# AN ANALYSIS OF COLLEGIATE AVIATION PILOTS AND FATIGUE

by

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*I would like to thank my parents, Jason and Christine, and my sister, Laura, for their unwavering support, confidence, love, and encouragement in helping me achieve my goals. Without them, I will not be where I am today. I would also like to thank my uncle, Prof. Teo, for all the support and inspiration he has shown me. Lastly, I would also like to thank my committee members, especially Dr. Keller, Dr. Mendonca, and Dr. Lu, for all their patience and guidance in helping me throughout this process.*

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# ABSTRACT

Flying an airplane is a complex operation. Pilots must be able to manipulate the three-dimensional flight characteristics, maintain situational awareness, aircraft configurations, interpret charts, and handle communications with air traffic control. This requires maximum cognitive and psychomotor skills. The National Transportation Safety Board (NTSB) has added reducing fatigue-related accidents is on their top ten most wanted list. According to the NTSB (2019), 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.18). Additionally, the Federal Aviation Administration (FAA) has called on stakeholders, including the academic community, to reduce the number of accidents in the general aviation sector (Federal Aviation Administration, 2018). After a review of extant literature, most fatigue research in aviation pertains to airline and military operations (Keller, Mendonca, & Cutter, 2019; Levin, Mendonca, Keller, & Teo, 2019; Mendonca, Keller, Lu, 2019). However, collegiate aviation students have differences such as class scheduling, maturity, and regulations. Thus, making collegiate aviation pilots a unique population. Therefore, the purpose of this study was threefold: 1) To investigate the causes and symptoms of fatigue among collegiate aviation students. 2) To investigate whether there is a statistically significant association between enrollment status and a participant's willingness to fly fatigued. 3) To investigate whether a participant's age and flight hours predict their willingness to fly while fatigued. The researcher used a mixed-methods online-based survey to answer the research questions. The researcher used convenience and judgment sampling to distribute the survey to eight collegiate aviation programs in the United States. A total of 248 ($n = 248$) participants participated in the survey. The results of the survey indicated that participants cited excessive workload, stress, and sleep-related issues (disturbances and poor quantity) as the most common causes of fatigue. Participants cited drowsiness, loss of concentration, and physical/mental discomfort, including irritation, as symptoms of fatigue. The results also indicated that there was a statistically significant association between enrollment status and a participant's willingness to fly while fatigued; students from higher enrollment statuses are more willing to fly fatigued. Lastly, the results indicated that age might be used as a predictor for a participant's willingness to fly while fatigued. Conversely, flight hours cannot be used as a predictor for a participant's willingness to fly while fatigued.

# CHAPTER 1: INTRODUCTION

The introductory chapter provides an overview of pilot fatigue in the collegiate aviation environment. This chapter includes the statement of the problem, research questions, significance of the study, statement of the purpose, definitions, assumptions, limitations, and delimitations.

## Statement of the Problem

Collegiate aviation flight students are aspiring professional pilots enrolled at a university or college (Aircraft Owner and Pilot's Association, *n.d.*). Traditionally, students enrolled in these programs concurrently take classroom and flight courses. The Federal Aviation Administration (FAA) regulates these programs. Flight training institutions in the United States can conduct flight training under either 14 CFR Part 61 or Part 141, most collegiate aviation flight training programs, however, operate under Part 141. The Federal Aviation Administration (FAA) provides additional oversight on the flight school and their flight training activities, including flight training curriculum, maintenance, and facilities under Part 141 rules. Due to the structure of a Part 141 program, students may receive credit towards flight hours as opposed to schools that operate under Part 61 (Electronic Code of Federal Regulations, Title 14, Chapter I, Subchapter H, Part 141, 2019b). In some collegiate aviation programs, students that obtained their Certified Flight Instructor certificate are frequently employed by their college to provide flight training. This training model benefits the student flight instructors as they can build flight hours to meet the minimum required for advancing their careers to the industry. The FAA, an agency under the United States Department of Transportation (US DOT), not only regulates Part 61 and Part 141 training curricula but also promotes safety efforts through enforcing rules and regulations (Federal Aviation Administration, 2019).

Nevertheless, some scholars posit there are insufficient rules regulating fatigue in flight training (Levin, Mendonca, Keller, & Teo, 2019; Keller, Mendonca, & Lu, 2019). The only rule that exists pertaining to 'duty time' is 14 CFR Part 61.195. This regulation limits the flight instructor's duty time to eight flight hours per twenty-four hour time period (Code of Federal Regulations, Title 14, Chapter 1, Subchapter D, Part 61, 2020). The reference to 'duty time' in this regulation only pertains to the flight instructor's logged flight time. It does not consider the times that the student flight instructor is taking academic classes/responsibilities or other employment duties. There are also no prescribed limitations on flight training hours in place for the student pilot; as a result, fatigue management is primarily their responsibility.

Although there has been extensive research conducted on fatigue in the aviation industry (French & Garrick, 2005; Hamsal & Zein, 2019; Roach, Darwent & Sletten, 2011), there are only a few fatigue-related research papers that focused on the collegiate aviation sector (Levin et al., 2019; McDale & Ma, 2008; Mendonca, Keller, & Lu, 2019). Collegiate aviation students have different needs and lifestyles than airline and military pilots. These potential differences may render previous studies on fatigue in aviation inadequate in addressing fatigue within the collegiate aviation industry. These differences cause for additional investigations to add to the current body of knowledge. Fatigue is directly connected to aviation safety. Although holistically the accident rate in aviation, in general, is declining, the General Aviation (GA) sector has the highest accident and incident rates when compared to all other aviation sectors (Federal Aviation Administration, 2018). Flight training activities fall under the umbrella of GA.

## Research Questions and Hypotheses

The following are the research questions:

1. What are the causes and symptoms of fatigue among collegiate aviation flight students?
2. Is there a statistically significant association between enrollment status and a participant's willingness to fly while fatigued?
   - $H_a$: There will be a statistically significant association between enrollment status and a participant's willingness to fly while fatigued.
   - $H_o$: There will not be a statistically significant association between enrollment status and participant's willingness to fly while fatigued.
3. Do age and flight hours predict participant willingness to fly while fatigued?
   - $H_a$: Age and flight hours predict participant willingness to fly while fatigued.
   - $H_o$: Age and flight hours do not predict participant willingness to fly while fatigued.

## Significance of the Problem

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" (ICAO, 2016, p. 2-1). The National Transportation Safety Board (NTSB) (2019) considered reducing fatigue-related accidents as an item on their Top Ten Most Wanted list. According to the NTSB (2019), 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.18).

Pilot fatigue is a significant problem in the aviation industry (Hartzler, 2014; Roach, Darwent, & Sletter, 2011). According to the NTSB, "nearly 20 percent of the 182 major NTSB investigations completed between January 1, 2001, and December 31, 2012, identified fatigue as a probable cause, contributing factor, or a finding" (NTSB, *n.d.*, p.1). In the past, there have been several technical advancements regarding aircraft design and reliability improvements. Examples include the addition of redundant aircraft systems and the use of new and improved materials (McDale & Ma, 2009). Despite such overall technological improvements, pilot error has remained at a steady rate of 70 percent since the 1940s (Gallagher & DeRemer, 1993). According to the 28th Nall Report (Aircraft Owners and Pilots Association, 2018), during the last ten years, approximately 73 percent of all non-commercial fixed-wing GA accidents were attributed to human error, while only approximately 18 percent of these accidents were attributed to mechanical issues. When the data was further broken down into only fatal accidents, pilot error accounted for approximately 76 percent of accidents. The Nall Report highlighted the need for continued research and analyses on the GA subset of the flying community, which encompasses collegiate aviation flight training.

GA operations are especially concerning as this group makes up to 95 percent of all aviation accidents (NTSB, 2016). In the NTSB (2016) report, collegiate aviation flight programs fall under the umbrella of 'instructional flight activity.' Accordingly, instructional flight activity contributed to approximately 14 percent of all GA accidents. Although not explicitly cited in accident reports, it is plausible that fatigue may be the underlying condition of these accidents. Collegiate aviation pilots, who are fulltime students themselves, may have challenging academic, social, and work schedules, that may not be conducive for proper sleep quality and quantity (Curcio, Ferrara & De Gennaro, 2006; Levin et al., 2019).

College can present a challenging environment for students. A significant number of college students experience some form of sleep disorder (Buboltz, Brown, & Soper, 2010; Kloss, Nash, Horsey, & Taylor, 2011; Lund, Reider, Whiting, & Prichard, 2010; Orzech, Salafsky, & Hamilton, 2011). These poor sleeping habits have resulted in negative impacts on these students. The negative impact may be mild or severe, ranging from poor physical and psychological health (Lund et al., 2010), decreased cognitive performance the following day (Kloss et al., 2010), poor academic performance (Orzech et al., 2011) to even using alcohol and psychoactive drugs (Lund et al., 2010). The lack of understanding of the nuances of fatigue among collegiate aviation pilots may create a gap in safety promotion efforts. A clearer understanding of fatigue-related issues may lead to a more informed faculty, flight instructors, students, and, ultimately, improvements to collegiate flight training programs.

## Statement of the Purpose

The purpose of this research was threefold. 1) To investigate the causes and symptoms of fatigue among collegiate aviation students. 2) To investigate whether there was a statistically significant association between enrollment status on a participant's willingness to fly fatigued. 3) Do age and flight hours predict participant willingness to fly while fatigued? Although there were extensive research studies on fatigue in aviation, most of these studies concentrate on airline and military flight operations (Keller et al. 2019; McDale & Ma, 2008). It seems there is a paucity of research within the collegiate aviation industry (McDale & Ma, 2008; Mendonca et al., 2019; Levin et al., 2019). College students are a unique group that has unique challenges that differentiate them from the rest of the aviation industry (Levin et al., 2019; Lund et al., 2010; McDale et al., 2008; Mendonca et al., 2019). In general, collegiate aviation students are between the ages of eighteen and twenty-two years old. Often, attending college is their first time living away from home. This newfound independence comes with time management responsibilities that may not be fully understood among these young adults. Moreover, college students face external pressures that may come in the form of academic, social, personal, and financial issues. These external pressures may also manifest themselves in the form of stress and anxiety. Without proper time and stress management, sleep may often be the most natural go-to means of sacrifice. The lack of enough sleep, coupled with sleeping problems experienced by most college students, negatively affects performance the following day (Buboltz et al., 2010; Kloss et al., 2010; Lund et al., 2010). When one takes into account the demands of flying into this existing problem, it is easy to see how college students are vulnerable to fatigue, and collegiate flight students are no exception.

This research aims to have a clearer understanding of fatigue among collegiate aviation students. Broadly, the researcher will identify:

1. The conditions that help to promote fatigue.
2. Symptoms of fatigue reported by participants.
3. Whether there is a statistically significant association between enrollment status and willingness to fly fatigued.
4. Whether age and flight hours predict participant willingness to fly while fatigued.

This increased understanding of fatigue among collegiate aviation students will increase awareness and understanding among faculty, management, and students. This awareness may lead to improvements to the safety of flight training, such as through the development and continuous improvement of their respective college's Fatigue Risk Management (FRM) plan. This newfound awareness could include educating and training students on the signs, symptoms, and dangers of fatigue among pilots, as well as empowering students to make an independent go, no go decisions on whether to proceed with a flight. Additionally, adding flight time limitations for both flight instructors and students each day can be considered.

This study allows faculty to know whether there is a statistically significant association between enrollment status and a participant's willingness to fly while fatigued. This knowledge will allow faculty to determine whether certain academic groups are more at risk of flying while fatigued. As a result, they can either provide additional fatigue training or at least pay closer attention to the high-risk group. Lastly, this study allows faculty members to determine whether age and flight hours can be used as a possible predictor for a student's willingness to fly while fatigued.

## Definitions

Active Task-Related Fatigue - Fatigue arising from the stresses and complexities involved in a high workload environment (Neubauer et al., 2012).

Collegiate Aviation Flight Student – A student enrolled in a flight program offered by a university (Keller et al., 2019)

Commercial pilot – An individual that is certified to fly an aircraft from compensation or hire. Commercial pilots must have a minimum of 250 flight hours and have at least a valid 2nd class medical certificate (Code of Federal Regulations, 2019c).

CAFI – Collegiate Aviation Fatigue Inventory (Operational Definition). CAFI refers to the list of survey questions used in the methodology of the research (Keller et al., 2019; Levin et al., 2019; Mendonca et al., 2019).

Fatigue - 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" (ICAO, 2016, p. 2-1).

Certified Flight Instructor – A flight instructor is certified to conduct flight training as well as to issue endorsements required to attain a pilot certificate (Code of Federal Regulations, 2019d).

Passive Task-Related Fatigue – Fatigue arising from the lack of mental stimulation or boredom involved in a low workload environment (Neubauer et al., 2012).

Private Pilot – A private pilot is certified to fly an aircraft with passengers, but not for compensation or hire (Code of Federal Regulations, 2019b).

Sleep-Related Fatigue - Fatigue that arises from increasing sleep debt as a result of low quality or quantity of sleep (ICAO, 2016).

Student pilot – The initial pilot certification, a student pilot, is one that has been approved to begin flight training by the FAA. A student pilot is not allowed to carry passengers and property as a pilot in command. A student pilot is not allowed to fly for compensation or hire (Code of Federal Regulations, 2019a).

Workload-related Fatigue – Fatigue that arises as a result of the nature of the activity, despite how well-rested the pilot is (ICAO, 2016).

## Assumptions

The following are the assumptions inherent to this thesis:

- Students enrolled in a collegiate aviation program should hold at least a Student Pilot Certificate.
- Students enrolled in a collegiate aviation program should be conducting at least some form of flight training.
- Students enrolled in a collegiate aviation program are full-time students and active flyers.
- Student survey responses are accurate and truthful.

## Delimitations

The following are the delimitations that are inherent to the research process of this thesis:

- This research does not focus on scheduled service aviation.
- This research does not focus on military aviation.
- This research does not focus on recreation flyers or sport aviation.
- This research does not focus on helicopter pilots.
- This research does not focus on collegiate aviation pilots outside of the United States and its territories.
- This research does not focus on pilots outside of a collegiate flight program.
- This research does focus on the causes and symptoms of fatigue.
- The results from the survey may be biased due to the Hawthorne effect.
- Data collection was conducted during the Fall 2019 academic semester.

## Limitations

The following are the limitations that are inherent to the research process of this thesis:

- This research utilized convenience and judgment sampling methods, which limits generalizability.
- This research was limited to the number of participants that responded to the CAFI survey.
- For Research Question #2, the assumption of having a sample size greater than five for each category was not met for graduate students; the sample size was five.
- The test for parallel lines assumption in Research Question #3 was violated.

- The Component Factor Analysis did not yield a completely simple structure. Four survey items weakly loaded against each other. However, the internal consistency and Cronbach's Alpha scores were acceptable throughout.
- The Hawthorne effect may have played a part in the methodology, thereby skewing the data. Participants may be unwilling to accurately report negative behavior or habits honestly in fear of possible repercussions.

# CHAPTER 2: LITERATURE REVIEW

Collegiate aviation programs are growing in the United States. These programs serve as a means to supply newly minted pilots to the aviation industry, to meet the increasing demand for new pilots in response to the global shortage (ICAO, *n.d.*; Tulis, 2007). According to the International Civil Aviation Organization (ICAO) (*n.d.*), "in the next 20 years, airlines will need to add 25,000 new aircraft to the current 17,000-strong commercial fleet. By 2026, 480,000 new technicians will be needed to maintain these aircraft and over 350,000 pilots to fly them" (p.1). Not surprisingly, there has been an uptick in enrollments to many collegiate aviation programs in the United States (Tulis, 2007). Four of the major universities offering flight training programs interviewed noted that enrollment had increased between eight and 260 percent during the past five years (Tulis, 2017). According to Tulis (2017), one university even purchased additional aircraft to meet the increasing enrollment numbers. As collegiate flight programs continue to increase in popularity, it is ever more crucial to study the pilots and human factors of this population. Collegiate aviation programs are the foundation for supplying job-ready pilots to the workforce (Airplane Owners and Pilots Association, 2019). According to the Law of Learning, primacy is "the state of being first, often creates a strong, almost unshakable impression and underlies the reason an instructor must teach correctly the first time and the student must learn correctly the first time" (Federal Aviation Administration, 2008, p. 2-11). Understanding primacy will underscore how poor knowledge of human factors in the collegiate environment might manifest itself later in the student's professional career.

This literature review chapter contains previous research conducted on topics such as the lifestyles of college students, fatigue among college students, and fatigue in the aviation industry. This literature review section begins with a case study of a fatigue-related accident involving a collegiate aviation student. The subsequent sections include the causes and symptoms of fatigue and fatigue among collegiate aviation students.

## Case Study

The following is a case study involving a Piper PA-28-161 with a registration number of N248ND. This aircraft was on a training flight conducted by the University of North Dakota's flight program. The pilot was a flight student at the university and enrolled in its commercial/instrument airplane course (NTSB, *n.d.*). The objective of the flight was to complete a long cross-country flight to three different airports with one segment no less than 250 nautical miles between the two airports (NTSB, *n.d.*). The second objective of the lesson was to fulfill the university's training requirements of having at least five hours of logged night flight time with at least ten takeoffs and landings in visual meteorological conditions (VMC) (NTSB, *n.d.*). Since it was during the summer, the sun did not set until approximately 9:30 pm. As a result, the student had to conduct the night flight portion of his cross country after 10:00 pm, to comply with the university's policy of night flight (NTSB, *n.d.*).

On July 6$^{th}$, the day before the fateful flight, the pilot indicated that he woke up at 8:00 am and went to bed at 2:00 am on July 7$^{th}$. The pilot told investigators that on July 7$^{th}$, he rose at around 7:30 – 8:00 am, and then proceeded to class at around 10:00 am. The pilot also reported he had a test in a class that day. After having his flight plan reviewed by his instructor, the pilot was assigned the aircraft N350ND, in which he proceeded to complete the preflight check. However, the student was unable to start the aircraft and was subsequently assigned another airplane, N248ND. After completing the preflight check, he departed Grand Forks International Airport (KGFK) at 6:15 pm. The first leg of his flight was to Airlake Airport (KLVN), where he arrived at 8:30 pm. The pilot then flew on the second leg of the flight to Crystal Airport, where he landed and had the airplane refueled at 9:30 pm. Additionally, the pilot reported that he had met a friend and had a heavy dinner at Crystal. The pilot departed Crystal Airport at 11:55 pm and climbed to 4500 feet (ft) mean sea level (MSL), where he contacted flight service (FSS) after crossing a visual checkpoint (NTSB, *n.d.*).

After the pilot misidentified his second visual checkpoint, the pilot elected to continue the flight using ground-based Very High-Frequency Omnidirectional Ranges (VOR) as well as Global Positioning System (GPS) for navigational guidance to his destination, Grand Forks International Airport. The pilot reportedly lost all recollection of all subsequent events of the flight, and only remembered opening his eyes and looking into the cornfield where the plane had crashed (NTSB, *n.d.*). The pilot was quoted as saying, "First, I should not have taken off thinking that I might get tired. I should have requested flight following to keep my attention. Possibly [I] should have recognized the symptoms of fatigue and possibly the state of consciousness and landed before losing consciousness." (NTSB, *n.d.*, p.1). This case study is an extreme example of the detrimental impacts fatigue can have on pilot performance in the context of the collegiate aviation industry. Not all fatigued pilots end up in accidents; however, more commonly, fatigue can be a precursor to a range of errors that may be overlooked, which leads to increased risk (Keller et al., 2019; ICAO, 2016).

## Causes and Symptoms of Fatigue

Mental fatigue is the temporary reduction in cognitive function as a result of poor quality of sleep the night before or the nature of the task involved. The causes of fatigue can be classified into two broad categories, Sleep-Related Fatigue and Workload-Related Fatigue (ICAO, 2016). Fatigue can impair both mental and physical performance (ICAO, 2016; Marcora, Staiano, & Manning, 2008).

### Sleep-Related Fatigue

According to Abrams (2015), sleep is “a state of reduced responsiveness, motor activity, and metabolism” (p. 494). Having a night of sufficient sleep is vital to maintain proper physical and mental bodily functions (Abrams, 2015; Draganich & Erdal, 2014; ICAO, 2016; Simon, Lahav, Shamir, Handler, & Maron-Katz, 2017). Failure to get the required amount of sleep “leads to decreased performance, inadequate alertness, and deterioration in health” (Abrams, 2015, p. 493). According to ICAO (2016), “periods of awake time needs to be limited. Getting enough sleep (both quantity and quality) on a regular basis is essential for restoring the brain and body” (p. 9). The recommended amount of sleep for an individual is approximately seven to nine hours per day (Abrams, 2015; ICAO, 2016). The side effects of sleep deprivation are similar to that of alcohol use (Kloss, Nash, Horsey, & Taylor, 2011; Williamson, 2000). A person’s cognitive performance with seventeen to nineteen hours of wakefulness is equivalent to having a Blood Alcohol Level (BAC) of 0.10, which is above the legal driving limit (Williamson, 2000).

Sleep is beneficial to the brain in two ways, both in terms of restorative function and information processing from the day before. The restorative theory states that during sleep, the body attempts to repair itself from the stresses and wears that it incurred throughout the day (Abrams, 2015; ICAO, 2016). On the other hand, the information processing theory states that during sleep, the saturated learning circuits in the brain are being restored to baseline levels.

Consequently, having sufficient quality and quantity of sleep helps with learning and the storage of memories. There are two categories of sleep, Non-Rapid Eye Movement (Non-REM) and Rapid Eye Movement (REM) sleep (Abrams, 2015; ICAO, 2016).

During non-REM sleep, there is a decrease in brain wave activity when compared to being awake. Non-REM sleep has three stages, one, two, and three. Stage one is considered a light sleep stage where the body transitions from the wakefulness stage to the sleeping stage. Stage two represents the transitioning phase from light sleep to deep sleep. Stage three is classified as deep sleep, where the brain wave slows down into a phase known as slow-wave sleep (SWS) (Abrams, 2015; ICAO 2016). During this phase, the brain stops processing information from the surrounding environment, and the brain cells begin firing in synchrony, creating higher peaks but slower electrical waves (ICAO, 2016).

Rapid Eye Movement (REM) typically begins 90 minutes after falling asleep and lasts for approximately an hour. Throughout a typical night, an individual may go through five or six cycles of REM sleep. During REM sleep, the brain wave activity resembles that of being awake. Vivid dreaming usually occurs during this phase of sleep (Abrams, 2015; ICAO, 2016). The body, however, is unable to move in response to brain signals because the nerve synapses are blocked at the brain stem. As a result, the brain's signals in response to dreaming cannot be acted out unless there is a disorder (ICAO, 2016). Figure 1 below illustrates the percentage of sleep time spend in each category.

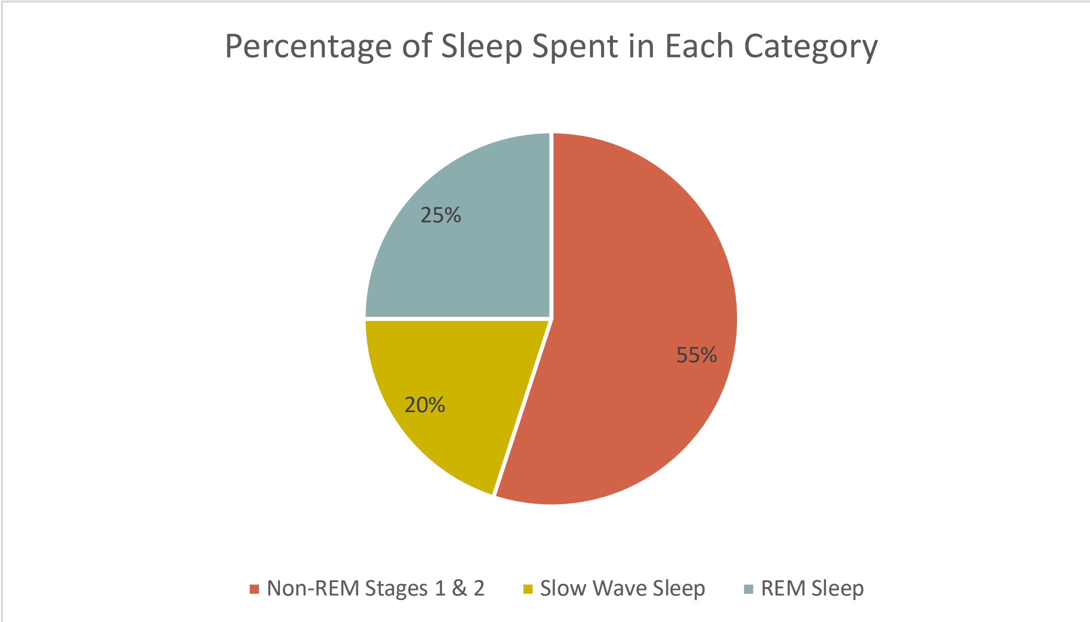


*Figure 1.* Percentage of sleep spent in each category of sleep. Adapted from "Manual for the Oversight of Fatigue Management Approaches" by International Civil Aviation Organization 2016, p.10. Copyright 2016 by the International Civil Aviation Organization.

According to Abrams (2015), there are multiple causes of sleep deprivation; some examples include voluntary behavior, personal obligations, work-related, and medical problems. Voluntary behavior consists of individuals who participate in activities that unintentionally promote chronic sleep deprivation for at least three months. Such activities may include intentionally staying up late to watch television or using other electronic devices. Personal obligations involve activities that the individual may not step away from, such as caring for someone. 'Work-related issues' involve individuals with work schedules that are not conducive to promote proper sleeping habits (ICAO, 2016; Peters, Wagner, Alicandri, Fox, Thomas, Thorne, Sing, & Balwinski, 1999). Being an airline pilot is one such example. With a non-fixed flight schedule and potentially flying through different time zones, makes it challenging to have a proper and fixed sleeping schedule. Another work-related issue that can impact the quality of sleep is sleeping in different locations, such as sleeping in a crew cabin or hotel (ICAO, 2016). Naps taken during work will be lighter and more prone to disturbance; however, there was evidence that naps do improve alertness and reaction time and can be used as a good temporary fatigue mitigation strategy (Hartzler, 2014; ICAO, 2016). Work conditions that require employees to be 'on-call' could also negatively affect sleep. The researchers found that having the expectation of being woken up prematurely resulted in sleep that was shorter and included lighter, non-REM (Stage one) sleep (ICAO, 2016). Medical problems such as sleep apnea may also cause difficulty in initiating and maintaining sleep (Abrams, 2015; ICAO, 2016). According to Abrams (2015), “the prevalence of sleep apnea is dramatically increasing due to an increase in chronic diseases such as hypertension and obesity” (p.496). The presence of sleep disorders will make it impossible to have a recuperative sleep even if the individual spends enough time in bed (ICAO, 2016). ICAO (2016) added that the use of caffeine, nicotine, alcohol, as well as environmental factors, also negatively affects sleep. Bright lights, sudden and loud noises, as well as non-ideal sleeping temperatures similarly negatively affect sleep. The ideal sleeping temperature is between 18 to 20 degrees Celsius (64 to 68 degrees Fahrenheit).

There are consequences associated with sleep deprivation. These consequences include alertness, performance, judgment, and mood degradation (Abrams, 2015; Alamir, 2018; Hartzler, 2013; ICAO, 2016; Kloss et al., 2010; Lund et al., 2011; Peters et al., 1999; Simon et al., 2017).

Alertness can be negatively affected due to a reduction in vigilance and sustained attention (Kendall, Kautz, Russo, & Kilgore, 2005). According to ICAO (2016), a study conducted by the United States National Transportation Safety Board (NTSB) on thirty-seven aircraft accidents concluded that “High time since awakening crews made about 40 percent more errors than low time since awakening crews” (p. 2-11). In this study, crews with high time since awakening (TSA) had, on average, 14 hours of wakefulness, while low TSA crews had an average of six hours. Errors often made by operators as a result of sleep deprivation include both errors of omission and errors of commission. Errors of omission occur when the operator forgets to perform something, while errors of commission occur when the operator does something wrong in nature (Kendall et al., 2005; Hartzler, 2014; ICAO, 2016). Sleep deprivation furthermore hurts visual performance, which resulted from decreased binocular convergence (Hartzler, 2014; Quant, 1992) as well as reduced visual stimulation to stimuli presented either centrally or peripherally (Kendall et al., 2005). Peters et al. (1999) also mentioned that being in a total sleep deprivation state negatively affects mistake mitigating actions; when an alert or slightly fatigued driver had a crash, the loud noise affiliated with the crash was sufficient to alert the driver to regain control of the vehicle. Conversely, a ‘totally sleep deprived’ driver may be awoken by the first crash, but was unable to regain control of the vehicle and was subsequently involved in additional crashes.

Sleep deprivation also negatively affects work performance the following day (ICAO, 2016; Lund et al., 2010; Peters et al., 1999). ICAO (2016) mentioned that “reducing the amount or the quality of sleep, even for a single night, decreases the ability to function and increases sleepiness the next day” (p. 2-13). Furthermore, it also increases their risk-taking behaviors, such as substance abuse and operating a motor vehicle while impaired (Alamir, 2018; Kloss et al., 2011; Lund et al., 2010).

Sleep deprivation may also negatively affect a person’s mood the following day. “The consequence of sleep deprivation during college are profound, including cognitive performance (i.e., memory and recall), decreasing life satisfaction, increased mood problems, increased somatic complaints, and increased interpersonal impairments” (Kloss et al., 2011, p.1).

Sleep debt is the result of not getting adequate amounts of sleep. Consecutive nights without adequate sleep will result in a buildup of sleep debt (Hartzler, 2014; ICAO, 2016). As the pressure of sleep debt continues to increase, “eventually, it becomes overwhelming, and people begin falling asleep uncontrollably for brief periods, also known as micro-sleep” (ICAO, p. 2-15, 2016). ICAO (2016) concluded by mentioning that the hours of sleep are inversely proportionate to performance degradation the following day. ICAO (2016) also cautioned that should sleep debt be allowed to persist, it will eventually become increasingly more challenging to detect as these individuals as they do not have the mental capacity to evaluate their functional status. This could potentially be catastrophic in the aviation industry, where a sleep-deprived pilot may not be aware that his/her performance has decreased due to as a result of sleep debt and thus does not take any corrective action.

**Workload-Related Fatigue**

According to ICAO (2016), “workload can contribute to an individual’s level of fatigue. Low workload may unmask physiological sleepiness while high workload may exceed the capacity of a fatigued individual” (p.2-29). Neubauer, Matthews, Langheim, and Saxby (2012) cited Desmond and Hancock (2001), mentioning that there are two types of workload-related fatigue, passive and active fatigue. A low workload environment and a perceived lack of control of a task are classified as passive fatigue while being overwhelmed and saturated with tasks at hand are classified as active fatigue (Desmond & Hancock, 2001; Neubauer et al., 2012).

According to ICAO (2016), there are three factors of workload that are often measured when used to identify fatigue causes. They are "The nature and amount of work to be done," "Time constraints," and "Factors relating to the performance capacity of an individual" (p.2-32).

### *High workload environment*

A high workload environment encourages the onset of active fatigue. During a high workload phase, stress and workload levels increases which may overwhelm and exceed the mental capacity of the individual, and such high mental workload will result developed into mental fatigue, also known as active fatigue (Desmond & Hancock, 2001; ICAO, 2016; Neubauer et al., 2012; Szalma & Teo, 2012). Szalma and Teo (2012) conducted a study to test the human adaptive response mechanism to stress and workload on task performance. The authors concluded that active fatigue causes performance, and most notably, accuracy to decrease. The researchers reported that participants' adaptive response to compensate for reduced accuracy was to slow their response time down, which proved useful only at "lower levels of temporal and structural demand" (p. 481). However, as mental demand increases, the researchers noted that participants instead favored speed over accuracy.

Marcora et al. (2009) mentioned that high cognitive demand not only degrades mental performance but physical performance as well. In their study, 16 participants were made to cycle till exhaustion "at 80% of their peak power output after 90 min of a demanding cognitive task (mental fatigue) or 90 min of watching emotionally neutral documentaries (control)" (p. 857). Although the presence of mental fatigue did not cause any noticeable physiological changes (cardiovascular response), participants with mental fatigue in the experiment reported more physical exertion (Marcora et al., 2009). The authors concluded that high cognitive demand (also known as active fatigue), created a sense of perceived physical exertion (Marcora et al., 2009). Participants subjected to active fatigue reported reaching "their maximal level of perceived exertion and disengaged from the physical task earlier" than participants in the control group (Marcora et al., 2009, p. 857). High workload and stress could also negatively affect sleep the following night (Fortunato & Harsh, 2006; ICAO, 2016) as the individual required a period of winding down from the day's work (ICAO, 2016).

***Low workload environment***

A low workload environment, similarly, also encourages the onset of passive fatigue (Desmond & Hancock, 2001; ICAO, 2016; Neubauer et al., 2012). This could include expressed as declining task engagement, motivation, and concentration (Neubauer et al., 2012). According to ICAO (2016), A "low workload situation may lack stimulation, leading to monotony and boredom, which could unmask underlying physiological sleepiness and thus degrade performance" (p. 2-32). ICAO (2016) also added that in order to maintain attention and focus on the task at hand, an individual in a low workload situation might require more effort to maintain such focus.

Passive fatigue is especially concerning during the age of automation (Desmond et al., 1998; Neubauer et al., 2012). There is a trend towards more significant implementations of technology, such as automation into the cockpit (Parasurannan & Byrne, 2002). Automation was introduced to reduce high workloads (an active fatigue situation) and increase the operator's performance by allowing him/her to concentrate on other non-automated tasks (Harris, Hancock Arthur & Caird, 1995). The introduction of automation was also intended to improve the operator's situational awareness (Parasurannan & Byrne, 2002). Harris et al. (1995) conducted an experiment to test human performance, workload, and fatigue with and without automation. Participants were split into two groups; one was allowed to use automation while the other group had to use manual control. Concerning an operator's workload, automation accomplishes its objective as "the automation tracking group reported lower workload compared to the manual (the group not using automation) group" (Harris et al., 1995, p. 181). However, the byproduct of this use case was that the reliance on automation might potentially cause the operator to be complacent, and the reduction in workload could also encourage fatigue (Harris et al., 1995). This may be hazardous as it negatively affects an operator's situation awareness. According to Harris et al. (1995), "when tracking was automated, resource management was more efficient, and fewer errors occurred, but light and gauge response times were longer" (p.181). Respondents also reported similar fatigue levels between both groups. A similar experiment conducted by Desmond, Hancock, and Monette (1998), split drivers into two groups (automation and manual driving). They were made to drive along a monotonous road in a driving simulator. Partway through the drive, the researchers failed the automation, and those who had maintained manual control of their vehicles throughout the experiment performed better recovery maneuvers versus those that relied on automation (Desmond et al., 1998). Parasurannan and Byrne (2002) also mentioned that pilots relying on automation were more likely to make seemingly “benign” errors. An example of such errors includes misconfiguring the autopilot by engaging the wrong autopilot mode (Parasurannan & Byrne, 2002). Although this may seem like a simple human error, a misconfigured autopilot mode may result in a catastrophic accident.

**Connections to Aviation**

In the aviation industry, the phases of flight that places the highest workload on the pilot are arrival, departure, final approach, landing, and takeoff (Ellis & Roscoe, 1982). Figure 2 shows the pilot’s mental workload across different phases of flight. Figure 2 was adopted from Aviation Supplies & Academics (2016). The Pilot Capability Line in Figure 2 shows the pilot’s overall mental capability, and the line is shown to regress with time due to the slow onset of fatigue as the pilot’s TSA increases. The red bars show the mental demand for each phase of flight imposed on the pilot. The white spaces between the red bars and the Pilot Capability Line illustrate the spare mental capability of the pilot during each phase of flight.

According to Figure 2, the approach and landing phases of flight place the highest mental demand on the pilot. The takeoff and taxiing phases of flight are in second place and third place, respectively. Conversely, the cruise phase of the flight places the least mental demand on the pilot.

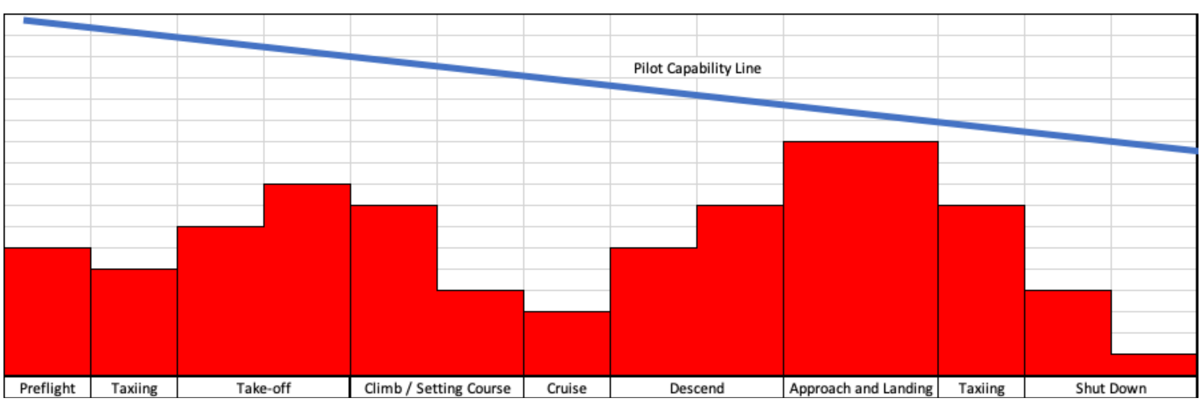


*Figure 2.* Pilot workload across different phases of flight. Adapted from “Enroute Flight: Mental Workload” by Aviation Supplies & Academics, Inc, p.1. Copyright 2016 by the Aviation Supplies & Academics, Inc.

Phases of flight that requires a low pilot mental workload, such as the cruise phase, may result in the onset of passive fatigue. On the other hand, high mental demand phases of flight, such as the approach and landing, may result in the onset of active fatigue. To make matters worse, the amount of spare mental capability the pilot has during the approach and landing phase of the flight may be limited, as illustrated by Figure 2 above.

## Fatigue Among College Students

College students usually compose of individuals aged 18 – 22 years old. Enrollment in college for these students is usually their first time away from home. This newfound independence may require these students to take up additional responsibilities, such as time, financial, stress, and workload management. These new responsibilities have frequently caused college students to be vulnerable to several sleep-related disorders (Curcio, Ferrara & Gennaro, 2006; Kloss et al., 2012; Levin et al., 2019; Lund et al., 2010; Medeiros, Mendes, Lima & Araujo, 2010). College students are additionally required to enroll in a minimum number of credit-hour courses per semester. To maintain full-time status, college students must take a minimum of 12 credit hours (Levin et al., 2019; Nelson, 2010).

Kloss et al. (2011) mentioned a study by Hicks and Pellegrini (2000) found that 68.3 percent of college students have sleep-related problems. More troubling, the authors noted, was that this was a sharp increase from 1982, which was only at 26.7 percent (Kloss et al., 2012). A study by Lund et al. (2010) also mentioned that approximately 60 percent of collegiate students have sleeping disorders.  On average, college students get approximately one to one-and-a-half hours less of sleep as compared to non-college adults (Kloss et al., 2011). This information translates to about 7-7.5 hours of sleep per night for college students versus the recommended 8.5 hours (Kloss et al., 2011; Lund et al., 2010). According to Lund et al. (2010), 25 percent of these students fall below the average and get less than 7 hours of sleep, while only 29.4 percent of students attained the recommended 8 hours of sleep.

The types of sleep disorders experienced by college students are “Inadequate Sleep Hygiene (ISH), Delayed Sleep Phase Disorder (DSPD), and Insomnia (Kloss et al., 2011, p.1). According to Kloss et al. (2011), ISH, which is common among college students, is a form of insomnia as a result of self-imposed sleep deprivation. ISH is a variant of insomnia that must be present for at least a month (Kloss et al., 2011).

DSPD "is a circadian rhythm sleep disorder marked by significant delays in sleep-wake cycles (e.g., bed after one a.m., wake time after ten a.m.), relative to societal norms" (Kloss et al., 2011, p. 555). DSPD usually starts from childhood, with a biological preference for later than usual bedtimes, and may usually be carried to adulthood (Kloss et al., 2011).

Insomnia is the difficulty in initiating, maintaining, or nonrestorative sleep and may cause either fatigue or attention problems the following day (Kloss et al., 2011). According to Kloss et al. (2011), there have been "no epidemiological studies have directly sampled college students according to standardized criteria for insomnia" (p. 556). Nevertheless, it was estimated that approximately 30 percent of the adult population has at least one symptom of insomnia, and about six to ten percent have chronic insomnia (Kloss et al., 2011).

**Fatigue on Academic Performance**

Fatigue negatively impacts a college student's academic performance (Alamir, 2018; Curcio, Ferrara & Gennaro, 2006; Van der Heijen, Vermeulen, Donjacour, Gordijn, Hamburger, Meijer & Weysen, 2018). This is because having insufficient restorative sleep would decrease a student's declarative and procedural learning abilities (Curcio et al., 2006). Therefore, the student may not absorb and retain new information they acquired from school. Alamir (2018) further mentioned that students with insufficient sleep generally had "low-grade point averages, compromised learning, and impaired mood" (p.1), as well as willingness to partake in unhealthy behaviors such as overeating or substance abuse.

Gaultney (2010) concluded that participants who were deprived of sleep for a single day tended to favor more straightforward mathematical questions as opposed to the more difficult questions. This data led the author to conclude that chronically sleep-deprived students may likely choose easier academic courses over other potentially more beneficial harder courses, thereby limiting their future professional options (Gaultney, 2010).

A study by Trockel, Barnes, and Dennis (2000) found that a student's wake-up time was a critical factor that was mostly responsible for determining their academic performance, above all other variables. Students who tended to wake-up at a later time generally faired poorer in their academics as compared to students that rise from bed earlier. This conclusion was also supported by Eliasson, Lettieri, and Eliasson (2010), that mentioned there were no significant differences in total sleeping times between high and low achievers - the only noticeable difference was their wake-up times and bedtimes.

## Fatigue in Collegiate Aviation Pilots

Collegiate aviation flight students are no exception when fatigue is concerned. Presently, there are a few studies conducted on fatigue in the collegiate aviation field (Levin et al., 2019; McDale & Ma, 2008). Collegiate aviation flight students are a niche group of pilots with unique challenges and pressures.

According to Levin et al. (2019), besides flying related courses, these aviation flight students were also required to maintain full-time status while also being entrenched in other college-related responsibilities. Some aviation colleges may require their students to complete a flight course within a single semester (Levin et al., 2019; Purdue University, 2019). A typical private pilot course at these universities usually concludes when the student passes their check-ride, and an FAA private pilot certificate is issued (Embry-Riddle Aeronautical University, 2019; Purdue University, 2019). Before the student is allowed to proceed with the check-ride, the student must pass three intermediate stage-checks (Purdue University, 2019). The minimum requirements to get the private pilot certificate are around 40 flight hours, pass the private pilot knowledge test, and pass the oral and practical flight test during the check-ride (Code of Federal Regulations, 2019a; Levin et al., 2019). The minimum requirements do not take into account the additional time required for studying the materials and remedial flight training if the student does not meet minimum standards. The commercial pilot certificate, on the other hand, requires the students to have a total of 200 flight hours (Code of Federal Regulations, 2019b; Levin et al., 2019). In some colleges, this usually comprised of three separate flight courses spread out over three semesters (Levin et al., 2019; Purdue University, 2019). As a result, these students have only 14-16 weeks in a given semester to complete meet the flight course requirements. Accordingly, to get 40-hours in a semester to meet the minimum requirements, a student and his/her instructor need to fly, on average, six hours per week (across three lessons) (Levin et al., 2019; Purdue University, 2019). This timeframe does not consider extraneous factors that may prevent these flight students from flying; weather, aircraft availability, and medical factors.

Some institutions may additionally penalize students if they fail to complete their flight course on time, such as by being dropped from their next required flight course (Keller, Mendonca, & Cutter, 2019). Such organizational pressures may compel these students to take on extra (non-scheduled) flight slots to make up for the lost time. Consequently, these students often sacrifice a healthy lifestyle, such as restorative sleep, proper nutrition, and social and personal activities (Keller et al., 2019; Levin et al., 2019).

Additionally, a part-time student flight instructor may be training several students during a given semester. This responsibility will multiply the amount of workload and pressure on these student flight instructors. As a result, further research is required to understand fatigue in collegiate aviation programs to improve overall safety.

Fatigued pilots have a higher probability of risk-taking (Alamir, 2018; Kloss et al., 2011; Lund et al., 2010). These risk takings could be attributed to external pressures or hazardous attitudes (Keller et al., 2019). According to the Federal Aviation Administration (2016), the five different types of hazardous attitudes, including Impulsivity, Macho, Invulnerability, Anti-authority, and Resignation. According to a study by Keller, Mendonca, and Cutter (2019), collegiate aviation flight students articulated hazardous attitudes when responding to fatigue-related written scenarios. The authors concluded that most collegiate aviation students displayed an invulnerability hazardous attitude. Research indicated that male students were more vulnerable to risk-taking as compared to female students. Females were more likely to follow the rules and to have an amplified pessimistic risk appraisal (Furedy, 2019). A study conducted by Waldron, McCloskey, and Earle (2005) concluded that male pedestrians were approximately 80 percent more likely to be involved in accidents as compared to females. It is unclear whether the risk-taking among males and females changes as they become fatigued. It is plausible that females will be less likely to fly while fatigued. Future studies should be conducted to connect fatigue and risk-taking among collegiate aviation students.

# CHAPTER 3: METHODOLOGY

The purpose of this study is to investigate the causes and symptoms of fatigue among collegiate aviation students, to investigate whether there was an association between enrollment status and willingness to fly while fatigued, and to investigate whether participants' age and flight hours predict their willingness to fly while fatigued. This research also aims to offer recommendations for best practices for both collegiate aviation flight students as well as their faculty members. This in-depth understanding of fatigue may help mitigate fatigue within the collegiate aviation program.

This methodology chapter will discuss the thesis research questions, methodology, research design, intended target population, research sample size, sampling approach, units of measurement, the instrument of assessment, data sources, data collection methods, data analysis procedures and trustworthiness, potential research biases, and lastly, the summary.

## Research Questions

The following are the research questions that the researcher aims to answer, to explore the issue of fatigue in collegiate aviation:

1. What are the causes and symptoms of fatigue among collegiate aviation flight students?
2. Is there a statistically significant association between enrollment status and a participant's willingness to fly while fatigued?
   - $H_a$: There will be a statistically significant association between enrollment status and a participant's willingness to fly while fatigued.
   - $H_o$: There will not be a statistically significant association between enrollment status and a participant's willingness to fly while fatigued.
3. Do age and flight hours predict participant willingness to fly while fatigued?
   - $H_a$: Age and flight hours predict participant willingness to fly while fatigued.
   - $H_o$: Age and flight hours do not predict participant willingness to fly while fatigued.

The first research question is, “What are the causes and symptoms of fatigue among collegiate aviation students?” There are two leading causes of fatigue, sleep-related, and task-related fatigue (ICAO, 2016). The onset of sleep-related fatigue depends on the quality and quantity of sleep the pilot had the night before. Task-related fatigue, however, depends on the nature of the task the pilot was involved in and can occur regardless of the pilot’s sleeping behavior. The symptoms of fatigue could come in two forms, physiological and psychological. Physiological symptoms of fatigue may vary from muscle soreness, lethargy, to heavy eyelids. In contrast, psychological symptoms of fatigue may come in the form of agitation, inability to concentrate, and slower response time. This research question seeks to understand the causes and symptoms of fatigue among the collegiate aviation population.

The second research question is, “Is there a statistically significant association between enrollment status and a participant's willingness to fly while fatigued?” This research question aims to identify how enrollment status will influence a student’s willingness to proceed with a flight despite knowing that he/she is fatigued.

The third research question is, “Do age and flight hours predict participant willingness to fly while fatigued?” This research question aims to identify how age and flight hours would influence the decision making of the participant to proceed with the flight even though he/she is fatigued.

## Research Type

This research study is human-subject oriented and finds a balance between theoretical and applied inquiries. Presently, most studies concerning mental fatigue among flight crews concentrate within the military and the airline industries. Notably, there are limited studies on this issue within collegiate aviation (Keller et al., 2019; Levin et al., 2019; McDale & Ma, 2008). The researcher aims to explore the causes and symptoms of fatigue within this unique population. This research also aims to explore external factors that may influence their decision-making process on whether to proceed with a flight while fatigued. This research offers recommendations for best practices to combat fatigue within the collegiate aviation industry.

## Population

The population in this study were full-time students enrolled in college flight programs in the United States. Most collegiate aviation flight programs are operated under 14 CFR Part 141 and are required to meet stringent oversight from the FAA. This population includes full-time students from all levels of flight training within the university, from student pilot trainees to student flight instructors. A typical collegiate aviation flight student is around 18-22 years old, has between one and 300 total flight hours, and takes general and aviation-related ground-based courses. Also, flight students have to take lab-based flight training courses, including both aircraft and simulator instruction. Students that attained both their commercial pilot certificate, and their flight instructor certificate, could work as part-time student flight instructors for their institution in addition to their full-time academic responsibilities. A full-time student typically takes at least twelve credit hours per semester.

## Sample

The researcher targeted eight colleges with an aviation flight program for this research. The sample size was approximately two hundred and fifty (n = 250) participants. These colleges offered collegiate aviation flight programs, are located within the Midwestern United States, and operate under 14 FAR Part 141 rules. The preferred participant for this study is between 18 – 25 years old, under 1000 flight hours, an active flight student (flown within the past six months), and enrolled as a full-time student in a collegiate aviation flight program.

## Sampling Approach

There are two methods for sampling both probability and nonprobability sampling. Simple Random Sample (SRS) is an example of probability sampling, while convenience and judgment sampling are examples of nonprobability sampling (Sekaran & Bougie, 2016). Accordingly, SRS assumes that every aspect of the population has a known and equal chance of being selected as a subject. As such, the advantage of this sampling method is that there would be high generalizability of the sample, and likewise its findings.

Convenience and judgment sampling, on the other hand, are examples of nonprobability sampling. Convenience sampling "refers to the collection of information from members of the population who are conveniently available to provide it" (Sekaran & Bougie, 2016, p.247). The advantage of convenience sampling is that members that are most easily accessible could be chosen as research participants, thus, making the data collection process more efficient, convenient, and cost-effective (Sekaran & Bougie, 2016). Judgment sampling "involves the choice of subjects who are most advantageously placed or in the best position to provide the information required" (Sekaran & Bougie, p. 248, 2016) and "is used when a limited number or category of people have the information that is sought" (p. 248).

Ultimately, the researcher chose nonprobability sampling by adopting both the convenience and judgment sampling methods. Convenience sampling was used in this methodology by reaching out to known faculty within these collegiate aviation programs to assist in the survey distribution. Judgment sampling was used in this research as the collegiate aviation flight students are a niche population. Thus, the researcher only sought students enrolled in a 14 CFR Part 141 collegiate aviation program. Consequently, all students from other forms of flight training, such as Fixed-Based Operations (FBO) flight schools, were excluded.

## Unit of Measurement

The survey, revised Collegiate Aviation Fatigue Inventory (CAFI-II) (see Appendix A), utilizes a mixture of both open-ended and close-ended type questions. This approach allowed the researcher to have a holistic understanding of the topic at hand to answer the research questions. The open-ended questions were free response-based, and thematic analysis was used to group responses based on their characteristics (Sekaran & Bougie, 2016). The closed-ended questions in the survey were Likert Scale-type questions. For Research Question one, the researcher used data from survey questions #8, #9, #10, #11, and #12. For Research Question two, the researcher converted the Likert Scale information of survey question #8.2 - *I have remarked out loud or to myself about how tired I was but proceeded with the flight anyway* and survey question #4, into nominal values to test for association between the two variables. For Research Question three, the researcher used the independent continuous variables from survey question #2 *age,* and question #6 *approximate total logged flight time*. The ordinal dependent variable was selected from question #8.2 - *I have remarked out loud or to myself about how tired I was but proceeded with the flight anyway*. The researcher combined Likert Scale responses 'Rarely,' 'Sometimes,' 'Often,' and 'Always' into category one, which were the undesirable responses. While 'Never' was category two, which indicated the desirable responses. Survey question 8.2 was abbreviated throughout this study as *willingness to fly while fatigued*.

## Research Instrument

The research instrument used in this study was the CAFI-II, a mixed-methods survey that yielded both qualitative and quantitative data (refer to appendix A). The CAFI-II was the second iteration of the original survey, the Collegiate Aviation Fatigue Inventory (CAFI). This study focused on the causes and symptoms of fatigue among collegiate aviation flight students, whether there was an association between enrollment status and willingness to fly while fatigued, and whether participants' age and flight hours predict their willingness to fly while fatigued. Follow up analyses will be completed in the future.

The CAFI was a modified version of a survey published by McDale and Ma (2008). Data from CAFI was instrumental in the publication of three scholarly papers (Keller et al., 2019; Mendonca et al., 2019; Levin et al., 2019). During its development, the CAFI underwent validity testing by six Subject-Matter Experts (SMEs) (Keller et al., 2019; Mendonca et al., 2019). The researchers made modifications to the survey based on feedback provided by the SMEs. The researchers further conducted beta testing with 24 participants who were students enrolled in a collegiate aviation program at a Midwestern University (Keller et al., 2019; Mendonca et al., 2019). According to Mendonca et al. (2019), Factor Analysis conducted on the CAFI yielded the following; the fatigue awareness subscale consisted of eight items and a Cronbach's Alpha of .755 ($\alpha = .755$), the causes of fatigue subscale consisted of 11 items with an alpha score of .747 ($\alpha = .747$), and the lifestyle subscale consisted of 7 items with an alpha score of .763 ($\alpha = .763$). The CAFI was found to be acceptably reliable, with a total of 26 items and an overall alpha score of .754 ($\alpha = .754$) during the beta test run.

After attaining IRB approval, the survey was distributed to 141 participants ($n = 141$) from an aviation flight program at a Midwestern University. All of the scales indicated an alpha score of .70 or higher, providing evidence of acceptable reliability (Mendonca et al., 2019).

For this study, the researcher made minor revisions to the CAFI to create the CAFI-II. These revisions were made on the recommendation of Purdue's Statistical Consulting Service. 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 type question. Similar revisions were made to questions in the lifestyle section, which probed the number of hours the participant spent on various listed activities. These revisions allow participants to more accurately report quantitative data instead of a scale range that existed in the previous multiple-choice type question.

The final version of CAFI-II consists of eight sections. The first section has the required Institution Review Board consent form. Participants in the survey were informed that they must be at least eighteen years old, an active pilot, and currently enrolled in a collegiate aviation flight program to participate. Participants were told that their participation was voluntary and that personally identifiable information would not be collected or released. Participants were also briefed on their rights, potential benefits, risks, and discomforts that may be associated with participating in this study. Only participants that agreed with the terms stipulated in the consent were allowed to proceed to the next section of the survey.

The second section of the survey was the demographics section. This section used a mixture of radio buttons as well as text boxes for participants to fill out. In this section, participants were asked demographics information potent to this study. These questions include their age, gender, enrollment status, highest flight certificate held, and their approximate total flight hours.

The third section of the survey was the fatigue awareness section. Respondents were provided with a list of fatigue symptom scenarios and were asked to rate their applicability via a five-point Likert Scale (Never – Always) question. Respondents were also given the option to list any other symptoms of fatigue that were not listed as an option in the previous question in a free-response based 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. Participants were also given the option to add additional causes that they felt contributed to fatigue that were not listed as an option in the previous question in a free-response question.

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 respondents were also presented with a free response question on whether any other factors were not listed that they felt significantly affected their sleep.

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. Similarly, participants were also asked to list any other factors that they felt were important that were not mentioned in the previous question via another free-response question.

The seventh section of the survey asks participants whether or not they felt that fatigue has negatively affected their flight training. Participants were presented with a five-point Likert Scale (Never – Always) question. The following questions were free response type questions that probe 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 like during those times of the day. Once again, this paper does not report all results, but the selected sections previously mentioned.

According to Sekaran & Bougie (2016), using a survey allows the researcher to obtain information about or from people that can assist in describing or explaining specific attitudes and behaviors. Using a survey "allows the researcher to collect quantitative and qualitative data on many types of research questions" (Sekaran & Bougie, 2016, p. 97). A survey can be used in both exploratory and descriptive research studies.

Since this research aims to answer the research questions, using a survey was appropriate for this research. The survey included both closed and open-ended questions. The closed-ended questions consist of single answer type demographics questions as well as situation-based questions using Likert Scales. The open-ended questions included free response type questions. Open-ended questions were incorporated into this research to allow participants to list additional information that the researcher did not include in the closed-ended Likert-Scale questions. By incorporating these open-ended questions, the researcher could have a more comprehensive understanding of the research topic by allowing the participants to list any other causes or symptoms that the researcher may not have thought of previously. The sample size of this research was approximately 250 participants from eight colleges. The colleges were selected based on their enrollment size, the program they offered, and their regional locations. The researcher used an online survey using the tool, Qualtrics as the medium to host the survey. After receiving approval from the IRB, the survey was activated in Qualtrics. The researcher reached out to known faculty representatives (point of contact) within each respective college to assist in survey distribution to their students. The researcher sent an email with the link to the survey to these representatives. The point of contact subsequently distributed the survey to the students by forwarding the email.

## Data Sources

There are two types of data used in this research, primary and secondary data. Primary data consisted of both quantitative and qualitative data collected from the survey. Quantitative data were collected from the Likert scale, yes/no, and demographic questions, and likewise, qualitative data were collected from open-ended questions. Secondary data comprised of previous research and peer-reviewed data obtained from the literature review.

## Data Collection Methods

The data collection method for this research was a web-based online survey tool called Qualtrics. The name of the survey was called CAFI-II. According to Sekaran and Bougie (2016), "Line questionnaires are usually created as "web forms" with a database to store the answers and statistical software to provide statistical analysis" (p. 143). Sekaran and Bougie (2016) added that using an online tool allows the survey to reach audiences that would otherwise be difficult or impractical to reach. Consequently, the conveniences of the online tool, Qualtrics, allowed the researcher to reach out to sample groups that would not be accessible otherwise, including colleges spread out across the United States. The survey was disseminated electronically (via an email link) to a faculty representative from each chosen collegiate aviation program. The faculty representative then subsequently disseminated the survey to their students by forwarding the email with the link. Three email reminders were sent out to these faculty representatives requesting them to remind their students to complete the survey. The survey contained both multiple-choice as well as open-ended questions. The data collection period was during the Fall 2019 academic semester.

## Data Analysis Procedures and Trustworthiness of Data

In this research, the data was collected and compiled within the Qualtrics system. The data was then downloaded and exported to SPSS. A Principal Component Analysis (PCA) was conducted along with the reliability measures. PCA is a statistical method that "simplifies the complexity in high dimensional data while retaining trends and patterns" (Lever, Krzywinski, & Altman, 2017, p.1) into principal components. PCA converts complex data into a few dimensions that serve as a summary of the features. PCA is useful as it looks for patterns or clustering in the data without prior knowledge about the nature of the data, such as whether they came from "different treatment groups or have phenotypic differences" (Lever et al., 2017, p.1).

*Research Question 1: What are the causes and symptoms of fatigue among collegiate aviation students?*

To answer research question one, the researcher used descriptive statistics to analyze responses from the Likert Scale portion of the survey. The researcher used the Thematic Analysis to analyze the qualitative data (open-ended questions) of the survey. According to Sekaran and Bougie (2016), there are three steps involved in this qualitative data analysis process, namely, "data reduction, data display, and drawing and verifying conclusions" (p. 333). Qualitative data, in general, can yield a large amount of information and thus must be coded and categorized. Data reduction was used in this research by categorizing the information from the free-response questions into separate broad categories. This reduced data could then be analyzed to form a hypothesis of theory through a process known as coding (Sekaran & Bougie, 2016).

The next step of the data analysis procedure was data display. Sekaran and Bougie (2016) mentioned that "Data display involves taking your reduced data and displaying them in an organized, condensed manner" (p.347). Charts, graphs, and diagrams are some examples of data display that was used in this research to present the data clearly and concisely. Drawing conclusions was the final phase of the data analysis section. This phase involved adding meaning to the data by looking for patterns and relationships in the data and thinking about explanations and how the data answers the research questions (Sekaran & Bougie, 2016). Frequencies of responses from the Likert Scale question were reported using charts, while information from the open-ended questions was coded and categorized and displayed using tables.

*Research question 2: Is there a statistically significant association between enrollment status and a participant's willingness to fly while fatigued?*

To answer research question two, the researcher used a chi-square test to test for association between Question #4, *enrollment status,* and Question #8 Item #2, *I have remarked (out loud or to myself) about how tired I was but proceeded with the flight anyway*.

The purpose of the chi-square test "is used to discover if there is there is an association between two categorical variables" (Laerd, 2016, p.1). Two assumptions are inherent to the chi-square test. In assumption #1, both variables must be categorical (Laerd, 2016). The two categorical variables were the willingness to fly while fatigue, which was a Likert-scale question (never – always), and enrollment status, which was a multiple-choice type question (freshmen – graduate). Assumption #2, both categorical data, should be independent of each other (Laerd, 2016). In this research, both willingness to fly while fatigue and enrollment status are independent groups.

The researcher used a 5x2 crosstab to analyze the data. According to Kent State (2020), cross-tabulation allows a researcher to describe any relationships that exist between the two categorical variables. The rows in the crosstabs were willingness to fly while fatigued, and the columns were the enrollment status (e.g., Freshmen and Sophomore). After the data was analyzed, the researcher made conclusions based on the observed relationships. An example of the contingency table is shown in Table 1 below.

Table 1

*Contingency table for Chi Square-Enrollment Status vs. Willingness to fly Fatigued*

| | | Willingness to fly while fatigued | | |
|---|---|---|---|---|
| | | No | Yes | Total |
| Enrollment Status: | Freshmen | | | |
| | Sophomore | | | |
| | Junior | | | |
| | Senior | | | |
| | Graduate | | | |

*Research question 3: Do age and flight hours predict participant willingness to fly while fatigued?*

To answer research question three, the researcher used an Ordinal Logistics Regression test. The Ordinal Logistics Regression test "is used to predict an ordinal dependent variable given one or more independent variables" (Laerd, 2015b, p.1). This test may be used to determine which independent variable may have a statistically significant effect on the dependent variable (Laerd, 2015b).

There are four assumptions inherent to the Ordinal Logistics Regression test. Assumption one states that there must be one ordinal dependent variable. Likert scale questions are an example of an ordinal variable (Laerd, 2015b).

Assumption two states that there must be one or more independent variables. These variables may be ordinal, continuous, or categorical. A continuous variable is a variable that can be measured, such as age or currency. A categorical variable is a variable that may only take one or a few fixed possible values, such as gender or ethnicity. Any ordinal independent variables present have to be treated as either a continuous or categorical (Laerd, 2015b).

Assumption three states that there must be no multicollinearity among the independent variables. Multicollinearity occurs when there are two or more independent variables that are highly correlated with each other. Assumption four states that there must be proportional odds (Laerd, 2015b).

After the data analysis, the next phase was the data display. The researcher used graphs and charts to display the data. Lastly, the researcher will make conclusions based on the data by observing any relationships or trends that may exist.

## Potential Biases

According to Pannucci and Wilkins (2010), bias is defined as "any tendency which prevents unprejudiced consideration of a question" (p. 1). Accordingly, bias can occur in any phase of the research process, including the research design, data collection, data analysis, or publication.

The researcher was previously an undergraduate student at a midwestern university majoring in Professional Flight, with a minor in Computer Information Technology. The researcher was also a part-time student flight instructor at that university and also currently enrolled in their aviation graduate program. As a result of the researcher's background, the researcher has first-hand and possibly greater knowledge on the topic of fatigue in collegiate aviation when compared to non-collegiate pilots. The researcher's background might influence the researcher to be more favorable towards collegiate aviation flight programs. In order to reduce potential biases during data analyses and reporting, the researcher followed best practices outlined by Pannucci and Wilkins (2010). Accordingly, to avoid potential research bias, the researcher used internal validity testing. By conducting internal validity testing on the survey before being published, the researcher will have confidence that the "study design, implementation, and data analysis have minimized or eliminated bias and that the findings are representative of the true association between exposure and outcome" (Pannucci & Wilkins, 2010, p. 1).

## Summary

In summary, this chapter detailed the methodology that was used in this research to investigate fatigue among collegiate aviation pilots. This chapter discussed in depth the research questions and their respective hypothesis, the research type, population of the study, the sample that will be used, the sampling approach, framework, units of measurement, research instruments, data sources, data collection methods, data analysis procedures, and trustworthiness, as well as potential researcher bias. Once again, this is mixed-methods research that aims to answer the following research questions:

1. What are the causes and symptoms of fatigue among collegiate aviation flight students?
2. Is there a statistically significant association between enrollment status and a participant's willingness to fly while fatigued?

    $H_a$: There will be a statistically significant association between enrollment status and participant willingness to fly while fatigued.

    $H_o$: There will not be a statistically significant association between enrollment status and participant willingness to fly while fatigued.
3. Do age and flight hours predict participant willingness to fly while fatigued?

    $H_a$: Age and flight hours predict participant willingness to fly while fatigued.

    $H_o$: Age and flight hours do not predict participant willingness to fly while fatigued.

In the following chapter, the researcher will present the results provided by respondents.

# CHAPTER 4: RESULTS

This chapter answers the research questions providing reported causes and symptoms of fatigue among collegiate aviation students. This chapter also answers whether there was a statistically significant association between enrollment status on a participant's willingness to fly while fatigued and whether participants' age and flight hours predicted their willingness to fly fatigued. Finally, this chapter discusses the description of the data conditioning and analyses, presentation of the data, and the conclusions.

## Description of Data Conditioning and Analyses

The data collection method used in this research was the online survey tool, CAFI-II. The researcher used both convenience and judgment sampling to select participants from collegiate aviation pilots in the United States. The researcher chose eight colleges from the Midwestern United States that offered an aviation flight training program for this study. Their enrollment was approximately 200 to 700 students.

In order to participate in the survey, the participants we required to consent to the survey with follows the approved Institutional Review Board (IRB) guidelines. Participants were subsequently asked 24 questions, including demographic information, causes of fatigue, symptoms of fatigue, lifestyle questions, as well as fatigue mitigation strategies. The CAFI-II survey can be found in Appendix A.

### Principal Component Analysis

The researcher performed a factor analysis as it is used as a means for data reduction by "seeking underlying unobservable (latent) variables that are reflected in the observed variables (manifest variables)" (UCLA, *n.d.*, p.1). The survey used in this research study is the Collegiate Aviation Fatigue Inventory – 2 (CAFI-II). CAFI-II is a mixed-methods survey examining the causes and symptoms of fatigue among collegiate aviation students as well as whether any external factors are influencing their willingness to fly while fatigued. Five sections used a Likert Scale type question. These sections are fatigue awareness, causes of fatigue, lifestyle, the impact of fatigue on flight training, and fatigue levels throughout the day. For this research, the researcher was mainly concentrating on fatigue awareness, causes of fatigue, and lifestyle questions. A Principal Factor Analysis (PCA) was conducted on each subscale Likert question using the Quartimax rotation. According to Laerd (2015a), there are four assumptions inherent to the PCA test: Assumption #1, there must be variables measured in the continuous level; ordinal variables are commonly considered under this assumption as a continuous variable. Assumption #2, there should be a linear relationship between all variables. Assumption #3, there should be no outliers. Assumption #4, there should be a large sample size, preferably at least 150 ($n = 150$) or at least five ($n = 5$) per variable. Although, according to Laerd (2015a), Likert Scale-type questions are often converted to numbers and treated as fixed intervals to be used for PCA, there is an ongoing debate as to whether Likert Scale data can be treated as such (Sullivan & Artino, 2013). However, some experts argued that adequate sample size of at least five per group (Laerd, 2015a; Sullivan & Artino, 2013) and data are approximately normally distributed, parametric tests, including the PCA, can be used (Sullivan & Artino, 2013). In this case, the researcher met the requirements and proceeded on with the PCA.

The fatigue awareness subscale had eight items, while the fatigue causes subscale had 11 items, and the lifestyle subscale had seven items. The first run of the PCA yielded the following:

1. Correlation $r \geq 0.3$
2. Kaiser-Meyer-Olkin (KMO) 0.857
3. Six components with Eigenvalues greater than 1
4. Bartlett's Test of Sphericity (p-value) less than 0.0005

The correlation matrix table (Refer to Appendix D) produced by SPSS indicated that all three Likert Scale questions, with a total of 26 items yielded a correlation value of at least 0.3 with at least one other question. According to Laerd (2015), a level of at least 0.3 and higher indicates the level of correlation is worthy of that variable's inclusion. The KMO and Bartlett's test yielded an overall KMO score of 0.857 and a p-value of less than 0.0005.

| KMO Measure | Meaning |
|---|---|
| KMO ≥ 9 | Marvelous |
| 0.8 ≤ KMO < 0.9 | Meritorious |
| 0.7 ≤ KMO < 0.8 | Middling |
| 0.6 ≤ KMO < 0.7 | Mediocre |
| 0.5 ≤ KMO < 0.6 | Miserable |
| KMO < 0.5 | Unacceptable |

*Figure 3.* Description of the Kaiser-Meyer-Olkins (KMO) scoring. Adapted from "Principal components analysis (PCA) using SPSS Statistics. Statistical tutorials and software guides." By Laerd Statistics, p.7. Copyright 2015 by Laerd Statistics.

According to Figure 3, a KMO score of between 0.8 and 0.9 is "meritorious." The Anti-Image Correlation table generated from SPSS, which measures the individual KMO score for each variable, yielded KMO scores ranging from 0.5 to 0.9. Accordingly, an individual KMO score should be at least $r > 0.5$; on the other hand, values lesser than 0.5 are considered "unacceptable" and should be removed. A p-value of less than 0.05 indicates that the data is statistically significant (Kaiser, 1974; Laerd, 2015).

The PCA yielded six components with Eigenvalues of greater than one (Refer to Appendix D), and these values accounted for 63 percent of the variance. According to Laerd (2015a), Eigenvalues measure the amount of variance accounted for by a component, and Eigenvalues of at least one reflects the variance of a single variable. As such, Eigenvalues less than one should not be retained. The scree plot (Refer to Appendix D) indicated that only two components contributed significantly to the total variance, as seen before the inflection point. Values after the inflection point contribute little to the total variance (Laerd, 2015a).

During the second run, the researcher elected to perform a forced extraction and reduced the components to three based on the three categories (*fatigue awareness, causes of fatigue*, and *lifestyle*) of the survey and based on the interpretation of the Eigenvalues and the scree plot. The researcher also adjusted the component analysis rotation to 'Quartimax.' After the forced extraction, the cumulative percentage of the variance of the three components was reduced to 47.8 percent.

After the forced extraction, the *fatigue awareness* subscales yielded strongly to a single factor component. *Fatigue awareness* items, one to eight, loaded strongly with a single factor component. The reliability test was conducted on all eight items and had a Cronbach's Alpha score of $\alpha = .890$. The alpha score, if any items were removed, did not show noticeable improvement.

The *causes of fatigue* subscale similarly yielded strongly to a single factor component after forced extraction. *Causes of fatigue* items one through eleven loaded strongly to a single factor component, except for items three, six, and nine. The reliability test conducted on the *causes of fatigue* subscale had a Cronbach's Alpha score of $\alpha = .860$. The alpha score did not show noticeable improvement if any items were removed.

The *lifestyle* subscale also yielded strongly to a single factor component after forced extraction. Lifestyle items one through seven, except for item three, loaded strongly to a single factor component. The reliability test conducted on the *lifestyle* subscale yielded an Alpha score of $\alpha = .715$. The alpha score did not show any improvement if any items were removed.

For the third run, the researcher elected to remove any items that did not yield strongly to a single component after the forced extraction mentioned above. The cumulative percentage of the variance of the three variables increased slightly to 49.2 percent.

Most causes of fatigue subscales yielded strongly to a single factor component during the third run, except for items #10 and #11. The reliability test conducted after removal of the *causes of fatigue* items #3, #6, and #9 yielded a Cronbach's Alpha score of $\alpha = .792$.

The lifestyle subscale similarly yielded strongly to a single factor component during the third run. All items showed a single factor component. The reliability test conducted after the removal of lifestyle item #3 yielded a Cronbach's Alpha score of $\alpha = .676$.

After comparing the results from the second and third run, the researcher decided to proceed without removing any items. Although more items yielded strongly to a single factor component after the removal of items, the overall Cronbach's alpha score, in general, showed a slight decline from $\alpha = .857$ before removal to $\alpha = .805$ after removal of items. Cronbach's Alpha "is a measure used to access the reliability, or internal consistency, of a set of scale or test items" (Goforth, 2015, p.1). An Alpha score closer to one ($\alpha \leq 1$) indicates that the items have shared covariance and most likely measuring the same causal concept. Conversely, a score closer to zero indicates that the items are independent of one another (Goforth, 2015). Ideally, the component analysis should yield a simple structure. The current structure is not simple; however, the structure is not overly complex either. Only four items weakly loaded to each other. The internal consistency test was acceptable throughout. The CAFI-II does yield evidence for the researcher to gain a clearer understanding of fatigue and provide robust recommendations. If the researcher had more time and resources, more questions and items would have been added into the CAFI-II. Additionally, the researcher would have completed independent validity testing.

**Demographics**

Demographic information was collected at the beginning of the survey. Demographics information included the participant's institution, gender, enrollment status, highest certificate held, age, and approximate total logged flight time. The demographics information is represented in Table 2.

Table 2

*Summary of Participant's Demographics*

| **Institution** | **Number (n)** | **Percentage** |
|---|---|---|
| Institution 1 | 68 | 27.40% |
| Institution 2 | 51 | 20.50% |
| Institution 3 | 42 | 16.94% |
| Institution 4 | 36 | 14.52% |
| Institution 5 | 30 | 12.10% |
| Institution 6 | 15 | 6.04% |
| Institution 7 | 5 | 2.02% |
| Institution 8 | 1 | .40% |
| Total | 248 | |
| **Gender** | | |
| Male | 189 | 76.20% |
| Female | 58 | 23.38% |
| Prefer not to say | 1 | 0.40% |
| Total | 248 | |
| **Enrollment Status** | | |
| Freshman | 55 | 22.18% |
| Sophomore | 49 | 19.76% |
| Junior | 63 | 25.40% |
| Senior | 67 | 27.02% |
| Graduate | 5 | 2.02% |
| Other | 9 | 3.63% |
| Total | 248 | |
| **Highest Certificate Held** | | |
| Student Pilot | 78 | 31.45% |
| Private Pilot | 79 | 31.85% |
| Commercial Pilot | 31 | 12.50% |
| Flight Instructor | 58 | 23.39% |
| Airline Transport Pilot | 2 | 0.80% |
| Total | 248 | |

Table 2 continued

| Age | Number (n) | Percentage |
|---|---|---|
| 18 - 20 | 146 | 58.86% |
| 21 - 23 | 76 | 30.64% |
| 24 - 26 | 15 | 6.05% |
| 27 - 30 | 4 | 1.61% |
| 31 - 40 | 5 | 2.00% |
| 41 - 50 | 2 | 0.8 |
| **Approximate total logged flight time** | | |
| 0 - 100 | 94 | 37.90% |
| 101 - 200 | 60 | 24.19% |
| 201 - 300 | 41 | 16.53% |
| 301 - 400 | 24 | 9.68% |
| 401 - 500 | 12 | 4.84% |
| 501 - 600 | 4 | 1.61% |
| 601 - 700 | 3 | 1.21% |
| 701 - 800 | 2 | 0.81% |
| 801 - 900 | 1 | 0.40% |
| 901 - 1000 | 4 | 1.61% |
| > 1000 | 3 | 1.21% |
| Total | 248 | |

*Note.* The percentages were rounded to the nearest hundredth.

## Research Questions

The following sections will address the research questions by displaying the results from CAFI-II and using multiple statistical analysis to interpret and add meaning to those results.

### Research Question 1

*Research Question 1: What are the causes and symptoms of fatigue among collegiate aviation flight students?*

To answer research question one, the researcher used the following questions from the CAFI-II: #10, #11, #8, #9, and #12. Question #10 pertains to the *causes of fatigue*, and respondents were given eleven options and had to answer via a Likert Scale how accurate the following statements were in describing the contributing factors to fatigue. The ten options are listed in Table 3 below.

Table 3

*Causes of Fatigue (Q10)*

| Questions | |
|---|---|
| 10.1 | Flying during the night (Sunset through sunrise) |
| 10.2 | Flying a long cross-country (2.5 hours or over) |
| 10.3 | Working a long day |
| 10.4 | Stress caused by family or other psychological conditions |
| 10.5 | Poor scheduling of flight lessons (e.g., too early, too late, or too many) |
| 10.6 | Poor scheduling of academic classes |
| 10.7 | Lack of health or fitness |
| 10.8 | Personal activities or other commitments (e.g., 2nd job) |
| 10.9 | Academic activities (e.g., midterms, student organizations, etc.) |
| 10.10 | Quality of sleep (Restlessness or interrupted sleep) |
| 10.11 | Not enough sleep |

A total of 227 (n = 227) participants answered question #10, as provided in Figure 4 below. According to Figure 4, approximately 80 percent of participants reported that working a long day has contributed to fatigue to at least some degree (sometimes, often, or always). Likewise, approximately 60 percent of participants mentioned that academic activities, such as midterms, contributed to fatigue to at least some degree. Conversely, however, only 34 and 28 percent of participants mentioned that flying during the night, and a lack of health and fitness contributed to fatigue, respectively.

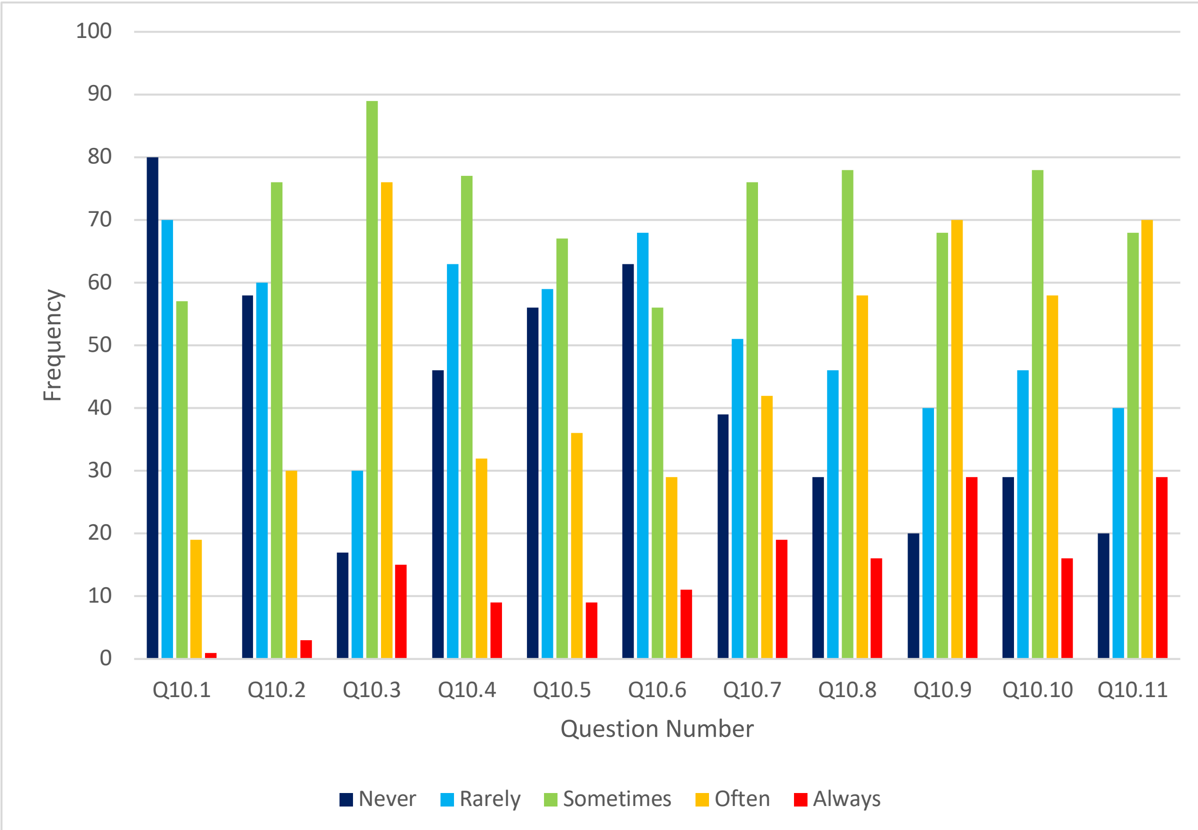


*Figure 4.* Data of responses to Question #10, *Causes of Fatigue*. Note: For data analysis, Never = 1, Rarely = 2, Sometimes = 3, Often = 4, Always = 5)

Question #11 is a follow-up free-response question asking participants to add any additional information that they felt was relevant to the *causes of fatigue* that the survey items may have missed in Question #10. This process allowed the researcher to gain more insightful information about the causes of fatigue. Seventy participants (n = 70) responded to this question. The researcher utilized a thematic analysis to organize the responses into the following themes. A thematic is a process where the researcher "focus(es) on identifying and describing both implicit and explicit ideas within the data" and classifying them into themes where "codes are then developed to represent the identified themes and applied or linked to raw data as summary markers for later analysis" (Guest, MacQueen, and Namey, 2011, p.10).

Table 4

*Causes of Fatigue* (Q11)

| Categories | Number (n) |
|---|---|
| Workload | 23 |
| Stress | 18 |
| Sleep-Related | 13 |
| Hunger | 6 |
| Sickness | 5 |
| Dehydration | 4 |
| Lack of Motivation in Flight Training | 2 |

Note. A participant may list a single, multiple, or no cause of fatigue.

In Table 4, after thematic analysis, there are seven broad categories of causes of fatigue listed by the participants. Twenty-three participants responded that workload was a contributor to the causes of fatigue. A participant mentioned that "*Having a long day of both classes and instructing,"* while another mentioned, *"Working dispatch at the flight school late into the night, overloading of academic coursework."* One participant also mentioned, *"Having to plan Cross Countries at 3 am to be off the ground by 6 am."* According to Abrams (2015), sleep deprivation may be caused by voluntary behavior, such as personal and work-related obligations. Additional examples of participant's responses are listed below:

*"Poor Scheduling"*

*"Long days, short rest period."*

*"Sometimes, if I am having a busy week, I will feel fatigued after a few days."*

*"Multiple flights in a row, delays due to MX or fueling, stress in general."*

*"long flight lessons, specifically dual."*

Eighteen participants responded that stress was their underlying cause of fatigue. The high mental activity caused by external pressures or increased workload may also result in the development of active task-related fatigue (Desmond & Hancock, 2001; ICAO, 2016; Neubauer et al., 2012; Szalma & Teo, 2012). One participant mentioned, "*Stress from other classes,"* while another mentioned that *"Definitely all of the other requirements from other classes adds up and* *takes a lot of time but adds huge stressors."* Other examples of participant's responses are listed below:

*"Traffic on the way to airport or poor weather, which causes irritability."*

*"Stress about completing a course without feeling like I'm rushing through the lessons."*

*"Students."*

*"mostly, I find flying into high-stress situations can cause a little mental fatigue."*

Thirteen participants listed sleep-related issues as a cause of fatigue. Sleep is beneficial to the body in multiple ways, including restoring and repairing the brain. For a typical adult, seven to nine hours of sleep is considered healthy (Abrams, 2015; ICAO, 2016). A participant mentioned *"not enough sleep,"* while another mentioned, *"I feel most of the factors can be linked back to previous lack of sleep."* Other participants mentioned:

*"Not enough sleep or poor quality of sleep, working two jobs, not having time for exercise."*

*"mostly lack of good sleep or long workdays in and out of the plane."*

*"Sleep is the biggest one if I don't get 8hrs I'll feel fatigued throughout the rest of the day."*

Six participants listed hunger as a *cause of fatigue*. Hunger as a cause of fatigue was unexpected as the researcher did not come across hunger during the literature review section. A participant mentioned, "*Not eating, drinking, (and) sleeping enough,"* while another mentioned *"hunger or sickness."* Some participants also mentioned the following:

*"Poor diet, not eating or staying hydrated before a flight because of nerves."*

*"Not eating for long periods of time due to nonstop flights has made me fatigued."*

Five participants mentioned sickness as a *cause of fatigue*. Sickness as a cause of fatigue was similarly unexpected, and thus not listed in the literature review. A participant mentioned that "*Sickness is a big problem for me,"* while another mentioned, *"Motion sickness caused me to feel tired and drained, making it almost impossible to focus."*

Four participants mentioned dehydration as a *cause of fatigue*. This finding, too, was unexpected. Some participants mentioned "*Dehydration"* while another mentioned, *"Not eating, drinking, (and) sleeping enough."*

The lack of motivation was cited by two participants as a cause of fatigue. A lack of motivation or interest may encourage the onset of passive fatigue (Desmond & Hancock, 2001; ICAO, 2016; Neubauer et al., 2012). A participant mentioned that he/she *"Disliked the program"* while another mentioned "*Lack of interest."*

Question #10 and #11 probed the participants on their personal experiences with situations that they felt causes of fatigue. These causes, however, were personal and may differ between each respective participant. In general, data obtained about the causes of fatigue from question #10 and #11 are consistent with the literature review. Sleep is essential for proper physical and mental bodily functions (Abrams, 2015; Draganich & Erdal, 2014; ICAO, 2016; Simon et al., 2017). The lack of sufficient sleep or extended periods of wakefulness diminishes a person's cognitive and physical functions, thereby negatively affecting their performance the following day (Abrams, 2015; Alamir, 2018; Curcio, Ferrara & Gennaro, 2006; ICAO, 2016; Van der Heijen, Vermeulen, Donjacour, Gordijn, Hamburger, Meijer & Weysen, 2018). The results also agreed with the literature review that collegiate aviation students, like regular college students, suffer from sleep-related disorders. There are many causes of sleep deprivation, including voluntary behavior, personal obligations, work-related, medical problems (Abrams, 2015; Curcio, Ferrara & Gennaro, 2006; Hicks & Pellegrini, 2000; Kloss, Nash, Horsey & Taylor, 2012; Levin et al., 2019; Lund et al., 2010; Medeiros, Mendes, Lima & Araujo, 2010). Participants mainly attributed their sleep disorders to academic workload, flight-related duties, among other duties and responsibilities.

Question #8 and #9 pertains to *fatigue awareness* among participants. In Question #8, participants were given a Likert Scale type question with eight unique situations that they felt maybe a symptom of fatigue. A total of 238 (n = 238) participants responded to Question #8. The items in question #8 are listed in Table 5.

Table 5

*Fatigue Awareness* (Q8)

| Question (Q) | |
|---|---|
| 8.1 | I have struggled to stay awake during a flight. |
| 8.2 | I have remarked (out loud to myself) about how tired I was but proceeded with the flight anyway. |
| 8.3 | I have overlooked mistakes during a flight because of reduced judgment caused by fatigue. |
| 8.4 | I have felt disinterested during flight activities because I was fatigued. |
| 8.5 | I have not given my best effort due to fatigue. |
| 8.6 | I have made mistakes during flight activities because I was fatigued. |
| 8.7 | I felt heightened irritation during a flight because I was fatigued. |
| 8.8 | My abilities to carry out tasks requiring concentration have been decreased due to fatigue. |

According to Figure 5, approximately 13 percent of participants reportedly agreed to a certain extent (Sometimes, Often, and Always) that they struggled to stay awake during flight activities was a symptom of fatigue. Similarly, approximately 34 percent of respondents agreed to a certain extent that they would still proceed with the flight, although they remarked to themselves (or out loud) that they were fatigued. Forty-two percent of participants also mentioned that they agreed to a certain extent that being disinterested in-flight activities was also a symptom of fatigue.

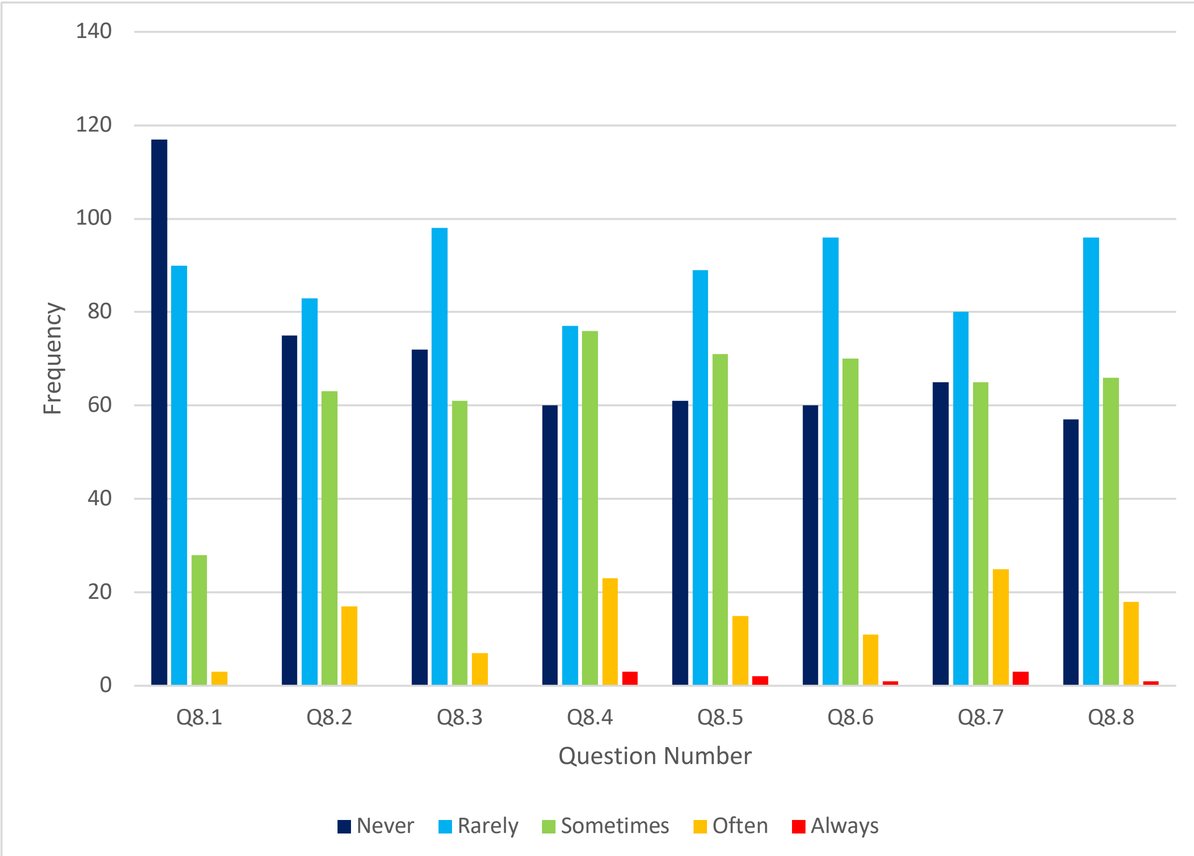


*Figure 5*. Data of responses to Question #8, *Fatigue Awareness*. Note: For data analysis, Never = 1, Rarely = 2, Sometimes = 3, Often = 4, Always = 5).

Question #9 is a free response-based question for participants to add in additional information that the researcher may have missed in Question #8. This free response question allowed the researcher to have a more holistic understanding of fatigue awareness and symptoms. A total of 209 (n = 209) participants responded to Question #9. The researcher used the coding process to categorize the free-response based questions into four broad categories, namely, making mistakes, physical/mental discomfort, delayed reaction time/loss of focus, and drowsiness. Table 6 contains the data from Question #9 after the thematic analysis.

Table 6

*Fatigue Awareness* (Q9)

| Categories | Number (n) |
|---|---|
| Drowsiness | 91 |
| Delayed reaction time / Loss of focus | 55 |
| Physical / Mental discomfort | 37 |
| Making mistakes | 22 |

Note. A participant may list a single, multiple, or no fatigue awareness symptoms.

According to Table 6, 91 participants listed drowsiness as a symptom of fatigue. This result is consistent with the literature review. Sleep debt builds up when a person does not have sufficient quality or quantity of sleep the night before (Hartzler, 2014; ICAO, 2016). Sleep debt acts like pressure, and it may eventually overwhelm the individual, causing him/her to sleep uncontrollably (ICAO, 2016). A participant mentioned that *"Overall tiredness and irritability,"* while another mentioned, *"General tiredness, noticing reduced comprehension, forgetting small and basic things (checklists, airspeeds, etc.)."* Some other participants mentioned the following:

*"Yawning"*

*"Constant yawning, drowsiness, slow reflexes."*

*"Overall foggy feeling, pressure behind eyes."*

*"Usually, it is a lack of energy for me, visible through my disinterest in taking part in activities that require me to perform physical action or mental action."*

Delayed reaction time or loss of focus is also another symptom of fatigue. This finding is consistent with the literature review. Fatigue can cause degradations to alertness, judgment, and overall performance (Abrams, 2015; Hartzler, 2013; ICAO, 2016; Kloss et al., 2010; Lund et al., 2011; Peters et al., 1999; Simon et al., 2017). Delayed reaction time and loss of focus could also result in the making of mistakes. In fact, according to Table 6, 22 participants mentioned making mistakes as a symptom of fatigue. One participant mentioned *"Forgetting checklist items or taking a while to react to situations,"* while another mentioned, *"Realizing that I have spaced out for a period of uneventful flight, as well as an inability to focus effectively on all aspects of* *the task at hand (ex. being unable to perfect a maneuver because focusing on a problem area leads to neglecting other aspects of the maneuver)”.* Other participants mentioned:

*“Slow reaction time, inability to quickly understand the conversation, stuttering during a conversation.”*

*“Feeling zoned out, heavy eyes, hard to concentrate, hard to keep a good scan, hard to pay attention to minute details.”*

*“Grouchy-ness, a simple mistake, or taking longer to answer a question I know I should know.”*

*“Not being able to focus and loss of interest.”*

Physical and mental discomforts are also symptoms of fatigue, according to 37 participants in Table 6. These findings were consistent with the literature review. Fatigue can cause a decrease in life satisfaction, communication impairments, as well as physical soreness (Kloss et al., 2011, p.1). Participants mentioned *“Headaches,” “Anxiety,”* and *“Irritability, drowsiness, mistakes being made.”* Some other participants mentioned:

*“Easy to irritate and slight thoughts of resignation.”*

*“Lethargy, easily irritated.”*

*“Drowsiness, irritability, and a lack of desire to fly.”*

*“Getting irritated because I was unable to focus.”*

*“Instructor sounding annoyed with every mistake I make.”*

Fatigue may also cause an individual to make more frequent mistakes. A study conducted by the NTSB concluded that pilots that are sleep deprived (measured in TSA hours) made approximately 40 percent more mistakes than non-sleep deprived pilots (ICAO, 2016). According to Table 6, 22 participants mentioned that making mistakes was a symptom of fatigue. Examples of participant responses include *“Mistakes or trouble explaining”* and *“I make some mistake and look back and tell myself I knew better.  Then I assess and realize fatigue could have had an impact.* Some participants mentioned the following:

*“I didn't pressure attention to my landing speed.”*

*"Decreased controllability, decreased concentration, decreased use of instruments."*

*"vision loss, body sluggish, careless."*

Question #12 pertains to the *lifestyle* section. In question #12, participants were presented with a Likert-Scale type question and had to rate how specific scenarios apply to their daily lifestyle. The items in Question #12 are listed in Table 7 below, while Figure 6 displays the data collected for Question #12.

Table 7

*Lifestyle (Q12)*

| Question (Q) | |
|---|---|
| 12.1 | I have a healthy academic and life balance |
| 12.2 | I regularly exercise |
| 12.3 | I maintain a healthy diet |
| 12.4 | I am good at workload management |
| 12.5 | I am good at stress management |
| 12.6 | I get adequate sleep every night (quality and quantity) |
| 12.7 | I prepare well to get adequate sleep (i.e., limit electronic device use, caffeine, disruptions, noise, etc.) |

A total of 222 (n = 222) participants responded to Question #12. According to Figure 6, approximately 66 percent of participants agreed to a certain extent (Agree to Strongly Agree) that they have good workload management. Similarly, approximately 58 percent of participants agreed to a certain extent that they have a healthy academic-life balance.

Conversely, only 45 percent of the participants agreed to a certain extent that they exercise regularly. Furthermore, only 32 percent of participants agreed to a certain extent that they take steps to better prepare themselves, both mentally and physically, for sleep.

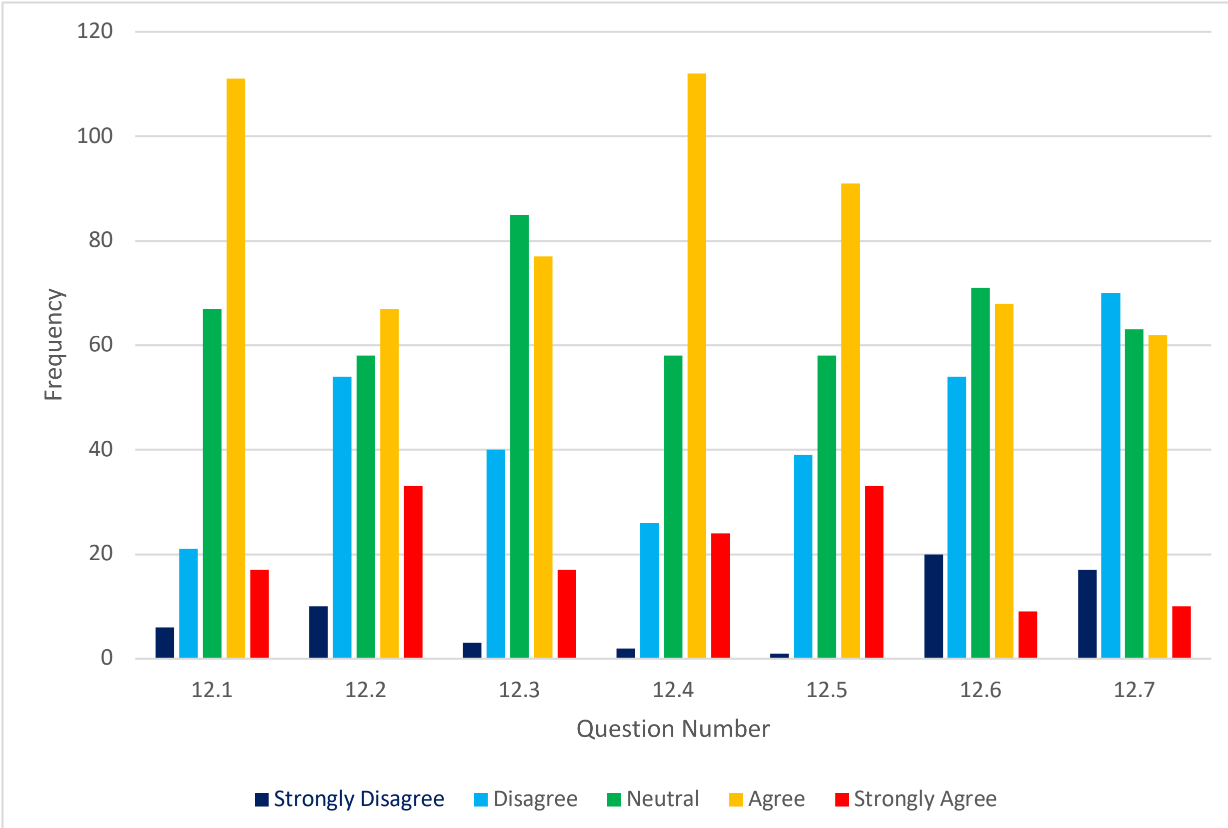


*Figure 6.* Data of responses to Question #12, *Lifestyle*. Note: For data analysis, Strongly Disagree = 1, Disagree = 2, Neutral = 3, Agree = 4, Strongly Agree = 5).

The results obtained from this lifestyle section is consistent with the literature review. As mentioned previously, fatigue could be caused by voluntary sleep deprivation the day before (Abrams, 2015). The reasons for voluntary sleep deprivation can be explained from the results obtained; only 58 percent of participants mentioned that they have an excellent academic-life balance, and 66 percent mentioned that they have good workload management practices.

**Research Question 2**

*Research Question 2: Is there a statistically significant relationship between enrollment status and a participant's willingness to fly while fatigued?*

The researcher hypothesized that there would be a positive relationship between enrollment status and a student's willingness to fly while fatigued. To answer research question two, the researcher used Question #3 "*Enrollment Status"* and Question #7 Item 2 *"I have remarked (out loud or to myself) about how tired I was but proceeded with the flight anyway."*

Data from Question #3 and #7 were converted to categorical variables, and the researcher used a Chi-square test to test for association between both variables (refer to Table 1). Since Question #7 Item 2 was a Likert Scale question, the data obtained was ordinal; as such, the researcher decided to convert the ordinal data into nominal data. Never and Rarely are grouped into the category ‘No,’ while Sometimes, Often, and Always are grouped into the category ‘Yes.’ The results from the crosstabulation were listed below in Table 8. Two hundred and twenty-nine (n = 229) participants responded to both question #3 and #7.

Table 8

*Enrollment status on willingness to fly while fatigued*

| | | | Willingness to fly while fatigued | | |
|---|---|---|---|---|---|
| | | | No | Yes | Total |
| Enrollment Status: | Freshmen | Count | 42 | 11 | 53 |
| | | Expected Count | 35.2 | 17.8 | 53 |
| | | % Within Enrollment status | 79.20% | 20.80% | 100% |
| | | % Within Fatigue Awareness | 27.60% | 14.30% | 23.10% |
| | | % Total | 18.30% | 4.80% | 23.10% |
| | Sophomore | Count | 34 | 11 | 45 |
| | | Expected Count | 29.9 | 15.1 | 45 |
| | | % Within Enrollment status | 75.60% | 24.40% | 100% |
| | | % Within Fatigue Awareness | 22.40% | 14.30% | 19.70% |
| | | % Total | 14.80% | 4.80% | 19.70% |
| | Junior | Count | 35 | 25 | 60 |
| | | Expected Count | 39.8 | 20.2 | 60 |
| | | % Within Enrollment status | 58.30% | 41.70% | 100% |
| | | % Within Fatigue Awareness | 23% | 32.50% | 26.20% |
| | | % Total | 15.30% | 10.00% | 26.20% |
| | Senior | Count | 40 | 26 | 66 |
| | | Expected Count | 43.8 | 22.2 | 66 |
| | | % Within Enrollment status | 60.60% | 39.40% | 100% |
| | | % Within Fatigue Awareness | 26.30% | 33.80% | 28.80% |
| | | % Total | 17.50% | 11.40% | 28.80% |
| | Graduate | Count | 1 | 4 | 5 |
| | | Expected Count | 3.3 | 1.7 | 5 |
| | | % Within Enrollment status | 20% | 80% | 100% |
| | | % Within Fatigue Awareness | 0.70% | 5.20% | 2.20% |
| | | % Total | 0.40% | 1.70% | 2.20% |

A Chi-Square test for association was conducted between enrollment status and the participant's willingness to fly while fatigued. One assumption that needs to be met is the expected cell frequency count.  According to Laerd (2016), all expected cell count frequencies should be greater than five. This assumption was not met for graduate students. The researcher, however, elected to continue with the analysis. According to the data from Table 8, there was a noticeable difference between the expected count and the actual count across all the five enrollment status categories, as well as the two willingness to fly while fatigued categories. According to Laerd (2016), this provided evidence that there might be an association between *enrollment status* and *willingness to fly while fatigued*. Table 9 below contains the Chi-Square Test.

Table 9

*Chi-Square Test*

| | Value | df | Asymptotic Significance (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 13.174 | 4 | 0.01 |
| Likelihood Ratio | 13.242 | 4 | 0.01 |
| N of Valid Cases | 229 | | |

Note. The researcher used the Pearson Chi-Square Test

According to Table 9, the Pearson Chi-Square value is $\chi^2(1) = 13.174$, and the Asymptotic Significance value from Pearson Chi-Square is less than .05 ($p < .05$). The Chi-square test indicated that there was a statistically significant association between *enrollment status* and *a student's willingness to fly while fatigued*. Furthermore, there is a moderately strong association between *enrollment status* and *a student's willingness to fly while fatigued*, with $\varphi = .24$, $p = .01$. Figure 7 below lists the Bar graph of a student's enrollment status on his/her willingness to fly while fatigued.

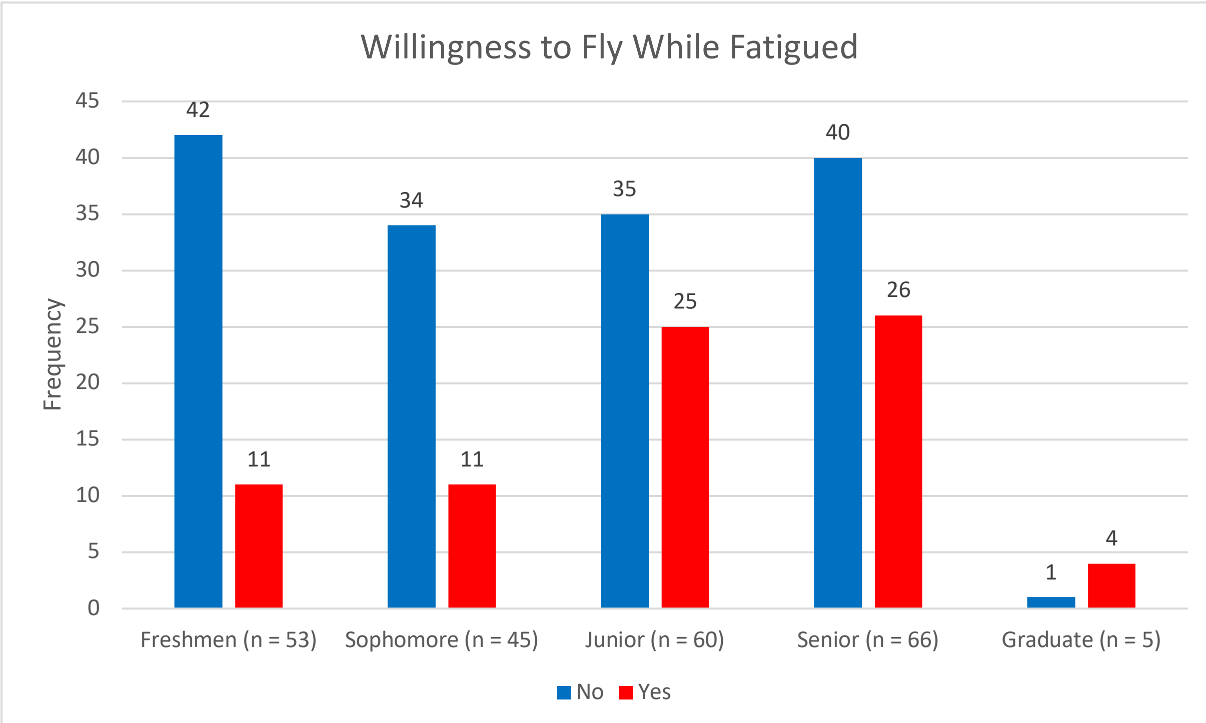


*Figure 7.* Graph of the frequency of a student's willingness to fly while fatigued against enrollment status. Likert scale responses never and rarely are grouped as 'No,' while sometimes, often, and always are group as 'Yes.'

To have a complete understanding of how enrollment status affected a student's willingness to fly while fatigued, and to account for the limitation of not meeting the Chi-square assumption of having cell counts being greater than five, the researcher decided to perform the Chi-Square test again. This time, combining the enrollment statuses, freshman and sophomores into the category 'lower classmen,' and combining junior, seniors, and graduate students into 'upperclassmen.' The results of the rerun are listed in Table 10 below. After the combination, there were a total of 98 (n = 98) participants that fell within the lower classmen category and a total of 131 (n = 131) participants that fell within the upperclassmen category.

According to Table 10 below, there was once again a difference between the expected count and the actual count, this similarly hinted at a possible association between *enrollment status* and *willingness to fly while fatigued.* According to Table 11, the Pearson Chi-Square value is $\chi^2(1) = 9.586$ with an Asymptotic Significance p-value of less than .05 ($p = .002$). According to the results, this similarly highlighted that there was a statistically significant association between *enrollment* and *willingness to fly while fatigued*. Under this second test, in Table 11, there was a moderately strong association between the variables with $\varphi = .205$, $p = .002$. Figure 8 below lists the bar graph of the combined participant's enrollment status on his/her willingness to fly while fatigued.

Table 10

*Combined enrollment status on willingness to fly while fatigued*

| | | | Willingness to fly while fatigued | | |
|---|---|---|---|---|---|
| | | | No | Yes | Total |
| Enrollment Status: | Lower Classmen | Count | 76 | 22 | 98 |
| | | Expected Count | 65 | 33 | 98 |
| | | % Within Enrollment status | 77.60% | 22.40% | 100% |
| | | % Within Fatigue Awareness | 50.00% | 28.60% | 42.80% |
| | | % Total | 33.20% | 9.60% | 42.80% |
| | Upper Classmen | Count | 76 | 55 | 131 |
| | | Expected Count | 87 | 44 | 131 |
| | | % Within Enrollment status | 58.00% | 42.00% | 100% |
| | | % Within Fatigue Awareness | 50.00% | 71.40% | 57.20% |
| | | % Total | 33.20% | 24.00% | 57.20% |

Note. Lower classmen consisted of Freshmen and Sophomores. Upperclassmen consisted of Juniors, Seniors, and Graduate students.

Table 11

*Chi-Square Test*

| | Value | df | Asymptotic Significance (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 9.586 | 1 | 0.002 |
| Likelihood Ratio | 9.839 | 1 | 0.002 |
| N of Valid Cases | 229 | | |

Note. The researcher used the Pearson Chi-Square Test

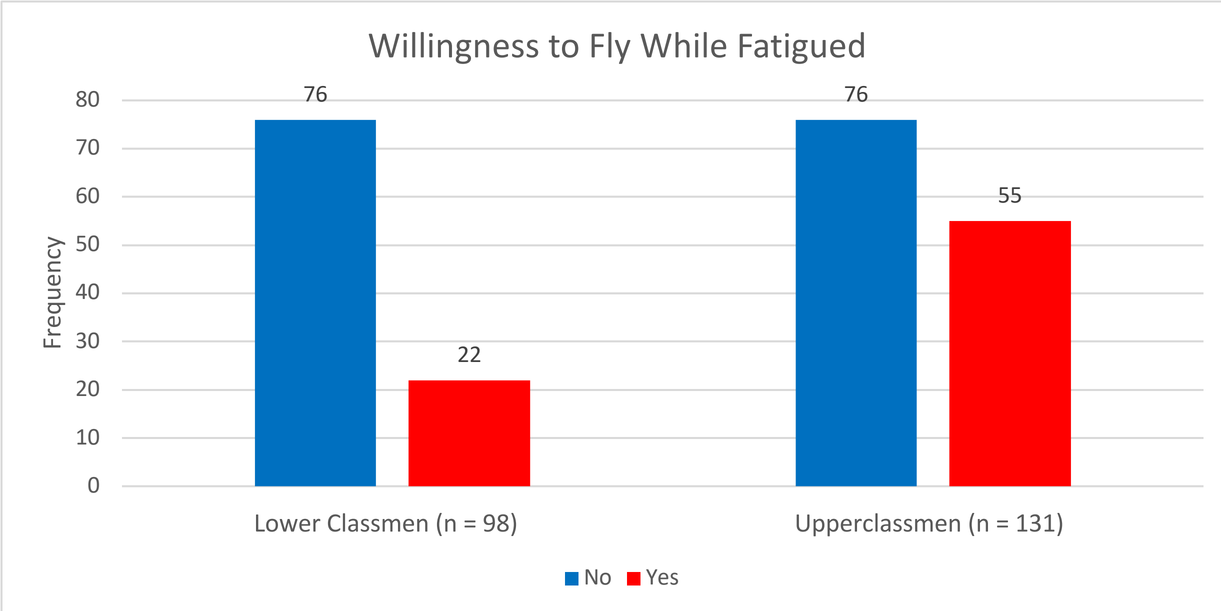


*Figure 8.* Freshmen and sophomores are classified into lower classmen, while juniors, seniors, and graduates were classified into upperclassmen. Likert scale responses never and rarely are grouped as 'No,' while sometimes, often, and always are group as 'Yes.'

**Research Question 3**

*Research Question three: Do age and flight hours predict participant willingness to fly while fatigued?*

For research question three, the researcher hypothesized that age and flight hours would predict a participant's willingness to fly while fatigued. To answer research question three, the researcher used an Ordinal Logistics Regression test using Question #2, *Age*, Question #6, *Approximate total logged flight time*, and Question #8 Item #2, *I have remarked (out loud or to myself) about how tired I was but proceeded with the flight anyway.*

The Ordinal Logistics Regression Test was used to predict the outcome of an ordinal dependent variable when presented with one or more independent variables. There are four assumptions inherent to the Ordinal Logistics Regression test. Assumption #1 states that there must be an ordinal dependent variable. Assumption #2 states that there must be at least one or more independent variables, which are either categorical or continuous. Assumption #3 states that there must be multicollinearity. Multicollinearity occurs when there are two or more independent variables that are highly correlated with each other. Assumption #4 states that proportional odds should be present (Laerd, 2015b). Proportional odds occur when "each independent variable has an identical effect at each cumulative split of the ordinal dependent variable" (Laerd, 2015b).

To answer research question three, the researcher decided to group the Likert scale responses in Question #8 into two categories, as illustrated in Figure 9 below. Category one included all the participants that have indicated that they have never flown while fatigued (Never), which was a desirable response. Category two included all the participants that indicated they have flown while fatigued at least once (Rarely, Sometimes, Often, Always), which was an undesirable response.

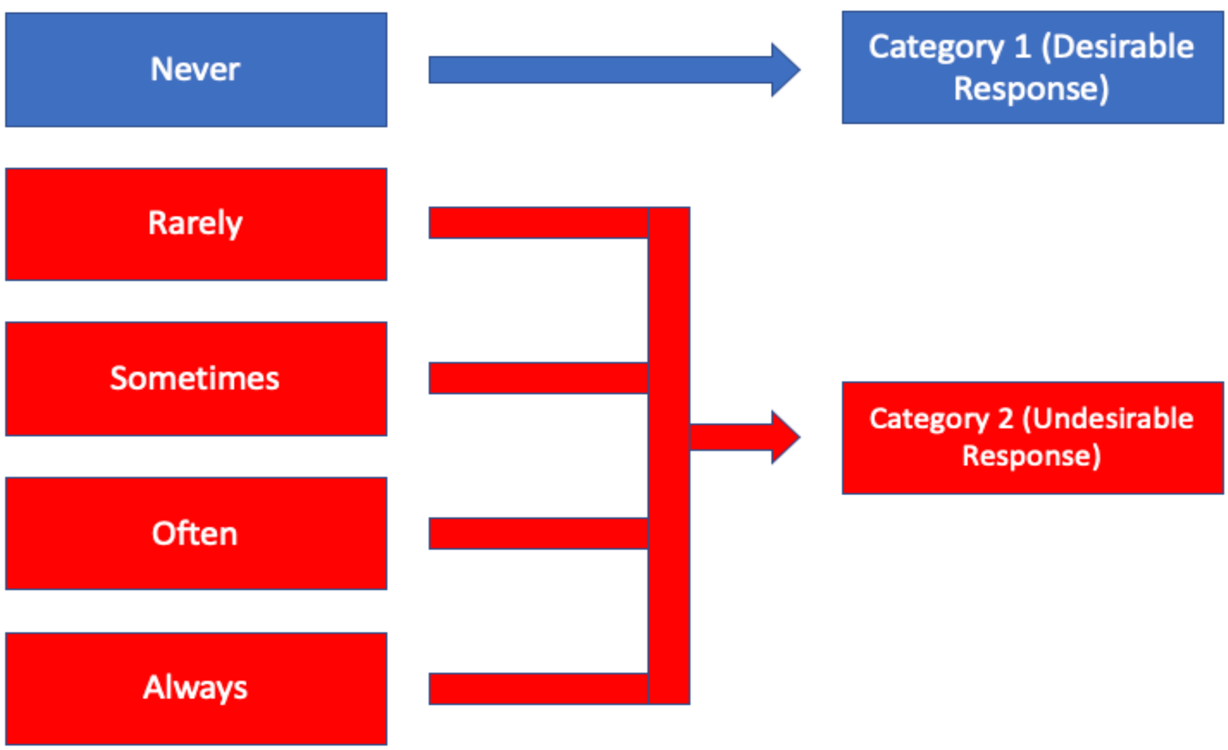


*Figure 9.* Participants' responses to the *willingness to fly while fatigued* Likert Scale question was grouped into two categories, desirable and undesirable responses.

Assumption #1 was met as the ordinal dependent variable used for this analysis was Question #8 Item #2, *I have remarked (out loud or to myself) about how tired I was but proceeded with the flight anyway,* which was a Likert Scale-type question. Assumption #2 was met as there was at least one independent variable, and they are *age* and *flight hours*. To test for multicollinearity in assumption #3, the researcher performed a linear regression test. The linear regression test yielded Tolerance values that are greater than 0.1 (both were 0.963) and Variance Inflation Factor (VIF) values less than ten. These findings indicated with confidence that there was no issue with collinearity in this data set (Laerd, 2015b). To test for proportional odds in assumption #4, the researcher performed a Full Likelihood Ratio test. The results of the test generated under the Test of Parallel Lines table indicated that the significance level was ($p < .0005$). If the assumption of proportional odds were met, the result would indicate a significance level of ($p > .05$). The results implied that assumption #4 was not met; however, the researcher elected to proceed with the Ordinal Logistics Regression test. This violation of the assumption was added to the limitations section in the next chapter.

The following were the results of the Ordinal Logistics Regression for Research Question Three. The deviance goodness-of-fit test indicated that the model was a good fit to the observed data, $\chi^2(517) = 472.350$, $p = .921$. The final model statistically significantly predicted the dependent variable over and above the intercept-only model, $\chi^2(2) = 10.456$, $p = .005$. An increase in age (years) was associated with an increase in the odds of flying while fatigued (by falling within category 2) with an odds ratio of 1.084 (95% Cl, 1.008 to 1.166), Wald $\chi^2(1) = 4.743$, $p = .029$. Conversely, an increase in flight hours was not associated with an increase in the odds of flying while fatigued (by falling within category 2) with an odds ratio of 1.000 (95% Cl, 1.000 to 1.001), Wald $\chi^2(1) = .514$, $p = .473$. Simply put, a participant that was a year older, would, on average, be 1.084 times more likely to choose a response that fell within category two over category one, with 95 percent of participants falling 1.008 and 1.166 times more likely. However, on average, a participant with a single flight hour additional would be 1.000 times more likely to choose a response that fell within category two over category one, with 95 percent of participants failing 1.000 to 1.001 times more likely.

## Summary

This chapter provided a detailed analysis of the data obtained from the CAFI-II survey. CAFI-II had a total of 248 ($n = 248$) participants overall, although not all participants answered every question. For research question one, the researcher answered the research question using descriptive statistics as well as thematic analyses. The researcher answered research question two using chi-square to test for association between both variables. For research question three, the researcher used the ordinal logistics regression to test for prediction between both variables.

# CHAPTER 5. DISCUSSIONS, CONCLUSIONS, AND RECOMMENDATIONS

The previous chapter discussed the results and provided a detailed analysis of the data collected from the CAFI-II survey. This chapter will discuss the summary of the study by discussing the results from the previous chapter, presents any study limitations, provides recommendations, and suggestions for further research on the study of fatigue within the collegiate aviation industry. Lastly, any final thoughts the researcher has for this study.

## Summary of the Study

There is a global shortage of pilots in the aviation industry, and the industry turns to these collegiate aviation programs as a means to supply them with newly minted pilots (Airplane Owners and Pilots Association, 2019; ICAO, *n.d.*, Tulis, 2007). It is crucial to instill best practices at this early stage of flight training as any human factor to mitigate risks. Additionally, failures that occur in the collegiate environment may trickle into the industry, thereby jeopardizing safety to the flying public. As an overview, this thesis provides an in-depth analysis of the issue of fatigue within the collegiate aviation flight programs operating under 14 CFR Part 141 rules. More specifically, this study explores the causes and symptoms of fatigue within the collegiate aviation industry. To answer this research question, the researcher sought out literature on the causes and effects of fatigue, fatigue within the aviation industry, as well as fatigue among college students. Furthermore, the researcher evaluated the CAFI-II, which was developed for this unique population. This study also sought to find out whether there was an association between enrollment status and a participant's willingness to fly while fatigued. The researcher hypothesized that there would be an association between participants' enrollment status and their willingness to fly fatigued. To answer this research question and test the hypothesis, the researcher performed a Chi-square test based on the data obtained from the CAFI-II. Lastly, this aimed to find out whether a participant's age and flight hours predict their willingness to fly while fatigued. The researcher hypothesized that age and flight hours would predict a participant's willingness to fly while fatigued. To answer this research question and test the researcher's hypothesis, the researcher used an Ordinal Logistics Regression test from the data obtained from CAFI-II.

The foundation of this study was adopted from previous studies and their findings on fatigue within collegiate aviation; these studies include Mcdale and Ma (2008), Levin et al. (2019), and Mendonca et al. (2019). The fact that the NTSB (2019) listed reducing fatigue-related accidents on their top ten Most Wanted list, highlights the importance of understanding fatigue across all aspects of aviation.

The survey used in this research is CAFI-II. The CAFI-II was a modification made from surveys developed for previous researches on the topic of fatigue in collegiate aviation (Levin et al., 2019; McDale & Ma, 2008; Mendonca et al., 2019). In the previous survey, the CAFI underwent validity testing with six SMEs, made adjustments based on the recommendations of these SMEs, and underwent further beta testing with 24 students enrolled in a collegiate aviation program.

This research study recruited flight students that are enrolled full-time in a collegiate aviation flight program operating under 14 CFR Part 141 rules. To be eligible to participate in the study, the participants have to declare that they were at least 18 years old, an active pilot (which meant that they flew within the past six months), and enrolled in a college program. The desired participant was between 18 – 25 years old, with approximately less than a thousand flight hours. However, not all participants fell within this category. Only a handful of participants were older and were more likely faculty members or professional flight instructors rather than students at the university. Overall, the age of the participants was evenly spread, with approximately 94% falling within the targeted age group. In terms of flight hours, 98 percent of participants had under a thousand flight hours.

The researcher forwarded an email link to the survey hosted on the online survey tool, Qualtrics, to faculty representatives of each college. These representatives subsequently forwarded the email to their students. Participants were first asked to agree to the terms of the study, as stipulated above. Subsequently, the participant had to provide demographics information, which includes, among others, age, flight hours, and enrollment status. Excluding the demographics section, the survey consisted of a total of 16 questions, which took approximately 20 minutes to complete. The data collection period was in the Fall semester of 2019.

Data were collected and stored in Qualtrics, which was subsequently downloaded to SPSS for data analysis. For research question one, a combination of descriptive statistics as well as the thematic analysis was used to identify the *causes and symptoms of fatigue within the collegiate aviation.* Questions used for this research question were #10 and #11, *causes of fatigue,* #8 and #9, *fatigue awareness,* and lastly, #12, *lifestyle.* Likert-scale data was converted into mean scores, and descriptive statistics were used to analyze the results. Thematic analysis was used on the data from the open-ended questions, where responses were sorted into broad categories and analyzed. For research question two, a Chi-square test was used to determine whether there was a statistically significant relationship between *enrollment status* and a *participant's willingness to fly fatigued.* To answer this question, the researcher used two categorical variables "*enrollment*" from the demographics section, and "*I have remarked (out loud or to myself) how tired I was, but proceeded with the flight anyway,*" from Question #8 Item #2, which was a Likert scale-type question. To analyze research question three, the researcher used the Ordinal logistics regression test to determine if there was a statistically significant prediction between *age, flight hours,* on a *participant's willingness to fly while fatigued. Age* and *flight hours* were obtained from the demographics section and are continuous variables in nature. *Willingness to fly while fatigued* information was obtained from Question #8 Item #2, "*I have remarked (out loud or to myself) how tired I was but proceeded with the flight anyway,*" which was a Likert-scale question.

## Results

The results of the study were analyzed to answer the three research questions. For research question one, *what are the causes and symptoms of fatigue among collegiate aviation students,* the results are as follows:

- *Causes of fatigue*

    1. A majority of participants mentioned that the amount of workload was one of the causes of fatigue. The amount of workload was mainly influenced by working a long day or from academic or personal activities. Collegiate

aviation flight students have to juggle between both fulltime academic classes as well as flight training. Some students reported having to work part-time in addition to their course load. A heavy workload could negatively influence the participant's quality and quantity of sleep.

2. Stress was also cited as a cause of fatigue by most participants. Stress is multifaceted, with many possible causes. Participants mentioned flight students, academic classes, flight environment, and relationships as contributors to stress. Stress could result in the development of active fatigue.
3. Additionally, participants cited Sleep-related problems as a cause of fatigue. Most participants mentioned that they have insufficient quality and quantity of sleep. Some participants attributed their sleep-related problems back to workload.

- *Symptoms of fatigue*

1. Participants cited drowsiness as a symptom of fatigue. Some examples mentioned by participants include yawning, slow reflexes, and a lack of energy.
2. Participants also mentioned physical and mental discomforts as a symptom of fatigue. Some participants mentioned symptoms such as heightened irritation, lethargy, and a general lack of interest.
3. Participants also mentioned that they noticeably made more mistakes when they perform flight duties while fatigued. Some participants mentioned that when fatigued, they do not practice good instrument and visual scan, tend to be more careless, and one participant even said vision loss.

The results of research question two, *is there a statistically significant relationship between enrollment status and a participant's willingness to fly while fatigued?* were:

1. During the first run, the independent variables consisted of all five enrollment statuses. For the second run, the researcher combined Freshmen and Sophomores as lower classmen and Juniors, Seniors, and Graduates as

upperclassmen. Participants from the lower academic class (Freshmen and Sophomores) were more reluctant to fly while fatigued. The results were consistent for both runs of the statistical analysis.

2. There was a statistically significant association between *enrollment status* and *willingness to fly while fatigued.* The results from the Pearson Chi-Square test indicated a value of $X^2 = 13.174$, $p = .01$ for the first run and $X^2 = 9.586$, $p = .002$ for the second run.

4. The results of the research question three, *do age and flight hours predict participant willingness to fly while fatigued?* were:

    1. There was a statistically significant prediction between *age* on the student's *willingness to fly fatigued*. According to the statistical analysis, the odds that a student will elect to fly fatigued increased by 1.084 times for an increase in a single year of age. The 95 percent Confidence Interval was between 1.008 to 1.166, with a significance of $p = .029$.

    2. There was no statistically significant prediction between *flight hours* and a student's *willingness to fly while fatigued*. According to the statistical analysis, a participants' likelihood of flying while fatigue would increase by 1.000 for every single increase in flight hour. The 95 percent Confidence Interval is between 1.000 and 1.001 with a significance of $p = .473$.

## Discussion of Results

The purpose of this study was to understand the fatigue within the collegiate aviation industry. More specifically, to understand the causes and symptoms of fatigue within the collegiate aviation industry, and whether there were statistically significant associations between enrollment status and a participant's willingness to fly while fatigued. Additionally, this research also aims to find out whether a participant's age and flight hours predict their willingness to fly while fatigued.

Fatigue is a well-known phenomenon and has been studied extensively. However, understanding fatigue in the context of collegiate aviation has not been extensively studied. This population of pilots is unique by having a different lifestyle as compared to pilots from other industries. These differences pose unique challenges. These challenges include heavy workload, stress, poor time management, as well as poor quality and quantity of sleep. In general, the results of the survey are consistent with the literature review. However, there were some unexpected findings:

- According to the data, 86 percent of participants mentioned in the lifestyle section (Question #12) that they agree to a certain extent (neutral, agree, and strongly agree) that they practice good workload management. However, 79 percent of participants mentioned in Question #10 that working a long day was a cause of fatigue. It is plausible that respondents were reluctant to admit that they do not have proper workload management. Another possible explanation could be that participants fail to associate workload and time management, and they may affect fatigue levels the following day. Simply put, participants may not understand how near-term workload and time management affects sleep-debt longitudinally.
- The symptoms of hunger or malnutrition are similar to fatigue and might often be misinterpreted (Carrol, 2016; Pelican, 1982). Hunger leads to tiredness, inability to maintain concentration, headaches, and even irritability (Carrol, 2016). In fact, if students allowed hunger to persist regularly to the point of malnutrition, their performance will suffer. An experiment conducted on malnourished children concluded that they performed poorly on the perceptual, psychological, and cognitive tests (Pelican, 1982).
- Sickness can be caused by a variety of situations, such as infections from foreign pathogens or motion sickness. In some cases, participants did not specify. According to Dizio and Lackner (1992), symptoms of motion sickness include nausea, vomiting, headache, dizziness, and drowsiness. Symptoms such as drowsiness are similar to fatigue and can be interpreted as such.
- Some participants also mentioned dehydration as a cause of fatigue. Dehydration may cause symptoms similar to fatigue, such as a reduction in cognitive function (Wilson

& Morley, 2003) this may result in the feeling of lethargy, reduced ability to concentrate, and general physical discomfort. It is, however, not related to fatigue.

- The understanding of how human-automation interaction played a role in the development of passive fatigue within the collegiate aviation industry was severely limited. This was partly because the researcher did not add any questionnaires to the CAFI-II that specifically probed participants on this topic. Furthermore, there was no mention of this issue by participants in the open-ended *causes of fati*gue question.

The symptoms of fatigue yielded results that were consistent with the literature review; this includes drowsiness, delayed reaction times, and an increase in mistakes made. There was, however, an unexpected finding:

- Approximately 44 percent of the participants mentioned 'drowsiness' as a common symptom of fatigue. However, when responding to Q8.1, roughly 87 percent disagreed to a certain extent (never or rarely) that they have ever struggled to stay awake during flight training. A possible explanation for this could be that participants are generally unwilling to admit that they struggled to stay awake while piloting an airplane. A pilot is held to the highest degree of expectation, and the participants may be unwilling to admit that they fell short of such an expectation.

With regards to research question two, whether *there was there a statistically significant relationship between enrollment status on a student's willingness to fly while fatigued*, the researcher was surprised that younger students (Freshmen and Sophomores) were less willing to fly while fatigued. These were surprising as lower classmen may not have as much experience as compared to their upperclassmen in recognizing fatigue causes and symptoms. A possible explanation is that these lower classmen could be too timid to acknowledge their shortcomings in fear of repercussions. Alternatively, these lower classmen could simply be more cautious as compared to their upperclassmen, which may be more complacent given their enrollment status. The conclusion to research question two yielded more evidence towards the outcome in research question three. Research question three aimed to find whether *a participant's age and flight hours predict their willingness to fly while fatigued.* Age can be a predictor of a student's willingness to fly while fatigued. On the other hand, the researcher was surprised that flight hours yielded no statistically significant prediction with a student's desire to fly while fatigued, even though enrollment and age are. A possible explanation could be that since a collegiate aviation pilot could gain hundreds of flight hours in a single year, the difference in attitudes yielded from a single flight hour may be negligent.

## Conclusions

The goal of this thesis was to explore the issue of fatigue within the collegiate aviation industry. More specifically, the survey examined the causes and effects of fatigue among collegiate aviation flight students, to determine whether there was a statistically significant association between enrollment status and willingness to fly while fatigued, and to determine whether a participant's age and flight hours predict their willingness to fly while fatigued.

There are many different *causes of fatigue*. A majority of participants mentioned that a heavy workload was one of the causal factors for fatigue. This finding was not surprising as collegiate aviation flight students were usually full-time students enrolled in a university. A heavy workload could negatively impact sleep the following night, as sleep may be the most convenient means of sacrifices for these college students, especially in the face of mounting academic, social, clubs, and part-time job-related responsibilities (Abrams, 2015). The fact that these students may be unprepared to handle these new-found responsibilities, attributed to the fact that they are young (18 – 22 years old) and that college was their first time living away from home, does not help either. A study conducted by Hicks and Pellegrini (2000) concluded that 68.3 percent of college students have sleep-related problems. In fact, college students usually got an hour to 1.5 hours less than the recommended amount of sleep (Kloss et al., 2011; Lund et al., 2010). Stress was also another *cause of fatigue* that was cited by the participants. Stress could arise from academic demands, familial or relationship issues, financial, or even relationship break down between students and their flight instructors. Sleep-related problems were another *cause of fatigue* that was cited by participants. The roots of sleep-related issues could vary from poor time management to sleep-related disorders like insomnia.

The *symptoms of fatigue* were wide-ranging as well. Participants commonly cited drowsiness as a common symptom of fatigue, which could come in the form of yawning or lethargy. Delayed reaction time and the loss of focus was also another symptom of fatigue mentioned in the survey. Slow reaction time, feeling spaced out, stuttering, and inability to comprehend information were examples cited by participants as evidence of delayed reaction time. Physical and mental discomforts were another symptom of fatigue. Participants commonly mentioned symptoms such as headaches, anxiety, and heightened irritation. Finally, participants indicated that they made more mistakes when they are operating an aircraft while fatigued. Not paying attention to all their cockpit instruments decreased controllability, and participants cited even vision loss.

There was a statistically significant association between enrollment status and willingness to fly while fatigued. Interpreting the data from the survey revealed that participants who are upperclassmen had a higher likelihood of electing to fly while fatigued.

There was a statistically significant prediction between age and willingness to fly while fatigued. Results from the Ordinal Logistics Regression test revealed that older participants were more likely to fly while fatigued. The data also revealed that there was no statistically significant prediction between flight hours and a participant's willingness to fly while fatigued.

## Limitations of the Study

There were some limitations to the current study. These limitations include not always getting the desired participants, sample participants not completing the entire survey, not meeting assumptions, and the validity and reliability of the questionnaires.

The desired participants for the study are full-time flight students (18 – 25 years old) enrolled in a FAR Part 141 collegiate aviation flight program. During the development of the survey, the researcher did not explicitly provide an age range for participants. This has resulted in some participants of the study being either significantly older than desired or were probably not students themselves.

Another limitation of the survey was that some participants did not complete the entire study. The researcher allowed participants to proceed to the next section of the study without forced completion in the hope of giving participants an avenue to skip questions that they did not feel comfortable answering.

The researcher was not able to meet an assumption for the Chi-Square test. According to Laerd (2016), all expected cell count for the Chi-Square table must be higher than five ($n > 5$);

however, the researcher was not able to fulfill this assumption for the graduate students' responses. As a result of not meeting this assumption, the researcher repeated the test; in the second attempt, the researcher decided to group the enrollment statuses into two categories, upperclassmen, and lower classmen. The second test run fulfilled the assumption for the Chi-square test.

In conducting the Ordinal Logistics Regression test, the researcher was not able to meet the assumptions of proportional odds. The researcher elected to continue with the test as all the other assumptions were met. Nonetheless, the results from the Ordinal Logistics Regression yielded valuable information and provided evidence that backed up the chi-square. Both tests indicated that upperclassmen might be at a higher risk.

In the original survey, CAFI underwent validity testing, as mentioned in the methodology. Although only small modifications were made to the CAFI-II, the researcher should have independently conducted validity and reliability testing on the CAFI-II.

## Recommendations

This study highlighted the significance and prevalence of fatigue within the collegiate aviation industry. Collegiate aviation flight programs serve as the foundation for most students aspiring to be a professional pilot in the aviation industry, whether for the airlines or the military. Mistakes or bad habits that these student pilots make should be quickly identified and eliminated before they get trickled down into the industry.

The threat of fatigue in collegiate should not be taken lightly by both flight students and faculties alike. Responses to the *causes of fatigue* section in the survey highlighted that workload management, stress, and sleep-related issues exist among collegiate aviation flight students. These research findings, including supporting materials from the literature review, should encourage both flight students and their respective institutions alike to emphasize and consider student well-being when making policies or academic-related decisions. External pressures affected by policies such as penalizing students that do not complete their courses in a single semester may drive these students to seek out every opportunity they have to fly, even though they may not be physically fit to do so. Faculty members of these collegiate aviation flight program could also consider limiting the number of courses (for example, no more than 15 credit hours) that a flight student is allowed to take in a single semester. Faculty members could also limit the amount of flight training hours a student can get during a single day, similar to the duty time limitations the FAA sets for flight instructors.

Students that are working as part-time Certified Flight Instructors (CFIs) play an essential role in aviation safety. These colleges should take into account these CFIs' academic and personal commitments and schedules when assigning them students. A CFI that is fatigued could not only seriously jeopardies the safety of flight, deliver poor instruction, but could also impart such bad habits to their student.

Having a fatigue awareness training for flight students would also potentially be beneficial. Students would be able to learn to quickly identify situations that cause fatigue, signs, and symptoms of fatigue, and fatigue mitigation strategies. By being bestowed with such knowledge, flight students would be able to make adjustments in their lifestyle during their foundational years before they enter the professional workforce.

Faculty and staff of these colleges should empower their students to make an independent go, no-go decision on whether or not to proceed with a flight. The consequences of flying while fatigued highlighted in the literature review and the survey are substantial. The case study presented at the beginning of the literature review showed how easily flying while fatigue could have ended the student’s life. Furthermore, flying while fatigue causes a degradation in performance, communication, mood, and the retention of knowledge, among others. To prevent students from being pressured to fly while fatigued, the faculty should ensure that there should be no consequences to these students should they elect to cancel their flight due to fatigue.

Both older students and upperclassmen (Junior, Senior, and Graduate) were more likely to proceed with a flight even though they acknowledged that they were fatigued. Faculty and staff should pay close attention to these groups of students. As such, the researcher recommends fatigue awareness training across all the academic levels of students as well as faculty members conducting flight training.

## Suggestions for Further Research

The results of the survey answered the three research questions; however, they also created an opportunity for additional future research. The following are the recommendations:

1. Increase sample size and diversity. The sample the researcher obtained were from eight collegiate aviation programs in the United States. Having a more diverse group of participants from aviation colleges from all across the country would be potentially beneficial, as it would allow the researcher to understand whether the findings from the data are universal across the country.
2. Explore what avenues collegiate aviation flight students have when they want to cancel their flight for fatigue. Is fatigue a legitimate reason to cancel a flight? What penalties, if any, would be incurred?
3. Explore more in-depth on what external pressures may be placed on these students to compel them to complete their course on time. More research should be done to explore how these pressures may affect a student's decision-making process.
4. An evidence-based fatigue management and mitigation training program should be developed as well as evaluated for dissemination to all flight students. Though it may be difficult to change the behavior of students, there may be an opportunity to increase their knowledge, awareness, and attitudes.
5. Explore more in-depth about how fatigue could affect a pilot's risk-taking behaviors.
6. Explore the possible reasons for the discrepancies between the reported results from the lifestyle section and the fatigue awareness section.

## Final Thoughts

Aviation is the still safest means of transport available today. It was said that in the past, aviation rules and regulations were written in blood; an aircraft accident and its subsequent investigations will usually bring about significant changes to the industry. Today, tools and technologies have enabled researchers to research potential safety-risk before they develop into serious accidents. According to the rules of primacy, knowledge and skills that are acquired first, often create a robust and almost unshakable impression on the student (Federal Aviation

Administration, 2008). The understanding of primacy should help colleges offering flight training programs to take the issue of fatigue among their students seriously and proactively take active steps to combat it before this human factor becomes habitual.

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# APPENDIX A. CAFI-II SURVEY

**Default Block**

**Fatigue Survey**
**IRB Protocol #: 2019-189**

Dear Fellow Pilot:

As part of the continuous process to mitigate the deleterious effects of fatigue during flight training activities, and consequently improve aviation safety, a research project is being conducted by Purdue researchers in the School of Aviation and Transportation Technology (SATT). The research project is focused on fatigue identification and management by collegiate aviation pilots.

You are eligible to participate in this study if you are at least 18 years old, and an active pilot (flown in the past six months) enrolled in a college program. The study will involve answering an online survey questionnaire addressing fatigue in aviation. It should not take you longer than 10 minutes to complete this assessment. Your identity will remain completely anonymous and confidential, and your participation is completely voluntary. You may stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

Your participation will help the aviation community gain a clearer understanding of fatigue related issues among collegiate aviation pilots. The researchers will make recommendation based on your collective responses.

Thank you for your participation!
Dr. Julius Keller
Dr. Flavio Mendonca

**Key Information**

Please take time to review this information carefully. This is a research study. Your participation in this study is voluntary which means that you may choose not to participate at any time without penalty or loss of benefits to which you are otherwise entitled. You may ask questions to the researchers about the study whenever you would like. If you decide to take part in the study, you will be asked to sign, or agree to this form, be sure you understand what you will do and any possible risks or benefits.

This study is part of a larger effort by Purdue researchers to understand the causes of fatigue and fatigue mitigation strategies by collegiate aviation pilots. This research project is focused on decision-making concepts, and strategies to prevent aircraft accidents due to fatigue, with the ultimate goal of improving aviation safety. You are being asked to participate in this project because of your aviation knowledge and experience. Researchers are expecting 500 collegiate aviation pilots from multiple programs to participate in this project. In order to be eligible to participate in the study, you must be at least 18 years old, a pilot, be directly involved with a collegiate aviation program, and have flown in the last six months.

**What will I do if I choose to be in this study?**

If you agree to the terms of this research study, you can agree and continue the survey. If you do not agree, the survey will end. The primary sections of the survey included fatigue awareness, mitigation, lifestyle, and demographics. There also open-ended questions so you can provide more in-depth answers. Your responses to scaled items and open-ended questions will be recorded for analyses.

**How long will I be in the study?**

It should not take you longer than 10 minutes to complete this survey. Your identity will remain completely anonymous and confidential, and your participation is completely voluntary. You may stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

**What are the possible risks or discomforts?**

You are at no greater risk than you would encounter in daily life or during the performance of routine physical or psychological exams or tests. If you experience frustration or undue stress during any part of the study, please quit the survey. Most importantly, please keep in mind that your participation is completely voluntary, and you can leave the experiment at any time without consequence. Breach of confidentiality is always a risk with data, but we will take precautions to minimize this risk as described in the confidentiality section.

**Are there any potential benefits?**

You may learn and/or enhance your aeronautical decision-making regarding fatigue identification and management. Additionally, the information obtained from this study may suggest ways to improve the ground and flight training of collegiate aviation pilots and even other aviation professionals. The researchers hope that the benefits to society will be a greater understanding of the fatigue identification and management in a collegiate aviation environment.

**Compensation:**

There is no compensation for completing this survey. However, we thank you for your time and you are appreciated.

**Confidentiality:**

Your confidentiality is of the highest concern to the researchers. Therefore, all data collected from you will remain anonymous and confidential. Only the authorized researchers will have access to identifying data. Responses to the online survey questionnaire will be captured on a secure Qualtrics® server. Data on Qualtrics® will be accessed, transcribed, and processed using password protected computer accounts. Researchers will de-identify and log this data into an excel spreadsheet. Most importantly, identifying information will not be used in the data analysis or in any subsequent presentation or document. Findings from this study may be published and presented in a scientific journal or conference. Moreover, raw data could be used during future research projects. It is important to note that any department at Purdue University responsible for regulatory and research oversight may review records from this project.

**My rights in this study:**

Your participation in this study is completely voluntary. You may choose not to participate or, if you agree to participate, you can withdraw your participation at any time without penalty or loss of benefits to which you are otherwise entitled. You may also decline to answer any question that makes you feel uncomfortable.

**Questions about the study:**

For any questions regarding your rights as a research participant and/or for research-related problems, you can contact the Principal Investigator (PI), Dr. Julius Keller, School of Aviation and Transportation Technology (SATT), Purdue University, at 765-494-9969 or keller64@purdue.edu, and/or the Co-PI, Dr. Flavio Mendonca, Purdue University SATT, 765- 496-6155. You may also contact the Purdue University Human Research Protection Program (HRPP), at (765) 494-5942, or via email at irb-questions@purdue.edu.

To report anonymously via Purdue's Hotline see www.purdue.edu/hotline. If you have questions about your rights while taking part in the study or have concerns about the treatment of research participants, please call the Human Research Protection Program at (765) 494-5942, email (irb@purdue.edu) or write to:

Human Research Protection Program - Purdue University Ernest C. Young Hall, Room 1032
155 S. Grant St.
West Lafayette, IN 47907-2114

**Documentation of Online Consent**

I will print a copy of this consent form after I have read it.

Do you consent to participate in this research study?

- ○ I agree to the terms of this research study
- ○ I Do Not agree to the terms of this study

**Demographics:**

Please provide some basic information about yourself so we can better categorize and understand the fatigue issues in the flight training environment. Again, your survey responses will remain anonymous.

**Please type in your age:**

[ ]

**Gender:**

- Male
- Female
- Prefer not to say

**Enrollment status:**

- Freshman
- Sophomore
- Junior
- Senior
- Graduate Student
- Other

**Highest certificate held:**

- Student
- Private
- Commercial
- CFI or CFII
- ATP

**Approximate total logged flight time (e.g.. 150, 230):**

**Please type in your institution:**

**Fatigue Awareness**

Please rank the accuracy of the statement describing your overall experience during all of your flight activities.

| | Never | Rarely | Sometimes | Often | Always |
|---|---|---|---|---|---|
| I have struggled to stay awake during a flight. | ○ | ○ | ○ | ○ | ○ |

| | Never | Rarely | Sometimes | Often | Always |
|---|---|---|---|---|---|
| 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 made mistakes during flight activities because I was fatigued. | ○ | ○ | ○ | ○ | ○ |
| 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. | ○ | ○ | ○ | ○ | ○ |

| | Never | Rarely | Sometimes | Often | Always |
|---|---|---|---|---|---|
| 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. | ○ | ○ | ○ | ○ | ○ |

| | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
|---|---|---|---|---|---|
| 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

◯ 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. CAFI-II IRB APPROVAL

**This Memo is Generated From the Purdue University Human Research Protection Program System, Cayuse.**

**Date:** November 20, 2019
**PI:** JULIUS KELLER
**Department:** PWL SATT, PWL DIRECTOR OF DINING
**Re:** Modification - IRB-2019-189
*Investigating Fatigue in Collegiate Aviation Using the CAFI-II*

The Purdue University Institutional Review Board has approved the modification for your study " *Investigating Fatigue in Collegiate Aviation Using the CAFI-II*. " The Category for this Exemption is listed below. This study maintains a status of exempt and an administrative check-in date of October 23, 2022. The IRB must be notified when this study is closed. If a study closure request has not been initiated by this date, the HRPP will request study status update for the record.

Specific details about your modification approval appear below.
**Decision:** Exempt
**Findings:**
**Research Notes:**

**What are your responsibilities now, as you move forward with your research?**

**Document Retention:** The PI is responsible for keeping all regulated documents, including IRB correspondence such as this letter, approved study documents, and signed consent forms for at least three (3) years following protocol closure for audit purposes. Documents regulated by HIPAA, such as Release Authorizations, must be maintained for six (6) years.

**Site Permission:** If your research is conducted at locations outside of Purdue University (such as schools, hospitals, or businesses), you must obtain written permission from all sites to recruit, consent, study, or observe participants. Generally, such permission comes in the form of a letter from the school superintendent, director, or manager. You must maintain a copy of this permission with study records.

**Training:** All researchers collecting or analyzing data from this study must renew training in human subjects research via the CITI Program ( www.citiprogram.org) every 4 years. New personnel must complete training and be added to the protocol before beginning research with human participants or their data.

**Modifications:** Change to any aspect of this protocol or research personnel must be approved by the IRB before implementation, except when necessary to eliminate apparent immediate hazards to subjects or others. In such situations, the IRB should still be notified immediately.

**Unanticipated Problems/Adverse Events:** Unanticipated problems involving risks to subjects or others, serious adverse events, and
noncompliance with the approved protocol must be reported to the IRB immediately through an incident report. When in doubt, consult with the HRPP/IRB.

**Monitoring:** The HRPP reminds researchers that this study is subject to monitoring at any time by Purdue's HRPP staff, Institutional Review Board, Research Quality Assurance unit, or authorized external entities. Timely cooperation with monitoring procedures is an expectation of IRB approval.

**Change of Institutions:** If the PI leaves Purdue, the study must be closed or the PI must be replaced on the study or transferred to a new IRB. Studies without a Purdue University PI will be closed.

**Other Approvals:** This Purdue IRB approval covers only regulations related to human subjects research protections (e.g. 45 CFR 46). This determination does not constitute approval from any other Purdue campus departments, research sites, or outside agencies. The Principal Investigator and all researchers are required to affirm that the research meets all applicable local, state, and federal laws that may apply.

If you have questions about this determination or your responsibilities when conducting human subjects research on this project or any other, please do not hesitate to contact Purdue's HRPP at irb@purdue.edu or 765-494-5942. We are here to help!

Sincerely,

Purdue University Human Research Protection Program/ Institutional Review Board

# APPENDIX C. CITI CERTIFICATES

Completion Date 25-Sep-2018
Expiration Date 24-Sep-2023
Record ID 27150546

This is to certify that:

**Aaron Zhen Yang Teo**

Has completed the following CITI Program course:

**Human Research** (Curriculum Group)
**Group 2.Social Behavioral Research Investigators and Key Personnel** (Course Learner Group)
**1 - Basic Course** (Stage)

Under requirements set by:

**Purdue University**

Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w994b96dd-5ff8-400d-8718-c4111fee66d8-27150546

Completion Date 24-Jul-2018
Expiration Date 23-Jul-2023
Record ID 27592438

This is to certify that:

**Aaron Zhen Yang Teo**

Has completed the following CITI Program course:

**Responsible Conduct of Research** (Curriculum Group)
**Responsible Conduct of Research (RCR) Training - Faculty, Postdoctoral, and Graduate Students** (Course Learner Group)
**1 - Basic Course** (Stage)

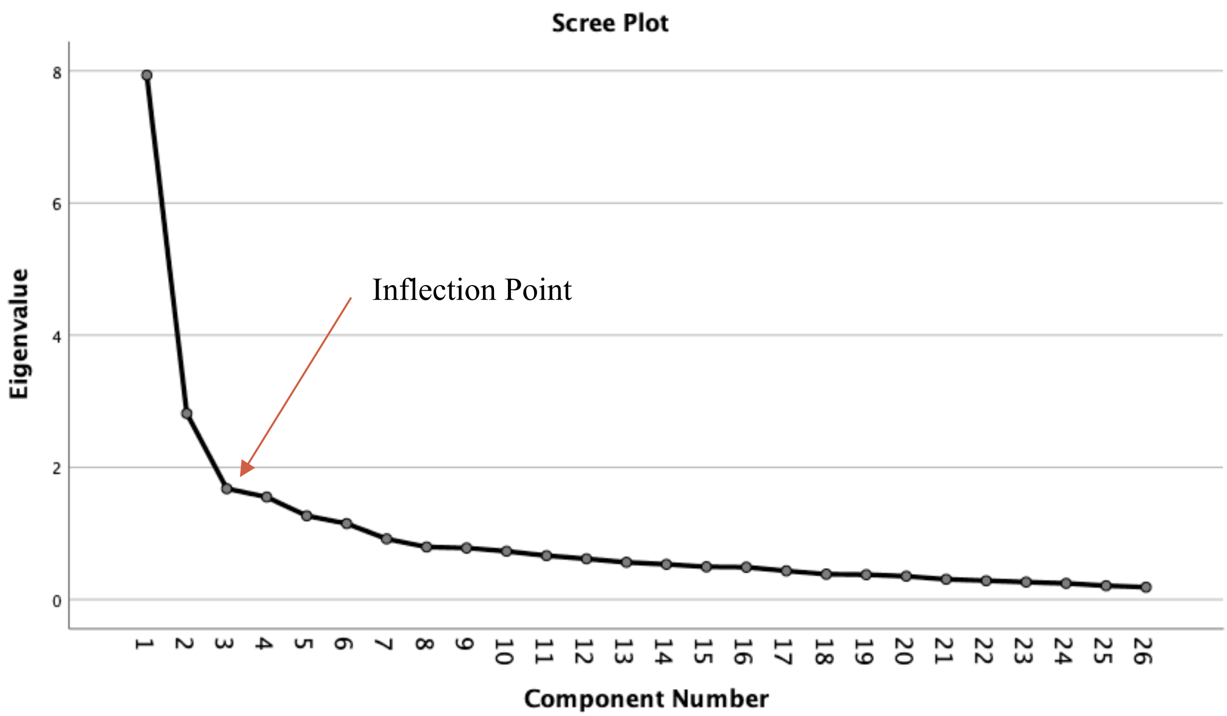
Under requirements set by:

**Purdue University**

Collaborative Institutional Training Initiative

Verify at www.citiprogram.org/verify/?w1c03c3d8-9331-4ddd-b21e-8c8fa920a311-27592438

# APPENDIX D. SCREE PLOT AND EIGENVALUES FROM SPSS



**Total Variance Explained**

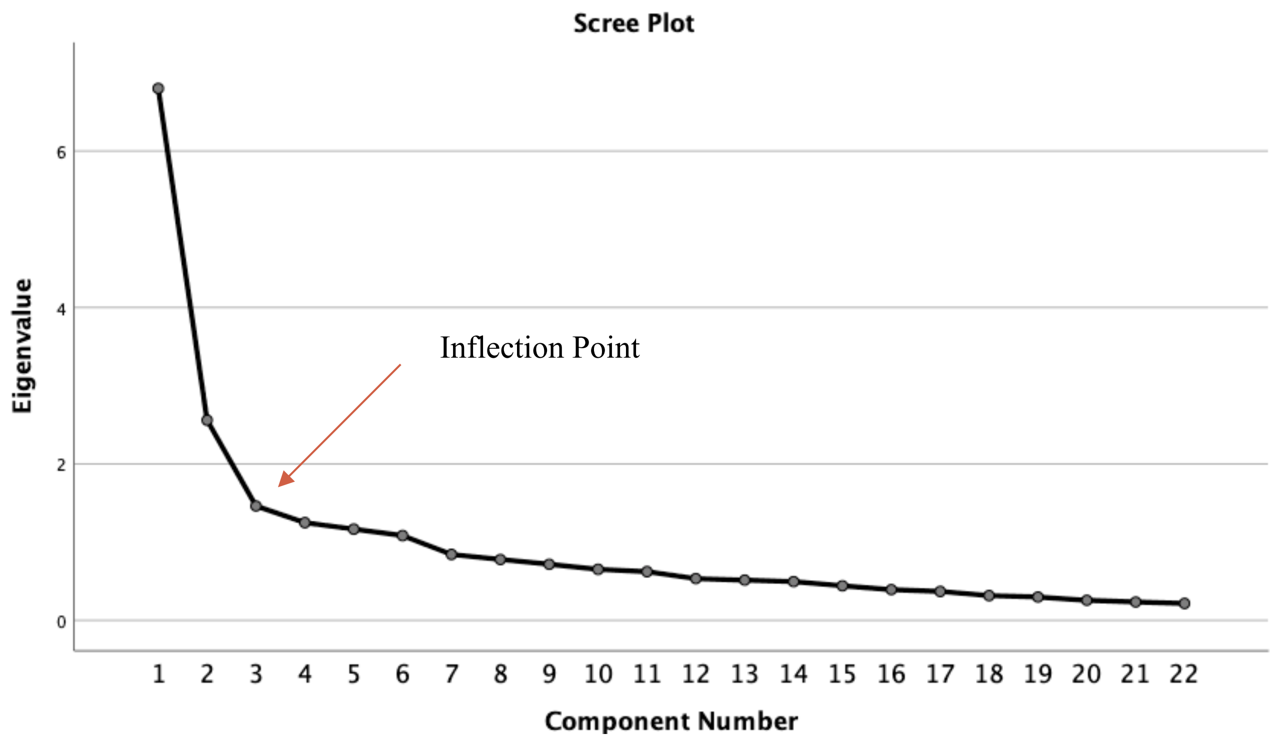
| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 7.934 | 30.514 | 30.514 | 7.934 | 30.514 | 30.514 | 5.089 | 19.574 | 19.574 |
| 2 | 2.815 | 10.828 | 41.342 | 2.815 | 10.828 | 41.342 | 3.527 | 13.564 | 33.138 |
| 3 | 1.677 | 6.450 | 47.792 | 1.677 | 6.450 | 47.792 | 2.121 | 8.158 | 41.296 |
| 4 | 1.550 | 5.961 | 53.753 | 1.550 | 5.961 | 53.753 | 1.923 | 7.395 | 48.691 |
| 5 | 1.267 | 4.872 | 58.625 | 1.267 | 4.872 | 58.625 | 1.886 | 7.252 | 55.943 |
| 6 | 1.149 | 4.420 | 63.046 | 1.149 | 4.420 | 63.046 | 1.847 | 7.103 | 63.046 |
| 7 | .916 | 3.525 | 66.570 | | | | | | |
| 8 | .795 | 3.056 | 69.626 | | | | | | |
| 9 | .779 | 2.996 | 72.623 | | | | | | |
| 10 | .729 | 2.805 | 75.428 | | | | | | |
| 11 | .663 | 2.549 | 77.977 | | | | | | |
| 12 | .615 | 2.367 | 80.344 | | | | | | |
| 13 | .563 | 2.164 | 82.507 | | | | | | |
| 14 | .531 | 2.044 | 84.551 | | | | | | |
| 15 | .494 | 1.902 | 86.453 | | | | | | |
| 16 | .488 | 1.877 | 88.330 | | | | | | |
| 17 | .433 | 1.665 | 89.995 | | | | | | |
| 18 | .382 | 1.471 | 91.466 | | | | | | |
| 19 | .375 | 1.444 | 92.910 | | | | | | |
| 20 | .352 | 1.355 | 94.264 | | | | | | |
| 21 | .306 | 1.177 | 95.441 | | | | | | |
| 22 | .284 | 1.093 | 96.534 | | | | | | |
| 23 | .263 | 1.012 | 97.546 | | | | | | |
| 24 | .244 | .937 | 98.483 | | | | | | |
| 25 | .208 | .800 | 99.283 | | | | | | |
| 26 | .186 | .717 | 100.000 | | | | | | |

# APPENDIX E. EIGENVALUES AND SCREE PLOT AFTER REMOVAL OF ITEMS

**Total Variance Explained**

| Component | Initial Eigenvalues | | | Extraction Sums of Squared Loadings | | | Rotation Sums of Squared Loadings | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % | Total | % of Variance | Cumulative % |
| 1 | 6.800 | 30.909 | 30.909 | 6.800 | 30.909 | 30.909 | 6.213 | 28.242 | 28.242 |
| 2 | 2.559 | 11.631 | 42.540 | 2.559 | 11.631 | 42.540 | 2.565 | 11.659 | 39.901 |
| 3 | 1.461 | 6.642 | 49.181 | 1.461 | 6.642 | 49.181 | 2.042 | 9.280 | 49.181 |
| 4 | 1.249 | 5.676 | 54.858 | | | | | | |
| 5 | 1.166 | 5.300 | 60.158 | | | | | | |
| 6 | 1.083 | 4.925 | 65.083 | | | | | | |
| 7 | .842 | 3.828 | 68.911 | | | | | | |
| 8 | .778 | 3.537 | 72.449 | | | | | | |
| 9 | .717 | 3.260 | 75.709 | | | | | | |
| 10 | .652 | 2.963 | 78.672 | | | | | | |
| 11 | .623 | 2.831 | 81.504 | | | | | | |
| 12 | .533 | 2.424 | 83.928 | | | | | | |
| 13 | .514 | 2.336 | 86.264 | | | | | | |
| 14 | .496 | 2.253 | 88.516 | | | | | | |
| 15 | .442 | 2.008 | 90.524 | | | | | | |
| 16 | .393 | 1.785 | 92.309 | | | | | | |
| 17 | .370 | 1.682 | 93.991 | | | | | | |
| 18 | .316 | 1.439 | 95.429 | | | | | | |
| 19 | .298 | 1.356 | 96.785 | | | | | | |
| 20 | .256 | 1.163 | 97.948 | | | | | | |
| 21 | .235 | 1.067 | 99.016 | | | | | | |
| 22 | .217 | .984 | 100.000 | | | | | | |

Extraction Method: Principal Component Analysis.


Scree Plot
Eigenvalue
Inflection Point
Component Number
0
2
4
6
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22