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Contributory Factors of Fatigue Among Collegiate Aviation Pilots: An Ordinal Regression Analysis

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Contributory Factors of Fatigue Among Collegiate Aviation Pilots: An Ordinal Regression Analysis

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Fatigue is a pervasive safety hazard in aviation affecting several aspects of a pilot's' ability to safely perform their jobs. Several factors can contribute to fatigue, including inadequate sleep, stress, long work hours, excessive workload, and inadequate nutritional habits. In addition to flight training, some factors including academic, social, part-time work, and emerging time management skills are unique for Title 14 Code of Federal Regulations (CFR) Part 141 collegiate aviation pilots. By utilizing the Collegiate Aviation Fatigue Inventory (CAFI-II) at eight flight programs (n = 422), the current study examined factors such as fatigue training received, time spent working/studying and socializing, and enrollment level. Ordinal regression was used to assess the odds ratios of fatigue among demographic study groups. Notable results indicated approximately fifty percent of respondents reported not having fatigue training, Juniors and Seniors reported a less frequency of fatigue training when compared to the other two enrollment levels, and they also had a higher probability of flying while fatigued. The researchers suggested improved targeted training as well as recommendations for fatigue risk management strategies.

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Introduction

Fatigue is the "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" (International Civil Aviation Organization, 2016, p. 2-1). From an aviation accident risk perspective, the National Transportation Safety Board (NTSB) (2016) has determined that "fatigue degrades a person's ability to stay awake, alert, and attentive to the demands of safely controlling a vehicle, vessel, aircraft, or train" (p.1). Center for Disease Control and Prevention (CDC) guidance indicates an individual's mental performance with 17 to 19 hours of being awake is similar to having a Blood Alcohol Level (BAC) of 0.05% and being awake for 24 hours is like having a BAC level of .10%. The latter is above the legal limit for driving in all states (CDC, 2017). According to the Title 14 Code of Federal Regulations (CFR) 91.17, no person may act or attempt to act as a crewmember of a civil aircraft while having a BAC level of .04% or greater. Regardless of the BAC level, the CFR 91.17 also prohibits anyone from acting as a crewmember while under the influence of alcohol (Electronic Code of Federal Regulations, 2021). Due to the detrimental effects of fatigue while operating a vehicle, the NTSB has continued to include reducing fatigue related accidents on their most wanted list (NTSB, 2020). The NTSB (2020) issued a statement, "we are calling for a comprehensive approach to combatting fatigue in transportation, focusing on research, education, and training" (p.1).

Research intersecting fatigue and aviation is not novel. Numerous studies have been conducted with scheduled service and military operations (Caldwell et. al, 2009; Gander, et. al, 2013; Gawron, 2016; Gore, et. al, 2010; Hartzell, 2014; Lee & Kim, 2018; Rabinowitz et. al, 2009). The research has included causes of fatigue, fatigue measurement and prediction, consequences of fatigue, and fatigue mitigation strategies (Bendak & Rashid, 2020). Despite the plethora of studies relating to fatigue among commercial airline pilots and military aviators, there has not been a similar body of literature on flight students and instructors in collegiate flight programs in the United States. This has given an impetus for more studies in this fledgling area of aviation safety.

The NTSB, International Civil Aviation Organization (ICAO), and the Federal Aviation Administration (FAA) have provided resources and guidance to the aviation community for the purpose of safety promotion efforts (NTSB, 2021; FAA, 2020; ICAO, 2016). Despite these laudable efforts, there are areas for improvement regarding the guidance and training efforts. Most fatigue mitigation guidance on fatigue is directed towards maintenance technicians, Part 121 (scheduled service), Part 135 (on-demand), and flight attendants (FAA, 2010a, 2010b, 2012, 2014). The Aircraft Owners and Pilots Association (AOPA), provides fatigue mitigation guidance for the general aviation (GA) community in the U.S. through periodic publications (AOPA, 2020). Though this is positive for safety promotion and training efforts, AOPA's guidance is generally directed towards the broader GA community which includes all flight operations except for scheduled service and military operations (AOPA, 2018a, 2020).

Traditionally, fatigue training in the collegiate aviation environment utilizes guidance from these sources. Often, fatigue lessons are delivered during ground school, academic courses such as human factors, aviation physiology, crew resource management, and basic aviation safety. During the practical flight examination, the FAA Flight Standards Service requires the assessment of pilot's knowledge and their ability to demonstrate the understanding of the recognition, causes, effects, and corrective actions of aeromedical and physiological issues including fatigue (FAA, 2018a). The reference study source is document FAA-H-8083-2 (Risk Management Handbook). In addition to training and education to meet certification standards, regulations are used to mitigate the consequences of fatigue.

Extensive regulations such as Federal Aviation Regulation (FAR) Part 117, which mandates flight and duty limitations as well as rest requirements for flight crews do not apply to the flight training environment (Electronic Code of Federal Regulations, 2020a). The only regulation that pertains to "duty time" for collegiate aviation pilots is the FAR 61.195. The FAR 61.195 limits Certified Flight Instructor (CFI) flight time to eight hours per 24-hour period (Electronic Code of Federal Regulations, 2020b).

Many collegiate aviation pilots including flight instructors are full-time students enrolled in 12 credit hours or more during the Fall and Spring semesters. In addition to flight training, these collegiate aviation pilots are expected to participate in student organizations, research projects, studying, social activities, and often have jobs while being employed as flight instructors (Keller et al., 2019). According to Beattie et al. (2019), students who are successful within the academic environment treat it like a full-time job and spend an average of 30 hours a week completing class-related activities including studying. If this is the standard to achieve academic success, it is necessary to understand the schedules and nuances of collegiate aviation pilots. A combination of the activities mentioned above are all known reasons that reduce sleep quantity, quality, and overall performance.

Further, fatigue can cause a decrease in academic performance resulting in a lower grade point average (Beattie et al., 2019; Satti et al., 2019). An excessive workload may negatively impact their goals of having a healthy lifestyle (McDale & Ma, 2008; Mendonca et al., 2019). Many collegiate aviation pilots fall within the 18-22 age range, and it may be the first time managing their lives independent of parental oversight. This scenario can present challenges in their development of time and stress management skills and predispose them to increased risk of mental, emotional, and physical fatigue (Abrams, 2015; Caldwell et al., 2009; Worley, 2018). Increased research into the effects of fatigue on this pilot population has become more imperative because of the safety implications to flight operations. Therefore, a comprehensive examination of fatigue among collegiate pilots is essential as part of safety promotion efforts within collegiate aviation programs"

Extant literature recommends organizations utilize a multidimensional approach beyond prescriptive regulations to identify, address, and mitigate the risks of fatigue within flight operations (Caldwell 2017; Dawson & McCulloch, 2005; ICAO, 2016). Effective Safety

Management System (SMS) processes such as the assurance and promotion aspects can enhance voluntary safety reporting and incident reporting, vital for management decision-making as well as policy improvements on fatigue (FAA, 2016).

Fatigue is the product of several factors ranging from physiological to emotional needs yet organizational factors (e.g., organizational pressures) could add to the complexity of fatigue management during flight operations (Caldwell, 2009). Different types of aviation operations offer their own complexity, whether it be early departures and/or late arrivals, crossing multiple time zones, working extended duty days, non-standard work hours, and rotating schedules. The investigation of previous aircraft accidents has indicated that fatigue identification and management is complex (NTSB, 2014a, 2014b; Transportation Safety Board of Canada, 2018). The effective management of fatigue during flight activities requires an approach that addresses physiological, organizational, and operational factors.

The ICAO standards and recommendations support two methodologies for managing fatigue in aviation: prescriptive and performance-based approaches, the latter by implementing a Fatigue Risk Management Systems (FRMS). ICAO defines FRMS as a "data-driven means of continuously monitoring and managing fatigue related safety risks, based upon scientific principles, knowledge and operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness" (2016, p. XVI). FRMS is a safety tool that seeks to achieve a realistic balance between safety and productivity. Effective FRMS is multi-faceted, incorporating reactive, proactive, and predictive methodologies that are based on operational experience and science (Rangan et al., 2020). According to Caldwell et al. (2019), the FRMS framework has been continuously adopted throughout the transportation industry.

In the U.S., The FAA has recommended air carriers and other aviation operators should develop and implement a science based FRMS (FAA, 2013). FRMS allows aviation operators to use their resources more efficiently and to leverage their operational flexibility while ensuring an acceptable level of safety (Caldwell et al., 2019). Other benefits of an effective FRMS include workload balance to mitigate fatigue, fatigue identification and management, educational efforts, and the management of fatigue risks to a level that is higher than a prescriptive approach.

There have been recommendations for fatigue risk mitigation strategies to be based on the knowledge gleaned from scientific inquiries and data-driven analysis (ICAO, 2016). Interestingly, FRMS utilizes the SMS tenets and processes to manage the hazard of fatigue and ICAO SARPs recommends that if the aviation service provider has a mature SMS, they can use the existing SMS processes to address the provisions of an FRMS through process integrations and alignments (ICAO, 2016). Though SMS is now mandated for Part 121 certificated carriers in the U.S., it is not required for collegiate aviation programs (FAA, 2016). However, some are actively engaged in the voluntary FAA SMS program for certificate holders not under the mandate of 14 CFR Part 5 which has components that could be beneficial for fatigue policy improvement (Adjekum, 2014; FAA, 2016).

ICAO recommends fatigue mitigation strategies to be based on the knowledge gleaned from data-driven analysis and suggests five primary methods for proactive fatigue risk identification namely: self-reported measures, surveys, performance data, research studies, and the analysis of time worked (ICAO, 2012; ICAO; 2016). The following section will highlight fatigue literature including recent fatigue research that pertains to collegiate aviation students.

Literature Review

Fatigue

Fatigue is a multifaceted and complex phenomenon (Avers & Johnson, 2018). According to Kloss et al. (2011), the negative effect of inadequate sleep is significant on human performance. A reduction of cognitive performance can be attributed to the interaction of deficient sleep quality, hours of being awake, and time of day or circadian rhythms (James et al., 2018). Related cognitive deficiency results from the interaction of multiple factors including sleep history, time awake, and time of day or circadian rhythms (Caruso, 2014; Simon et al., 2017; Van Dongen, 2000). In conjunction with a healthy lifestyle, an individual should aim to achieve between 7 and 9 hours of sleep each night for optimal performance (ICAO, 2016; National Sleep Foundation, 2021). Sleep is valuable in two primary ways. The body needs time for restoration and information processing. Throughout the time of being awake the body encounters stress from physical, mental, and emotional standpoints. Therefore, sleep permits restoration and repair (Barger, et al., 2018). Regarding information processing, the body repairs neural pathways to regular levels during sleep cycles (ICAO, 2020).

The adverse consequences of fatigue on pilot performance are well researched and documented within the broader aviation environment. Previous research (Marcus & Rosekind, 2017) and the investigation of aircraft accidents (NTSB, 2014a, 2014b) have indicated that it is difficult to determine fatigue as a causal factor during the investigation of an accident or incident. However, Rosekind (2015) found out that fatigue was a contributing factor in approximately 20 % of aviation accidents between 2001 and 2012. Even though data suggest that the General Aviation (GA) accident rate has been declining in the U.S., the 28th Nall Report indicated GA accounted for 95% of all aviation accidents during the last 10 years up till 2018 (FAA, 2018b; AOPA, 2018).

Approximately 73% of these GA accidents had some form of human error listed as a probable cause or contributing factor. Moreover, flight instruction activity accounted for 14% of all general aviation accidents in the United States. Fatigue may be an underlying condition for accidents and incidents at a much higher number than reported. Even with the challenges of listing fatigue as a probable cause, the NTSB has released more than 50 fatigue related recommendations since 1970 (NTSB, 2018). In addition to incidents and accidents, a more common outcome is poor performance. For instance, sleep deprivation among college students leads to a decrease in cognitive performance, i.e., Grade Point Average (GPA), a decrease in satisfaction, and an increase in negative interpersonal interactions. Moreover, acute and chronic fatigue can have deleterious effects on an individual's quality of life (Kloss, 2011).

Job demands or excessive workload is a significant predictor towards fatigue thus reducing cognitive and behavioral performance (Fan & Smith, 2017). Studies of diverse groups of workers in High Reliability Organizations (HROs) show that work scheduling practices can create conditions that exacerbate the risk of fatigue-related cognitive impairment. The ICAO

Document 9966 (2016) also suggests that work schedules can have an impact on time on duty (fatigue causal factor). Yet, schedules may not allow periodic extended opportunities for recovery. Moreover, "rotating schedules is that at certain times, such as on the night shift, an individual will be working when their circadian drive for sleepiness is high, and their performance is at its poorest" (p. 2.26). Fatigue training has been shown to be one effective countermeasure. A systematic review of fatigue training and performance outcomes has indicated improvements in safety and health outcomes of individuals (Barger et. al, 2018). One objective of the current study is to understand the impact of pilot workload, social activities, and formal fatigue awareness training on fatigue management among collegiate flight students.

Fatigue in Collegiate Aviation

In the United States, collegiate aviation programs are one of the main sources of producing professional pilots (Mendonca, et al., 2019). Empirically based assessments of the behaviors of collegiate pilot training populations that predisposes them to fatigue, and of the associated safety risks are essential. Such assessments provide findings for promoting desirable safety behavioral outcomes in the collegiate pilot training environment. Levin et al. (2019) found the leading causes of fatigue among collegiate aviation pilots were insufficient resting time and an inadequate work-life balance. The researchers also noted that half of the respondents did not consider themselves to have consistent healthy eating, exercise, and stress management habits. In another quantitative survey-based assessment of fatigue in collegiate flight programs, Romero et al. (2020) suggested that respondents knew about the correct strategies for combating fatigue but had challenges managing high academic workloads and ensuring regular sleep patterns essential for quality sleep.

Mendonca et al. (2019) distributed the Collegiate Aviation Fatigue Inventory-I (CAFI-I) to collegiate aviation pilots and results indicated 51% of the respondents had previously continued with a flight despite being extremely fatigued. Seventy-eight percent of the participants reported they committed errors and did not always give their best effort during flight training activities due to fatigue. Keller et al. (2019) presented participants with six vignettes on flight scenarios which entailed sleep deprivations, stress, mental and physical fatigue. Respondents were asked to qualitatively provide desirable or appropriate alternatives to the scenarios. For instance, one scenario told the story of a 14-hour day that included physical and mental fatigue then a long night flight and respondents were supposed to make a “Go/ No Go” decision as well as answer why. Almost half of the thirty-five participants responded with a “Go” decision.

The qualitative analysis in the Keller et al. (2019) study found that some participants struggled to communicate desirable alternatives, lacked knowledge of the human limitations, and expressed succumbing to external pressures such as staying on schedule to finish their flight course. However, during other scenarios some responses articulated desirable decision-making processes and expressed viable alternatives. Despite the positive responses, there were enough undesirable responses within the dataset the authors suggested fatigue training was lacking (Keller et al., 2019). Keller et al. (2020) examined self-reported sleepiness and fatigue provided evidence that collegiate aviation pilots had the highest median of fatigue at 08:00 Hrs. Instead of a desirable reporting of fully awake and refreshed, respondents indicated perceptions of feeling of "a little tired, less than fresh" throughout the entire study (Keller et. al., 2020). Mendonca et. al. (2021), found that 60 % of respondents felt fatigued during their flight activities.

A clearer understanding of fatigue among collegiate aviation pilots, may provide the flight training community a pathway for safer and more efficient operations. The researchers of this study distributed the Collegiate Aviation Fatigue Inventory-II (CAFI-II) to eight collegiate programs in the United States through convenience sampling methods. The CAFI-II was developed to determine fatigue awareness, causes of fatigue, lifestyles, workload, and impact of fatigue on flight training activities (Keller et al., 2021). Though collegiate aviation pilots are typically 18-22 years old, diversity of experiences can be found at each enrollment level, particularly with workload. Another aim of the current study was to determine which collegiate aviation pilot demography had the highest propensity to fly fatigued. Additionally, understanding if students perceive they have received fatigue training or not may have implications on fatigue mitigation efforts. Therefore, the research objectives for this study were:

1. To determine the frequency of formal fatigue training received by respondents during their enrollment in collegiate aviation programs.
2. To determine times spent on academic, employment and social activities.
3. To determine whether enrollment levels, fatigue training status and total flight hours are significant predictors of reported frequency of fatigue during flight training.

The following section will discuss the sample population, research instrument, procedures, research questions, and data analyses.

Methodology

Participants

All eight universities are in the Midwestern region of the United States and represented small, medium, as well as large university flight programs. Initial notifications of the study were sent to the points of contact including Faculty, Chairs, and Chief Flight Instructors within each program. The research instrument was then forwarded to the pilot group. All eight programs are accredited by the Aviation Accreditation Board International (AABI) and are certified under Federal Aviation Regulation Part 141. All participants in this study were collegiate aviation pilots including instructors who were identified as students. The researchers sought collegiate aviation pilots, aged 18 years or older, who had previously flown in the last 6 months, and were currently enrolled in a collegiate aviation flight training program. The estimated number of pilots enrolled in the eight programs was 700.

Research Instrument

As stated earlier in this paper, the Collegiate Aviation Fatigue Inventory (CAFI) was a modified version of a survey published by McDale and Ma (2008). Data from CAFI-I was instrumental in the publication of three scholarly papers (Keller et al., 2019; Levin et al., 2019; Mendonca et al., 2019). During its development, the CAFI underwent content validity checks by six Subject-Matter Experts (SMEs) (Mendonca et al., 2019). The researchers made modifications to the survey based on feedback provided by the SMEs. Subsequently, the team conducted beta testing with 24 participants who were students enrolled in a collegiate aviation program at a Midwestern University in the U.S. The Mendonca et al. (2019) study utilized a Principal Component Analysis (PCA) (n = 122). The analyses revealed an overall Kaiser-Meyer-Olkin (KMO) measure of 0.78, with individual KMO measures all greater than 0.6. Bartlett's Test of Sphericity was statistically significant ($p < .0005$). The PCA yielded the following three components: the fatigue awareness subscale consisted of eight items and a Cronbach's Alpha of .867, the causes of fatigue subscale consisted of 11 items with an alpha score of .793, and the lifestyle subscale consisted of 7 items with an alpha score of .734. The reliability and consistency of the CAFI was found to be acceptable, with a total of 26 items and an overall alpha score of .754 and further results were reported in the Mendonca et al. (2019) study.

For this study, the researchers made minor revisions to the CAFI to create the CAFI-II. Revisions included changing the multiple-choice range questions in the demographic section of 'age' and 'approximate total logged flight time' to "fill in the blank" slot option. Similar revisions were made to questions in the lifestyle section, which surveyed the number of hours the participant spent on various listed activities. These revisions allowed participants to report quantitative data more accurately instead of a predetermined scale range. A factor analysis was not run for the current study.

The final version of CAFI-II consists of eight sections. The first section had the required IRB consent form. The second section of the survey was the demographics section. The third section of the survey was the fatigue awareness section. Respondents were provided with a list of fatigue symptoms and were asked to rate their applicability via a five-point Likert Scale (Never – Always) question. The fourth section of the survey was the causes of fatigue section. Similarly, participants were presented with a list of situations that may encourage the onset of fatigue. Participants were asked via a 5-point Likert Scale (Never – Always) question to rate their applicability based on personal experiences.

The fifth section of the survey involved lifestyle choices. Respondents were given a list of lifestyle choices and had to rate their applicability on a 5-point Likert Scale (Strongly disagree – Strongly Agree) question. The sixth section of the survey contained personal solutions that participants may undertake to reduce or mitigate fatigue. In this section, participants were told to rank (one being most applicable and ten being the least) among a given list of situations, which they felt was the best solution that they have taken to mitigate the effects of fatigue.

The seventh section of the survey asked participants whether they felt that fatigue had an impact on their flight training. Participants were presented with a five-point Likert Scale (Never – Always) question. There were open-ended style questions that queried the participant's typical weekly schedule, including hours spent on the weekends for different types of chores, social activities, and hours spent on the weekdays for social activities. The eighth section of the survey asked about the participant's circadian rhythms. In this section, participants were presented with different times of the day (early morning 6:00 am – 9:00 am) and using a 7-point Likert scale (Fully alert – completely exhausted) question, the participants had to rate what their fatigued state was typically like during those times of the day. The survey can be found in Appendix A.

After IRB approval the survey was distributed to the collegiate aviation programs through email using an anonymous Qualtrics® survey link. Three reminders were sent throughout the data collection period. The data collection period was the end of Fall 2019 and the beginning of the Spring 2020 semester. Results and discussions related to specific questions in this study were presented and conclusions proffered.

Data Analysis

All data collected were anonymous and downloaded from Qualtrics then imported into IBM SPSS 26®. Participant's workload and socializing hours as well as fatigue training received were reported using descriptive statistics. An ordinal logistics regression test was selected to understand the predictors, enrollment level, fatigue training received, and reported total flight hours. Ordinal logistic regression is used to predict an ordinal dependent variable given one or more independent variables. More specifically, the test can determine which independent variable will significantly affect the dependent variable and determine how well the model predicts the dependent variable (Kleinbaum & Klein, 2010).

The predictor variables for this study were enrollment level, fatigue training received, and approximate total flight hours. Enrollment categories were First-Years, Sophomores, Juniors, and Seniors. The dependent variable was the survey item "fatigue impacts my flight training activities". The participants selected from a ranked scale: 'Never', 'Rarely', 'Sometimes', 'Often', and 'Always'. Specifically, the research questions for this study were:

1. How many participants have received fatigue training while enrolled in their flight training program?
2. What are the reported typical hours spent on working (work and study) and socializing?
3. Do the independent variables enrollment level, fatigue training received (Yes or No), and total flight hours predict the reported frequency of fatigue during flight training?

Results

Demographics

Demographic information was collected as part of the survey, including gender, enrollment level, highest certificate held, approximate total logged flight time, and name of their institution. Not all participants respond to the demographic items and all percentages were rounded to the nearest tenth. Seventy-eight percent of respondents were male while 21.7% were female ($n = 373$). The youngest participant age was 18 years old while the oldest respondent was 40 years old. The mean age was ($M = 20.58$, $Mdn = 20$, $SD = 2.627$). Most of the participants were Student or Private Pilots and had 200 hours or less of flight time. The demographic fit the ideal target group for this study. Table 1 details the distribution of the demographics.

Table 1
Summary of Participant's Demographics

Institution	**(n)**	**Percent**
Institution 1	98	26.6%
Institution 2	67	18.2%
Institution 3	51	13.9%
Institution 4	39	10.6%
Institution 5	36	9.8%
Institution 6	34	9.2%
Institution 7	23	6.3%
Institution 8	20	5.4%
Total	**368**	**100%**
Gender	**(n)**	
Female	81	21.7%
Male	292	78.3%
Total	**373**	**100%**
Age	**(n)**	**Percent**
18-21	304	81.5%
22-25	65	17.4%
26-29	3	.8%
30+	1	.3%
Total	**373**	**100%**
Enrollment Level	**(n)**	**Percent**
First-Years	72	19.3%
Sophomores	90	24.1%
Juniors	105	28.2%
Seniors	106	28.4%
Total	**373**	**100%**
Highest Certificate Held	**(n)**	**Percent**
Student Pilot	99	26.5%
Private Pilot	157	42.1%
Commercial Pilot	52	13.9%
Certified Flight Instructor	65	17.4%
Total	**373**	**100%**
Approximate Total Flight Time	**(n)**	**Percent**
0 - 100	144	38.6%
100 - 200	112	30.0%
201 - 300	62	16.6%
301 - 400	26	7.0%
401 - 500	12	3.2%
501 - 600	4	1.1%
601 - 700	4	1.1%
701 - 800	1	.3%
801 - 900	0	0%
901 - 1000	1	.8%
1001+	2	.5%
Total	**373**	**100%**

Note. The percentages were rounded to the nearest tenth.

Research Question One

How many participants received fatigue training while enrolled in their flight training program?

Two hundred and ninety-seven (n = 297) individuals responded to this question. Forty-nine percent responded that they had received fatigue training during their academic or flight training course work while 50.2% responded they had not. Each of the eight-flight training programs had respondents indicate they did not receive fatigue training. The percentages contributing to the 50.2% (did not receive fatigue training) ranged from 3.4% to 9.8%. The range of "did not receive fatigue training" overall frequencies and percentages of student responses are shown in Table 2. To further understand the frequency of received training the researchers elected to separate the data by enrollment level. First-Years and Sophomores had a higher percentage of receiving fatigue training while Juniors and Seniors had a higher percentage of not receiving fatigue training. These results can be found in Table 3. Figure 1 shows the data in a column chart.

Table 2
Overall Responses

Response	Count	Percent
Yes	148	49.8%
No	149	50.2%
Total	297	100%

Note. Percentages are rounded to the nearest whole number.

Table 3
Responses by Enrollment Level

		Yes	No	Total
First-Years	Count	39	17	56
	% within Enrollment Level	69.60%	30.40%	100.00%
	% of Total	13.10%	5.70%	18.90%
		Yes	**No**	**Total**
Sophomores	Count	37	20	57
	% within Enrollment Level	64.90%	35.10%	100.00%
	% of Total	12.50%	6.70%	19.20%
		Yes	**No**	**Total**
Juniors	Count	34	53	87
	% within Enrollment Level	39.10%	60.90%	100.00%
	% of Total	11.40%	17.80%	29.30%
		Yes	**No**	**Total**
Seniors	Count	38	59	97
	% within Enrollment Level	39.20%	60.80%	100.00%
	% of Total	12.80%	19.90%	32.70%
		Yes	No	Total
	Total Count	148	149	297
	% of Total	**49.80%**	**50.20%**	**100.00%**

Note. Percentages are rounded to the nearest tenth.

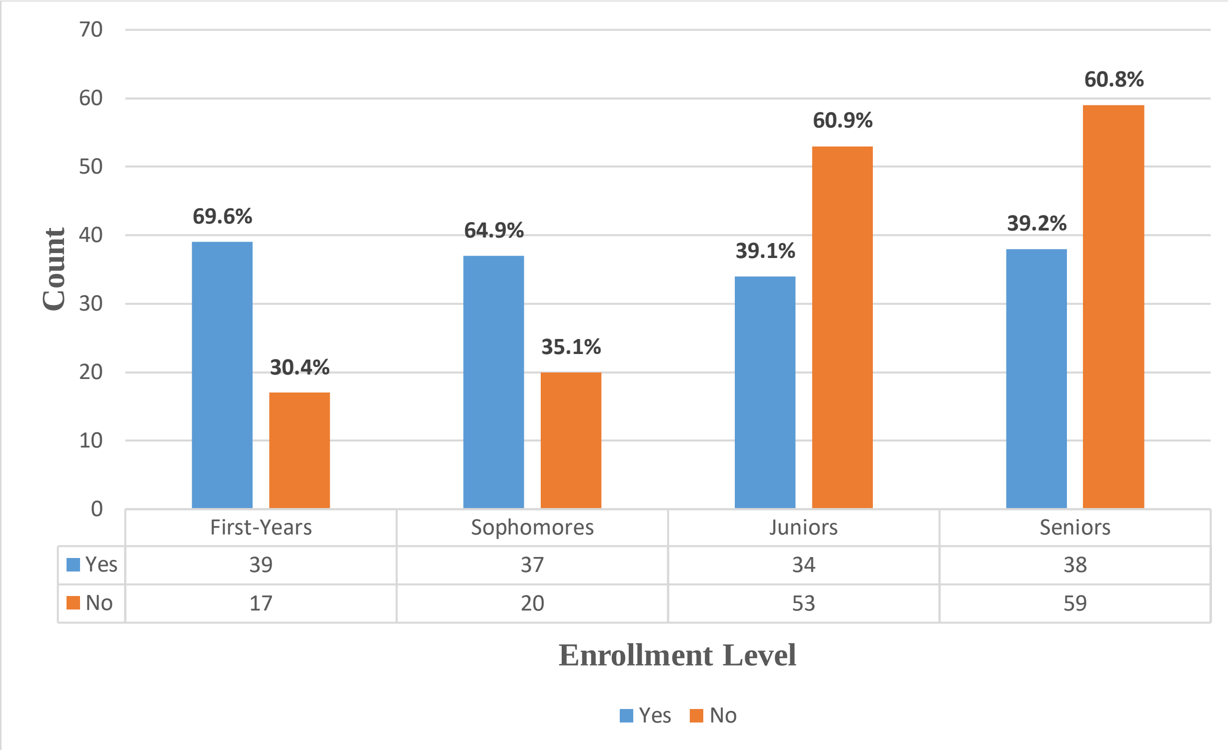


Figure 1. Enrollment Level and Count of Responses for Receiving Fatigue Training.

Note. Percentages are from within the enrollment level.

Research Question Two

What are the reported typical hours spent working, studying, and socializing?

There were 282 responses for the survey item that requested hours worked per week Monday through Sunday. The prompt within the survey item asked to participants to include time spent working as well as studying. Results showed the mean hours worked per week was close to 33 hours (M = 33.09, Mdn = 30, SD = 19.014). The minimum reported hours worked per week was zero while the maximum was reported as 78 hours per week (see Table 4).

Table 4
Descriptive Statistics for Hours Worked per Week

Item	Hours Worked Monday-Sunday
N	282
Mean	33.09
Median	30.00
Mode	0
Std. Deviation	19.014
Variance	361.529
Minimum	0
Maximum	78

The hours worked in a week were binned into ranges to access the counts using a feature within IBM SPSS 26®. Approximately 45% of respondents to the survey item reported working and studying between 0 and 29 hours per week. Approximately 41% reported working and studying between 30 and 57 hours per week while approximately 14.28% reported working and studying between 58 and 78 hours per week. Figure 2 shows the hour ranges, counts, and percentages from the total count.

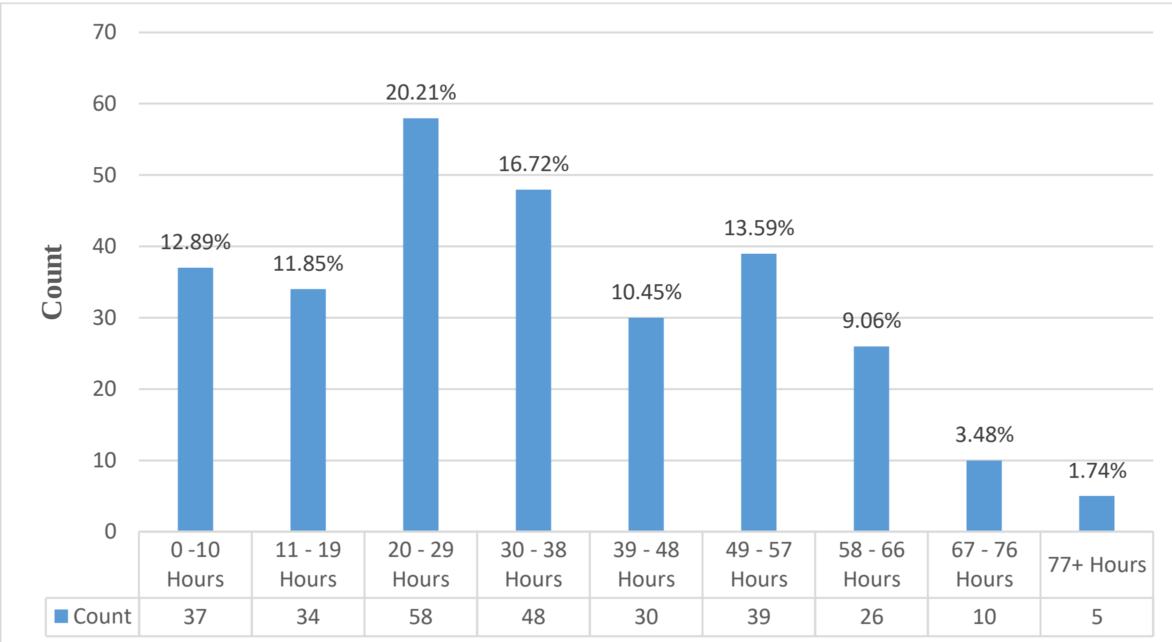


Figure 2. Range of Hours Worked Per Week.

Note. Percentages are from the total responses to the question (N = 282). The range consists of hours worked per week Monday-Sunday.

To further understand the participants' workload, the researchers broke down the hours by enrollment level and hours worked. Results indicated Juniors and Seniors worked more hours per week than First-Years and Sophomores. However, Juniors and Seniors accounted for more of the survey respondents. In fact, there were 49 more responses from Juniors and Seniors. Reported hours worked per week by enrollment level is found in Figure 3.

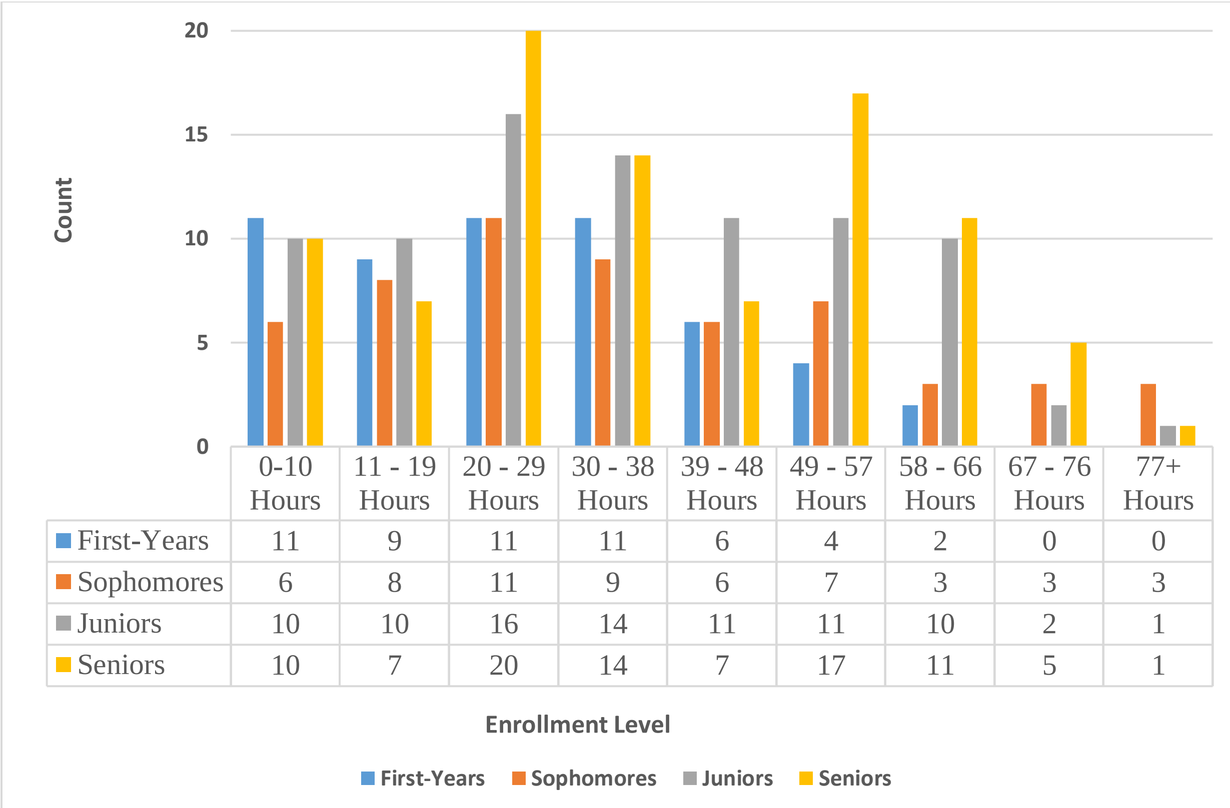


Figure 3. Range of Hours Worked per Week by Enrollment Level.

Respondents were also asked to provide the amount of time in hours spent socializing. Two hundred and ninety-two responses were obtained (n = 292). Results showed the mean hours spent socializing per week was close to 15 hours (*M* = 15.38, *Mdn* = 12, *SD* = 12.324). The minimum hours reported was zero hours while the maximum was 69 hours. Table 5 shows the descriptive statistics for hours worked per week.

Table 5
Descriptive Statistics for Hours Spent Socializing Per Week.

Item	Hours Socializing Monday-Sunday
N	292
Mean	15.38
Median	12.00
Mode	8
Std. Deviation	12.324
Variance	151.872
Minimum	0
Maximum	69

Once again, the researchers utilized SPSS 26® to bin the hours into ranges to assess the counts. Approximately 46% of respondents to the survey item reported socializing between zero and 10 hours per week. Approximately 46% reported socializing between 11 and 32 hours per week while 8.21% reported socializing between 33 and 69 hours per week. Figure 4 shows the hour ranges, counts, and percentages from the total count. Similar to the hours worked analyses, the researchers included the hours by enrollment level and hours spent socializing. Results indicated Juniors and Seniors socialized more hours than First-Years and Sophomores in almost all of the range categories. Hours spent socializing per week by enrollment level is found in Figure 5.

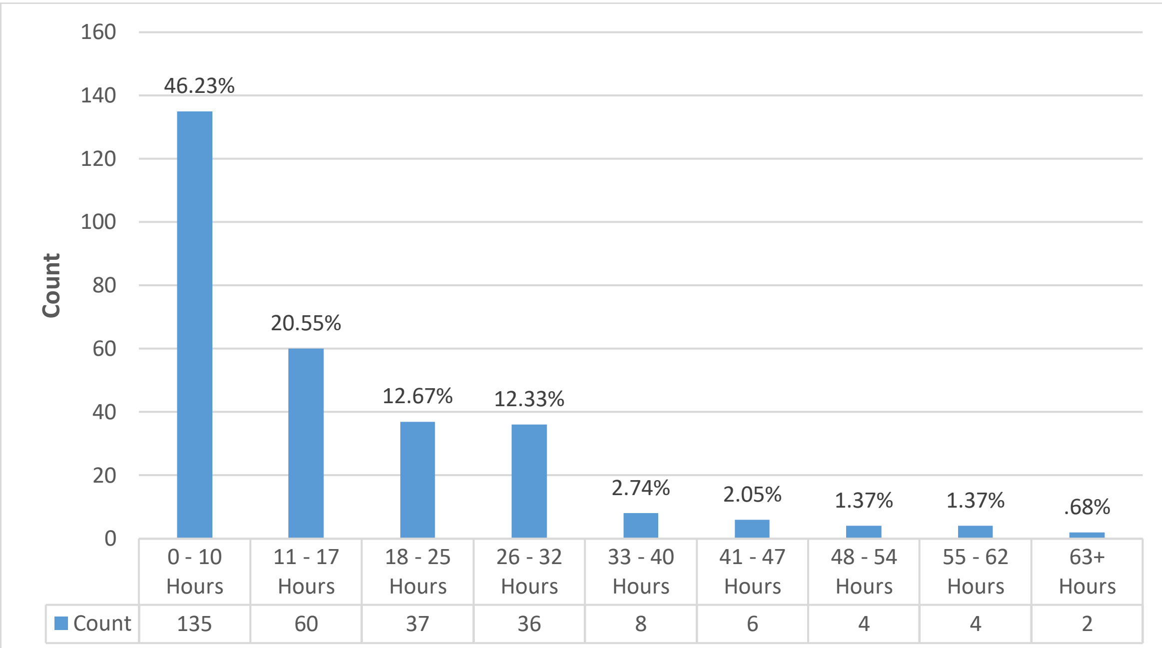
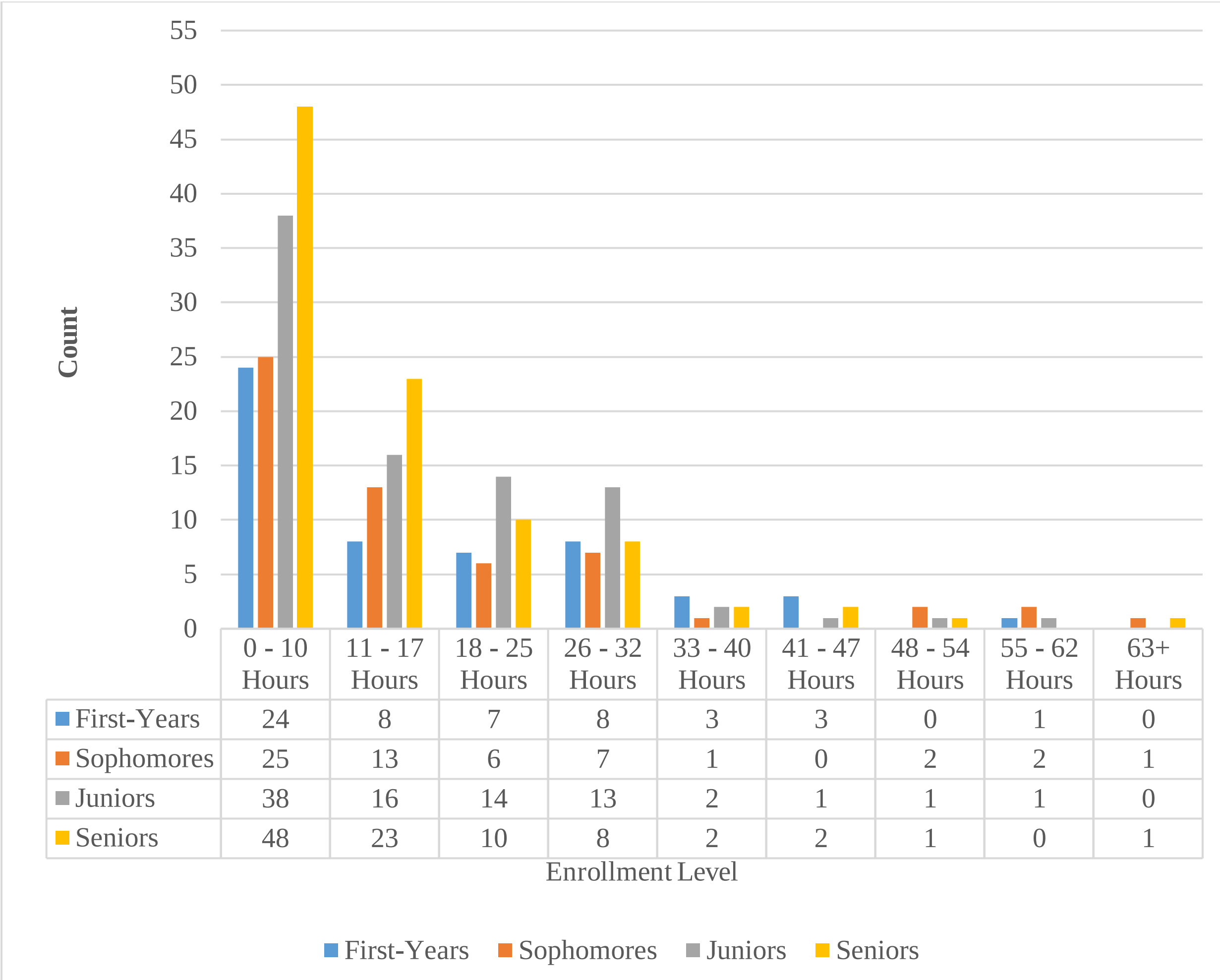


Figure 4. Range of Socializing Per Week.

Note. All responses combined reported hours spent socializing Monday-Sunday.



	0 - 10 Hours	11 - 17 Hours	18 - 25 Hours	26 - 32 Hours	33 - 40 Hours	41 - 47 Hours	48 - 54 Hours	55 - 62 Hours	63+ Hours
First-Years	24	8	7	8	3	3	0	1	0
Sophomores	25	13	6	7	1	0	2	2	1
Juniors	38	16	14	13	2	1	1	1	0
Seniors	48	23	10	8	2	2	1	0	1

Figure 5. Range of Socializing per Week by Enrollment Level.

Research Question Three

Do the independent variables enrollment level, fatigue training received (Yes or No), and total flight hours predict the reported frequency of fatigue during flight training?

The null hypothesis for this research question is H_o: Enrollment level, fatigue training, and approximate total flight hours do not predict the frequency of fatigue during flight training activities.

A cumulative odds ordinal logistic regression with proportional odds was run to determine the effect of enrollment level, fatigue training, and flight time, and the reported frequency that fatigue impacts flight training activities. See Table 6 for an overall distribution of variables and sample size.

Table 6
Variables and Descriptive Statistics

		n	Marginal Percentage	* Scale Combined	n	Percent
Fatigue During Flight Training Activities	Never	23	7.9%	No	169	57.9%
	Rarely	146	50.0%			
	Sometimes	94	32.2%	Yes	123	42.1%
	Often	22	7.5%			
	Always	7	2.4%			
Enrollment Level	First-Years	55	18.8%			
	Sophomores	56	19.2%			
	Juniors	86	29.5%			
	Seniors	95	32.5%			
Fatigue Training	Yes	146	50.0%			
	No	146	50.0%			
Total		292	100.0%			

Note. For the scale combined column, Never and Rarely=No while Sometimes, Often, and Always=Yes

An ordinal regression has four assumptions that need to be met. The researchers chose to use $p < .05$ as the cutoff value for significance for all tests. The first assumption requires an ordinal dependent variable. Question #16, "*fatigue impacts my flight training activities",* was a Likert scaled item and had the following options as a response; 'Never', 'Rarely', 'Sometimes', 'Often', and 'Always'. The second assumption requires at least one independent variable. Once again, the independent variables were, enrollment level, fatigue training received, and flight time. Flight time was measured at the continuous level and established in the analysis as a covariate. The third assumption tested for multicollinearity. To test for multicollinearity, the researchers utilized the linear regression test within SPSS®. The linear regression test yielded *Tolerance* values that were greater than 0.1. The Tolerance value for enrollment level was .652, received fatigue training was .936, while flight hours was .618. All three Variance Inflation Factor (VIF) values were less than ten. These findings indicated there was no issue with collinearity.

To check the assumption for proportional odds, the researchers performed a Full Likelihood Ratio test. The results of the test generated the Test of Parallel Lines. To pass this assumption, the Test of Parallel lines should be statistically not significant, $p > .05$. As assessed by the full likelihood ratio test, the assumption as met, $\chi2(15) = 21.843$, p = .112. Most cells were sparse with zero frequencies in 772 (76.1%) of cells therefore deviance goodness-of-fit test was used. Results indicated the model was a good fit to the observed data, $\chi2(803) = 543.387$, p = .677. Table 7 shows the goodness-of-fit results. The final model statistically significantly predicted the dependent variable over and above the intercept-only model, $\chi2(5) = 17.769$, p = .003. Table 8 shows the model fitting information.

Table 7
Goodness-of-Fit Test Statistics

	Chi-Square	df	Sig.
Pearson	864.838	803	.064
Deviance	543.387	803	.677

Table 8
Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	621.825			
Final	604.056	17.769	5	.003

The next step was to determine which variable(s) were significant predictors on frequency of fatigue impacting flight training reported by participants. The Test of Model effects indicated enrollment level and fatigue training received were the only significant variables in the model. The variable enrollment level was, $\chi2(3) = 12.134$, $p = .007$ while flight training received was, $\chi2(1) = 3.883$, $p = .049$. Data for the Test of Model Effects is shown in Table 9.

Table 9
Test of Model Effects

Variable	Type III		
	Wald Chi-Square	df	Sig.
Enrollment Level	12.134	3	0.007
Training Received	3.883	1	0.049
Total Flight Time	0	1	0.992

With four categories of enrollment, there were six comparisons that needed to be made. These comparisons are First-Years vs Seniors, Sophomores vs Seniors, Juniors vs Seniors, Juniors vs First-Years, Sophomores vs Juniors, and First-Years vs Sophomores. The reference category in the first run only provided three of the comparison. To obtain all the comparisons the researchers had to recode and rerun the enrollment categories. The parameter estimates output shows the initial and consecutive pairwise comparisons and can be found in Appendix B. The following section will provide interpretation of these comparisons.

Two of the comparison provided statistically significant results, Seniors vs First-Years and Juniors vs First-Years. Juniors and Seniors had higher odds of falling in a higher frequency category of the dependent variable- "*fatigue impacts my flight training activities*". The odds of Seniors reporting a higher frequency of fatigue impacting their flight training was 3.95, 95% CI [1.77, 8.83] times higher than that of First-Years with a statistically significant effect, $\chi2(1) = 11.24$, $p < .001$.

The comparison for Juniors vs First-Years was determined in the second run of the analyses with the categories recoded and reordered. The odds of Juniors reporting a higher frequency of fatigue impacting their flight training was 3.00, 95% CI [1.45, 6.18] times higher than that of First-Years with a statistically significant effect, $\chi2(1) = 8.85$, $p < .001$. The remaining comparison were not statistically significant but are reported in the following paragraphs.

The odds of Seniors reporting a higher frequency of fatigue impacting their flight training was 2.05, 95% CI [0.99, 4.25] similar to Sophomores and was not statistically significant effect, $\chi2(1) = 3.74$, $p = .05$. The odds of Seniors reporting a higher frequency of fatigue impacting their flight training was like Juniors and was not statistically significant, .076, 95% CI [.42, 1.36], $\chi2(1) = 0.86$, $p = .35$. Regarding Sophomores vs Juniors, the odds of Sophomores reporting a higher frequency of fatigue impacting their flight training was 1.56, 95% CI [0.80, 3.84] similar to that of Juniors and not statistically significant effect, $\chi2(1) = 1.68$, $p = .20$. The First-Years vs Sophomores comparison can be found in the third run of the data. The odds of First-Years reporting a higher frequency of fatigue impacting their flight training was slightly lower and not statistically significantly different when compared to Sophomores, 0.52, 95% CI [.25, 1.09], $\chi2(1) = 3.04$, $p = .08$.

Participants were asked if they had received fatigue training during their flight training program. The odds of reported fatigue training recipients experiencing a higher frequency of fatigue during flight activities was 1.583, 95% CI [1.002, 2.499] times that of fatigue training non-recipients with a statistically significant effect, $\chi2(1) = 3.883$, $p = .049$. This is an interesting result. Participants were also asked to provide their approximate total flight hours. This continuous variable was added to the model as a covariate. Reported total flight hours did not indicate a significant effect, $\chi2(1) = 0.00$, $p = .992$.

Discussions and Conclusions

The purpose of this study was to gain a clear understanding of fatigue training provided to collegiate aviation pilots, their typical workload and time spent socializing, and factors that may lead respondents to indicate a higher frequency of fatigue while conducting flight training activities. The first question answered in this study pertained to fatigue training among the respondents. The responses to "*have you received fatigue training during your enrollment in the flight program*" were almost evenly split between "yes" and "no". This is a concerning finding considering the insidious nature of fatigue and its deleterious effects during flight operations. While the authors recognize that many flight programs incorporate human factors training into their curriculum, the responses indicate some of the fatigue training and education may not be meeting critical learning outcomes of identifying fatigue risk factors and application of effective mitigation strategies during flight operation activities.

As part of the practical standards for pilots in the U.S., the Airmen Certification Standards (ACS) requires the assessment of pilot's knowledge and ability to demonstrate an understanding of the recognition, causes, effects of aeromedical and physiological issues such as fatigue including the relevant corrective actions (FAA, 2018a). Some collegiate aviation programs use informal discussion-based format for lessons on fatigue. Other collegiate aviation programs also introduce concepts on fatigue through aviation safety and human factors courses that analyzes accident case- studies. There may be a need to review curriculum to include more comprehensive and data-driven content analyses on fatigue risk management education and recommended by ICAO SARPs.

Though it is a challenge to control student behavior outside of the classroom or flight deck and simulator laboratories, increasing the intentionality of fatigue training may promote desirable safety behaviors (Barger et. al, 2018). These behaviors can include the ability to understand the leading causes of fatigue, signs, and symptoms, best practices for sleep preparation, how to handle disruptions, workload management, as well as fatigue related decision-making before and during flight operations i.e., talking with an instructor.

Integrated fatigue training using Safety Management System processes such as safety promotion can be productive. This can be done by incorporating fatigue training as part of the continuous improvement efforts of safety required in a functional SMS of an organization. Additionally, collegiate programs with SMS can utilize other components of SMS namely; Safety Policy, Risk Management, and Safety Assurance to enhance fatigue management. The SMS policy must have provisions that spells out fatigue as one of the safety risks that needs to be managed and who will have responsibilities and accountabilities for fatigue management in the program. It will also highlight leaderships commitment to provide resources to mitigate the adverse effects of fatigue in flight operations. Risk management tools can be used to identify and recommend effective controls for fatigue. Data on fatigue in an organization can be used for periodic evaluation of the effectiveness of any fatigue management plan adopted. Finally, collegiate aviation programs with a voluntary SMS program can adopt and integrate commercial airline FRMS components that can be beneficial for fatigue policy improvement.

Understanding workload is imperative to fatigue mitigation efforts and the second research question of this study queried hours spent working and socializing. The average reported time working and studying per week was 30 hours while the average time socializing was 15 hours per week. Romero et al. (2020), reported approximately 77 % of collegiate aviation respondents were enrolled in 12 credits or more per academic semester and another research finding suggests that academically successful students' study approximately 30 hours per week (Beattie et al., 2019).

It is highly recommended that fatigue risk matrices that provides guidance on quantifying the risk associated with student's workload be developed in Part 141 training programs. As noted in the results section of this study, Juniors and Seniors work and socialize more than First-Years and Sophomores. This provides evidence that fatigue training should be different for these groups. A future research direction may focus on how hours spent flying, time of flight slot, time spent studying, and working part time jobs influences fatigue management among this collegiate pilot population. Future research can also track pilot's workload in detail in terms of period of the semester.

For the final research question, the researchers included enrollment level, fatigue training received, and reported total flight hours as independent variables. Results from the ordinal regression analyses indicated Juniors and Seniors were two to three times more likely to report a higher frequency of fatigue when compared to First-Years and Sophomores. The results also indicated that Juniors and Seniors reported higher hours of work and socializing. These findings seem intuitive since Juniors and Seniors may be more engaged in leadership roles in extramural campus associations/activities and that can adversely affect time management needed for quality sleep. At this student academic level in the universities sampled some of the respondents can live outside the dormitories and are free to engage in more socializing and may engage in unhealthy eating habits which are fatigue risk factors and adversely affect quality sleep.

As upperclassmen, many collegiate aviation pilots turn 21 which allows them to legally visit bars and spend copious amounts of time in nightclubs. Some may also have changes in family lifestyles i.e., married, engaged to partners, and or having kids. These factors may be more disruptive to effective time management and quality sleep schedules. Others may be engaged in excessive and extraneous shift work to pay for college upkeeps and that can affect rest cycles especially night shifts that could have detrimental effects on circadian rhythms. Some may also be CFIs and undergraduate students while working extra jobs and combining academic loads with family responsibilities. These are some of the psycho-social factors that can potentially explain the differences observed from the findings. Adjekum (2014) in a study on safety culture in collegiate aviation suggests peer to peer advocacy for personal safety by peers advocating and encouraging lifestyles among themselves that minimizes fatigue risk factors. The findings from that study encouraged submission of safety reports on fatigue related flight events by collegiate aviation pilots and informal safety meetings moderated by peers where feedback from safety office is discussed.

Further, results indicated Juniors and Seniors had the lowest reported fatigue training. Evidence indicates those who said “yes” for having received fatigue training were 1.5 times more likely to report higher levels of fatigue. This may be due to the fact they are more aware of their fatigue and human limitation but still choose to meet the demands of the day. Specificity and recency of the type of fatigue training may be helpful in future studies. Some of the academic-based fatigue training tends to be done during the first and second years of enrollment. That may create a knowledge gap in terms of any formalized training on fatigue apart from the briefs required during flight operations with CFIs. It may be expedient to have higher levels courses in fatigue risk management which can be part of recurrent crew resource management or safety management system courses. Routine data collection and analysis on fatigue risk factors utilizing behavioral and subjective measures such as brief fatigue inventories and technology will improve organizational fatigue mitigation and management efforts (Shahid et al., 2012). Further, organizations can account for students assigned to instructors, track cancellations due to fatigue, use additional workload data such as credit hours in progress, limit late flights with early morning starts (particularly in the summer), and foster an environment that encourages work life balance.

The authors acknowledge some limitations to the study. This study utilized convenience sampling methods which inhibit generalization to the larger pilot population. All responses were from four-year university programs and did not include two-year community colleges. It is assumed that respondents were truthful and accurate when answering the survey items. There may have been cases of social desirability biases in the responses where respondents may not provide answers that makes them feel bad in social standings. Despite the limitations of this study, the results may be valuable to collegiate aviation program leaders, pilots, regulators, and human factors and aviation safety scholars.

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Appendix A

Demographics
Age:
Gender:
Enrollment status:
Highest Certificate Held:
Approximate total logged flight time:
Institution

Fatigue Awareness
Please rank the accuracy of the statement describing your overall experienceduring all of your flight activities.

	Never	Rarely	Sometimes	Often	Always
I have struggled to stay awake during a flight.					
I have remarked (out loud or to myself) about how tired I was but proceeded with the flight anyway.					
I have overlooked mistakes during a flight because of reduced judgment caused by fatigue.					
I have felt disinterest during flight activities because I was fatigued.					
I have not given my best effort due to fatigue.					
I have felt heightened irritation during a flight because I was fatigued.					
My abilities to carry out tasks requiring concentration have been decreased due to fatigue.					

What symptoms cause you to realize you are fatigued?

Causes of Fatigue
Please rank the accuracy of each statement describing contributing factors which may have led to fatigue during flight activities.

	Never	Rarely	Sometimes	Often	Always
Flying during night (sunset through sunrise).					
Flying a long cross-country (2.5 hours or over).					
Working a long day.					
Stress caused by family or other psychological conditions.					
Poor scheduling of flight lessons (e.g., too early, too late, or too many).					
Poor scheduling of academic classes.					
Lack health or fitness.					
Personal activities or other commitments (e.g., 2nd job).					
Academic activities (e.g., midterms, student organizations, etc.).					
Quality of sleep (restlessness or interrupted sleep).					
Not of enough sleep.					

Please comment on other factors that contributed to fatigue:

Lifestyle

Given each item, please select the accuracy of the statement describing your current lifestyle.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I have a healthy academic and life balance.					
I regularly exercise.					
I maintain a healthy diet.					
I am good at workload management.					
I am good at stress management.					
I get adequate sleep every night (quantity and quality).					
I prepare well to get adequate sleep (i.e., limit electronic device use, caffeine, disruptions, noise, etc.)					

In your experience what are the most significant factors that inhibit your quality/quantity of sleep?

Personal Solutions

Please read through the entire list then rank (click and drag) in order the following personal solutions to mitigate fatigue, 1 being the most important and 10 being the least important. You can provide factors that are not listed in the comment box below.

Reduced workload
Scheduled breaks
More sleep
Efficiency in scheduling of classes and flight activities
Management of sleep preparation
Self-awareness of fitness to fly
Guaranteed rest for a given amount of flying time
Physical exercise
Healthy eating habits
Better management of non-work issues

What other personal solution(s) do you find important?

Based on your overall experience during all of your flight activities.

	Never	Rarely	Sometimes	Often	Always
Fatigue impacts my flight activities.					

How many hours do you typically work per week Monday-Friday? (include studying, working, student organizations, etc.) (e.g., 1, 2, 3)

How many hours do you typically work per weekend Saturday-Sunday? (include studying, working, student organizations, etc.) (e.g., 1, 2, 3)

How many hours do you typically socialize per week Monday-Friday (e.g., 1, 2, 3)

How many hours do you typically socialize per weekend Saturday-Sunday? (e.g., 1, 2, 3)

Have you ever received fatigue training during your academic or flight training course work? Yes or No

What specific method do you use to ensure you are fit to fly?

Please identify in general your fatigue level during the specified time periods. We may be able to understand of your preference for morning or evening.

	Fully alert	Very lively but not at peak	Ok, somewhat fresh	A little tired, less than fresh	Moderately tired, let down	Extremely tired, very difficult to concentrate	Completely exhausted, unable to function effectively
Early morning (6am-9am)							
Morning (9am-noon)							
Early afternoon (noon-3pm)							
Afternoon/early evening (3pm-6pm)							
Evening (6pm-9pm)							
Night (9pm-6am)							

Please provide any comments that would help improve the survey (unclear items, length of survey, areas that were not addressed, etc.) Thank you for your feedback and participation.

Appendix B

Parameter Estimates

	Parameter	B	Std.Err	95% Wald CI Lower	95% Wald CI Upper	Wald Chi-Square	df	Sig.	Exp (B)	95% Wald CI Lower	95% Wald CI Upper
Threshold	Fatigue=.00	-2.80	0.38	-3.54	-2.05	54.25	1	0.00	0.06	0.03	0.13
	Fatigue=1.0	0.10	0.32	-0.53	0.73	0.10	1	0.76	1.11	0.59	2.08
	Fatigue=2.0	2.04	0.36	1.35	2.74	32.97	1	0.00	7.72	3.84	15.51
	Fatigue=3.0	3.56	0.48	2.61	4.51	54.15	1	0.00	35.31	13.67	91.25
Enrollment Level	First-Years	-1.37	0.41	-2.18	-0.57	11.24	1	**0.00**	0.25	0.11	0.57
	Sophomores	-0.72	0.37	-1.45	0.01	3.74	1	0.05	0.49	0.24	1.01
	Juniors	-0.28	0.30	-0.86	0.31	0.86	1	0.35	0.76	0.42	1.36
	Seniors	0[a]							1.00		
Fatigue Training	Yes=.00	0.46	0.23	0.00	0.92	3.88	1	**0.04**	1.58	1.00	2.50
	No=1.00	0[a]							1.00		
Flight Hours	Flight Hours	7E-6	0.00	0.00	0.00	0.00	1	0.99	1.00	1.00	1.00
					Comparison2						
Enrollment Level	Sophomores	0.66	0.38	-0.08	1.39	3.04	1	0.08	1.93	0.92	4.03
	Juniors	1.10	0.37	0.37	1.82	8.85	1	**0.00**	3.00	1.45	6.18
	Seniors	1.37	0.41	0.57	2.18	11.24	1	**0.00**	3.95	1.77	8.83
	First-Years	0[a]							1.00		
					Comparison 3						
Enrollment Level	Juniors	0.44	0.34	-0.23	1.11	1.68	1	0.20	1.56	0.80	3.04
	Seniors	0.72	0.37	-0.01	1.45	3.74	1	0.05	2.05	0.99	4.25
	First-Years	-0.66	0.38	-1.39	0.08	3.04	1	0.08	0.52	0.25	1.09
	Sophomores	0[a]							1.00		
					Comparison 4						
Enrollment Level	Seniors	0.28	0.30	-0.31	0.86	0.86	1	0.35	1.32	0.73	2.37
	First-Years	-1.10	0.37	-1.82	-0.37	8.85	1	**0.00**	0.33	0.16	0.69
	Sophomores	-0.44	0.34	-1.11	0.23	1.68	1	0.20	0.64	0.33	1.25
	Juniors	0[a]							1.00		

Note. The parameter estimates were rounded to the nearest hundredth. Significance levels were rounded to the nearest hundredth. Bold indicates the significant results at .05.