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Pilot Study: Foam Wedge Chin Support Static Tolerance Testing

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14. ABSTRACT

Along with the development of helmet-mounted technologies, new generations of aviator helmets have seen an increase in weight and the forward displacement of helmet center of gravity. Along with these changes, complaints of neck pain thought to be due to these new helmet-mounted display helmets have increased in recent years. To pursue a solution to this, Defence Research and Development Canada came up with a high-level concept of attaching a foam wedge to the chest to support the helmet weight. The U.S. Air Force, in collaboration with Defence Research and Development Canada, has since pursued this concept and created a foam wedge prototype to mitigate the increase in helmet weight and forward center of gravity. The purpose of this pilot study was to determine the feasibility and tolerability of the foam wedge prototype. The results of this study are meant to determine whether further research should be pursued into the application of the foam wedge chin support. Four subjects (two males and two females) not accustomed to wearing helmets donned the Joint Strike Fighter Generation II helmet, the MBU-20/P mask, and a standard PCU-15/P flight harness. Subjects were seated in an advanced concept ejection seat at a reclining angle of both 8 and 30 degrees. The foam wedge was attached to the chest of each of the subjects using Velcro prior to the start of testing. The subjects completed various routine pilot activities. At the conclusion of each testing session, subjects completed a qualitative questionnaire regarding the comfort, fit, and positive benefits that could potentially come from the use of the foam wedge to mitigate neck pain. Overall, testing showed that the use of the foam wedge did not adversely affect simulation of cockpit activities. Very minimal neck discomfort was recorded throughout the trials, making the foam wedge a good prospect for mitigating helmet-induced neck pain. Subjects very strongly believed that there is a legitimate benefit to pilots that choose to use the foam wedge, and therefore feel that the device should be made available to aviators. From the results of this pilot study, it is recommended that further testing into the foam wedge's pain mitigation performance should be compared with a control group that does not utilize the foam wedge.

15. SUBJECT TERMS

High-performance aircraft, helmet-mounted display, helmet-induced neck pain, foam wedge, pain mitigation

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1.0 SUMMARY

Along with the development of helmet-mounted technologies, new generations of aviator helmets have seen an increase in weight and the forward displacement of helmet center of gravity. Along with these changes, complaints of neck pain thought to be due to these new helmet-mounted display helmets have increased in recent years. To pursue a solution to this, Defence Research and Development Canada came up with a high-level concept of attaching a foam wedge to the chest to support the helmet weight. The U.S. Air Force, in collaboration with Defence Research and Development Canada, has since pursued this concept and created a foam wedge prototype to mitigate the increase in helmet weight and forward center of gravity. The purpose of this pilot study was to determine the feasibility and tolerability of the foam wedge prototype. The results of this study are meant to determine whether further research should be pursued into the application of the foam wedge chin support. Four subjects (two males and two females) not accustomed to wearing helmets donned the Joint Strike Fighter Generation II helmet, the MBU-20/P mask, and a standard PCU-15/P flight harness. Subjects were seated in an advanced concept ejection seat at a reclining angle of both 8 and 30 degrees. The foam wedge was attached to the chest of each of the subjects using Velcro prior to the start of testing. The subjects completed various routine pilot activities. At the conclusion of each testing session, subjects completed a qualitative questionnaire regarding the comfort, fit, and positive benefits that could potentially come from the use of the foam wedge to mitigate neck pain. Overall, testing showed that the use of the foam wedge did not adversely affect simulation of cockpit activities. Very minimal neck discomfort was recorded throughout the trials, making the foam wedge a good prospect for mitigating helmet-induced neck pain. Subjects very strongly believed that there is a legitimate benefit to pilots that choose to use the foam wedge, and therefore feel that the device should be made available to aviators. From the results of this pilot study, it is recommended that further testing into the foam wedge's pain mitigation performance should be compared with a control group that does not utilize the foam wedge.

2.0 INTRODUCTION

Along with the development of helmet-mounted technologies, new generations of aviator helmets have seen an increase in weight and the forward displacement of helmet center of gravity (CG). Along with these changes, complaints of neck pain thought to be due to these new helmet-mounted display helmets have increased in recent years. It has been noted by the U.S. Air Force (USAF) that between 2006 and 2014, the rate of neck pain (and injury) in fighter and bomber pilots increased by approximately 20.6% [1]. In 1988, Vanderbeek found that 30% of fixed wing pilots had experienced neck injury in the past month, and 63.6% experienced neck injury in the past year [2]. Murray cited that over the course of a career, 81% of helicopter pilots experience neck pain, along with 84% of crew members [3]. This correlation between helmet technology advancements and increased neck pain indicates that either helmet-mounted display helmets need to be reduced in weight or have their CG become more neutral or an intervention needs to be created to help support the weight of these helmets. Defence Research and Development Canada (DRDC) has noted that Canadian helicopter pilots have been mitigating helmet-induced neck pain by placing a fist against the chest and under the chin to support some of the helmet load. This is potentially problematic because it means that pilots are taking one hand off of the helicopter controls. To pursue a solution to this, DRDC came up with a high-level

concept of attaching a foam wedge to the chest to support the helmet weight. The USAF at Wright-Patterson Air Force Base, in collaboration with DRDC, has since pursued this concept and created a foam wedge prototype to mitigate the increase in helmet weight and forward CG. Although DRDC intended to solve a problem for helicopters, the USAF believes that this application might be adaptable to mitigate neck pain in high-performance jet aviators during the 1-G phase of flight if it can be made safe for ejection. The purpose of this pilot study was to determine the feasibility and tolerability of the foam wedge prototype. The results of this study are meant to determine whether further research should be pursued into the application of the foam wedge chin support.

3.0 METHODS AND PROCEDURES

Four subjects were used for this pilot study, two males and two females, to account for a more complete population. A non-human research approval was granted by the Institutional Review Board. It is important to note that none of the subjects were accustomed to wearing helmets, making them more susceptible to neck pain than an active duty aviator. The original intent of the study was to use a Joint Helmet Mounted Cueing System helmet mockup because of its extreme forward CG. Due to time constraints, the Joint Strike Fighter Generation II helmet was worn, along with the MBU-20/P mask. To allow normal breathing, the mask did not have an oxygen hose attached. A standard PCU-15/P flight harness was also worn by each of the subjects. The harness was pre-tensioned to simulate normal operational use. Subjects were seated in an advanced concept ejection seat (ACES II) with a testing setup that allows for the seat reclining angle to be changed between 8 and 30 degrees. Both of these cockpit seat configurations were tested for tolerance, as they encompass the seat angles of USAF fighter jets. The 8-degree configuration was used over a 13-degree configuration because it is a more extreme angle than would normally be seen, and it was a more stable fixture configuration than the 13-degree seat configuration. The foam wedge was attached using Velcro to the chest of each of the subjects prior to the start of testing. The wedge prototype was made using Plastazote® LD45 polyethylene foam material (Zotefoams plc, Croydon, UK). Figure 1 shows an example of the subject setup, including the foam wedge.

Each of the tolerance testing sessions allotted approximately 15 minutes for putting on all of the equipment, including the helmet, and 45 minutes worth of testing time in the ACES II seat. At intervals of 5 minutes, subjects were asked to complete various activities that would be normal for a pilot during normal flight. These activities include checking six and reading numbers shown left and right (5, 20, and 35 minutes), identifying a number forward and at feet (10, 25, and 40 minutes), picking up a pen off the floor from in-between feet (15 minutes), and tying one shoe lace (30 minutes). The numbers displayed for checking six were placed at the same point that they appear during centrifuge trials for checking six. This includes extending 12 inches laterally from the center of the seat head rest and extending 13 inches to the posterior of the head rest for the 30-degree seat configuration or 24 inches posterior for the 8-degree seat configuration. At the conclusion of each testing session, the subject completed a qualitative questionnaire regarding the comfort, fit, and positive benefits that could potentially come from the use of the foam wedge to mitigate neck pain.

Figure 1. Subject seated in 30-degree position.

4.0 RESULTS AND DISCUSSION

Initial testing sessions were conducted at Wright-Patterson Air Force Base in the Biodynamics Lab using the ACES II seat. Testing was conducted over the course of 2 days: 1 day for the 8-degree cockpit seat configuration and 1 day for the 30-degree configuration. The 30-degree seat recline was completed on the first day of testing. Each of the four subjects completed the testing wearing the harness, Joint Strike Fighter Generation II helmet, MBU-20/P mask, and foam wedge. It is important to note that while donning all the equipment, subjects were wearing the helmet without the foam wedge. Because of this, there may have been a slight amount of induced pain and fatigue on the subjects prior to the start of testing. On average throughout both configurations, the subjects wore the helmet for just under 9 minutes prior to the start of the test. In the most extreme case, the first subject wore the heavy helmet with a forward CG 22 minutes prior to testing. The intervals between each activity were then adjusted and each interval was limited to 3 minutes, for a total testing time of 27 minutes (Subject 1, 30-degree position). All of the rest of the subjects completed the entire 45-minute-long test. During the 8-degree seat configuration, each of the subjects completed the entire 45-minute-long test. While reading numbers during check six and looking forward and below, correct and incorrect answers were recorded. During the 30-degree recline seat configuration, it was found that all subjects answered every number check correctly. The 8-degree seat recline results also showed that all subjects answered all number checks correctly. Each of the numbers shown was approximately the size of a piece of printer paper. It was speculated that the numbers were too large, and the argument was made that the large numbers allowed the subjects to utilize their peripheral vision, rather than having to focus on the numbers. Even so, this was an effective method to show that the foam wedge did not impede the ability to turn the head to the side to check six.

The collected results from the subject questionnaires analyzed subject comfort, wedge support size and firmness, as well as any chin, chest, or neck discomfort. From the 30-degree configuration, it was shown that neck soreness was experienced at various times throughout the trial depending on the subject. Along with this, three out of the four subjects experienced some

form of soreness at the upper rear region of the neck, although the highest amount of pain was described as a 4 on a scale of 10 (10=very painful). During the 8-degree trials, one subject experienced neck soreness near the lower rear neck region, while another described it in the upper rear neck region. Chest and chin discomfort were also described as no discomfort, up to a mild discomfort throughout all of the testing. One reason that was cited for slight chest discomfort is that the shear force caused by the wedge on the chest was irritating when the wedge was not firmly attached and kept static during use. Following testing from the 30-degree seat configuration, some slight attachment adjustments were made to address this issue and ensure that the foam wedge stayed more stationary on the chest. To do this, a Velcro strap extending from one side of the harness to the other strapped the foam wedge more firmly in place. It is also important to note that the overall shape and firmness were considered very acceptable, with data showing that a slight firming of the chin support would be beneficial.

Participants were able to pick up the pen off the ground in only three out of the eight trials, but this was due to the limited mobility of the harness rather than the foam wedge impeding subject movement. Three out of the four respondents described being able to tie his or her shoe as relatively easy in each of the trials. The other subject had difficulty reaching the shoe due to the harness restraint. Table 1 shows the results.

Table 1. Average Results from Subject Questionnaires

Subject	Seat Angle (deg)	Pre-Test Helmet Time (min)	Comfort[a]		Chin Support Size[b]	Support Firmness[c]	Discomfort[d]			Activities[e]			Benefit to Pilots[f]
			Overall	Helmet			Chest	Chin	Neck	Check Six	Pick Up Pen	Tie Shoes	
Avg	30	11.25	5.50	6.00	4.75	6.25	2.75	2.50	2.50	8.75	4.00	7.00	9.00
Avg	8	6.25	6.75	6.25	5.25	4.50	2.25	2.50	2.50	8.75	3.00	7.00	8.50
Total	Both	8.75	6.13	6.13	5.00	5.38	2.50	2.50	2.50	8.75	3.50	7.00	8.75

[a]10=comfortable.
[b]10=too large.
[c]10=too soft.
[d]10=very painful.
[e]10=easy.
[f]10=very beneficial.

From the results of this testing, it was found that the subjects believed that offering a more refined foam wedge would be very beneficial to pilots to mitigate neck pain and fatigue. It was also noted that the wedge did not seem to impair any of the cockpit activities that were evaluated. One area of concern was that the foam wedge transferred the forces of the helmet to the lower back, rather than eliminating the effects of them altogether. This was more of a concern with the 8-degree configuration, although the subjects were not sure if this same lower back soreness would be observed even without the use of a helmet. Another observation that was made was that much less adjustment to the wedge was occurring with the updated attachment method. Along with this, subjects seemed to be more likely to lean the head forward further into the wedge, rather than having the head biased toward the seat rest. Any failure to complete activities was due to the harness restraint system preventing mobility, as well as a lack of arm length. Another significant takeaway, as can be seen in Figure 1, is that the mask and oxygen hose (the cutout where the hose would be attached can be seen) will not impede the use of the foam wedge.

5.0 CONCLUSION

Overall, testing showed that the simulation of cockpit activities was not adversely affected due to the use of the foam wedge. Although not all participants were able to pick up the pen off the floor or tie their shoes, this was caused by the limited motion when the harness was strapped into the seat. Some minor changes to the foam wedge need to be addressed, including a better developed attachment method for the wedge for helicopter pilots, as they do not wear a harness during flight. Very minimal neck discomfort was recorded throughout the trials, making the foam wedge a good prospect for mitigating helmet-induced neck pain. Subjects very strongly believed that there is a legitimate benefit to pilots who choose to use the foam wedge, and therefore feel that the device should be made available to aviators. From the results of this pilot study, it is recommended that further testing into the foam wedge's pain mitigation performance should be compared with a control group not utilizing the foam wedge.

6.0 REFERENCES

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2. Vanderbeek RD. Period prevalence of acute neck injury in U.S. Air Force pilots exposed to high G forces. Aviat Space Environ Med. 1988; 59(12):1176-1180.
3. Murray M, Lange B, Nømberg BR, Søgaard K, Sjøgaard G. Specific exercise training for reducing neck and shoulder pain among military helicopter pilots and crew members: a randomized controlled trial protocol. BMC Musculoskelet Disord. 2015; 16:198.

APPENDIX A
Subject Questionnaire

Foam Wedge Static Testing Questionnaire

Date/Time of Exposure:_____ **Subj ID**:_____ **Config.**_____

Overall Body Comfort:

Not Tolerable **Very Comfortable**

1 2 3 4 5 6 7 8 9 10

Helmet Comfort:

Not Tolerable **Very Comfortable**

1 2 3 4 5 6 7 8 9 10

Chin Support Size:

Too Small **Too Large**

1 2 3 4 5 6 7 8 9 10

Chin Support Firmness:

Too Hard **Too Soft**

1 2 3 4 5 6 7 8 9 10

Chest Discomfort/Pain:

Complete Lack of Discomfort **Very Painful**

1 2 3 4 5 6 7 8 9 10

Chin Discomfort/Pain:

Complete Lack of Discomfort **Very Painful**

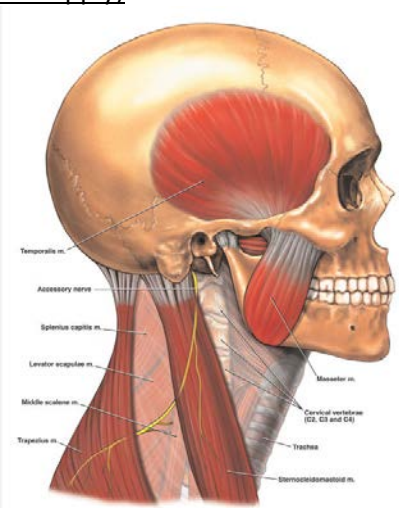
1 2 3 4 5 6 7 8 9 10

Neck Discomfort/Pain:

Complete Lack of Discomfort **Very Painful**

1 2 3 4 5 6 7 8 9 10

Region of Neck Discomfort/Pain (circle all regions that apply):



Upper Rear **Lower Rear** **Upper Front** **Lower Front**

Approximate Time that Neck Discomfort/Pain Began:

Ability to Turn Head Sideways ("Check Six"):

Not Able to Complete **Easy to Complete**

1 2 3 4 5 6 7 8 9 10

Ability to Pick Item Off Floor:

Not Able to Complete **Easy to Complete**

1 2 3 4 5 6 7 8 9 10

Ability to Adjust/Tie Shoe:

Not Able to Complete **Easy to Complete**

1 2 3 4 5 6 7 8 9 10

Benefit to Pilots as an Option:

Don't Make Available **Make Available**

1 2 3 4 5 6 7 8 9 10

Additional Comments

_____
_____
_____
_____
_____
_____
_____

APPENDIX B
Questionnaire Results

Subject	Seat Angle	Mask	Pre-Test Helmet Time (min)	Overall Comfort	Helmet Comfort	Chin Support Size	Support Firmness	Chest Discomfort	Chin Discomfort	Neck Discomfort	Neck Pain Region	Start of Pain	Check Six	Pick up Pen	Tie Shoe	Benefit to Pilots
				10 = comfortable	10 = comfortable	10=too large	10=too soft	10=very painful	10=very painful	10=very painful	-	-	10 = easy	10 = easy	10 = easy	10 = very beneficial
1	30°	No	22	5	5	5	8	1	3	4	Upper Rear	20 min	8	1	10	9
2	30°	Yes	9	5	5	5	5	4	1	1	N/A	N/A	10	10	10	10
3	30°	Yes	10	5	8	4	7	3	3	3	Upper Rear	40 min	9	1	1	8
4	30°	Yes	4	7	6	5	5	3	3	2	Upper Rear	0 min - minimal	8	4	7	9
Average	30°	-	11.25	5.50	6.00	4.75	6.25	2.75	2.50	2.50	-	-	8.75	4.00	7.00	9.00
1	8°	Yes	5	5	3	5	5	1	1	6	Upper Rear	20 min	10	1	8	8
2	8°	Yes	11	10	9	6	4	5	2	1	N/A	N/A	9	9	9	10
3	8°	Yes	4	6	7	5	5	1	3	1	N/A	N/A	8	1	3	7
4	8°	Yes	5	6	6	5	4	2	4	2	Lower Rear	10 min	8	1	8	9
Average	8°	Yes	6.25	6.75	6.25	5.25	4.50	2.25	2.50	2.50	-	-	8.75	3.00	7.00	8.50
Total	Both	-	8.75	6.13	6.13	5.00	5.38	2.50	2.50	2.50	-	-	8.75	3.50	7.00	8.75
									Arms were too short to reach the pen.							
									Unable to tie shoe.							

Subject	Seat Angle	Mask	Date	Start Time	Comments
1	30°	No	5/18/2017	9:17 AM	If design is refined, could be useful for 1G.
2	30°	Yes	5/18/2017	9:55 AM	-
3	30°	Yes	5/18/2017	11:07 AM	Had some jaw discomfort, might be good to have different sizes of wedges.
4	30°	Yes	5/18/2017	12:00 PM	Once the wedge was positioned correctly and velcroed secure, it was not very noticeable in feeling that a wedge was even there, but the weight of the helmet was alleviated from the neck. Having the mask with the rubber bottom contact the wedge was very helpful.
Average	30°	-	-	-	
1	8°	Yes	6/13/2017	9:13 AM	Neck fatigue and headache about 20 minutes into testing, and continued until the end.
2	8°	Yes	5/31/2017	8:53 AM	Definitely offer to helicopter pilots. Base needs to be irmly held in place and never move once pilot positions it.
3	8°	Yes	5/31/2017	9:44 AM	Felt as though the discomfort was just transferred to the mid-back. Not sure if the discomfort would have been present without the helmet.
4	8°	Yes	5/31/2017	10:45 AM	Some jaw discomfort from chin support pushing the mask into the chin.

APPENDIX C
Number Check Results

Configur:	30 Degrees				
Subject	Time (min)	Left	Right	Front	Below
1	5				
	10				
	20				
	25				
	35				
	40				
2	5				
	10				
	20				
	25				
	35				
	40				
3	5				
	10				
	20				
	25				
	35				
	40				
4	5				
	10				
	20				
	25				
	35				
	40				

Configur:	8 Degrees				
Subject	Time (min)	Left	Right	Front	Below
1	5				
	10				
	20				
	25				
	35				
	40				
2	5				
	10				
	20				
	25				
	35				
	40				
3	5				
	10				
	20				
	25				
	35				
	40				
4	5				
	10				
	20				
	25				
	35				
	40				

	Correctly identified number
	Incorrectly identified number

LIST OF ABBREVIATIONS AND ACRONYMS

ACES	advanced concept ejection seat
CG	center of gravity
DRDC	Defence Research and Development Canada
USAF	U.S. Air Force