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Pilot Awareness and Preventative Measures of Ultraviolet Radiation Effects at Altitude

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PILOT AWARENESS AND PREVENTATIVE MEASURES OF ULTRAVIOLET
RADIATION EFFECTS AT ALTITUDE

by

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Bachelor of Science, Everglades University, 2003
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A Thesis
Submitted to the Graduate Faculty

of the

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in partial fulfillment of the requirements

for the degree of

Master of Science
in Aviation

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This thesis, submitted by Michael Eric Thompson in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.



Mark Dusenbury, Ph.D. - Chairperson

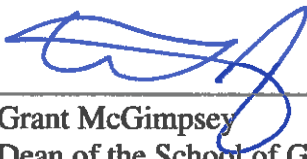


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This thesis is being submitted by the appointed advisory committee as having met all of the requirements of the School of Graduate Studies at the University of North Dakota and is hereby approved.



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Dean of the School of Graduate Studies

April 27, 2017

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 Effects at Altitude

Department Aviation

Degree Master of Science

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Michael Eric Thompson
04/20/2017

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To my loving wife and children,
This was not possible without your support!

ABSTRACT

Ultraviolet radiation exposure to pilots while flying at altitude is an issue that has not been widely distributed to the aviation community. Ultraviolet radiation can have long term effects on pilots, and yet there remains a gap in the practical understanding and the preventative measures that can be taken. The following literature review outlines the potential hazards that pilots face from ultraviolet radiation. The aim of the study was to investigate how UV exposure can affect flight crews at altitude. Armed with this knowledge we need to bring ideas to help produce a greater understanding of the effects UV radiation can have.

Further educational tools will need to be disseminated to the aviation community so that a greater awareness is developed. These preventative steps will develop a culture over time which has the potential to change the way we approach our time in a cockpit. Pilots are driven by a mission, and if new parameters are introduced, such as applying sunscreen before flight, we will see long time benefits.

CHAPTER I INTRODUCTION

Ultraviolet radiation is part of the electromagnetic spectrum wavebands between 100 – 400 nanometers. UV-B (290-320 nm) is the major wavelength responsible for causing sunburn, and it directly damages the cellular DNA. UV-A (320-400 nm) has less energy than UV-B, but it penetrates deeper in the skin and has a negative effect on the human molecules (Chorley et al., 2014). Gone unprotected, the human skin is susceptible to several forms of cancer.

In 2015, a study published in the Journal of the American Medical Association (JAMA) Dermatology described the increased incidence of Ultraviolet (UV) exposure to pilots. They reported, "Pilots flying for 56.6 minutes at 30,000 feet receive the same amount of UV-A carcinogenic effective ultraviolet radiation as that from a twenty-minute tanning bed session" (Sanlorenzo et al., 2015, p.451). In response, major public news agencies, such as the US News and World Report, detailed the risks of sun exposure for pilots (Leonard, 2014).

Flight crews are also exposed to ionizing radiation that is produced by the sun and penetrates the earth's atmosphere. The Federal Aviation Administration (FAA) formally stated in 1994 that airline crews are exposed to ionizing radiation with a corresponding prompt to inform crews of this risk along with potential risks to health (Friedberg & Copeland, 2003). This report prompted questions of what is ionizing radiation and how radiation effects the crew

The definition of ionizing radiation is "subatomic particles that, on interacting with an atom, can directly or indirectly cause the atom to lose an electron or even break apart its nucleus. Such occurrences in body tissue may cause health issues" (Friedberg & Copeland, 2003, p. 1). While ionizing radiation is harmful to flight crews it is outside the scope of this research project and therefore the concentration will be on the effects of UV radiation.

According to Chorley, Higlett, Baczynska, Hunter and Khazova (2014), because ultraviolet radiation (UVR) increases by "10-12 percent every 1000-meter altitude", pilots could be exposed to two to three times the ultraviolet radiation than at ground level (p. 936). These authors further state, clouds that reflect both UVR and other components in the sky, increasing the exposure to the eyes. This increase in ultraviolet radiation exposure has multiple effects on pilots. In a meta-analysis conducted by Shantha, Lewis and Nghiem (2015), pilots have approximately "twice the incidence of melanoma compared with the general population." (p. 829). These authors recommend further research on occupational protection. Chorley et al. (2014) suggests, "Information on the levels of solar UV exposures is essential for the assessment of the occupational risk of pilots developing sun-related eye disorders and skin cancers" (p. 936). Based on the research of UV radiation exposure in flight, it is important to increase the awareness of pilots through education and proper gear.

Experimental Hypothesis

A study was conducted to gauge pilot's knowledge of Ultraviolet radiation at altitude. It was designed to find out if any pilots use the proper gear to reduce the effects of ultraviolet radiation at altitude. The experimental hypothesis looked to see if there are

significant difference between the pilots use of sunglasses and sunscreen after viewing an educational video on the negative effects of ultraviolet radiation at altitude.

Statement of the Problem

Pilots may not have the proper training on how to avoid ultraviolet radiation or they are unaware of the increased ultraviolet radiation exposure at altitude. One could argue that a culture has developed among pilots that it is not necessary to wear protective gear. Subsequently, they are not consistently utilizing ultraviolet radiation protective measures. Currently there is a lack of consistent education during pilot training on UV radiation exposure. There is an opportunity to incorporate ultraviolet radiation protection measures into pilot training.

There are preventative tools such as sunglasses, sunscreen and UV protective clothing that are readily available to pilots. Despite the availability of these tools, the challenge exists in connecting the known research to the action of the pilots in the cockpit. Pilots are guided by checklist, yet there is no procedural guidance on how to apply these tools to protect their health.

Research Questions

This study aims to answer the following research questions related to pilot awareness and preventative measures of ultraviolet radiation effects at altitude:

1. Did pilots with over 5000 hours have prior training on the effects of ultraviolet radiation at altitude?
2. Did confidence to identify risk of UV radiation factors increase after viewing the educational video?

3. Did knowledge of UV radiation risks increase after watching the educational video?
4. Are pilots that fly at high altitudes more likely to use sunscreen because of the known risks of UV radiation?
5. Did knowledge of the risks of UV radiation and the preventative measures increase or decrease at 21 days?
6. Did pilots increase their use of sunscreen prior to flying, after viewing the educational video?
7. Did pilots increase their use of sunglasses while flying, after viewing the educational video?
8. Did participating flight departments implement awareness programs because of the education?
9. After viewing the educational video, did the pilots share this information with other flight departments?
10. Are pilots that fly at high altitudes more likely to wear sunglasses because of the known risks of UV radiation?

Key Terms

Ionizing radiation: "subatomic particles that on interacting with an atom can directly or indirectly cause the atom to lose an electron or even break apart its nucleus. Such occurrences in body tissue may cause health issues" (Friedberg & Copeland, 2003, p. 1).

Ultraviolet Radiation: “defined as the waveband 100-400 nm. It is generally subdivided into UV-A (315-400 nm), UV-B (280-315 nm), UV-C (100-280 nm). The main source is from the sun” (Chorley et al., 2014).

kilojoules Per Meter Squared: “a unit of energy equaling 1000 joules”
(Dictionary.cambridge.org Unabridged. Retrieved March 25, 2017 from
Dictionary.cambridge.org website
<http://dictionary.cambridge.org/us/dictionary/english/kilojoule>

CHAPTER II

Review of the Literature

Pilot Exposure to Ultraviolet Radiation

Ultraviolet radiation is part of the electromagnetic spectrum wavebands between 100 – 400 nanometers (Chorley et al., 2014). Ultraviolet radiation was divided into three bands by the Second International Congress on Light in 1932. The three bands were called UV-A, UV-B and UV-C (Lucas, McMichael, Smith, & Armstrong, 2006). See

Table 1. Categories of Ultraviolet Radiation

Type of Ultraviolet Radiation	Electromagnetic Spectrum Waveband (nm)
UV-A	400-315 nm
UV-B	315-280 nm
UV-C	280-100 nm

Per Lucas et al. (2006), ultraviolet radiation is produced by the sun and projected toward the earth. The earth's atmosphere, including the ozone layer is responsible for absorbing all the UV-C and a large percentage of UV-B, while UV-A can pass through the atmosphere untouched.

The amount of UV radiation that pilots are exposed to depends on several factors. The variation in UV exposure for pilots can be attributed to the time of day, light reflection from clouds or ground snow, the position of the sun, different types of aircraft windshields, and the pilots use of sunglasses (Chorley et al., 2014). Another major factor

that these authors have highlighted is the altitude at which commercial aircraft fly. “UV radiation increases by 10-12 percent every 1000 m in altitude. This translates to a 170-290 percent increase in UV radiation between sea level and a cruise altitude of 35,000.” (Chorley et al., 2014, p. 895).

Chorley et al. (2014) conducted a study to examine how UV exposure can be measured in a cockpit during an actual flight. The objective was to obtain an occupational dose that could then be compared with international guidance. Different types of equipment were used to measure the UV-A irradiance and Blue Light irradiance at cruise altitudes. The results showed UV-A irradiance measured from a fixed position off the aircraft’s windscreen to increase by a factor of 50 in comparison to the measurement taken at ground level. In addition, Blue Light irradiance increased by a factor of 50-60 when compared to the measurement taken at ground level.

Chorley et al. (2014) concluded that during the example flight listed above, the crew was subjected to 97 kilojoules per meter squared level of UV-A exposure. Ocular UV-A exposure for this flight measured 20 kilojoules per meter squared looking down and 26 Kilojoules per meter squared looking forward. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has set exposure limit values on ocular UV-A radiation to not exceed 10 kilojoules per meter squared within an 8-hour working day (Chorley et al. 2014).

Negative Effects of Ultraviolet Radiation

Because UV radiation increases with altitude, pilots are at greater risk for the damaging effects UV radiation can cause. Pilots have a higher occupational risk of developing UV radiation related skin cancer and eye disorders (Chorley et al., 2014

Cancer. Because pilots are exposed to long periods of UV radiation, skin cancer is a concern. The most common types of skin cancer are melanoma and nonmelanoma which includes basal cell carcinoma (BCC) and cutaneous squamous cell carcinoma (SCC) (Diepgen, Fartasch, Drexler & Schmitt, 2012). Occupational skin cancer was not always linked to UV radiation exposure in the industrial workplace but thought to be more related to chemical carcinogens or ionizing radiation (Diepgen et al., 2012, p. 76).

UV radiation exposure is not limited to just pilots while flying at altitude. Outdoor occupational workers have a high risk as well, but there seems to be a lack of awareness to the effects of UV radiation exposure as they perform their duties. A study done by McCool, Reeder, Robinson, Petrie and Gorman (2009) outlined the perceptions from outdoor workers of the risks of excess sun-exposure. The study took 1,131 outdoor workers from nine occupational groups and were given a questionnaire, which covered the areas of skin cancer awareness and knowledge of sunscreen use.

In the study the authors found significant differences between occupational and social demographics. Females were more concerned with the effects of sun-exposure than males, as were the older workers to younger workers. There was a perceived level of priority difference with males being less concerned with sun protection than females. Younger workers had a higher priority with sun protection compared to older and less educated Outdoor workers.

Ultraviolet radiation exposure causes physical changes. Ultraviolet radiation causes chronic skin damage which will result in wrinkles in the skin and a change from a person's original skin color to red or brown spots. The alarming effect from UV radiation is the carcinogenic damage to the skin and eyes. UV radiation damages cells,

which in turn decreases the immune system (Diepgen et al., 2012). Occupational sun exposure is one of the main risks for both basal and squamous cell cancers. Basal cell carcinoma (BCC) arises from the human skin and can be extremely invasive and destructive. Squamous cell carcinoma (SCC) also has a destructive pattern and it metastasizes, leaving a brown or red scaly area on the individual's skin (Diepgen et al., 2012). Both BCC and SCC are primarily found in fair colored skin individuals.

Author Carrera et al. (2013) emphasizes that sun exposure is the greatest risk factor for skin cancer, stressing that primary prevention measures must be taken to reduce risks. Interestingly, the eyes are also susceptible to cancer just as the skin (Behar-Cohen et al., 2014). Chronic effects of the sun are cumulative over time. Even on a cloudy day there is a risk of damage due to increased scatter by the clouds, with different levels of reflection depending on the surface (Behar-Cohen et al., 2014). Table 2 demonstrates how different surface types have a greater reflectiveness.

Table 2. Percent Reflectiveness of UV Radiation

Surface Type	Percent Reflectiveness of UV Radiation
Grass	2 – 5 %
Concrete	10 %
Snow	94 %

This is important to note for pilots who work in conditions of sun exposure, and sun reflection.

Ocular Effects. Pilots exposure to UV-B is greatly reduced by the type of aircraft windscreen used, but the amount of UV-A and short wavelength blue light entering the cockpit remains harmful to the human eyes. A large percentage of UV radiation is absorbed by the cornea and lens, with less than one percent absorbed by the retina. They

further note, that short wavelength blue light penetrates the retina ten percent of the time, and over time has shown to deteriorate its structure (Chorley, Evans, & Benwell, 2011).

It has been widely known for over a century that there is a correlation between sunlight exposure and the development of cataracts, with a granular look at UV radiation as the source (Behar-Cohen et al., 2014). Further studies have been conducted on a wide range of ocular pathologies. One such study indicates pilots have a higher incidence of cataracts (Chorley et al., 2011). Another study has indicated that UV radiation could be associated with iris melanoma in individuals with light iris color. The study stresses that these individuals should use effective means of protective measures such as UVR blocking eyewear with anti-reflective coating on the back of the lens (Behar-Cohen et al., 2014).

Aircraft Windshields as a UVR Barrier. For a pilot, an aircraft windshield is the primary barrier from the outside elements and hazards such as rain, snow, sleet and birds (Nakagawara, Montgomery, & Marshall, 2007). Windshields absorb a large percentage of UV-B radiation (Sanlorenzo et al., 2015). A study conducted by Nakagawara et al. (2007) found that a high percentage of UV-A radiation could pass through a commercial aircraft windshield. Standards are required for the manufactures of aircraft windshields but during research Chorley et al. (2011) found that the only optical transmission requirement was for a minimum transmission of the total visible light, allowing UV-A to pass through. Most commercial aircraft windshields are built by PPG Aerospace, and are comprised of a multilayer tempered glass construction. The design is made for strength and de-icing capabilities.

Tools for UV Protection

Tools for sun protection are described by their Ultraviolet protection factor (UPF) rating. There are different variables that can change the effectiveness of the UPF. The UPF rating can further be delineated by the effectiveness against UV-A and UV-B rays. Clothing, eye protection and sunscreen are all tools that can be utilized. It is recommended that clothing have a UPF rating of greater than forty (Diepgen et al., 2012).

Clothing. We think of sunscreen as having a sun protection factor (SPF) as a protective measure against harmful UVB radiation. Clothing has its own classification known as UV protection factors (UPF) which describes its benefit of protecting against UVB and UVA (Diaz & Lee, 2012). Clothing can be an effective barrier to sun exposure, however there are many variables. The type of fabric, the tightness of the weave, the color, and the weight of the fabric can all influence the effectiveness (Diaz & Lee, 2012). Even the way the clothing is washed can be a factor. Unbleached fabrics reflect and absorb more UV than bleached fabrics. Diaz and Lee (2012) found that, "denim has a UPF of 1,700 compared to cotton which has a UPF of 5 to 9" (p. 112). They also share that loose-fitting clothing affords a higher UPF than tight or wet clothing.

In recent years, the ability to impregnate fabric with UVA and UVB absorbing particles, has allowed lighter weight clothing to become an effective option for protection. There continues to be a larger scale development of photoprotective clothing lines, each having their own UPF rating displayed on the tags (Diaz & Lee, 2012). Clothing is a better protector if the sleeves are long, the neck is high, and the legs are covered (Diepgen et al., 2012). UPF ratings are found on clothing tags. Hats, rated by

their sun protection factor (SPF), can also be a tool to use. In addition, hats with 360 degree brims offer the highest protection.

Combining the effects of sunscreen (SPF) and the benefits of the UV protection factors of light-weight clothing, there is a greater barrier to the harmful UV radiation effects.

Eyewear. Sunglasses are another tool to use against UV radiation effects.

Whereas clothing utilizes the UPF rating, and hats use the SPF rating, eyewear is now using a new label of E-SPF which stands for eye-sun protection factor (Behar-Cohen et al., 2014). These authors explain E-SPF rating takes into consideration both the UV transmission and the UV reflectance of the glasses since UV reflection from the inside can cause considerable eye exposure. It is accepted that eyewear aids in protecting the eye from UV damage (Behar-Cohen et al., 2014). What type of glasses, the shade of glasses, and reflective coating are all factors that continue to be studied.

Sunscreen. Studies have shown that the risk of skin cancer is directly related the time one spends outdoors (McCool, Reeder, Robinson, Petrie & Gorman, 2009).

According to these authors "Improving sun protection among outdoor workers is an identified public health and occupational health issues in New Zealand and elsewhere" (p. 404). Because modifying to off peak sun exposure is not an option for pilots, sunscreen can be utilized to decrease the risk of cancer. Most sunscreens today are made to absorb, filter and reflect UV light from both UVA and UVB exposure. Many factors affect the protection capabilities of sunscreen such as time of day, altitude, sweating and water exposure (Diaz & Lee, 2012). It is recommended to use a sunscreen with an SPF of 15,

at least. Reapplications are stressed every two to three hours. Caution should be taken as there are no UV indicators to give any warning signs of exposure.

Conclusion

Ultraviolet radiation in the cockpit is a risk to pilots. The literature emphasized the ultraviolet exposure to pilots at altitude. The literature review revealed a host of damaging effects to the eyes, skin and cancer effects. Preventative measures referred in the literature are currently available to pilots and include sunscreen, sunglasses, clothing and sunvisors.

CHAPTER III

Methodology

Pilots participate in various training throughout their career; however, there is a lack of literature on the training for pilots protection from UV radiation. This study plans to address this gap by increasing both knowledge of UV radiation exposure and the awareness of available preventative measures.

Project Purpose

The purpose of this study was to increase pilot awareness of the possible effects of ultraviolet radiation at altitude. The study has three goals:

1. Pilots will have increased knowledge of the effects of UV radiation at altitude.
2. Pilots will report increased use of preventative measures such as sunscreen, sunglasses and long sleeves.
3. Pilots will confirm that they have shared their knowledge of preventative measures with other pilots.

Research Design

This was a study with a single-group, pre-test and post-test design with a twenty-one day follow up survey. The survey design suggests the collection of pre-test baseline data, and then post-test outcome data at the individual level (Creswell, 2014).

Study Population

The study population was comprised of twenty-two corporate pilots from four flight departments located in the Mid-west area. The inclusion criteria consisted of those who were currently flying mid-size or large corporate jet, consistently above 40,000 feet. The selection process warranted a convenient sample, as the limited number of available pilots prevented a random sample. This was a quantitative study.

Data Instruments and Collection Methods

Institutional Research Board (IRB) approval was obtained for this project. The data instrument used was Qualtrics Survey®, a web based survey tool. Microsoft Excel®, IBM SPSS® and the Qualtrics® web based survey tools were utilized to conduct statistical testing and analysis on the collected datasets.

The author of this research paper has twenty-five years of experience in commercial aviation and used this knowledge to develop the research questions. For the self-efficacy questions, a Likert scale survey was used, requiring answers that range from: strongly disagree, disagree, agree, strongly agree.

One week prior to the surveys being emailed out, a call to the Chief Pilot's office of each flight department was made to request participation in this survey. Once permission was granted by the Chief Pilot, a recruitment email was sent to all the accepting participants. The recruitment email outlined the purpose of the study with the following steps to be taken.

First the participant was asked to take a pre-education survey utilizing a Qualtrics® hyperlink. The pre-education survey started with an informed constant

statement attached, followed by questions broken down into three components: demographics, knowledge, and self-efficacy.

Secondly, the participant utilized a hyperlink to access an educational video. This video was created from a power point slideshow and distributed through Vimeo video sharing. The informational curriculum was designed to inform the participants of the hazards of UV radiation along with preventative measures. The educational video was developed by the author of this paper, as his own experience in commercial aviation provided the hands-on knowledge needed to provide the proper education.

Thirdly, the participant completed a post-educational survey utilizing a Qualtrics® hyperlink, consisting of the same components. This survey will be used to see what they learned from the educational video.

A final survey was sent to all participants via email twenty-one days later. The follow up survey was accessed by a Qualtrics® hyperlink. The survey consisted of the same components as the pre-education and post-education survey with some additional questions. These questions were designed to capture any changes the participant made in their operating procedures because of the education received.

The flow pattern for the study was to conduct the pre-education survey, watch the educational video, and then take the post-survey. The follow survey was sent to each participant twenty-one days later. Figure 1 demonstrates this process.

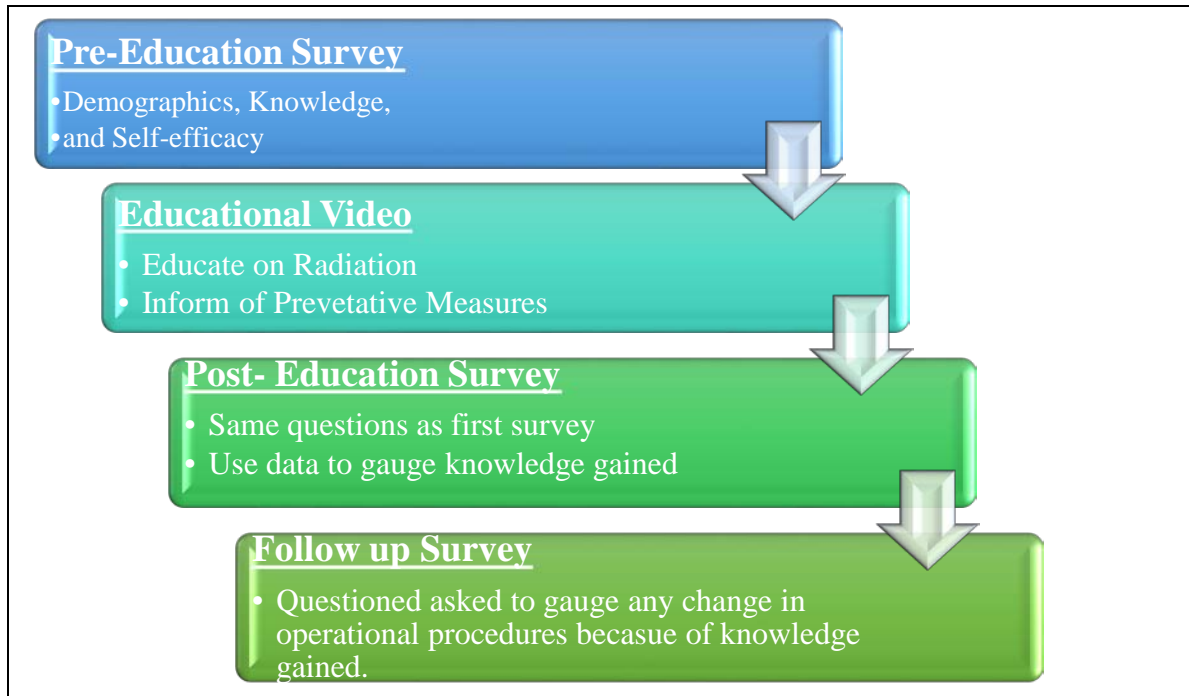


Figure 1. Collection Method Flow Chart

Course Description

An educational video with voice over from the primary investigator was provided for each participant. The video was designed to bring awareness of the risk that ultraviolet radiation has on pilots flying at altitude. To help mitigate the associated risks, participants learned about proactive measures such as applying sunscreen and sunglasses.

Variables in the Quantitative Survey Questions

To gain data on the participating pilot’s knowledge regarding the effects of ultraviolet radiation and preventative measures, the same survey was given during the project (Table 3). A pre and post-educational survey, followed by a twenty-one day follow up survey was given to the participants. Each survey contained questions that covered demographics, knowledge and self-efficacy (Table 3).

Table 3. Variables Collected in Quantitative Survey

	Abbreviated Questions	Answers
Categorical	Pilots receive more UV radiation at 30,000 feet vs. 10,000 feet?	True
Categorical	The incidence of melanoma in pilots is?	Twice that of general public
Categorical	Aircraft with laminated windshields are designed to block?	UVB but a high percentage of UVA can pass through
Categorical	UV exposure in the cockpit leads to?	Cataracts and iris melanoma
Categorical	Sunglasses and sunscreen have their own rating system?	Yes or No
Categorical	Ocular damage is increased by?	A low E-SPF and back reflectance from sunglasses.
Categorical	Do you wear sunglasses in the cockpit?	Yes or No
Categorical	Do you know the E-SPF rating of your sunglasses?	Yes or No
Categorical	UVA and UVB sunscreen is made to do the following?	All of the above
Categorical	Do you apply sunscreen before flying?	Yes or No
Categorical	Which of the following increases risk of UV radiation exposure?	All of the above
Categorical	Formal training of occupational exposure to UV radiation?	Yes or No
Categorical	Formal training of preventative measures of UV radiation exposure?	Yes or No
Categorical	What type of shirt so you wear?	Short or long sleeve
Categorical	Does your flight department have reminders about self-protection from UV exposure?	Yes or No Fill in the blank

Table 3. cont.

Variable Type	Abbreviated Questions	Answers
Continuous	How many flight hours have you logged?	#
Continuous	Under what FAR do you fly?	91, 135, 121
Continuous	What is your aircraft cruising level?	#
Continuous	How many hours a month do you fly?	#
Interval	I am confident that I can identify UV risk factors in the cockpit.	Likert scale 1-5
Interval	I am confident that I know what preventative measures to take to avoid UV radiation.	Likert scale 1-5
Categorical	Following the UV radiation education, are you consistently wearing sunglasses in the cockpit?	Yes or No
Categorical	Following the UV radiation education, are you consistently wearing sunscreen in the cockpit?	Yes or No
Categorical	Since the UV radiation education, have you shared this information?	Yes or No
Categorical	Since the UV radiation education, have you changed uniforms?	Yes or no

CHAPTER IV

Data Analysis and Interpretation

Demographics of Study Population: Research Question One

In a preliminary study of 22 pilots, the demographics included experienced pilots with over 5000 hours of flight time. Notably, this expert group of pilots have 5000 hours at an altitude above 39,000 feet and yet there was a lack of knowledge of the ultraviolet radiation hazards. With over 90 percent never formally trained on the health risks, this pilot group has a high potential of harmful effects of ultraviolet radiation, a potential target for practice change.

It is interesting to note the lack of standard uniform for the pilots (55.56 percent short sleeve and 44.44 percent long sleeve). The literature search reveals a constant exposure to ultraviolet radiation and yet there is not a standard design to utilize uniforms as a protective barrier. Rather, the unstandard uniforms suggest possible focus of style instead of a utilitarian function that should be standardized. Other industries such as the medical field and nuclear plants have instituted regulatory safeguards with regard to uniforms as a protective tool (Diepgen et al., 2012). Further research to incorporate UV impregnated clothing and standard long sleeve style, could create a consistent preventative use amongst pilots.

The three surveys and educational video were sent to twenty-two pilot participants. The response rate included eighteen (81.8 percent) with the pre-educational

survey, seventeen (77.3 percent) with the post-educational survey, and eleven (50 percent) with the follow up survey. Of the participants, 100 percent had over 5000 hours of flight time, with 38.89 percent logging over 8000 hours. 100 percent of the pilots fly under Federal Aviation Regulation Part 91 with an aircraft cruising altitude above 39,000 feet. The pilot respondents (100 percent) flew an average of 11-50 hours per month.

In the pre-educational survey, 55.56 percent of the pilots wore a short sleeve uniform and 44.44 percent wore long sleeve. To address research question one, did pilots with over 5000 hours have prior training on the effects of ultraviolet radiation at altitude? Of the respondents, 88.89 percent stated they had not received formal training on the hazards of occupational UV radiation exposure. There was 94.44 percent of the subjects never trained on any preventative measures that can be taken against UV radiation exposure.

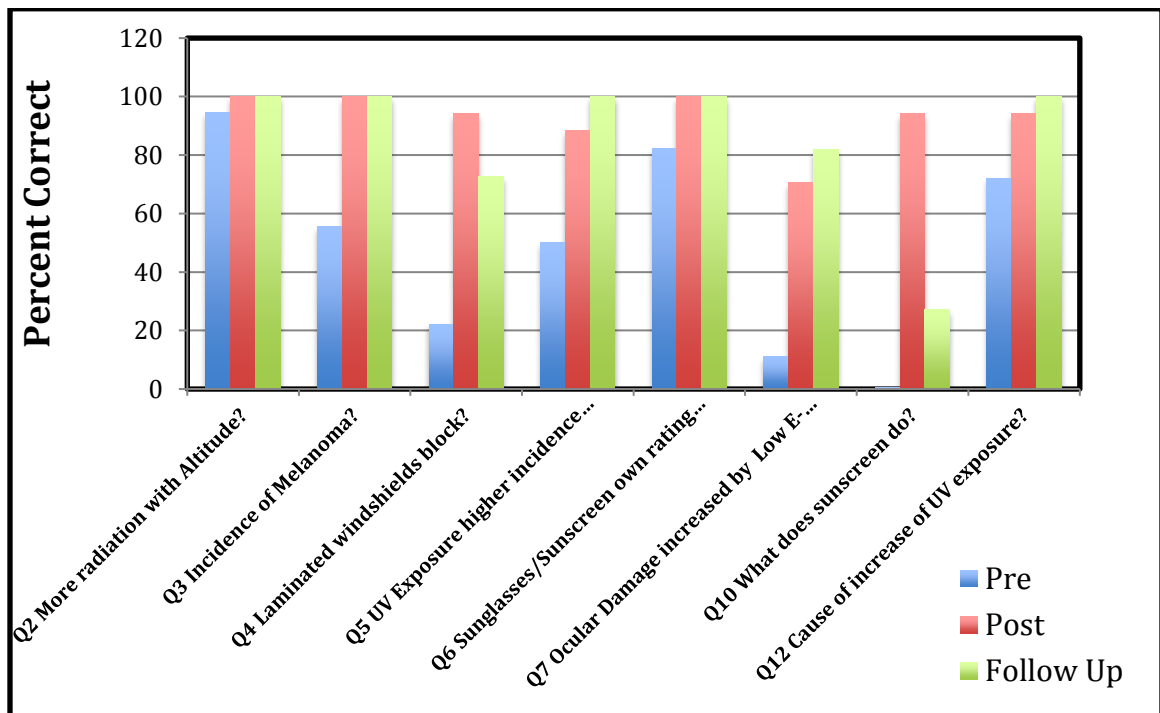
Knowledge of Study Population: Research Questions Three and Five

The research question three queried, "Did knowledge increase after watching the educational video?" Eight questions in both pre-survey and post-surveys, respectively, addressed the pilots' knowledge of UV radiation exposure and preventative measures (Table 3). In the pre-survey 94.4 percent of the pilots knew that UV radiation increased with an increase in altitude. One hundred percent of the pilot group incorrectly answered the question regarding the role of sunscreen in the pre-survey. Only two of the eighteen respondents answered the question regarding ocular damage correctly.

Knowledge increased to over 80 percent for seven of the eight questions in the post educational survey (exception was question number 7 regarding ocular damage (70.59 percent). At the twenty-one-day interval, questions 2,3,5,6,12 were answered

correct. Research question five was asked if knowledge increased or decreased at 21 days? From the post survey to the twenty-one day follow up survey, there was a decrease in the knowledge regarding the role of sunscreen with only three of the eleven follow up survey respondents answered question ten correctly (from 94.14 percent in the post survey to 27.27 percent in the follow up survey), suggesting a decrease in knowledge retention from the initial educational setting. These findings regarding knowledge are illustrated in Table 4.

Table 4. Survey Questions Percent Correct

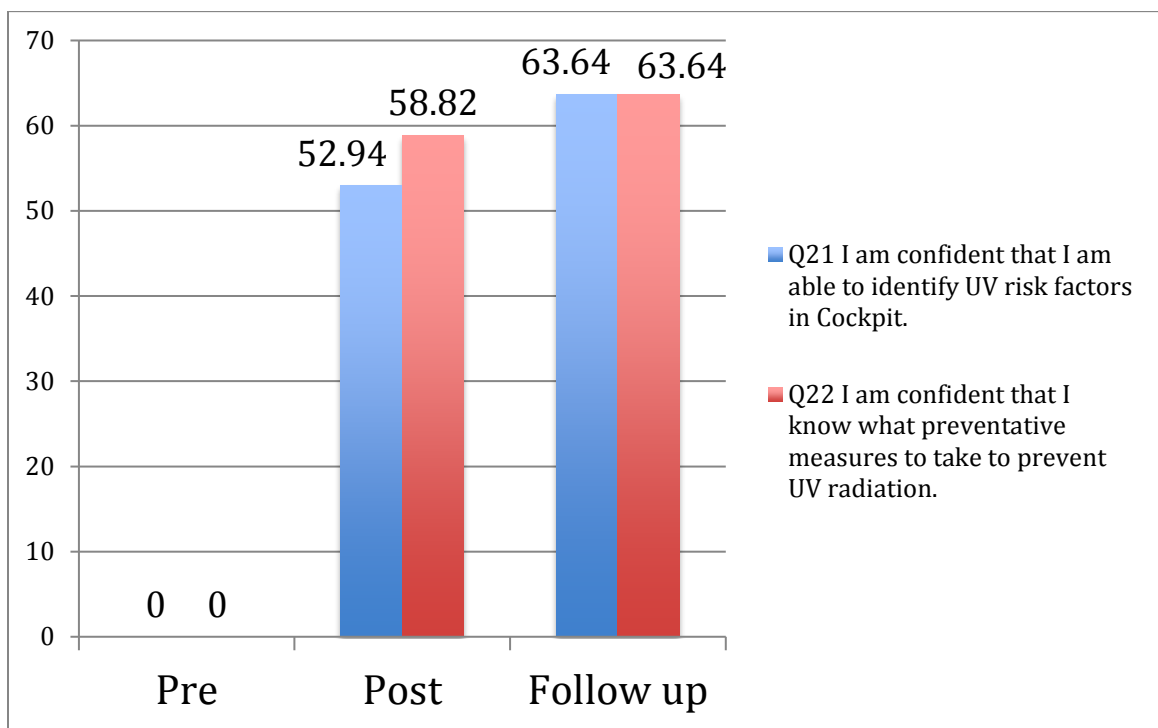


Confidence: Research Question Two

Research question two asked, "Did confidence to identify risk of UV factors increase after viewing the educational video?" Two questions on the survey addressed confidence in the pilots to identify ultraviolet risk factors (question number 21) and to take preventative measures (question number 22). In the pre-survey, the pilots had zero

confidence that they could identify ultraviolet risk factors and zero confidence to take preventative measures (Table 5). After viewing the educational video, confidence increased on the post survey to 52.94 percent for identifying risk factors and 58.82 percent for recognizing preventative measures for UV radiation exposure. On the 21 day follow up survey, the pilots had a slight increase to 63.64 percent for both identification of risk factors and preventative measures.

Table 5. Participant Confidence



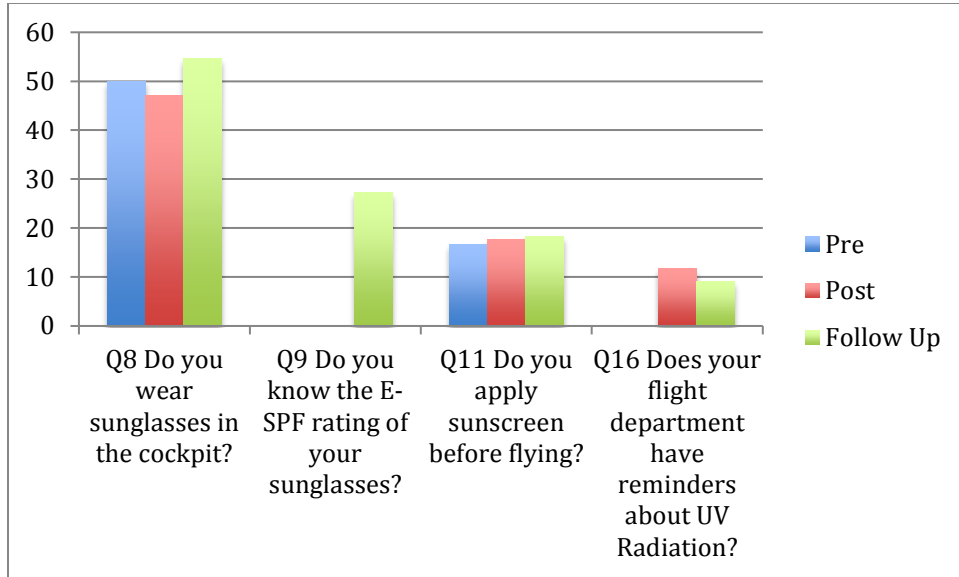
Action Questions: Research Question Seven, Six, Four and Ten

Research question seven asked, "Did pilots increase their use of sunglasses after watching the educational video?" Less than 55 percent of respondents in all three surveys reported wearing sunglasses when flying (Table 6); however, when asked in a different format in the follow up survey, 81.82 percent of respondents stated they wore sunglasses in the cockpit. Research question number six asks, "Did pilots increase their use of

sunscreen after watching the educational video?" Less than 27% of pilots recorded applying sunscreen prior to flying (question 11 and 24). Three pilots (increased from zero) knew the E-SPF rating of their sunglasses in the follow up survey (question 9).

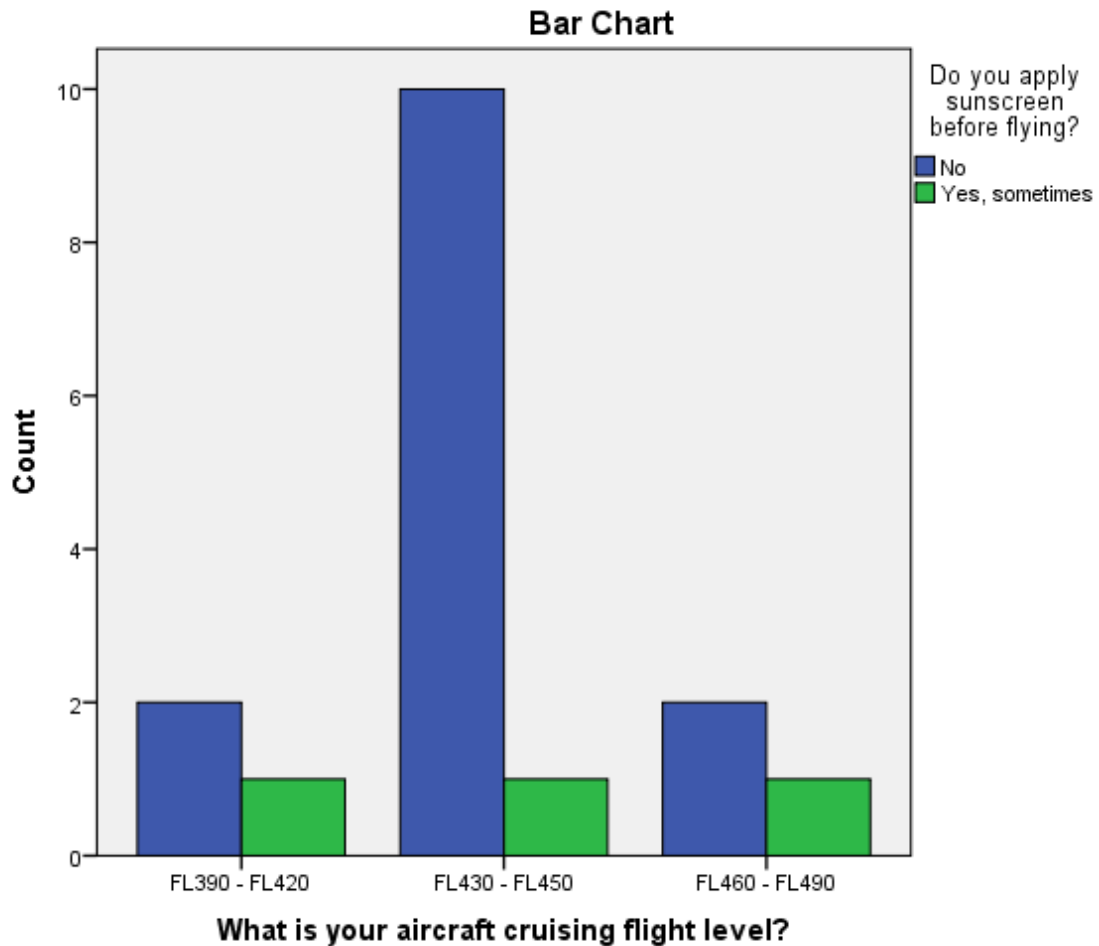
Table 6 illustrates the results from research questions seven and six.

Table 6. Pre, Post and Follow up Survey Responses of Action Items



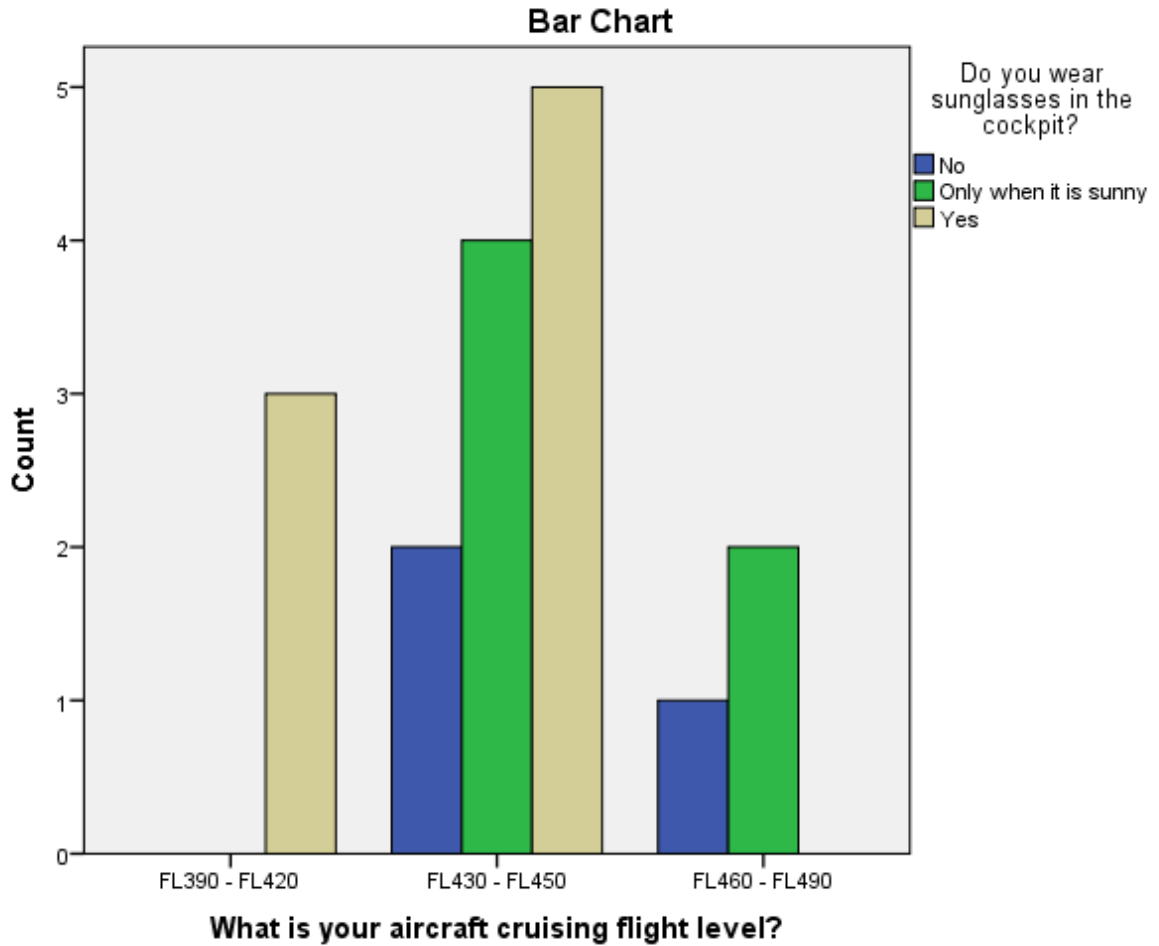
To answer the research question four, "Are pilots that fly at high altitudes more likely to use sunscreen?", a chi-square test was conducted in SPSS to investigate the relationship between a pilot's typical cruise altitude and if they apply sunscreen prior to the flight. The test revealed no significant relationship between the variables, $X^2(2, N=17) = 1.57, p = .46$. Although the results were not significant, descriptive data shows pilots in this sample are not likely to apply sunscreen during high altitude operations (Table 7).

Table 7. Relationship between Altitude and Sunscreen Use



To answer research question ten “Are pilots that fly at high altitudes more likely to wear sunglasses?”, a chi-square test was conducted in SPSS to investigate the relationship between a pilots typical cruise altitude and if they wear sunglasses in the cockpit. The test revealed no significant relationship between the variables, $X^2(4, N=17) = 6.05, p = .20$. Although the results were not significant, descriptive data shows pilots in this sample are likely to wear sunglasses during high altitude operations, particularly when it is sunny (Table 8).

Table 8. Relationship Between Altitude and the Use of Sunglasses



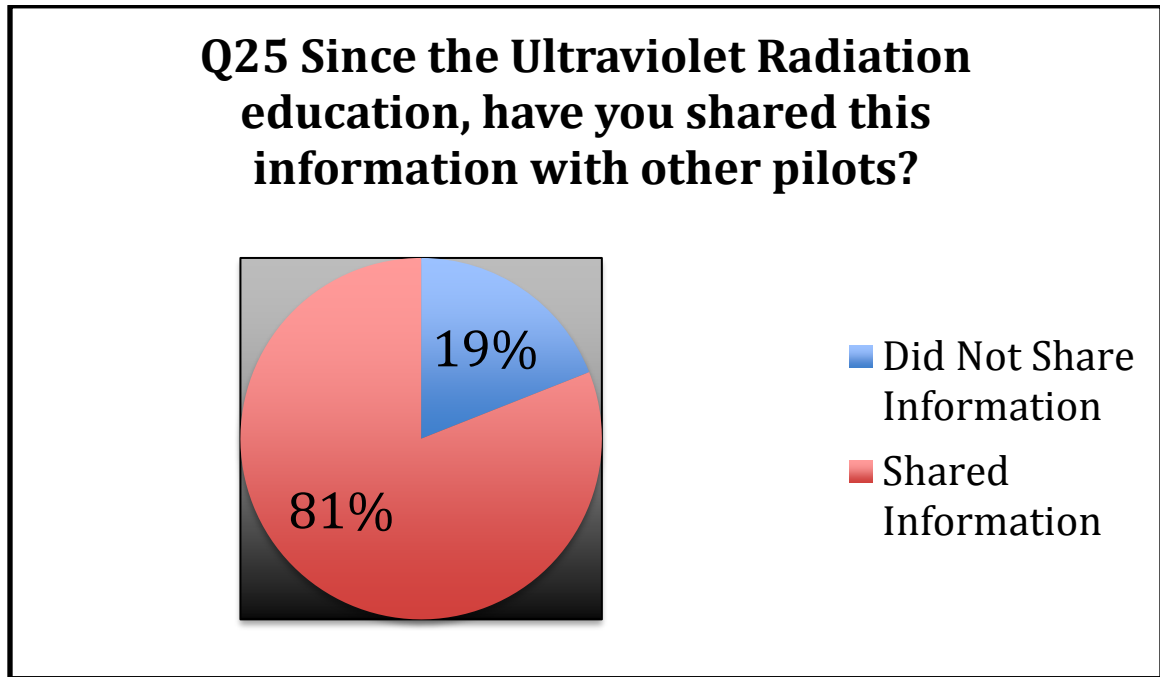
Knowledge Shared with Other Pilots: Research Question Eight and Nine

The assimilation research question nine asked, "After viewing the educational video, did the pilots share this information?" As Table 9 shows, in the post survey, 81% of the respondents shared this information with other pilots. In this way, the initial education session was able to spread beyond the 18 pilots.

The final research question eight asked, "Did participating flight departments implement awareness programs because of the education?" In an open comment area, one

pilot wrote, "After taking the first survey and watching the video, our safety officer decided to hang a sign in the office reminding pilots to "Apply Before you Fly."

Table 9. Dissemination of Information



CHAPTER V

Discussion

In examining the literature and reviewing the data, there are points of discussion with regard to knowledge and confidence results. Although the survey included 22 pilots, the recommendation is to expand on this initial study to share the importance of utilizing the preventative actions that are available.

Knowledge

The series of surveys addressed knowledge of ultraviolet radiation risk and protection. The majority of pilots (94.4 percent) understood the connection of increased ultraviolet radiation and altitude. However in the pre-survey, they did not understand the actual role of sunscreen as a protective tool (100 percent incorrect). In addition, the connection of ocular damage was missed by the majority (88.88 percent). This points to target education that should be emphasized in future studies.

Although knowledge did increase in the post and follow up surveys (Table 4), there was a significant decrease in knowledge in the follow up survey with regard to the role of sunscreen (94.14 percent post survey to 27.27 percent in follow up survey). A focus of the benefits and actual action of sunscreen should be a future focus.

Confidence

In the pre-survey, zero pilots were able to identify UV risk factors or preventative measures. Even after the educational video, this was only raised to 63.64 percent of pilots being able to feel confident to know the preventative measures to prevent the damaging

effects of UV radiation in the cockpit. The question remains why the pilots could not feel confident in understanding the preventative measures. What is blocking the link between knowledge and confidence in this pilot group? Further study should be done to evaluate the effectiveness of the educational tool as a way to create this link between knowledge and confidence.

Action Items

The intent of the educational video was to increase the use of sunscreen and sunglasses amongst this pilot group. However, less than 60 percent wore sunglasses in the follow up survey. Notably, there was an even lower number of action for those applying sunscreen before flying (27 percent). Again, this shows a break down between the acquired knowledge and the application of this knowledge to change practice. Despite the pre-survey knowledge of increased ultraviolet rays at altitude, there was still not a significant relationship between pilots flying at altitude and the application of sunscreen. This is interesting in the fact that the knowledge had increased but lacked the implementation.

Recommendations for Dissemination

Based on this authors experience, there are opportunities to disseminate this health information to a broader audience. The opportunity may be in forming a trademark of "Apply before you Fly!". Slogan signs on entrance doors into the hangar, window clings on the mirrors in the flight department and "Apply before you Fly!" Posters in the training room. Repetition of viewing this slogan may trigger action within the aviation community.

Pilots have an inherent training schedule throughout their career. This allows ample opportunity to reach every pilot on a consistent basis. It is interesting to note that historically the training focus for pilots has been oriented to aircraft expertise with little regard for pilot health and maintenance. A compact three minute video in the simulation pre-brief could be watched, detailing both the health risks of flight and the preventative actions against UV radiation.

Upon entering the simulator, there should be a "Apply Before you Fly!" sign to prompt a conversation from the instructor about the importance of always entering a cockpit with protective sunscreen and sunglasses. In this way, a culture, guided by respected training centers, could be established.

With notable interest, this sample of pilots are required to obtain a First Class Medical every six months from an Aviation Medical Examiner (AME). Notably, the health risks of ultraviolet radiation at altitude could be discussed at each visit, along with a full body skin check. An educational video on ultraviolet preventative measures could be played in the waiting area, and sample sunglasses and sunscreen available.

With the rise of formal aviation training through universities, students should be educated in the possible deleterious effects of ultraviolet radiation and subsequent tools to minimize these effects. With the influence the university has on beginning students, the culture could be developed as an expectation with each flight. Just as a pre-flight is important for a successful flight, applying protective gear is important for a successful healthy career.

Strengths and Limitations

The strength of this study is the identification of health information that has been largely missed in the training of pilots. It is alarming that over 90 percent of pilots were not aware of the harmful exposure to ultraviolet radiation at altitude. The information in the research field of pilot health has not been assimilated into practice for pilots, this research attempts to address this gap. It is important to note that research such as this has not been previously studied within the aviation community.

Although the sample size was small, it is notable that knowledge did not equate to action of greater sunscreen and sunglasses use. This may be used as a target when setting up a statistically significant research study. A strength of maintaining knowledge over time was seen in the series of three surveys, although if this could be lengthened over six months to one year, a greater assessment of knowledge and practice could be done.

The limitations include the small sample size limiting the ability to generalize to the greater pilot population. The respondents were limited to the Midwest and Part 91, which is a limitation as ultraviolet radiation risk is present for all pilots at altitude. This small sample of convenience could have introduced bias. Further limitations include the lack of randomization and a sample that included only pilots with over 5,000 hours. Experienced pilots may be further from current university education that may include health considerations for pilots.

The survey questions in Qualtrics® were not in a statistically validated tool, however, preliminary information gleaned is valuable for further research. In reviewing the responses, it would have been beneficial to ask the follow up question of why the pilots did not apply protective gear, despite the knowledge of the harmful effects of

ultraviolet radiation at altitude. In addition, a question of potential barriers to using protective gear would perhaps assist in understanding moving knowledge into action. In further studies, the survey questions should better align to draw a deeper understanding of why pilots choose not to use preventative measures.

Future Direction

This preliminary study on pilot awareness and preventative measures of ultraviolet radiation at altitude provided insight into the lack of pilot awareness of this topic. The initial goal was to connect awareness into action with each flight. In this small group of 22 pilots, there was no significant change in preventative practice after the provided education.

Further research should focus on the practical implementation of these preventative measures into daily practice. Some examples could include, packets of sunscreen available inside the cockpit, sunscreen dispenser hanging on the wall prior to entering the hangar or crew room. Pilot uniforms could easily be converted to a UPF shirt that would help block harmful UV radiation. One could argue that developing a culture of health conscious pilots could lead aviation in a positive direction.

Research to understand the barriers to moving knowledge into action with regard to health safety measures should be explored. Further studies should be done to identify ultraviolet hazards in the cockpit, such as back reflectance of sunglasses. Advances in technology may promote research for windshields that could block both UVA and UVB rays. Future studies should focus on isolating UV radiation from entering the cockpit. A study to understand human motivation for making health choices would be applicable to incorporating preventative measures for ultraviolet protection.

Conclusion

The literature emphasized the increase in ultraviolet exposure to pilots at higher altitudes. The literature review revealed a host of damaging effects to the eyes, skin and cancer effects. Preventative measures referred in the literature are currently available to pilots and include sunscreen, sunglasses, clothing and sunvisors. Pilots are checklist driven and understand the importance of precisely following them. One could argue that a checklist should be made for health protection prior to entering the cockpit. It is important to take this research and disseminate to the aviation community. Linking the research to actual practice of prevention is vital.

This small study aimed to identify the risk, increase knowledge and inspire action with preventative measures. The pilots gained knowledge, but the challenge still exists of how to implement change amongst the pilot group. By developing a larger awareness with trigger signs, cultural change and education, the "Apply Before you Fly!" message may promote a stronger well being of our pilot force.

APPENDICES

Appendix A
Informed Consent Statement

**UNIVERSITY OF NORTH DAKOTA
Institutional Review Board
Informed Consent Statement**

Title of Project: **Pilot Awareness and Preventative Measures of
Ultraviolet Radiation Effects at Altitude**

Principal Investigator: *Mike Thompson, (612) 562-7178, aviator300@outlook.com*

Advisor: *Mark Dusenbury, (701) 777-5495, dusenbur@aero.und.edu*

Purpose of the Study:

The purpose of this study is to determine a knowledge base among corporate flight departments on the dangers of cosmic and ultraviolet radiation. The study will seek to bring awareness to flight crews and the possible mitigation techniques against the harmful UV radiation. This will be accomplished through a pre-survey followed by an educational video. A post survey will be provided to determine any change in operating procedures of the crews.

Procedures to be followed:

You will be asked 21 questions that pertain to the subject matter explained above. The survey will be divided into three sub-categories: Demographics, knowledge, and self-efficacy.

Risks:

There are no risks in participating in this research beyond those experienced in everyday life.

Benefits:

- You might learn more about yourself by participating in this study. You might have a better understanding how important it is to protect yourself from the effects of UV radiation. You may learn new procedures that you can implement within your corporation.
- You might learn how important it can be to recognize signs of UV radiation exposure.

Duration:

The survey will take about 10 minutes to complete.

Statement of Confidentiality:

The survey, questionnaire, interview, focus group does not ask for any information that would identify who the responses belong to. Therefore, your responses are recorded

anonymously. If this research is published, no information that would identify you will be included since your name is in no way linked to your responses.

All survey responses that we receive will be treated confidentially and stored on a secure server. However, given that the surveys can be completed from any computer (e.g., personal, work, school), we are unable to guarantee the security of the computer on which you choose to enter your responses. As a participant in our study, we want you to be aware that certain "key logging" software programs exist that can be used to track or capture data that you enter and/or websites that you visit.

Right to Ask Questions:

The researcher conducting this study are Mike Thompson. You may ask any questions you have now. If you later have questions, concerns, or complaints about the research please contact Mike Thompson at (612) 562-71787 during the day. If you need further assistance you can contact Mike’s advisor, Mark Dusenbury at (701) 777-5495.

If you have questions regarding your rights as a research subject, you may contact The University of North Dakota Institutional Review Board at (701) 777-4279. You may also call this number with problems, complaints, or concerns about the research. Please call this number if you cannot reach research staff, or you wish to talk with someone who is an informed individual who is independent of the research team.

General information about being a research subject can be found on the Institutional Review Board website “Information for Research Participants”
<http://und.edu/research/resources/human-subjects/research-participants.cfm>

Compensation:

You will not receive compensation for your participation.

Voluntary Participation:

You do not have to participate in this research. You can stop your participation at any time. You may refuse to participate or choose to discontinue participation at any time without losing any benefits to which you are otherwise entitled.

You do not have to answer any questions you do not want to answer.

You must be 18 years of age older to consent to participate in this research study.

Completion and return of the survey implies that you have read the information in this form and consent to participate in the research.

Please keep this form for your records or future reference.

Appendix B
Survey Questions

21 Day Follow Up Survey

Q1 Please enter your Subject ID #

Q2 Pilots flying at 30,000 feet receive more UV radiation than pilots flying at 10,000 feet?

- True (1)
- False (2)
- I don't know (3)

Q3 Studies have shown that the incidence of melanoma in pilots is:

- The same as the general public (1)
- Less than the general public because of the aircraft windshield (2)
- Twice the incidence of melanoma than the general public (3)
- I don't know (4)

Q4 Aircraft with laminated windshields are designed to block

- UVA and blue light (1)
- All UVA and UVB (2)
- Some of UVB, but a high percentage of UVA can pass through (3)
- I don't know (4)

Q5 Ultraviolet radiation exposure in the cockpit leads to a higher incidence to the following:

- Cataracts (1)
- Iris melanoma in those with light iris color (2)
- There is no difference between pilots and general public (3)
- Both A and B (4)
- I don't know (5)

Q6 Both sunglasses and sunscreen have their own rating system for UV protection?

- Yes (1)
- No (2)
- I don't know (3)

Q7 Ocular damage is increased by:

- A low E-SPF index (1)
- A high E-SPF index (2)
- Back reflectance from sunglasses (3)
- Both A and C (4)
- Both A and B (5)
- I don't know (6)

Q8 Do you wear sunglasses in the cockpit?

- No (1)
- Only when it is sunny (2)
- Yes (3)

Q9 Do you know the E-SPF rating of your sunglasses?

- Yes (1)
- No (2)

Q10 UVA and UVB sunscreen is made to do which of the following?

- Absorb both UVA and UVB (1)
- Filter UVA and UVB (2)
- Reflect UVA and UVB (3)
- All of the above (4)
- I don't know (5)

Q11 Do you apply sunscreen before flying?

- No (1)
- Yes (2)
- Yes, sometimes (3)

Q12 Which of the following increase risk of ultraviolet radiation exposure to pilots?

- Time of day (1)
- Light reflection from snow cover or clouds (2)
- Different types of windshields (3)
- Altitude (4)
- All of the above (5)
- I don't know (6)

Q13 Have you ever had formal training regarding the occupational exposure of ultraviolet radiation to pilots?

- Yes (1)
- No (2)
- I don't know (3)

Q14 Have you ever had formal training on preventative measures of ultraviolet radiation effects?

- Yes (1)
- No (2)
- I don't know (3)

Q15 What type of shirt do you wear in the cockpit?

- Short Sleeve (1)
- Long sleeve (2)

Q16 Does your flight department have reminders regarding self-protection from ultraviolet radiation?

- Yes (1)
- No (2)
- If yes, please describe (3) _____

Q17 How many flight hours have you logged?

- 1500 - 3000 (1)
- 3001 - 5000 (2)
- 5001 - 8000 (3)
- 8001 - 10000+ (4)

Q18 Under what Federal Aviation Regulation do you fly?

- Part 91 (1)
- Part 135 (2)
- Part 121 (3)

Q19 What is your aircraft cruising flight level?

- FL350 - FL380 (1)
- FL390 - FL420 (2)
- FL430 - FL450 (3)
- FL460 - FL490 (4)

Q20 How many hours on average a month do you fly?

- 0 -10 (1)
- 11 - 50 (2)
- 51 - 100 (3)

Q21 I am confident that I am able to identify ultraviolet risk factors in the cockpit

- Strongly AGREE (1)
- Mildly AGREE (2)
- Neutral (3)
- Mildly DISAGREE (4)
- Strongly DISAGREE (5)

Q22 I am confident that I know what preventative measures to take to prevent ultraviolet radiation

- Strongly AGREE (1)
- Mildly AGREE (2)
- Neutral (3)
- Mildly DISAGREE (4)
- Strongly DISAGREE (5)

Q23 Following the ultraviolet radiation education, are you consistently wearing sunglasses in the cockpit?

- Yes (1)
- No (2)

Q24 Following the ultraviolet radiation education, are you consistently applying sunscreen before flying?

- Yes (1)
- No (2)

Q25 Since the ultraviolet radiation education, have you shared this information with other pilots?

- Yes (1)
- No (2)

Q26 Since the ultraviolet radiation education, has your flight department considered utilizing uniforms that are made of UV protective material?

- Yes (1)
- No (2)

REFERENCES

- Behar Cohen, F., Behar-Cohen, F., De Ayguavives, Krutmann, J., Reme, C., & Ortega García, P. (2013). Ultraviolet damage to the eye revisited: Eye-sun protection factor (E-SPF_{reg}), a new ultraviolet protection label for eyewear. *Clinical Ophthalmology*, 8, 87-104. doi:10.2147/OPHTH.S46189
- Carrera, C., Puig Butillè, J., Aguilera, P., Ogbah, Z., Palou, J., Lecha, M., . . . Puig, S. (2013). Impact of sunscreens on preventing UVR-induced effects in nevi. *JAMA Dermatology*, 149(7), 803-13. doi:10.1001/jamadermatol.2013.398
- Chorley, A. C., Chorley, A., Benwell, M. J., & Benwell, M. (2011). Civilian pilot exposure to ultraviolet and blue light and pilot use of sunglasses. *Aviation, Space, and Environmental Medicine*, 82(9), 895-900. doi:10.3357/ASEM.3034.2011
- Chorley, A., Higlett, M., Baczynska, K., Hunter, R., & Khazova, M. (2014). Measurements of pilots' occupational solar UV exposure. *Photochemistry and Photobiology*, 90(4), 935-940. doi:10.1111/php.12269
- Diaz, J., Diaz, J. H., & Nesbitt, L. (2013). Sun exposure behavior and protection: Recommendations for travelers. *Journal of Travel Medicine*, 20(2), 108-118. doi:10.1111/j.1708-8305.2012.00667.x

- Diepgen, T. L., Diepgen, T. L., Fartasch, M., Drexler, H., & Schmitt, J. (2012). Occupational skin cancer induced by ultraviolet radiation and its prevention. *British Journal of Dermatology*, *167*, 76-84. doi:10.1111/j.1365-2133.2012.11090.x
- Friedberg, W., & Copeland, K. (2003). *What Aircrews should Know about their Occupational Exposure to Ionizing Radiation*,
- Langner, I., Langner, I., Blettner, M., Gundestrup, M., Storm, H., Aspholm, R., . . . Linnarsjö, A. (2004). Cosmic radiation and cancer mortality among airline pilots: Results from a european cohort study (ESCAPE). *Radiation and Environmental Biophysics*, *42*(4), 247-256. doi:10.1007/s00411-003-0214-7
- Leonard (2014, December 17). For Pilots, flying may be just as dangerous as fake bake. *US News and World Report*. Retrieved from <http://www.usnews.com/news/articles/2014/12/17/for-pilots-flying- may- be- just-as-dangerous-as-fake-bake>
- McCool, J., Reeder, A., Robinson, E., Petrie, K., & Gorman, D. (2009). Outdoor workers' perceptions of the risks of excess sun-exposure. *Journal of Occupational Health*, *51*(5), 404-411. doi:10.1539/joh.L9030
- Nakagawara, V. *Optical radiation transmittance of aircraft windscreens and pilot vision*
- Radiation, W. S. U. (2006). Global burden of disease from solar ultraviolet radiation. environmental burden of disease series, no. 13. *World Health Organization, Geneva*,

McCool, J., Reeder, A., Robinson, E., Petrie, K., & Gorman, D. (2009). Outdoor workers' perceptions of the risks of excess sun-exposure. *Journal of Occupational Health*, 51(5), 404-411. doi:10.1539/joh.L9030

Nakagawara, V. *Optical radiation transmittance of aircraft windscreens and pilot vision*

Radiation, W. S. U. (2006). Global burden of disease from solar ultraviolet radiation. environmental burden of disease series, no. 13. *World Health Organization, Geneva*,

Shantha, E., Lewis, C., & Nghiem, P. (2015). Why do airline pilots and flight crews have an increased incidence of melanoma? *JAMA Oncology*, 1(6), 829-830.