

January 2012

Noise Exposure in Medical Helicopter Flights

Melissa Constance Hay

University of South Florida, m_hay@juno.com

Follow this and additional works at: <http://scholarcommons.usf.edu/etd>



Part of the [Occupational Health and Industrial Hygiene Commons](#)

Scholar Commons Citation

Hay, Melissa Constance, "Noise Exposure in Medical Helicopter Flights" (2012). *Graduate Theses and Dissertations*.
<http://scholarcommons.usf.edu/etd/4331>

This Thesis is brought to you for free and open access by the Graduate School at Scholar Commons. It has been accepted for inclusion in Graduate Theses and Dissertations by an authorized administrator of Scholar Commons. For more information, please contact scholarcommons@usf.edu.

Noise Exposure in Medical Helicopter Flights

by

Melissa Hay

A thesis submitted in partial fulfillment
of the requirements for the degree of
Masters of Science in Public Health
Department of Environmental and Occupational Health
College of Public Health
University of South Florida

Major Professor: Steven Mlynarek, Ph.D.
Thomas E. Bernard, Ph.D.
Yehia Hammad, Sc.D.

Date of Approval:
October 30, 2012

Keywords: NIOSH Methods, hospital, OSHA, 1910.95, Occupational Noise

Copyright © 2012, Melissa Hay

Acknowledgments

I would like to first thank my Lord and Savior, Jesus Christ for promising to never give me more than I can handle. Although, I have felt like I have come close, you have always given me the grace and strength to continue.

Thank you to my amazing parents, Jeffrey and Karen Hay, family and friends that have supported me throughout my education. Thanks for always pushing me to be better than I thought I could be and the giving me support to get there. And Uncle Jack for putting the occupation of Industrial Hygiene into my head in the first place.

I would like to thank the National Institute for Occupational Safety and Health (NIOSH) and the Sunshine ERC, supported by Training Grant No. T42-OH008438, for providing the funds to allow me to pursue my Masters degree without the financial heartache that most students endure.

I would also like to thank my committee members and professors Dr. Steve Mlynarek, Dr. Thomas Bernard, and Dr. Yehia Hammad for their guidance throughout this process. Thanks to Adam Marty for his advice and instruction throughout this process. And special thanks to Dr. Ferriolo for his statistical genius and consistent support.

Thank you to Moffitt Cancer Center for providing me with employment, support and opportunities while pursuing my degree. Without this institution and its employees I would not be where I am today.

A special thanks to Robert Booth who gave me the idea to pursue this research project that was both interesting and fun, something that, I feel, most students can not claim about their thesis projects.

Table of Contents

List of Tables	iii
List of Figures	iv
List of Abbreviations	v
Abstract	vi
Introduction	1
Background	1
Purpose	3
Literature Review	4
Noise-Induced Hearing Loss – McReynolds	4
Noise Exposure During Alpine Helicopter Rescue Operations – Küpper et al	5
The Hospital-Based Helicopter – Pasic and Poulton	5
Methods	7
Helicopter Lay-Out	7
Sampling Strategy	10
Area Samples	10
Front Cockpit Area of Helicopter	10
Rear Crew Area of Helicopter	11
Personal Samples	12
Pilot Data Collection	12
Nurse and Paramedic Data Collection	13
Personal Sample of Helmet of Nurse and Paramedic	14
Mannequin Helmet Testing	14
Results	18
Area Samples	18
Front Cockpit Area of Helicopter	18
Rear Crew Area of Helicopter	18
Personal Samples	19

Personal Sample of Helmet of Nurse and Paramedic	23
Mannequin Helmet Testing	24
Discussions and Conclusions	26
Area Samples	26
Personal Samples	26
Personal Sample of Helmet of Nurse and Paramedic	27
Mannequin Helmet Testing	28
Recommendations	29
Recommendations for Future Research	31
References	32
Appendices	33
Appendix I: Equipment List	34
Appendix II: IRB Approval	35

List of Tables

Table I	Permissible Noise Exposures from OSHA.gov	2
Table II	Area Samples in the Front Cockpit Area of Helicopter	18
Table III	Area Samples in the Rear Crew Area of Helicopter	18
Table IV	All Data from Helicopter Flights	19
Table V	ANOVA Effect Tests	19
Table VI	Pilot Calculated Reference Duration, Dose, and TWA	20
Table VII	Nurse Calculated Reference Duration, Dose, and TWA	21
Table VIII	Paramedic Calculated Reference Duration, Dose, and TWA	21
Table IX	Inside Helmet vs. Outside Helmet Data	23
Table X	Mannequin with Nurse Helmet	24
Table XI	Mannequin with Paramedic Helmet	25

List of Figures

Figure 1	Outside View	8
Figure 2	Cockpit Area of Helicopter	8
Figure 3	Rear Crew Area of Helicopter – Rear-facing Seats	9
Figure 4	Rear Crew Area of Helicopter – Bench and Stretcher	9
Figure 5	Aerial view showing placement of investigator for Area Samples	11
Figure 6	Dosimeter placement for Pilot	12
Figure 7	Dosimeter placement for Nurse and Paramedic	13
Figure 8	Mannequin – Front View	15
Figure 9	Mannequin – Side View	15
Figure 10	Testing Mannequin – Wearing Helmet	16
Figure 11	Lowest Setting	16
Figure 12	3 O’Clock Setting	16
Figure 13	6 O’Clock Setting	17
Figure 14	9 O’Clock Setting	17
Figure 15	Highest Setting	17
Figure 16	Pilot Lavg and Dose Plots	22
Figure 17	Nurse Lavg and Dose Plots	22
Figure 18	Paramedic Lavg and Dose Plots	22
Figure 19	Graph of Lavg Levels from Inside Helmet vs. Outside Helmet Data	23
Figure 20	Graph of Mannequin with Nurse Helmet Results	24
Figure 21	Graph of Mannequin with Paramedic Helmet Results	25

List of Abbreviations

ANR	Active Noise Reduction
dBA	Decibels – A- Weighted scale
Hz	Hertz
Lavg	The average level over the study. This measurement takes into account the threshold and exchange rate entered in the setup menu.
NIHL	Noise Induced Hearing Loss
NIOSH	National Institute for Occupational Safety and Health
NRR	Noise Reduction Rating
OSHA	Occupational Health and Safety Administration
PPE	Personal Protective Equipment
SEL	The Sound Exposure Level is the constant sound level which, if lasting for one second, would deliver the same amount of acoustical energy as that accumulated over the entire study.
SPL	Sound Pressure Level
TWA	Time-Weighted Average

Abstract

The purpose of this project was to evaluate noise exposures of helicopter pilots, nurses and paramedics at a hospital by collecting area and personal samples, determining noise levels inside the helmet, and evaluating the current selection of personal protective equipment (PPE).

Measurements gathered during personal sampling were statistically analyzed and calculated using OSHA 1910.95 App A to determine dose, reference duration and the Time-Weighted Average (TWA).

Using a mannequin head, with the noise dosimeters in the ears, tests were performed on the headset inside the helmets to determine the sound pressure levels generated from the radio communications at different volume levels.

According to our results, the crew is not exposed to hearing levels above the OSHA permissible exposure limit (PEL), because their flight times are usually only 20-30 minutes and the dose was not above 22% of the OSHA limit. If the total flight times were 6.5 hours or more, the crew could be above the OSHA PEL. Testing the helmet speakers resulted in a recommendation that the setting not be set above the 6 o'clock position so that the crew would not be exposed to sound pressure levels about 80 dBA.

Introduction

Background

According to the National Institute for Occupational Safety and Health (NIOSH) approximately 22 million US workers are exposed to hazardous noise levels at work (NIOSH). Exposure to excessive noise, especially over a long period of time, can cause short-term, long-term or permanent hearing losses. A temporary threshold shift is a change in hearing that returns after being removed from the noise source. Many people experience a temporary threshold shift after going to a loud concert that results in having difficulty hearing afterwards, but the next day their hearing has returned to normal. According to OSHA 1910.95(g)(10)(i), a standard threshold shift is a change in hearing threshold relative to the baseline audiogram of an average of 10 dB or more at 2000, 3000, and 4000 Hz in either ear. Unlike temporary threshold shifts, permanent threshold shifts may represent significant hearing loss.

Tinnitus is a ringing, buzzing or roaring within the ear and is usually a temporary effect of being exposed to loud noises, but can become permanent. After exposures to loud noises like at rock concert or gun range, people can experience tinnitus. Tinnitus can continue in some cases throughout a person's lifetime and can become debilitating. Most permanent hearing losses occur because of acoustic trauma, like exposure to loud noises, which cause the hair cells within the cochlea to break, and unfortunately those hairs do not grow back.

High levels of noise can potentially cause hearing loss to those exposed to it, so the Occupational Health and Safety Administration (OSHA) has created a Occupational

Noise Exposure Standard to protect workers from these hazards. OSHA has mandated that personnel exposed to noise above 85 dBA over an 8-hour day should be enrolled in a hearing conservation program to reduce the risk of hearing loss from occurring. Personnel exposed to noise above 90 dBA over an 8-hour day would be above the Permissible Exposure Limit (PEL) set by OSHA and would require protective measures to be put into place. OSHA also uses a 5 dBA exchange rate as the time is decreased by half. So in a 4-hour period of time the dBA allowable exposure would increase by 5 dBA to be 95 dBA and so on. See Table I.

Table I: Permissible Noise Exposures from OSHA.gov

Duration per day, hours	Sound level dBA slow response
8.....	90
6.....	92
4.....	95
3.....	97
2.....	100
1 1/2	102
1.....	105
1/2	110
1/4 or less.....	115

Footnote(1) When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions: $C(1)/T(1) + C(2)/T(2) + C(n)/T(n)$ exceeds unity, then, the mixed exposure should be considered to exceed the limit value. Cn indicates the total time of exposure at a specified noise level, and Tn indicates the total time of exposure permitted at that level. Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

Protective measures could be engineering procedures such as building a wall to contain the source of the noise or finding a way to remove the noise source all together. Another option to protect the workers is to use administrative procedures such as removing the employee from the source of the noise or rotating the job role with another personnel so that the noise threshold is not reached. A final option is personal protective equipment (PPE). Earphones, helmets or earplugs are all types of PPE. In the case of helicopter personnel, it is very difficult to use engineering or administrative procedures to lessen the exposure to the noise.

Personnel working in medical helicopters can be exposed to high levels of noise during flights simply because helicopters are very noisy. Furthermore, the crew must maintain constant communication, so each member of the crew must wear a microphone

and speaker inside the helmet to communicate with each other. At times the speaker volume inside the helmet can be turned very loud in order to compensate for the noise being emitted from the helicopter. All of these noise sources combined can cause hearing damage to the personnel.

Purpose

The purpose of this project was to evaluate noise exposures of helicopter pilots, nurses and paramedics by collecting area and personal samples, determining noise levels outside and inside the helmet, and evaluating the current selection of personal protective equipment (PPE).

Literature Review

The following research studies were reviewed before beginning this study in order to gain insight on the studies that had already been performed. McReynolds broke down the various noise protection options in his article entitled, "Noise-Induced Hearing Loss." He focuses on how employers should protect their medical helicopter personnel from noise-induced hearing losses. Küpper et al (2003) researched helicopter noise during Alpine Rescue Operations in, "Noise Exposure During Alpine Helicopter Rescue Operations." In 1986 Pasic and Poulton wrote about their study of helicopter noise entitled, "The Hospital-Based Helicopter," and concluded that hearing protection was not necessary. The results of these three studies are summarized below:

Noise-Induced Hearing Loss – McReynolds

The purpose of McReynolds article was to "raise awareness of the consequences of noise exposure and subsequent NIHL (Noise-Induced Hearing Loss) as they pertain to HEMS (Helicopter Emergency Medical Services) professionals," (McReynolds). McReynolds defined and explained the former and current OSHA Regulations and Recommendations as well as the elements of a hearing conservation program and action plans. He then provided examples, advantages and disadvantages of hearing protection devices. McReynolds concluded by explaining how employers can train and educate their employees on the proper ways to protect themselves, explained recordkeeping and audiometric evaluations to find baselines for employees.

Noise Exposure During Alpine Helicopter Rescue Operations – Küpper et al

Küpper et al (2003) measured points inside and outside the helicopter that represented areas where the helicopter personnel would be positioned. He tested three different types of helicopters, Alouette II and III and Ecureuil. He found that the highest noise levels were measured outside the Alouette III (and were nearly identical for the Alouette II) helicopter, and ranged between 114.9-120.8 dBA. They found levels of 104.6-106.5 dBA inside the helicopter during noise monitoring for the Alouette III and 106-109 dBA for the Alouette II. The Ecureuil noise levels outside the aircraft were found to range between 109-111 dBA, and inside they were 99-101 dBA.

Küpper et al then measured and averaged the 8-hour time-weighted average of noise exposure. They found in Switzerland, where the Alouette II and III were used, the noise exposure was over 85 dBA and averaged between 90 and 105 dBA 52.8% of all days monitored. In Austria, where the primary helicopter utilized is the Ecureuil, also averaged 90 to 105 dBA, on 62.5% of days. They also found that the Ecureuil aircraft is less noisy, but that the crews in Austria usually have longer flights, which equate to higher noise exposures.

Küpper et al concluded that the helicopter personnel of the alpine region were at risk of noise induced hearing loss based on the measurements regularly being above 85 dBA. They also recommended noise protection and regular follow-up with occupational medicine professional to monitor their hearing.

The Hospital-Based Helicopter – Pasic and Poulton

Pasic and Poulton (1985) found that hearing protection for the helicopter personnel was not necessary. This is very interesting because the noise levels that they recorded were between 85 to 90 dBA. Their conclusions were based on the data published by OSHA in 1985, and since that time the allowable noise levels have

changed, and are now become more protective. Based in the data provided, Pasic and Poulton most likely would have concluded that hearing protection should be worn. Pasic and Poulton's noise measurements were based on sound levels from a Bell 206L Longranger II helicopter. Pasic and Poulton did note that the pilot was subject to noise levels at 100 dBA and showed no decline in perceptive ability for the first 8 hours of working. But after that initial 8 hours, they showed significant decrease in intellectual judgment, in the next 4 hours of monitoring. Pasic and Paulton did not explore the association among noise exposure, decreased intellectual judgment and decreased flight safety.

Methods

This project addressed many different issues concerning the noise in the helicopter. Area samples were taken to determine the general level of noise in the forward cockpit and rear crew areas of the helicopter. These were important in determining an average level inside the aircraft and what any non-helicopter personnel passengers could be exposed to. A second part of the project was to collect personal samples from each of the three group members (pilot, nurse and paramedic) of the crew that are on every flight. After determining the levels of noise, the next part of the project was to evaluate the noise inside the helmets worn by the crew and determine if the noise levels inside were above the OSHA PEL. Finally, the speaker system was evaluated to see if there should be a recommended setting that the helmet volume should be set to.

Helicopter Layout

The BK helicopter has two areas separated by a thick cloth partition (see Figures 1-4). The cockpit area of the BK helicopter has two seats. When seated inside the helicopter cockpit area, the pilot utilizes the right seat and the left seat is used by the paramedic on the way to the scene. The left seat is normally empty on the return flight as both the nurse and paramedic are tending to the patient on the way back the hospital. The rear crew area of the BK Helicopter has two rear facing seats that are back-to-back with the front cockpit seats of the helicopter. A bench seat sits on the right of the helicopter facing the stretcher that is on the left side of the helicopter.



Figure 1: Outside View



Figure 2: Cockpit Area of Helicopter



Figure 3: Rear Crew Area of Helicopter – Rear-facing Seats



Figure 4: Rear Crew Area of Helicopter – Bench and Stretcher

Sampling Strategy

All noise sampling was performed using five separate Quest Q-300 Noise Dosimeters. The dosimeters were set to record the A-Weighted scale in slow mode in accordance with OSHA guidelines (OSHA).

Dosimeters for personal samples were only worn during flights; no 8-hour tests were done. According to one helicopter chief nurse, most flights average about 20-30 minutes and are normally in the local area, although at times they will receive calls to pick-up patients from other medical facilities that need to be treated at the hospital so those flights may be longer. The hospital also averages about 30 flights per month.

Area Samples

Front Cockpit Area of Helicopter

The cockpit area sample was taken while on a maintenance flight so the investigator was able to sit in the front cockpit area both to the location and back (see Figure 5). After the doors were closed sound level sampling were started so that outside noises would not be included in the sample. Levels were recorded when the engine was started, at lift off, while cruising, and landing. The flight was approximately 12 miles, from the hospital to the airport. After landing the pilot performed checks on the helicopter systems. The helicopter was not turned off and no individuals exited the helicopter during the checks. On the return flight the investigator measured the sound levels while idling on the ground, during liftoff, while cruising and when landing back at the hospital. The noise levels were not recorded on the Quest 300 dosimeter, instead, the investigator turned the dosimeter level to SPL, which displays the maximum SPL during the previous second.

Rear Crew Area of Helicopter

The rear crew area sampling was taken on a trip to pick up a patient from a medical center 45 miles away and bring them back to the hospital (see Figure 5). On the trip the helicopter flew over water. The medical center did not have a helipad so the helicopter landed in a rarely used side road and was turned off while the patient was retrieved and brought back to the landing site. Samples on this trip were taken after the doors were closed and included: lift off, cruising over land and over water, near the left door, over the patient bed where the patients head would be, the ceiling of the aircraft, over the bench seat, and while landing. When returning, sound levels were recorded before the doors were closed, during lift off, while cruising over land and water, while landing and while the engine was shutting down after landing. The noise levels were not recorded on the Quest 300 dosimeter, instead, the investigator turned the dosimeter level to SPL, which displays the maximum SPL during the previous second.

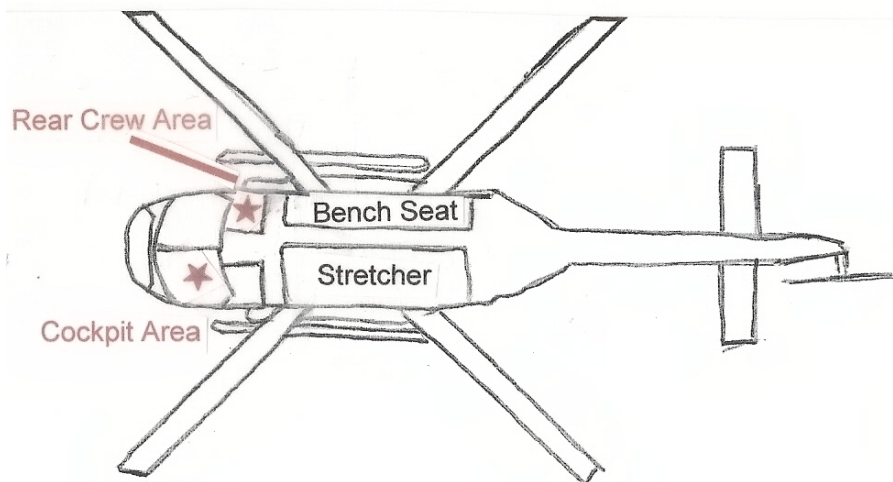


Figure 5: Aerial view showing placement of investigator for Area Samples
*Figure not drawn to scale

Personal Samples

Personal samples were taken from the helicopter pilot, nurse and paramedic during flights. Three samples (one from each of the pilot, nurse and paramedic) from each of ten flights were recorded and used in the data analysis, except for one flight on 2/25/12 the pilot data were not recorded.

Pilot Data Collection

The pilot wore the microphone on the helmet since the seatbelt would interfere with the microphone being placed on the front of the uniform (see Figure 6). The dosimeter was turned on while the pilot was preparing for the flight, before the helicopter was started. The pilot turned on the dosimeter then entered the helicopter, ran through the necessary checks then started the helicopter and closed the pilot door.



Figure 6: Dosimeter placement for Pilot

Nurse and Paramedic Data Collection

The nurse and paramedic both placed the dosimeter in a pocket on the vest that is worn for every flight and the microphone was clipped to the vest to a strap in the front just a few inches from the ear. Due to the uniform worn by the nurse and paramedic, there was not a good place to clip the microphone that would have been closer to the users ear without interfering with their work (see Figure 7). The nurse and paramedic turned on their dosimeter prior to engine start while putting on their safety vest. Before entering the helicopter they are required to do inspections to the helicopter, such as checking the doors and latched before entering. While the paramedic and nurse did their checks the helicopter was being started so they were actually exposed to the direct engine noise on the outside of the craft. After performing their checks the nurse enters the rear of the helicopter, while the paramedic enters the front cockpit area. The nurse is in the rear so that they can communicate with the medical personnel on scene and prepare the rear for the patient.



Figure 7: Dosimeter placement for Nurse and Paramedic

At the scene or hospital, where the patient is picked up, the nurse and the paramedic leave the helicopter to get the patient, while the pilot stays with the helicopter to monitor the radio. Depending on the length of time it will take to get the patient, the helicopter will be left running while the patient is loaded, which would be called a "hotload." The dosimeters were turned off after helicopter shutdown was complete.

Personal Sample of Helmet of Nurse and Paramedic

During one flight the nurse and paramedic each wore a dosimeter inside their helmet earpieces to determine the actual levels of noise that they were exposed. This was not done to test or evaluate the helmets Noise Reduction Rating (NRR), but to try and determine realistic exposures during a flight.

Mannequin Helmet Testing

The final kind of testing done was on the helmet to determine the levels of noise at each setting from the speakers of the helmet. A Styrofoam mannequin head was purchased and a dosimeter microphone was placed in each of the ears (see Figure 8 and 9). Two helmets were tested, a nurse helmet and a paramedic helmet (see Figure 10). Unfortunately, the volume dial does not have marked settings so readings were taken at the lowest setting, at the 3 o'clock, 6 o'clock, 9 o'clock and highest setting positions (see Figures 11-15). On a normal flight the radio would be dialed into specific stations needed for information needed for that flight. Each of these different stations can enter the helmet speakers at a different volume regardless of the setting on the dial connected to the helmet. For the mannequin helmet testing all stations were set to on so that all stations were entering the helmet. With all stations entering the helmet, louder stations were accounted for assuming that someone was communicating on them.



Figure 8: Mannequin – Front View



Figure 9: Mannequin – Side View



Figure 10: Testing Mannequin – Wearing Helmet



Figure 11: Lowest Setting



Figure 12: 3 O'clock Setting



Figure 13: 6 O'clock Setting



Figure 14: 9 O'clock Setting



Figure 15: Highest Setting

Results

Area Samples

Front Cockpit Area of Helicopter

Representative high values of area samples in the front cockpit area of the helicopter are shown in Table II below.

Table II: Area Samples in the Front Cockpit Area of Helicopter on 3/2/2012

To Destination		From Destination	
Activity	SPL (dBA)	Activity	SPL (dBA)
Engine Start Up	93	Idling on ground	90.1
Engine Lift Off	91.9	Engine Lift off	106
Cruising	86.7 - 97.8	Cruising	88.2 - 98.5
Landing	90.6	Landing	89.9

Rear Crew Area of Helicopter

Representative high values of area samples in the rear crew area of helicopter are shown in Table III below.

Table III: Area Samples in the Rear Crew Area of Helicopter on 3/1/2012

To Destination		From Destination	
Activity	SPL (dBA)	Activity	SPL (dBA)
Lift Off	92.5	Startup*	90-93
Cruising	90.7 - 94.4	Lift Off	92.9
By Left Door**	98.5	Cruising	92.9 - 96.4
Patient Bed	94.8	Cruising Over Water	95
Ceiling	95.8	Landing	97
Over Bench Seat	94.1	Engine Shut-Down	90.8 - 91.4
Cruising Over Water	96.5 - 98	<p>* Before door was closed ** Facing rear of helicopter</p>	
Cruising Over Land	98.5		
Landing	94.0 - 94.4		

Personal Samples

Results of personal samples of all personnel are shown in Table IV below. “The Lavg is the average level over the study. This measurement takes into account the threshold and exchange rate entered in the setup menu.” (Quest).

Table IV: All Data from Helicopter Flights

Flight	Flight Date	Pilot (dBA)	Nurse (dBA)	Paramedic (dBA)	Average Recording Time (min:sec)
1	2/19/12	92.5	91	88.5	75:29
2	2/21/12	94.8	90.8	91.3	12:54
3	2/24/12	91.1	92	94	47:48
4	2/25/12		87.8	90.5	16:30
5	2/25/12	89.3	94.2	92.1	29:10
6	2/29/12	87.5	92.8	92	43:00
7	3/1/12	93.4	91.9	89	21:45
8	3/2/12	89.7	94.8	91.6	29:55
9	3/4/12	92.8	92.1	89.8	68:40
	Average	91.4	91.9	91.0	39:28
Average for All		91.4 dBA			

*Actual recording time varied about 11% between each position. Time shown is the average recording time.

The resulting output of the personal sampling data were recorded and transferred to JMP statistical suite. Differences of position as well as run number were analyzed using an analysis of variance, ANOVA. The effect due to position and individual run were both non-significant, see Table V. As a result of these findings, no post hoc tests were performed.

Table V: ANOVA Effect Tests

Response Dose					
Effect Tests					
Source	Nparm	DF	Sum of Squares	F Ratio	Prob > F
Position	2	2	125.33220	0.5028	0.6147
Run	8	8	424.34196	0.4256	0.8878

Lavg taken from the dosimeter, calculated dose and calculated Time-Weighted Average (TWA) were analyzed and are displayed in Tables VI - VIII. Dose is the percentage of time that the exposure exceeded OSHA's allowable limit. Dose was calculated by using the following formula given by OSHA $D = 100 (C(1)/T(1) + C(2)/T(2) + \dots + C(n)/T(n))$ where $C(n)$ indicates the total time of exposure at a specific noise level, and $T(n)$ indicates the reference duration corresponding to the measured sound level, Lavg, given as $T = 8/2^{(L_{avg} - 90)/5}$. TWA is calculated according to OSHA with formula, $TWA = 16.61 \log(10) (D/100) + 90$.

Table VI: Pilot Calculated Reference Duration, Dose, and TWA

Flight	Flight Date	Time (min)	Lavg (dBA)	Reference Duration, T (hour)	Dose	TWA (dBA)
1	2/19/12	89.7	92.5	5.7	21.1%	78.8
2	2/21/12	14.9	94.8	4.1	17.3%	77.3
3	2/24/12	52.8	91.1	6.9	4.7%	68.0
5	2/25/12	28.1	89.3	8.8	0.7%	54.4
6	2/29/12	41.5	87.5	11.3	0.3%	48.2
7	3/1/12	24.0	93.4	5.0	10.5%	73.8
8	3/2/12	31.7	89.7	8.3	1.1%	57.3
9	3/4/12	69.2	92.8	5.4	20.1%	78.4
	Average	44.0	91.4	6.9	9.5%	67.3

Table VII: Nurse Calculated Reference Duration, Dose, and TWA

Flight	Flight Date	Time (min)	Lavg (dBA)	Reference Duration, T (hour)	Dose	TWA (dBA)
1	2/19/12	83.4	91.0	7.0	7.0%	70.8
2	2/21/12	11.4	90.8	7.2	0.8%	55.4
3	2/24/12	49.8	92.0	6.1	8.3%	72.0
4	2/25/12	15.8	87.8	10.9	0.1%	42.8
5	2/25/12	29.4	94.2	4.5	22.5%	79.2
6	2/29/12	42.0	92.8	5.4	12.2%	74.8
7	3/1/12	20.1	91.9	6.1	3.1%	65.0
8	3/2/12	29.9	94.8	4.1	34.6%	82.4
9	3/4/12	68.8	92.1	6.0	12.3%	74.9
	Average	38.9	91.9	6.4	11.2%	70.0

Table VIII: Paramedic Calculated Reference Duration, Dose, and TWA

Flight	Flight Date	Time (min)	Lavg (dBA)	Reference Duration, T (hour)	Dose	TWA (dBA)
1	2/19/12	83.5	88.5	9.8	1.2%	58.3
2	2/21/12	12.4	91.3	6.7	1.3%	58.5
3	2/24/12	40.8	94.0	4.6	27.2%	80.6
4	2/25/12	17.2	90.5	7.5	1.0%	56.9
5	2/25/12	30.0	92.1	6.0	5.4%	68.9
6	2/29/12	45.4	92.0	6.1	7.6%	71.4
7	3/1/12	21.2	89.0	9.2	0.4%	50.9
8	3/2/12	28.2	91.6	6.4	3.6%	65.9
9	3/4/12	68.1	89.8	8.2	2.5%	63.3
	Average	38.5	91.0	7.2	5.6%	63.9

This data were analyzed using a box and whisker plot. Which indicated both measures of central tendency as well as variation. Plots were separated by position and analyzed for LAVG and dose separately. See Figures 16 - 18 below.

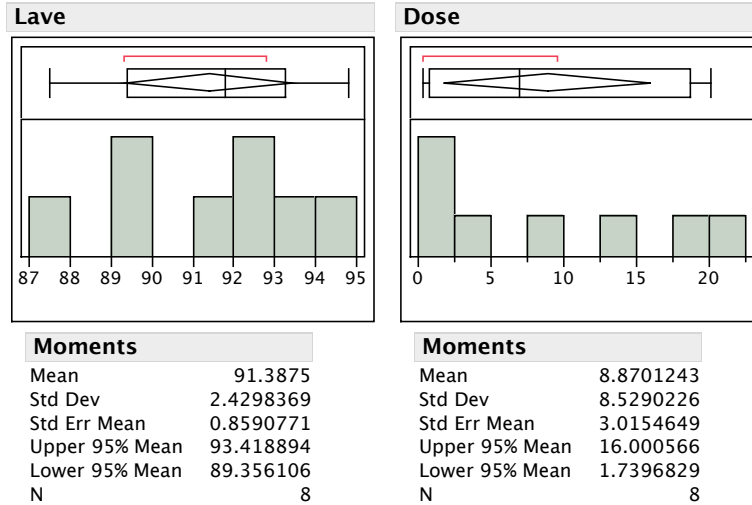


Figure 16: Pilot Lavg and Dose Plots

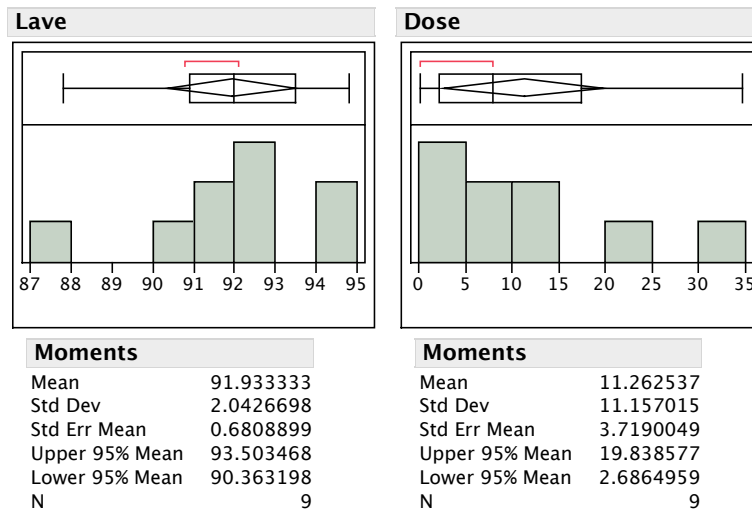


Figure 17: Nurse Lavg and Dose Plots

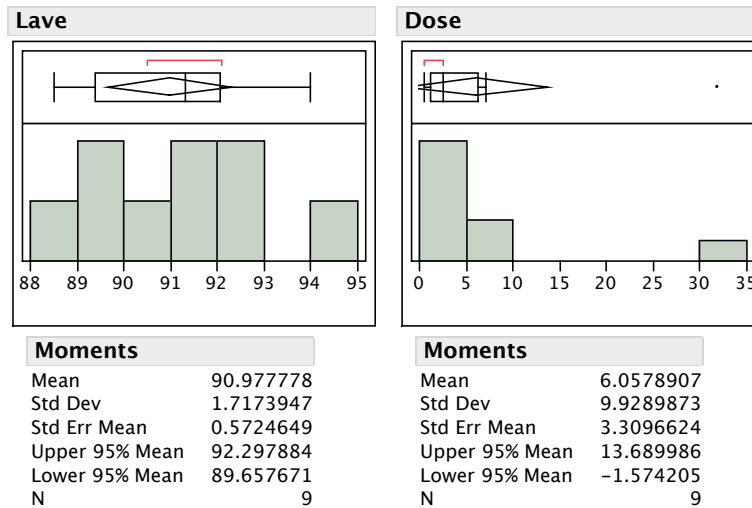


Figure 18: Paramedic Lavg and Dose Plots

Calculated doses were relatively small with a few outlying exceptions. This includes measurements that exceeded a 30% dose level. Additionally, these plots showed wide variation in pilot data.

Personal Sample of Helmet of Nurse and Paramedic

While performing area samples and during conversations with the helicopter personnel it was discovered that the speaker system within the helmet could be a cause of noise exposure. To determine the noise level inside the helmet, a microphone connected to a dosimeter was placed inside the earpiece while a separate dosimeter was used outside the helmet. After the flight, the two samples were analyzed. The data are shown in Table IX and Figure 19 below.

Table IX: Inside Helmet vs. Outside Helmet Data

	Nurse	Nurse Helmet	Nurse Difference	Paramedic	Paramedic Helmet	Paramedic Difference
Date	2/19/12			2/19/12		
	SPL (dBA)			SPL (dBA)		
Lavg	91	86.5	4.5	88.5	85.1	3.4

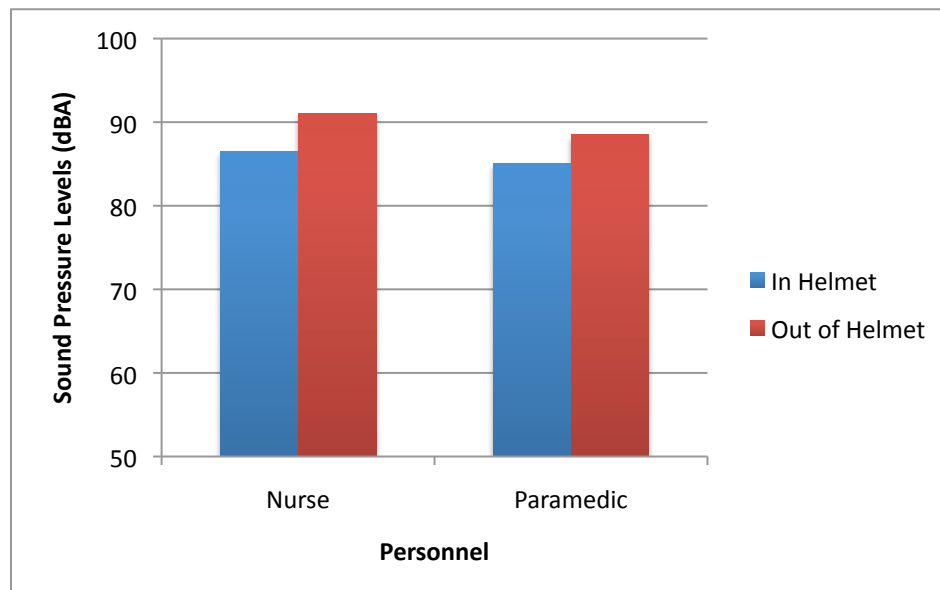


Figure 19: Graph of Lavg Levels from Inside Helmet vs. Outside Helmet Data

The nurse's helmet appeared to reduce overall noise 4.5 dBA from 91 dBA to 86.5 dBA. The paramedic's helmet appeared to reduce overall noise 3.4 dBA from 88.5 dBA to 85.1 dBA. This test was not performed to determine a Noise Reduction Rating, but to evaluate if further evaluation of the headsets should be performed. Due to the fact the noise inside the helmets is generated by the radio and speakers the investigator performed tests to determine where the volume should be set in order to be protective against hearing loss.

Mannequin Helmet Testing

To determine the Sound Pressure Levels that came out of the headset at different volume settings a mannequin was constructed with dosimeter microphones in the ear area. Our results are shown in Tables X and XI and Figures 20 and 21 below.

Table X: Mannequin with Nurse Helmet

Setting	Left Speaker (dBA)	Right Speaker (dBA)	Average Left Speaker (dBA)	Average Right Speaker (dBA)
Low	69.9 - 80	69.9 - 82.9	74.95	76.4
3 o'clock	70 - 84	71.6 - 85	77	78.3
6 o'clock	74 - 85	73 - 85.3	79.5	79.95
9 o'clock	75.7 - 87	76 - 86.9	81.35	81.45
High	80.1 - 92	81 - 94	86.05	87.5

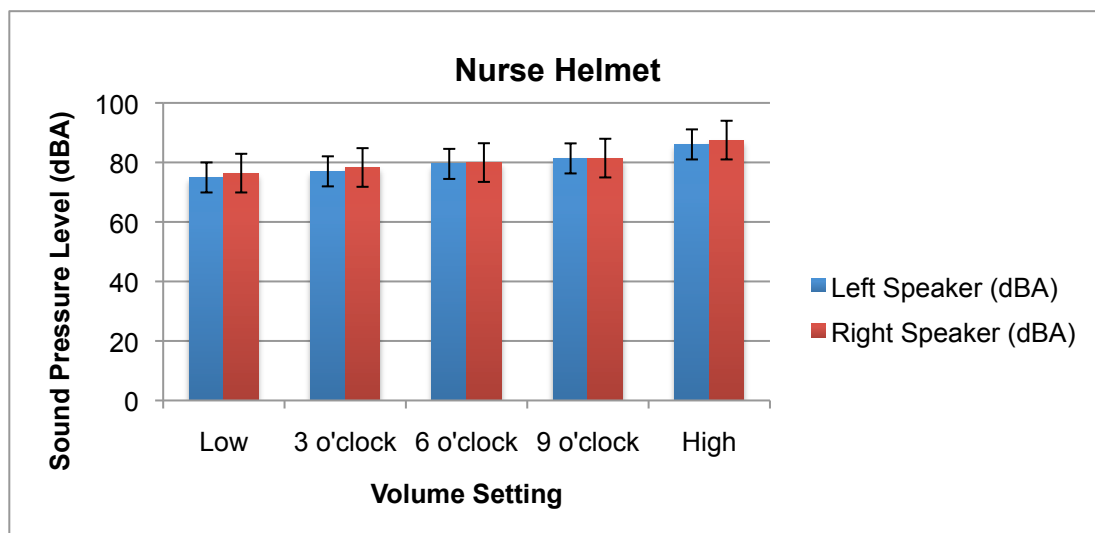


Figure 20: Graph of Mannequin with Nurse Helmet Results

Table XI: Mannequin with Paramedic Helmet

Setting	Left Speaker (dBA)	Right Speaker (dBA)	Average Left Speaker (dBA)	Average Right Speaker (dBA)
Low	69.9 - 78	69.9 - 79.3	73.95	74.6
3 o'clock	71 - 83.4	71.8 - 84	77.2	77.9
6 o'clock	73.8 - 86.7	73.6 - 85	80.25	79.3
9 o'clock	76.7 - 87.4	78.4 - 86.7	82.05	82.55
High	80.1 - 94.3	81.3 - 96.7	87.2	89

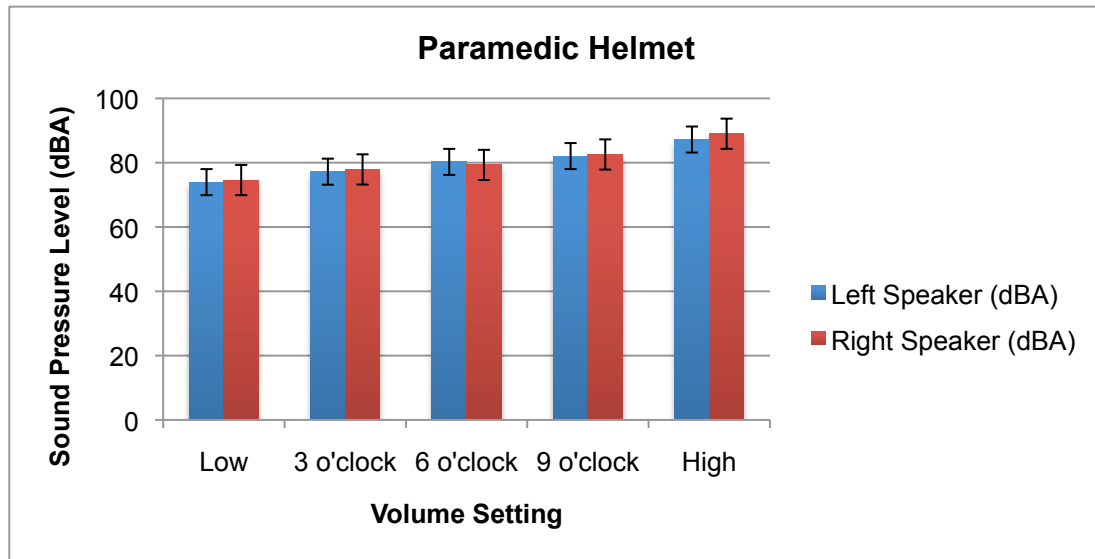


Figure 21: Graph of Mannequin with Paramedic Helmet Results

Discussion and Conclusions

The results gathered from this study appear to be consistent with the results gained from other similar studies.

Area Samples

In mapping the helicopter, there are places and times during flight when exposures were over 90 dBA. These results are consistent with both Küpper et al and Pasic and Poulton's results of area sampling.

Sources of error during area sampling were errors that might be expected from manual data recording and equipment error.

Personal Samples

Due to the length of time for the flights the OSHA mandated PEL is not reached. According to Tables VI-VIII (pages 24-25) if the reference durations for the pilot were approximately 6.94 hours, 6.35 for the nurses and 7.2 hours for the paramedic then the OSHA limits would be reached and the noise protection would need to be required. Because of the requirement for helmets to be worn and the speaker system inside of the helmet, noise protection is already worn even without the OSHA requirement. These results of personnel are consistent with Pasic and Poulton's results from measuring the pilot.

Unfortunately, the hospital does not mandate a specific helmet to be worn for the members of the crew. For this study we assumed that the helmets did not provide any

hearing protection for the helicopter crew. Two of the crew helmets were Gentex SPH-4 model helmets, but it is the headset and speaker system that actually would provide the noise reduction in the helmet and there was no data on those items.

Sources of error during personal sampling were errors that might be expected from manual data recording or the helicopter personnel not wearing the microphone as instructed. If the equipment was not working correctly or if the battery was low (batteries were checked after every flight and changed as needed) this could have resulted in equipment error.

Personal Sample of Helmet of Nurse and Paramedic

The simple test of putting a microphone in the headset to measure the outside exposure vs. the exposure inside the helmet showed that the volume level, although lower than the noise level outside the helmet, could be a problem. It would seem that the headsets need to be adjusted in a way that the crew is protected from the noise exposure that come from it. The voices can seem quite tolerable and “safe” and another station or frequency starts to talk and the volume is much higher coming into the headset for that station. This can become frustrating for the crew if they are busy with a patient and a louder than normal station or voice is coming into their headset. This can also become a hazard for the hearing of the crew.

Sources of error during personal sampling of the helmet verses the personnel sample were errors that might be expected from manual data recording or the helicopter personnel not wearing the microphone as instructed or if the microphone did not stay in the earpiece of the helmet. Due to the fact that the microphone had a cord it should be noted that the seal of the earpiece would not have been as tight as if would have been without the cord, so the results could be slightly skewed. If the equipment was not

working correctly or if the battery was low (batteries were checked after every flight and changed as needed) this could have resulted in equipment error.

Mannequin Helmet Testing

The mannequin helmet testing was done under the assumption that while the volume was set at each level, various frequencies would be heard through the headset in the helmet and recorded through the microphones attached to the headset. While the testing was going on the investigator wore a separate headset so that they could also hear what noises were being recorded by the mannequin. Although the investigator has high certainty that close to equal stations were recorded throughout the test, a source of error still could exist if louder stations were recorded during a certain volume setting and not for another. Also, because the data needed to be written down while the mannequin was set up, user error might be expected from manual data recording. The mannequin head does not have the same features as a real human head. Although the fit of the helmet to the mannequin was surprisingly snug, it was not a perfect fit, and the investigator did press the earpiece to the mannequin in order to provide the best-fit possible. Even with the holding of the headset to the mannequin, because of the material of the mannequin, Styrofoam, it is possible that some data could have been lost because a better seal would exist between the leather of the headset and pliable human skin as opposed to the porous rigid Styrofoam. Also, due to the material of the mannequin, it is possible that some of the noise coming from the headset could have been absorbed in to the material of the mannequin instead of the microphone.

Recommendations

It would be in the best interest of the hospital to attempt to streamline the helmet and headsets of the personnel. Having one kind of helmet that is customizable for each crewmember would make the maintenance easier as well as re-ordering parts that break or new helmets as new personnel are hired on. It would also give a better idea of what the NRR and other specifications for the helmet are. Although the helicopter crew does not currently have exposures that warrant the need for hearing protection, this would provide the crew with protection if they changed the length of flights or type of helicopter used.

A training on the new helmet as well as yearly training on noise protection and the hazards associated would hopefully be beneficial in helping the crew be informed. Even though the OSHA 8-hour PEL's were not reached in our study, it is possible, although unlikely, for them to be reached if the flight durations were extended.

The headsets for inside the helmet should also be more standardized. The hospital should look into headsets with Active Noise Reduction (ANR) headsets such as the Bose A20 Aviation Headset or similar. These types of headsets remove the repetitive noises in order to reduce the unwanted sounds. These would be ideal for nurse and paramedic in the helicopter because the repetitive noises of the helicopter do not need to be monitored but these crewmembers. Many of the pilots are retired military pilots and have had experience with ANR headsets. Most pilots feel unsafe with them because the headsets reduce the noises of the aircraft that the pilot wants to hear in order to

determine if the aircraft is running properly. So the use of ANR headsets for the pilots should be a decision made by each individual pilot.

According to the data collected by the mannequin testing it would be best if the crew did not turn the volume in the speakers above the 6 o'clock position. The highest SPL given were about 86.7 dBA, and considering the duration of most of the flights it would mostly likely still be below the hazardous threshold. Many of the helicopter personnel have claimed and have shown to have hearing losses already, so demanding a particular setting would not be the best or safest idea, but a suggestions to prevents some of the louder frequencies from entering the helmet would be advantageous.

Recommendations for Future Research

Based on the findings of this study, future research could be done in the following areas:

- Because neonates are more susceptible to hearing damage than adults, evaluating the isolates used to transport them and determining if further noise dampening or hearing protection should be provided to those patients.
- While this study took place, the hospital was looking into purchasing a new helicopter. Perhaps advising on the kind of helicopter purchased with regard to noise would be beneficial. After the purchase of the new helicopter, this study should be done again to determine if the noise levels are significantly different and if more protective equipment would be needed.
- Further evaluation of the personnel that work both on helicopters and ambulances to determine the exposure to those employees on both vehicles.
- Many of the other studies researched evaluated vibration as well. Although most of the flight durations are short, long-term hazards of vibration are a possibility; it could be a good study to look into.

References

- Küpper T, Steffgen J, Jansing P. "Noise Exposure during Alpine Helicopter Rescue Operations." *Ann Occup Hyg* 48.5 (2004): 475–81. Print
- McReynolds Michael. "Noise-Induced Hearing Loss." *Air Medical Journal* 24.2 (2005): March–April, 73-78. Print
- NIOSH. "Noise and Hearing Loss Prevention." *Centers for Disease Control and Prevention*. Centers for Disease Control and Prevention, 10 May 2011. Web. 09 Aug. 2012. <<http://www.cdc.gov/niosh/topics/noise/>>.
- OSHA. "Occupational Noise Exposure." OSHA.gov. OSHA. Web. 04 June 2012. <http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9735>.
- Pasic Thomas, Poulton Thomas. "The Hospital-Based Helicopter." *Arch Otolaryngol* 111 (1985): 507-508. Print
- "Quest Technologies - A 3M Company." *QuestTechnologies.com: Frequently Asked Questions*. N.p., n.d. Web. 10 June 2012. <<http://questtechnologies.com/Faq.aspx>>.

Appendices

Appendix I Equipment List

#1 Quest Technologies Q-300 Noise Dosimeter
Serial #: QC9070033 – R3377
Oconomowoc, Wisconsin USA
Calibrated 8/11/11 by JM
Calibration Due 8/11/12

#2 Quest Technologies Q-300 Noise Dosimeter
Serial #: QC8110018
Oconomowoc, Wisconsin USA
Calibrated 8/11/11 by JM
Calibration Due 8/11/12

#3 Quest Technologies Q-300 Noise Dosimeter
Serial #: QC9010031 – R3085
Oconomowoc, Wisconsin USA
Calibrated 8/11/11 by JM
Calibration Due 8/11/12

#4 Quest Technologies Q-300 Noise Dosimeter
Serial #: QC0060150 – R3901
Oconomowoc, Wisconsin USA
Calibrated 8/11/11 by JM
Calibration Due 8/11/12

#5 Quest Technologies Q-300 Noise Dosimeter
Serial #: QC0060156 – R3904
Oconomowoc, Wisconsin USA
Calibrated 8/11/11 by JM
Calibration Due 8/11/12

Microphone
Part Number: 056-963

Styrofoam Mannequin Head
Item model number: 0077
ASIN: B00466BA1C

Camera Tri-pod

Appendix II IRB Approval



DIVISION OF RESEARCH INTEGRITY AND COMPLIANCE
Institutional Review Boards, FWA No. 00001669
12901 Bruce B. Downs Blvd., MDC035 • Tampa, FL 33612-4799
(813) 974-5638 • FAX (813) 974-5618

10/31/2011

Robert Booth
Environmental and Occupational Health
12214 Wood Duck Place
Tampa, FL 33617

RE: Exempt Certification for IRB#: Pro00004329
Title: Noise exposure in medical helicopter flights.

Dear Mr. Booth:

On 10/31/2011 the Institutional Review Board (IRB) determined that your research meets USF requirements and Federal Exemption criteria as outlined in the federal regulations at 45CFR46.101(b):

(2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless:
(i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

As the principal investigator for this study, it is your responsibility to ensure that this research is conducted as outlined in your application and consistent with the ethical principles outlined in the Belmont Report and with USF IRB policies and procedures. Please note that changes to this protocol may disqualify it from exempt status. Please note that you are responsible for notifying the IRB prior to implementing any changes to the currently approved protocol.

The Institutional Review Board will maintain your exemption application for a period of five years from the date of this letter or for three years after a Final Progress Report is received, whichever is longer. If you wish to continue this protocol beyond five years, you will need to submit a new application. Should you complete this study prior to the end of the five-year period, you must submit a request to close the study.

We appreciate your dedication to the ethical conduct of human subject research at the University of South Florida and your continued commitment to human research protections. If you have any questions regarding this matter, please call 813-974-5638.

Sincerely,

A handwritten signature in cursive script that reads "John A. Schinka, Ph.D.".

John A. Schinka, Ph.D., Chairperson
USF Institutional Review Board