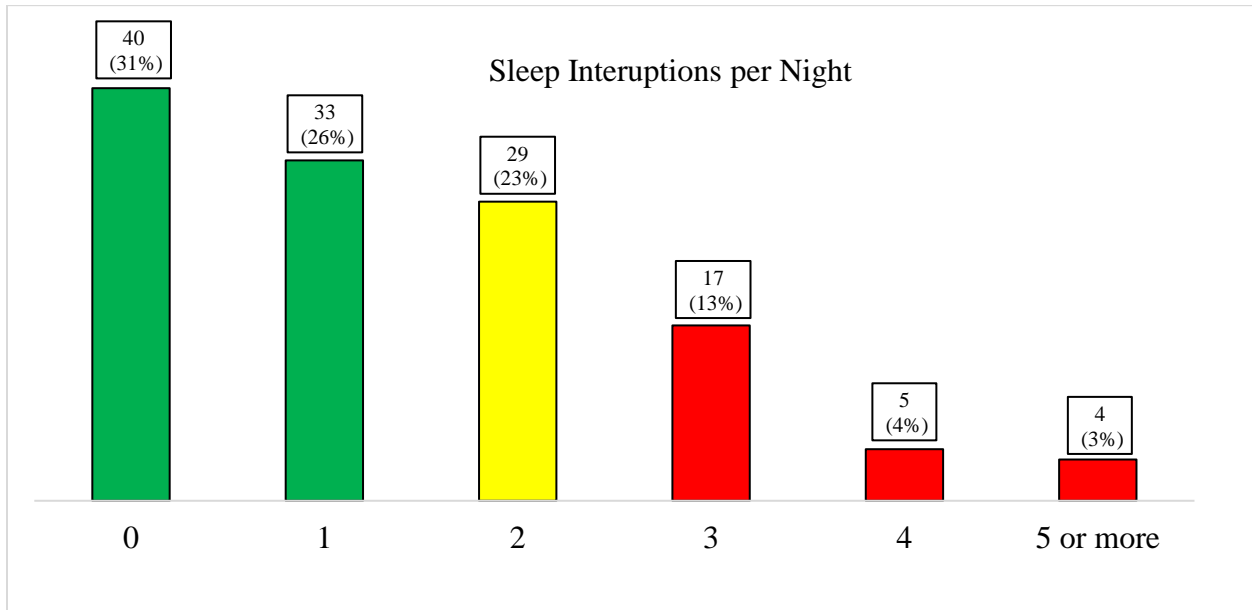


Figure 4. Number of Sleep Interruptions per Night.

Using a Likert-type scale, participants weighted their levels of fatigue during flight operations that occurred at different times of the day. On days students conducted flight operations, the majority of respondents indicated that their fatigue levels were greatest during early morning operations, between 6:00 am and 9:00 am. They also reported their levels of fatigue to be the greatest during the same time period on days without flight operations. The lack of quality sleep was consistent with previous research from Levin et al.(2019), that found 66% of the respondents indicated that they were not getting a fully adequate quantity or quality of sleep each night.

Factors Contributing to Fatigue. Participants ranked a list of 12 factors that could contribute to fatigue, and ordered them from least influential to most influential on their fatigue. Of the list of 12 factors that contribute to their fatigue, flying after a long day was shown to be the most influential on their perceived fatigue levels. Conversely, sleeping next to a partner was shown to be the least impactful on their fatigue. Figure 5 displays the ranking of the remaining factors the respondents believe impact their fatigue levels.

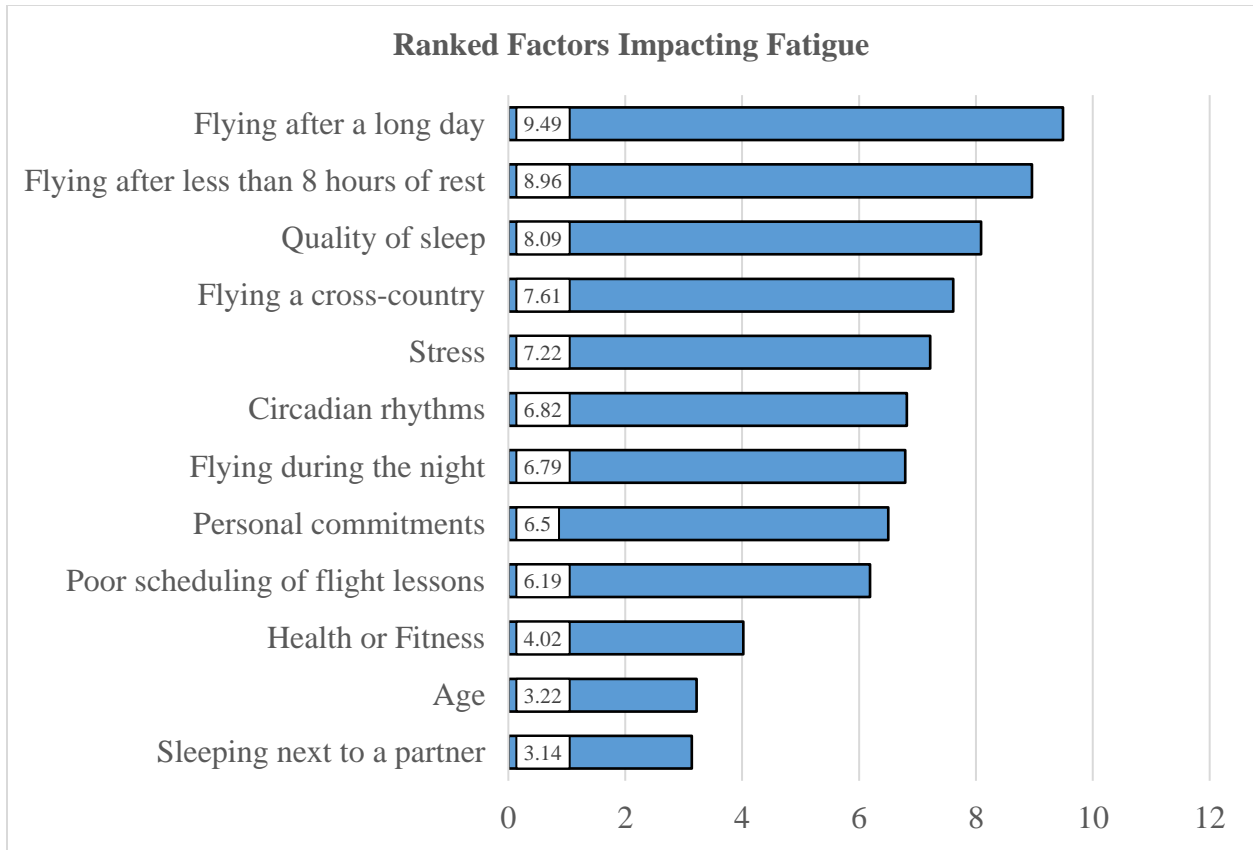


Figure 5. Ranked Factors Impacting Fatigue of Collegiate Flight Students.

Strategic Adjustments

Phillips (2015) states that exertion-induced fatigue in transportation industries causes some sort of strategic cognitive adjustment in order to maintain performance while fighting against symptoms of fatigue. Motivation has a large influence on the strategic adjustments made by transportation workers in the operational environment where safety is a prime concern. The authors extend the concept of strategic adjustments to include lifestyle or behavioral changes that can have a positive influence on chronic or acute fatigue.

Respondents ranked a list of solutions they could use to manage their own fatigue. Figure 6 shows a ranked list of factors respondents believe could prevent fatigue during flight training.

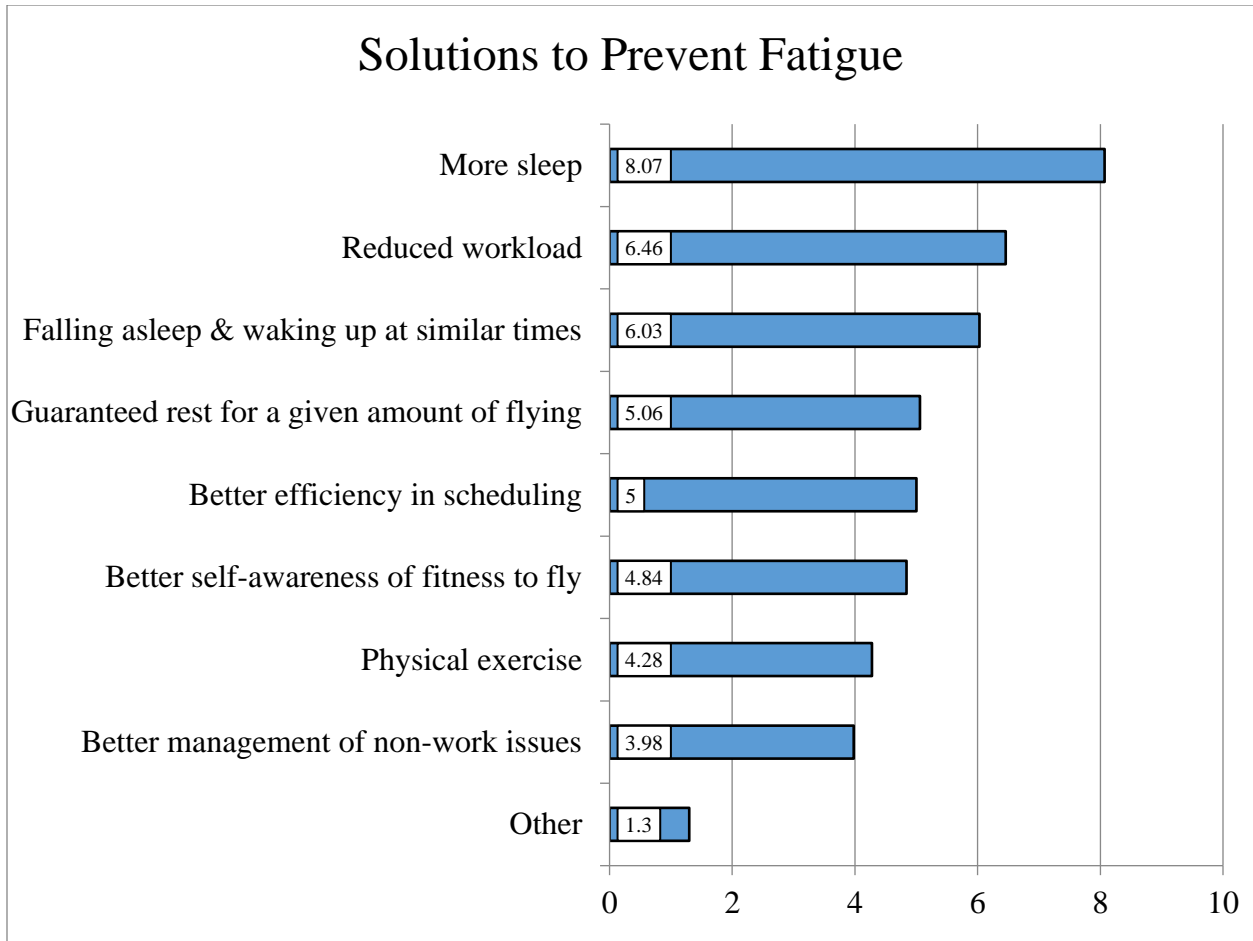


Figure 6. Ranking of solutions to prevent fatigue.

Discussion and Conclusions

This section provides an assessment of the results gathered from the responses to the questionnaire. Phillips (2015) definition of fatigue is used here as a guide to discuss the implications of the data collected through the questionnaire. The results of the survey provide insight into the way collegiate flight students interact with fatigue, which helps the fatigue management stakeholders develop curricula, regulations, and policies aimed at mitigating the adverse impacts of fatigue within the aviation industry. Many of the findings support previous research by Levin et al. (2019).

A Suboptimal Psycho-Physiological State

Nearly all (95%) of the respondents believe fatigue impacted their flight training. This result reveals the prevalence of fatigue within the sample, justifying more attention toward educating pilots about the interactions of fatigue and flight training.

The data contained in Figure 1 reveal some troubling realities about how pilots interact with fatigue and flying. Each of the situations in Figure 1 represent an undesirable interaction

with fatigue and flight training. Disagreement or strong disagreement with each scenario is the most desirable, or *safe* response. Neutral responses, agreement, or strong agreement with any scenario represents risks to flight training or an *unsafe* response. Figure 6 repeats the scenarios from Figure 1 but dichotomizes responses between safe and unsafe behaviors to show the prevalence of unsafe responses to these scenarios.

Falling asleep while flying is certainly an obvious warning sign, but other less obvious warning signs exist within the data. For example, almost 73% of the 128 respondents attributed disinterest in their flight training to being fatigued. The prevalence of fatigue-related apathy and other, less obvious unsafe behaviors are displayed in Figure 7. This is important because it clearly shows that unsafe, fatigue-related behaviors impact collegiate flight training.

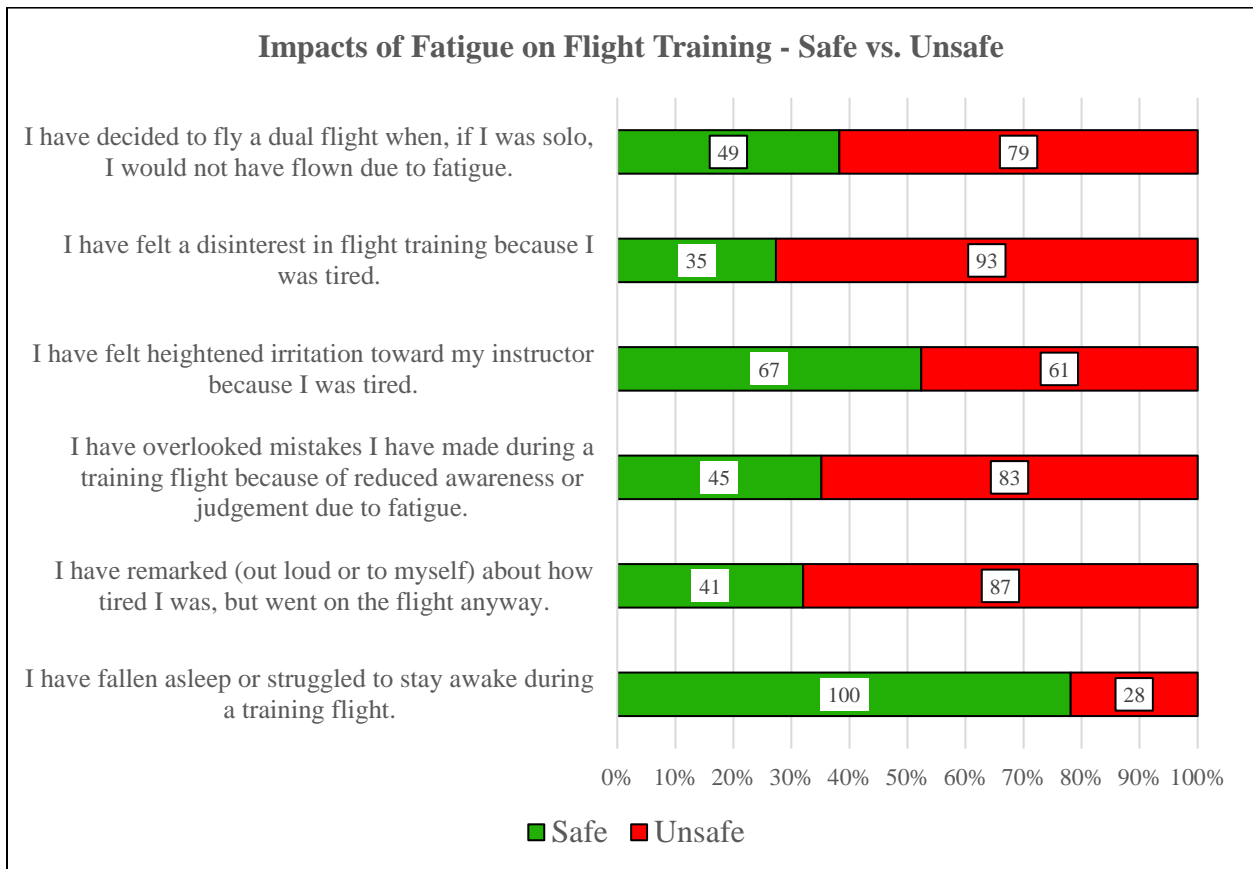


Figure 7. Safe and Unsafe Impacts of Fatigue on Flight Training

Exertion

Nearly all respondents claimed that fatigue impacted their flight training. Thirty-eight percent of respondents claimed to feel refreshed after a night's sleep; both indicate fatigue-related risk factors. According to their responses, respondents were sleeping enough during the week and weekends, and their academic workloads and weekly school schedules indicate they dedicated a substantial amount of energy on school-related activities. Their irregular sleep habits may reveal more about their fatigue than their workload or amount of sleep.

The times the respondents reported going to sleep and waking both shifted at least one hour later on the weekends compared to the weekdays. It would appear that most of the participants within this study had sleep patterns that were consistent with other studies investigating the sleep habits of college students. The late bed times and early wake times are consistent with other studies that have investigated the sleep quality and quantity of college students (Eliasson, Lettieri, & Eliasson, 2010; Buboltz, Brown, & Soper, 2001). Although the respondents may get adequate sleep, their shifting bed and wake times from the weekdays to the weekends may contribute to the prevalence of fatigue within the study sample.

Interrupted sleep is low quality sleep. Waking one or two times per night may not impact the overall quality of sleep, but having sleep interrupted more than twice each night can reduce the overall quality of sleep and lead to fatigued conditions. Twenty percent of the respondents reported having their sleep interrupted more than two times each night, which is certainly impactful on their ability to recharge.

Some students managed their fatigue by supplementing their nightly sleep with naps. Napping provides the opportunity to increase the daily quantity of sleep or make-up for poor sleep caused by excessive interruptions. Previous research indicated that naps improve physiological and psychological performance (Pink, 2018). The results indicated that many students do not nap to help manage their sleep debt. Nearly 33% of respondents indicated they napped to manage their fatigue. Most of the students who reported napping indicated that they usually took a nap in the early afternoon or evening, which fortunately are the best times of the day to nap based on normal circadian rhythms (Pink, 2018).

Strategic Adjustments

Lifestyle choices are integral to proper fatigue management. Strategic lifestyle adjustments are necessary to react to various demands that affect fatigue. Students identified that the best strategies for managing their fatigue were to sleep more, reduce workload, and keep a regular schedule. Many students did not rank exercise high in importance for managing fatigue. This is similar to the findings by Levin et al., (2019). Research has shown that physical exercise has a tremendous benefit for lowering stress and increasing the quality of sleep (Pilcher, Ginter, & Sadowsky, 1997; Trockel, Barnes, & Egget, 2017).

Overall, the students recognize they are fatigued and that it has a negative impact on their flight training. Many of the students identify the proper strategic adjustments they need to make to manage fatigue (reduce workload, more sleep, and keep a regular sleep schedule). However, they do not seem to be making those adjustments. They indicate that they lack enough quality sleep and have high workloads and do not keep a regular sleep schedule.

Threats and Limitations

A lack of face validity is a one major threat to the results of this study because of insufficient operationalization of the construct of fatigue (Drost, 2011). Although Phillips (2015) provided a framework for communicating and discussing the results of the survey, it was not used to shape an operational definition for the survey respondents to use as a guide for the

questionnaire. Because each participant used their own, independent, subjective definition of fatigue, the authors cannot be sure the responses to the questionnaire that related to the construct of fatigue were similarly understood by all respondents.

The non-probability sampling technique used in this study limits the generalizability of the data generated from the questionnaire. Because the convenient sample is not representative of the entire collegiate flight student population, the results of this research can only be generalized to the students who responded to the survey. These students, however, are not unlike other collegiate flight students, and the results can be considered to help develop a complete picture of the interaction between collegiate flight students and fatigue.

This research replicated a survey used in previous research. The instrument used was not a validated instrument. The categorical nature of the questions adapted from previous research limited the analysis to descriptive statistics rather than more sophisticated inferential analysis. Future research in this area should focus on using questions that yield data that generate more meaning than a simple descriptive analysis.

Recommendations

The results indicate that collegiate aviation education may have a problem with fatigue similar to other parts of the aviation industry. While the results are not generalizable, it is not hard to imagine that the conditions at institutions similar to the study institution may yield similar findings. This needs to be studied so that we can help the future aviation professionals recognize and combat fatigue.

Several recommendations for further research come from the findings of this study. First, expanding the sampling frame of this study to a regional or national sample to improve generalizability of the study. Second, broadening the scope of the research to include all aspects of collegiate aviation education rather than just flight training may indicate if fatigue is endemic to aviation education as a whole or limited to flight training. Third, numerous respondents in this study indicated interrupted and ineffective sleep patterns. Studying collegiate aviation student sleep patterns may shed light on how the sleep habits of aviation students differ from those of the general collegiate student population. Finally, if this study were replicated or expanded upon, the survey instrument should be updated to reflect current survey best practices that would be conducive to a greater depth of analysis.

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