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Fatigue can be deleterious to pilot performance. The National Transportation Safety Board has called on the aviation community to reduce fatigue related accidents. Currently, there are few studies and guidance specific to collegiate aviation pilots. The current study is part of a larger effort by the authors to gain a clearer understanding of fatigue within the collegiate aviation environment. Collegiate aviation pilots are a unique group with different schedules, lifestyles, and demands when compared to airline, military, and on-demand pilots. The purpose of this study was to examine self-reported fatigue and sleepiness measures. Research instruments included the Karolinska Sleepiness Scale and the Samn-Perelli Fatigue Scale. The research team recruited thirty-two collegiate aviation pilots from a large Midwestern university. Participants were asked to record their sleepiness and fatigue ratings four times a day, at intervals, for a total of four weeks over four months. Approximately 5,000 total data points were collected. Results indicated a significant difference between the times of day. The 8:00 a.m. recording time had the highest median fatigue and sleepiness score. There were no significant differences between the days of the week. However, overall median fatigue and sleepiness scores indicated participants were slightly fatigued and sleepy throughout the data collection period.

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According to the National Transportation Safety Board (NTSB) (2018), fatigue is a "pervasive problem in transportation that degrades a person's ability to stay awake, alert, and attentive to the demands of safely controlling a vehicle, vessel, aircraft, or train" (p. 1). The International Civil Aviation Organization (ICAO) (2020) defines fatigue as:

> a physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member's alertness and ability to safely operate an aircraft or perform safety-related duties. (p. 1)

Fatigue related accidents have become a concern for safety professionals. Consequently, reducing fatigue related accidents has been listed on the National Transportation Safety Board's top ten most wanted list since 2016 (NTSB, 2020). The NTSB is calling for a comprehensive approach to reducing the risks of fatigue in all sectors of transportation. Recommendations for combatting fatigue in the aviation sector include research, education, and training. The NTSB, the Federal Aviation Administration (FAA), aviation stakeholders, and the research community have worked extensively to address the issue, however, there seems to be a gap in these efforts. For instance, the FAA's existing policies and training are specific to maintenance technicians, scheduled services, and on-demand flight operations (FAA, 2010, 2012, 2014). Furthermore, the only FAA regulation for duty time during flight training is the Federal Aviation Regulation (FAR) 61.195. This regulation restricts flight instruction duties, which in the collegiate aviation environment often consists of upper-level college students. Specifically, the regulation restricts flight instruction hours to a maximum of eight per twenty-four hours (Electronic Code of Federal Regulations, 2020a).

Although this is a positive mitigation tool, the regulation does not consider all the tasks undertaken by the collegiate aviation pilots including instructions. Collegiate aviation pilots are a unique population. In addition to flying, these pilots face rigorous course loads, expectations to participate in student organizations, social activities, and often have part time jobs (Keller, Mendonca, & Cutter, 2019; Levin, Mendonca, Keller, & Teo, 2019; Mendonca, Keller, & Lu, 2019). According to Beattie, Laliberté, Michaud-Leclerc, and Oreopoulos (2019), students who thrive in the academic environment spend on average 30 hours a week studying. Many collegiate aviation pilots are in the 18-22 age range. Moreover, this is frequently their first time living away from home. Therefore, these individuals may be the least prepared group of pilots, as they are just beginning to develop their time management and coping skills while learning how to safely and effectively fly. Previous studies have indicated that a holistic approach to mitigate fatigue, which includes conducting research utilizing multiple methodologies, evidence-based training and education programs is vital (Mendonca et al., 2019; Signal, Ratieta, & Gander, 2006).

Purpose

The purpose of this study was to investigate the role of day of the week and time of the day on reported levels of sleepiness and fatigue by collegiate aviation pilots at a large Midwestern professional flight program. The research team utilized the 10-point Karolinska Sleepiness Scale (KSS) and the seven-point Samn-Parelli Fatigue Scale (SPS) to identify patterns in sleepiness and fatigue, respectively, throughout the day and longitudinally (ICAO, 2012). ICAO (2012) suggests using these scales to obtain a large data set efficiently. However, there are biases with self-reported measures. Findings of this study will contribute to the larger project which is intended to improve fatigue awareness, mitigation and management, training, and education for collegiate aviation pilots (Keller et al., 2019; Mendonca et al., 2019; Romero, Robertson, & Goetz, 2020). The following sections will discuss fatigue and the relationship to safety as well as previous research pertaining to self-reported sleep measures.

Literature Review

Time of Day, Fatigue, and Errors

An examination of the literature indicates fatigue awareness and mitigation are directed towards military and airline pilots (French & Garrick, 2005; Hamsal & Zein, 2019; Roach, Darwent, Sletten, & Dawson, 2011). There seems to be only a few studies that are specific to collegiate aviation pilots. The effects of sleep deprivation and physical fatigue are a continual focal point in transportation safety research. From 2016 to 2020, "Reduce Fatigue-Related Accidents" has been on the NTSB Most Wanted List as a primary safety focus (NTSB, 2018, p. 1). Many studies have been conducted with commercial airline and military flight crews (Gander et al., 2013; Powell, Spencer, Holland, Broadbent, & Petrie, 2007; Sieberichs & Kluge, 2016). Commercial flight crews are limited in duty time and flight time per day, while also subject to minimum rest requirements per 14 Code of Federal Regulations (CFR) Parts 117, 121, and 135 (Electronic Code of Federal Regulations, 2020b). Despite the importance for aviation safety, a prescriptive approach to mitigate fatigue in flight operations does not always consider other factors contributing to fatigue other that work duration (Signal et al., 2006). Even with regulatory rest protections, Mallis, Banks, and Dinges (2010) found only 50 to 75% of a normal rest period appears to account for sleep.

ICAO (2016) suggests that sleep loss may affect a pilot's ability to "anticipating events, planning and determining relevant courses of action - particularly under novel situations" (pp. 2-14). Pilots are required to plan and anticipate future actions and make split-second decisions, especially when critical life-threatening situations arise. According to Williamson and Feyrer (2000), 17 to 19 hours of wakefulness is equivalent to having a Blood Alcohol Content (BAC) of .10. The NTSB labels the hours of wakefulness as the *Time Since Awakening* (TSA) (NTSB, 1994). TSA measures the number of hours when the pilot first rises from bed to the time of the accident (NTSB, 1994). Flight crews with high TSA were recorded to have as much as 40% more mistakes overall as compared to low TSA counterparts (NTSB, 1994). NTSB data also indicate that errors of omission made by crews with high TSA rose by 75% (NTSB, 1994). Similarly, errors with monitoring automation rose by around 136% in pilots with high TSA flight crews (NTSB, 1994). As fatigue increases, errors made by an individual become more difficult to detect and correct (ICAO, 2016).

According to O'Hagan, Issartel, McGinley, and Warrington (2018), seven pilots participated in two 24-hour training sessions, one including an 8-hour rest period, and one without the rest period. The participants were prompted to complete tasks measuring cognitive flexibility, working memory, situational awareness, and hand-eye coordination every eight hours throughout each session. Results indicated the participant instrument scan and hand eye coordination suffered as well as pilot judgement due to fatigue. After 24 hours of continuous wakefulness the pilots reported significant levels of fatigue. Lopez, Previc, Fischer, Heitz, and Engle (2012) studied performance of Air Force pilots after 35 hours of sleep deprivation. Significant effects of fatigue began to show after 19 hours of wakefulness. Slight increases in performance were observed in the morning hours of the following day. This was possibly due to peaks in the circadian rhythm cycle, yet performance was still significantly lowered when compared to the beginning of the testing session. This finding may directly relate to collegiate student pilots who may not have the best sleep practices. The human body needs a consistent sleep cycle to be able to function at best performance. Students who have varying sleep schedules, late nights, and early mornings are highly subject to decreases in performance (Lopez et al., 2012).

The period in the day a flight occurs also has a significant effect on pilot performance due to circadian cycles. Early morning flights between the hours of midnight and 6:00 a.m. have shown decreases in performance regardless of the amount of rest received prior to duty. Mello et al. (2008) analyzed Brazilian airline pilot errors in relationship to the time of day. The data showed 9.5 errors per 100 flight hours during the early morning hours while later times of day averaged 6.7 errors per 100 flight hours. Previc et al. (2009) also noted the effect of circadian cycle in performance of pilots. Fatigue significantly increased and performance decreased at midnight. A slight decrease in fatigue and sleepiness did not occur until after 9:30 a.m.

These articles provided evidence that relationships exist between time of day, fatigue levels, and errors. Additionally, the methodologies provide an adequate framework for collegiate aviation pilots. Though there have not been many studies specific to collegiate aviation pilots, there has been a recent emerging effort by scholars.

Fatigue within the Collegiate Aviation Flight Environment

Mendonca, Keller, and Lu (2019) validated and distributed the Collegiate Aviation Fatigue Inventory (CAFI) to a Midwestern collegiate aviation flight program. One hundred and twenty-two pilots responded to the survey. Results indicated that 92% reported to have never fallen asleep or struggled to stay awake during a flight. However, 51% indicated they proceeded with a flight despite being extremely tired. Additionally, respondents reported cognitive dysfunction during flight activities. Moreover, their responses suggested that lack of sleep was a primary cause to their fatigue. In another study, researchers surveyed collegiate aviation pilots. Results indicated flying after a long day, flying after less than eight hours of rest, and insufficient quality of sleep were the top three causes of fatigue (Romero et al., 2020).

Keller et al. (2019) utilized fatigue-related scenarios to understand pilot decision-making. Results indicated participants did not always express desirable decision-making processes. Additionally, findings indicated participants had insufficient knowledge about the effects of fatigue as well as effective mitigation strategies. Pilots reported external factors such as organizational pressures as a key aspect towards undesirable decisions. Levin, Mendonca, Keller, and Teo (2019) reported that 86% (n = 141) of the surveyed participants believed that fatigue had a negative impact on the safety of a flight operation. Additionally, approximately 85% of respondents indicated they had not been formally trained on fatigue topics. It is important to mention that Keller et al., (2019), Mendonca, Levin, Keller and Teo (2019), and Romero et al. (2020) have clearly argued that further fatigue research within a collegiate aviation environment is fundamental for aviation safety and efficiency. The previous studies pertaining to fatigue within the collegiate aviation environment did not use self-reported measures. Therefore, examining fatigue with a different methodology will add to the body of knowledge.

Measuring Fatigue Through Self-Reporting Measures

According to ICAO (2016), there are five methods for proactive fatigue identification. These five are self-reporting measures, surveys, performance data, research studies, and the analysis of time worked. Benefits to utilizing rating scales such as the Karolinska Sleepiness Scale (KSS) and Samn-Parelli Scale (SPS) include the simplicity, cost-effectiveness, and ability to collect a large amount of data (ICAO, 2012). However, self-reported scales are subject to biases. These biases may come in two primary ways. First, a respondent may not want to tell the truth about their fatigue state. Secondly, a person may not always be able to accurately detect the true level of fatigue because of its insidious nature and or the individual's emotional status (Garwon, 2016). There has yet to be a study in the collegiate aviation environment utilizing self-reported measures. However, robust studies using both the KSS and the SPS have been published from the airline environment (Gander et al., 2013; Gawron, 2016; Powel et al., 2007; Van den Berg et al., 2015).

Van den Berg et al. (2015) measured flight crew members fatigue and sleepiness to evaluate the effectiveness of fatigue management strategies during ultra and non-ultra-long-range flights. Participants were asked to provide their responses before and after a sleep break during the flight. Additionally, the participants were asked to rate their workload and complete a five-minute Psychomotor Vigilance Test (PVT). Results indicated the fatigue and sleepiness ratings were higher on the non-ultra-long-range flights. This provided evidence that longer flights do not always constitute more fatigue. This was attributed to better management of sleep recovery periods between ultra-long-range flights. It was recommended that airlines should further investigate workload patterns for shorter flights. In another study, the KSS and SPS were used to evaluate pilots operating long-range and ultra-long-range flights. It was found that total sleep time was a significant predictor for both the KSS an SPS ratings (Cosgrave, Wu, van den Berg, Signal, & Gander, 2018). Levo (2016) utilized the KSS to measure pilot sleepiness over the course of five flights. Results indicated a higher fatigue rating after the fourth flight during the week that was recorded. This study contributed to understanding workload management and fatigue risk management efforts. Previous studies (Gander et al., 2013; Honn, Satterfield, Mccauley, Caldwell, & Van-Dongen, 2016; Shahid, Shen, & Shapiro, 2010) have demonstrated that both the KSS and SPS are valid tools to assess subjective measures of sleepiness and fatigue, respectively.

Pilot fatigue is a serious detriment to aviation safety. As pilots become more fatigued performance decreases while accepted standards of performance and safety decreases (Caldwell, 2012). The review of literature indicated there are few fatigue studies pertaining to collegiate aviation pilots and there may be a gap in fatigue training and education; however, there is an emerging effort in that direction (Keller et al., 2019; Levin et al., 2019; Mendonca & Keller, 2020; Romero et al., 2020). Once again, this study is part of a larger effort to gain a clearer understanding of fatigue specific to the collegiate aviation pilots. Previous phases of the research project utilized surveys and fatigue-related decision-making scenarios (Keller et al., 2019; Levin et al., 2019; Levin & Teo, 2019; Mendonca, Keller, Lu, 2019). When combining the results of the different studies, the collegiate aviation community may have a clearer understanding of the issue and could then develop more efficient holistic strategies to mitigate fatigue during flight training activities. In order to understand fatigue and sleepiness among collegiate aviation pilots, the following research questions were addressed:

1. Is there a significant difference between the time of day (8:00 a.m., 12:00 p.m., 4:00 p.m., and 9:00 p.m.) and the median KSS scores?
2. Is there a significant difference between the time of day (8:00 a.m., 12:00 p.m., 4:00 p.m., and 9:00 p.m.) and the median SPS scores?
3. Is there a significant difference between days of the week and the median KSS scores?
4. Is there a significant difference between days of the week and the median SPS scores?

Methodology

Sample

The participants in this study were undergraduate students enrolled in a Midwest Part 141 four-year collegiate aviation flight program. All participation was in accordance to Institution Review Board (IRB) guidelines. Researchers sought collegiate aviation pilots, aged 18 years or older, who had previously flown in the last six months, and were currently enrolled in a Part 141 flight training program.

Recruitment and Procedures

After obtaining IRB approval, the research team sent an email asking for participation. Two information sessions were conducted to accommodate student schedules. During the information sessions, the prospective participants were informed about the research project, their rights as participants, the procedures, and then given consent forms to sign. The participants who agreed to continue were re-informed of the procedures, asked to provide demographic information, and to sign the consent form. A presentation was given to describe the scales and their purpose.

The researchers asked students to document their fatigue and sleepiness levels at 8:00 a.m., 12:00 p.m., 4:00 p.m., and 9:00 p.m. each day, using the SPS and KSS, respectively. The data collection process occurred during four weeks spread in four consecutive months.

The weeks out of the four months were randomly selected through an online random number generator. Two reporting weeks were at the end of the Fall 2019 semester and the remaining two weeks were at the Spring 2020 semester. The research team desired to have a broad perspective of fatigue and sleepiness levels longitudinally. Each day at the four sampled times, a reminder was sent to the participants for them to record their sleepiness and fatigue scores. Participants received $20 each week for a total of $80.

Research Instruments

The research team utilized the 10-point Karolinska Sleepiness Scale (KSS) and the seven-point Samn-Perelli Scale (SPS) (ICAO, 2012) to identify patterns in fatigue and sleepiness throughout the day and longitudinally during alternate weeks throughout the period of four months. ICAO (2012) suggests using these scales to obtain a large dataset efficiently. According to Gander et al., (2013), both scales, recommended by ICAO (2012), have been used in the airline industry. The KSS and SPS are very similar in nature; however, they are used to assess different constructs, subjective sleepiness, and subjective fatigue levels. Sleepiness often pertains to the physiological act of falling asleep while fatigue may be more physical. For example, an individual may have obtained nine hours of sleep but had to take a challenging check ride which required extreme concentration. They may not be sleepy after the check ride but mentally fatigued. The research team decided to use both scales because it would not significantly increase participant time to report while providing an abundance of data. It was estimated it would take participants a few seconds to record their responses. Table 1 shows the KSS and SPS scales.

Table 1.
Karolinska and Samn-Perelli scales

Karolinska Sleepiness Scale (KSS) 10-point scale	Samn-Perelli Fatigue Scale (SPS) 7-point scale
1=Extremely alert	1=Fully alert, wide awake
2=Very alert	2=Very lively, responsive, but not at peak
3=Alert	3=Okay, somewhat fresh
4=Rather alert	4=A little tired, less than fresh
5=Neither alert nor sleepy	5=Moderately tired let down
6=Some signs of sleepiness	6=Extremely tired, very difficult to concentrate
7=Sleepy, but no effort to keep awake	7=Completely exhausted, unable to function effectively
8=Sleepy, but some effort to keep awake	
9=Very sleepy, great effort to keep awake, fighting sleep	
10=Extremely sleepy, can’t keep awake	

Note. International Civil Aviation Organization. (2012). *Measuring fatigue*. Retrieved from https://www.icao.int/safety/fatiguemanagement/FRMS%20Tools/Doc%209966.FRMS.2011%20Edition.en.pdf

Data Analysis

The data collection period was during the Fall 2019 and Spring 2020 semesters. The researchers combined the data within a spreadsheet by scale, time of day, and week. Then the data was transferred over to SPSS®. Demographics, descriptive statistics, and four Kruskal-Wallis H tests are reported in the results section. The Kruskal-Wallis H test is a non-parametric test that can determine if there are significant differences between groups of independent variables (time of day and days of the week) on a ordinal dependent variable (self-reported fatigue and sleepiness measures) (Laerd Statistics, 2020).

Results

Demographics

Thirty-two participants (*n* = 32) agreed to participate in the study. Ninety-one percent were male while nine percent were female. Eighty-one percent of the participants were between the ages 18-20, 13% were between the ages 21-25, and six percent were between ages 26-35. Twenty-eight percent were freshmen, 34% were sophomores, 22% were juniors, 13% were seniors, while three percent were combined degree program students. The combined degree program allows undergraduates to enroll into graduate courses. Twenty-five percent of the participants held student certificates, 47% held private pilot certificates, 28% held commercial certificates. Twenty-five percent had less than 100 hours of total flight hours, 43% reported between 101-200 total flight hours, 25% percent reported 201-400 hours of total flight time, and seven percent reported between 401-1,000 total flight hours. These demographics are shown in Table 2.

Table 2.
Summary of participant demographics

Gender		
Male	29	91%
Female	3	9%
Total	32	100%
Enrollment Status		
Freshman	9	28%
Sophomore	11	34%
Junior	7	22%
Senior	4	13%
Combined Degree	1	3%
Total	32	100%
Highest Certificate Held		
Student	8	25%
Private	15	47%
Commercial	9	28%
Total	32	100%
Flight Hours		
<100	8	25%
101-200	14	43%
201-400	8	25%
401-1000	2	7%
Total	32	100%

Note. The percentages were rounded to the nearest whole number.

Research Question One

Is there a significant difference between the time of day (8:00 a.m., 12:00 p.m., 4:00 p.m., and 9:00 p.m.) and the median KSS scores?

In order to answer the first research question, the first analysis conducted was for the KSS measures. After four weeks of data collection, 2,789 total data points were obtained. Figure 1 shows the box plot for distribution of the reported KSS scores.

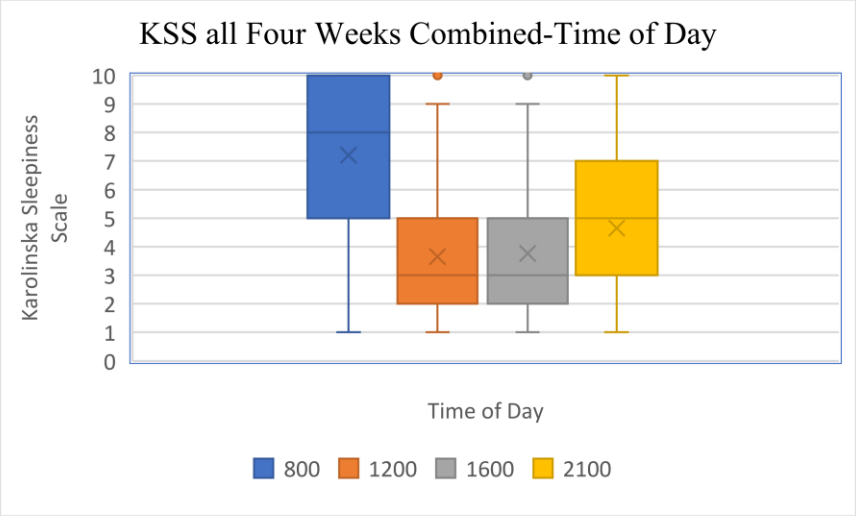

Figure 1. KSS box plot for all four weeks combined and time of day.

A Kruskal-Wallis H-test was run to determine if there were significant differences between the KSS scores during the four time periods of the day: Morning 8:00 a.m. (*n* = 707), Noon 12:00 p.m. (*n* = 704), Afternoon 4:00 a.m. (*n* = 698), and Night (9:00 p.m. (*n* = 680). Distributions of median KSS scores were similar for all identified time periods of the day, as assessed by visual inspection of the boxplot. Median KSS scores decreased from Morning 8:00 a.m. (*M*= 8-Sleepy, but some effort to keep awake), to Noon 12:00 p.m. (*M* = 3-Alert), remained the same for the Afternoon 4:00 a.m. (*M* = 3 Alert), then slightly increased for the Night 9:00 p.m. period (*M* = 5-Neither alert nor sleepy). The median KSS scores were statistically significantly different between time of day, $\chi 2(3) = 600.532$, $p < .001$.

Subsequently, pairwise comparisons were performed using Dunn's (1964) procedure. A Bonferroni correction for multiple comparisons was made with statistical significance accepted at the $p < .0083$ level. This post hoc analysis revealed statistically significant differences in KSS scores between all the times periods of day except for the Noon 12:00 a.m. and Afternoon 4:00 p.m. time periods. Table 3 shows the pairwise comparisons for the time of day and KSS scores.

Table 3.
Pairwise comparisons of time of day and KSS scores

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
12:00 p.m.-4:00 p.m.	-42.167	42.723	-.987	.324	1.000
12:00 p.m.9:00 p.m.	-312.774	43.006	-7.273	.000	.000
12:00 p.m.-08:00 a.m.	924.303	42.586	21.704	.000	.000
4:00 p.m.-9:00 p.m.	-270.607	43.097	-6.279	.000	.000
4:00 p.m.-08:00 a.m.	882.136	42.678	20.670	.000	.000
9:00 p.m.-08:00 a.m.	611.529	42.961	14.234	.000	.000

Note. Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .05.
a. Significance values have been adjusted by the Bonferroni correction for multiple tests (.0083).

Research Question Two

Is there a significant difference between the time of day (8:00 a.m., 12:00 p.m., 4:00 p.m., and 9:00 p.m.) and the median SPS scores?

In order to answer research question two, the second analysis was conducted for the SPS measures. After four weeks of data collection, 2,738 total data points were obtained for all four time periods 8:00 a.m., 12:00 p.m., 4:00 p.m., and 9:00 p.m. Figure 2 shows the box plot for distribution of the reported SPS scores.

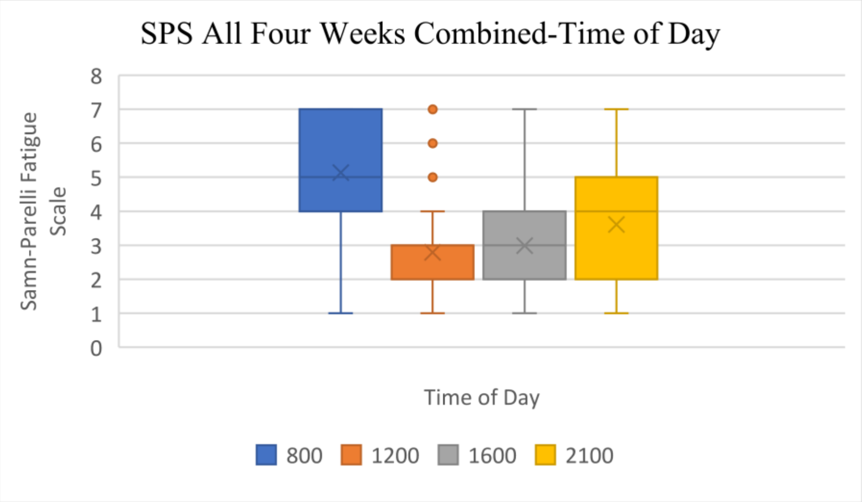

Figure 2. SPS box plot for all four weeks combined and time of day.

A Kruskal-Wallis H test was run to determine if there were differences in SPS scores between the four time periods of the day: Morning 08:00 a.m. (*n* = 700), Noon 12:00 p.m. (*n* = 682), Afternoon 4:00 (*n* = 677), and Night 9:00 (*n* = 679). Distributions of median SPS scores were similar for all the identified time periods, as assessed by visual inspection of the boxplot. Median SPS scores decreased from Morning 08:00 a.m. (*M* = 5-Moderatley tired, let down), to Noon 12:00 p.m. (*M* = 3-Okay, somewhat fresh), remained the same for the Afternoon 4:00 p.m. (*M* =3-Okay, somewhat fresh), then slightly increased for the Night 9:00 p.m. period (*M* = 4-A little tired, less than fresh). SPS scores were statistically significantly different between time of day, $\chi2(3) = 600.205$, $p < .001$.

Subsequently, pairwise comparisons were performed using Dunn's (1964) procedure. A Bonferroni correction for multiple comparisons was made with statistical significance accepted at the $p < .0083$ level. This post hoc analysis revealed statistically significant differences in SPS scores between all the times periods of day except for the Noon 12:00 p.m. and Afternoon 4:00 p.m. time periods. Table 4 shows the pairwise comparisons for the time of day and SPS scores. Both scales provided similar evidence to fatigue levels at the recorded times.

Table 4.
Pairwise comparisons of time of day and SPS scores

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
12:00 p.m.-4:00 p.m.	-106.178	42.309	-2.510	.012	.073
12:00 p.m.-9::00 p.m.	-394.690	42.278	-9.336	.000	.000
12:00 p.m.-08:00 p.m.	935.998	41.959	22.307	.000	.000
4:00 p.m.-9:00 p.m.	-288.512	42.356	-6.812	.000	.000
4:00 p.m-08:00 a.m.	829.820	42.038	19.740	.000	.000
9:00 p.m.-08:00 a.m.	541.308	42.006	12.886	.000	.000

Note. Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .05.
a. Significance values have been adjusted by the Bonferroni correction for multiple tests (.0083)

Research Question Three

Is there a significant difference between days of the week and the median KSS scores?

Regarding the KSS by days of the week, there were 2,797 data points collected. Figure 3 shows the box plot for distribution of the reported KSS scores.

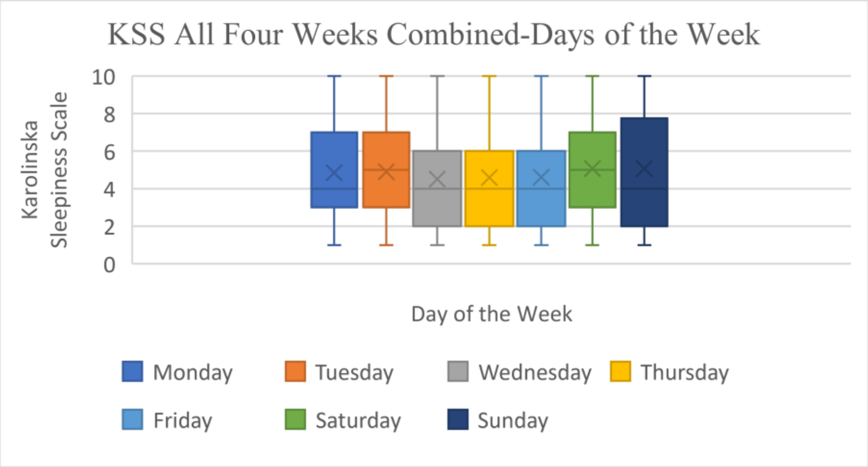

Figure 3. KSS box plot with all four weeks combined and days of the week.

Another Kruskal-Wallis H test was run to determine if there were differences between KSS scores and each day of the week: Monday (*n* = 432), Tuesday (*n*= 412), Wednesday (*n* = 407), Thursday (*n* = 407), Friday (*n* = 390). Saturday (*n* = 377), and Sunday (*n* = 372). Distributions of median KSS scores were similar for all seven days of the week, as assessed by visual inspection of the boxplot. Median KSS scores were also similar for each day. Monday (*M* = 4- A Rather Alert), Tuesday (*M* = 5-Neither alert nor sleepy), Wednesday (*M* = 4- A Rather Alert), Thursday (4- Rather Alert), Friday (4- Rather Alert), Saturday (*M* = 5- Neither alert nor sleepy), and Sunday (*M* = 4- Rather Alert). Median SPS scores were not statistically significantly different between the days of the week, $\chi 2(3) = 12.422$, $p = .053$.

Research Question Four

Is there a significant difference between days of the week and the median SPS scores?

The fourth and final statistical test is for the SPS scores and days of the week. After four weeks of data collection, 2,817 total data points were obtained for all seven days of the week. Figure 4 shows the box plot for distribution of the reported SPS scores.

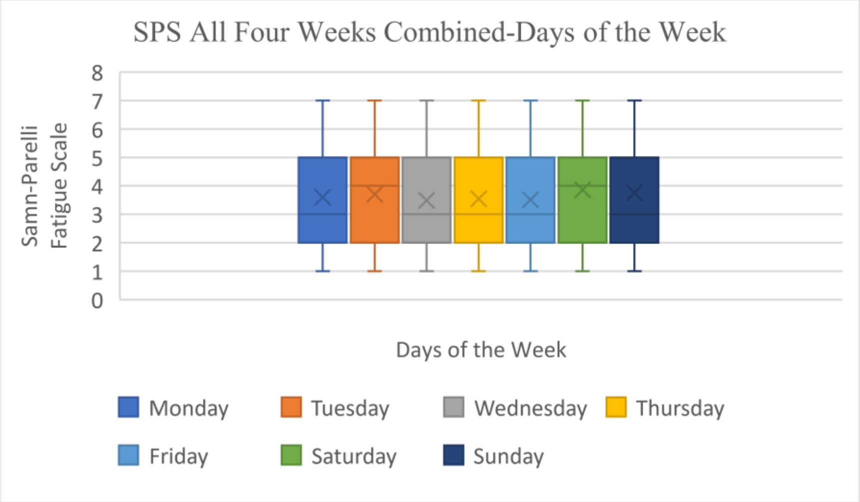

Figure 4. SPS boxplot with all four weeks combined and days of the week.

The final Kruskal-Wallis H test was run to determine if there were differences in SPS scores between each day of the week: Monday (*n* = 438), Tuesday (*n*= 412), Wednesday (*n* = 403), Thursday (*n* = 409), Friday (*n* = 402). Saturday (*n* = 386), and Sunday (*n* = 367). Distributions of median SPS scores were similar for all days of the week, as assessed by visual inspection of the boxplot. Median SPS scores were also similar for each day. Monday (*M* = 3-Okay, somewhat fresh), Tuesday (*M* = 4-A little tired, less than fresh), Wednesday (*M* = 3-Okay, somewhat fresh), Thursday (*M* = 3-Okay, somewhat fresh), Friday (*M* = 3-Okay, somewhat fresh), Saturday (*M* = 4-A little tired, less than fresh), and Sunday (*M* = 3-Okay, somewhat fresh). Median SPS scores were not statistically significantly different between the days of the week, $\chi 2(3) = 9.900$, $p = .129$. Both scales provided similar evidence.

Discussion and Conclusion

This study is part of larger research effort and sought to understand fatigue and sleepiness among collegiate aviation pilots at a large Midwestern university. The collegiate aviation flight training environment is the primary source for producing professional pilots in the industry. Therefore, they must be trained appropriately and prepared for their current training environment and future challenges as professional pilots in the industry. Collegiate aviation is safe. This is proven by the thousands of successful flight training operations that occur each year. However, pilot fatigue is a serious detriment to aviation safety and can inhibit learning as well as student progress. A proactive approach through data collection is necessary to mitigate threats to safe flight operations (ICAO, 2012). This study provided robust information for not only collegiate aviation pilots but also flight training managers. The Kruskal-Wallis H test provided evidence the sample population was mostly fatigued and sleepy during the 08:00 a.m. recording time. This result is in alignment with previous research. According to Mello et al. (2008), the most errors by pilots were committed in the morning hours when fatigue levels were high. Interestingly, a previous study by Mendonca et al. (2019) suggested that collegiate aviation pilots are more fatigued during the early hours of the day (6:00am to 9:00am).

There were no significant differences found between the days of the week for both the KSS and SPS scales. Interestingly, the participants median SPS score for each day of the week ranged from *3-Okay, somewhat fresh* to *4-A little tired, less than fresh* while the KSS median score ranged from *4-Rather alert* to *5-Neither alert nor sleepy*. This may indicate the participants were slightly sleepy and fatigued while making it through each day. Desirably, students should feel alert, fresh, and lively throughout the day. It is not new knowledge that best method to prevent fatigue is getting enough rest (Caldwell, 2012; ICAO, 2016). According to Romero et al., (2020), collegiate aviation pilots have struggled to get adequate sleep in both quantity and quality. This may be due to inadequate sleep preparation including preparing a proper sleeping environment i.e. temperature, putting away electronic devices, noisy dorm rooms, and planning for 7-9 hours of sleep. Additionally, Mendonca, Keller, and Lu (2019) found that students battle with having healthy lifestyles. Therefore, future research can further examine the barriers to effective sleep and lifestyle habits. This can be accomplished through focus groups and interviews. Though it is impossible to control student behavior outside of the classroom, it is possible that proper research-based training and education can promote desirable behaviors.

The authors acknowledge this study had several limitations. It was conducted at one collegiate aviation program and resources were limited. Additionally, there is potential bias in self-reporting data such as reluctance to be truthful and reporting the true nature of the fatigue level. Moreover, the researchers utilized a convenience sampling method, which unfortunately, did not include flight instructors. Caution should be given towards generalizing the results of this study to all collegiate aviation pilots. Furthermore, the researchers did not ask participants to report what they were doing prior to and the moment of reporting or the quality of their sleep. Nonetheless, results can still provide the foundation for safety efforts and research strategies to mitigate fatigue during flight training.

Practical applications may be derived from this study. Management and faculty can require formal fatigue mitigation and management training to all flight students. Program leaders can continue to develop and implement fatigue risk management systems, as suggested by ICAO (2012). In addition, the use of self-reported measures in conjunction with student workload management should be encouraged. Lastly, it is recommended that a robust assessment of fatigue be conducted prior to adding early morning and or later flight slots for the purpose of increasing capacity. Specific attention should be given to existing early morning and late flight slots as well as student-to-instructor ratio.

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