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Costs and Benefits of Physical Therapy Program Implementation for Air Force Fighter Pilots

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COSTS AND BENEFITS OF PHYSICAL THERAPY PROGRAM IMPLEMENTATION FOR AIR FORCE FIGHTER PILOTS

THESIS

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Abstract

Air Force fighter pilots face risks associated with neck and spine injuries sustained while operating fighter aircraft. Studies from the flying and medical communities indicate that muscle-strengthening prehabilitative care may decrease the risk of flying related injuries in high performance aircraft pilots. For this reason, the U.S. Air Force provided $24.9M to implement the Optimizing the Human Weapon System (OHWS) program. The program provides physical therapy and strength training to fighter pilots in participating units at twenty-one Air Force bases with the intent of reducing injury rates and time out of the cockpit. From a healthcare perspective there is interest in the effectiveness of the program in injury reduction. From a funding perspective there is interest in the potential for a positive net present value (NPV) of the OHWS investment. This research utilizes injury data obtained from the Force Risk Reduction (FR2) tool to analyze injury rates, injury types, physiological injury locations, as well as medical and non-medical injury costs to form an NPV estimate for the OHWS program. The research finds that the OHWS program provides a NPV of $12.5M assuming the potential effects on injury reduction and fighter pilot separations from active duty service that the program provides.

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Christian G. Erneston

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COSTS AND BENEFITS OF PHYSICAL THERAPY PROGRAM IMPLEMENTATION FOR AIR FORCE FIGHTER PILOTS

I. Introduction

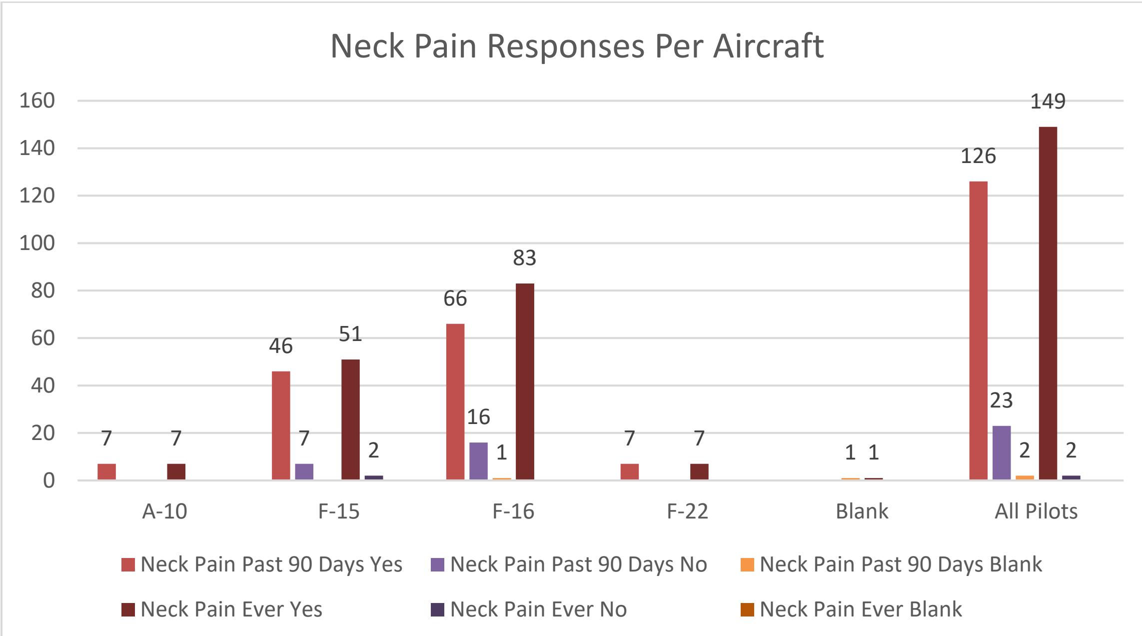
Air Force personnel must understand proper maintenance of aircraft to ensure they provide key combat capabilities. Perhaps just as important is optimization of the human weapon system. Air Force pilots must be fit to fight. High-performance (fighter) aircraft are capable of withstanding accelerations greater than ten times gravity. This environment increases the risks associated with neck and spine injury.

Fighter pilots need to maintain total environmental awareness when operating fighter aircraft. This need, when coupled with high g loading (often with abrupt onset) creates a predilection for cervical spine injury while pilots perform routine movements within the cockpit (Jones, 2000). Drew (2000) attempted to quantify the extent of spinal injuries in pilots of high-performance aircraft through the use of an extensive survey. One hundred sixty-one high-performance and non-high-performance aircraft pilots were surveyed with a 49% response rate. Of the respondents, a majority (54%) of high-performance aircraft pilots reported acute spinal symptoms, especially neck pain, associated with high-g loading occurring either during or shortly after flying missions.

Experiments have been conducted to address the efficacy of physical training programs designed to increase neck muscle strength and endurance in high performance aircraft pilots. A 2004 study found that a training period of six to eight months significantly increased neck muscle strength and endurance in an experimental group of pilots in comparison to a control group that did not participate in the standardized exercise program. The researchers recommended larger experimental and control groups coupled with longer observation periods in order to draw further conclusions concerning reducing neck pain complaints in pilots of high performance aircraft. They believed it likely that there was a correlation between neck muscle strength and endurance and neck pain (Alricsson, Harms-Ringdahl, Larsson, Linder, & Werner, 2004).

In response to the assertions made by researchers like Alricsson et. al, the Air Force launched the Optimizing the Human Weapon System (OHWS) program in 2020 in three commands: Air Combat Command (ACC), Pacific Air Forces (PACAF), and United States Air Forces in Europe (USAFE). The program is designed to meet the unique physical needs of Air Force fighter pilots through a comprehensive "pre-habilitative" physical training program that employs focused strength and conditioning, physical therapy, and athletic training (Selfridge Air National Guard Base, 2020). To determine the scope of the Air Force funding requirement, the program utilized a 2017 questionnaire developed by the Aeromedical Research Support Division of the U.S. Air Force Schoolhouse of Aerospace Medicine (USAFSAM). The questionnaire provided decision makers with information on the type and frequency of injuries sustained by fighter pilots to aid in determining program funding levels. The questionnaire was distributed to 149 high-performance aircraft pilots, many of whom indicated experiencing flying-related neck pain. The results of the survey are depicted graphically in Figure 1.

Figure 1. *Neck Pain Related to Forward Helmet Center of Gravity*



Note. Adapted from U.S. Air Force School of Aerospace Medicine (2019). *Pilot Questionnaire to Characterize Neck Pain Related to Forward Helmet Center of Gravity (U.S. Air National Guard)* [PowerPoint Slides].

The OWHS program was proposed based on a medical paradigm shift toward prehabilitative care prior to an injury rather than rehabilitative care following one. This shift has also manifested in the world of professional sports to prevent injuries and facilitate recuperation (Carli & Scheede-Bergdahl, 2015) (Hewett & Bates, 2017, p. 2655). Increases in the knowledge of human physiology and medicine over the past two decades now allow medical professionals to identify underlying mechanisms that lead to catastrophic injuries in athletes like anterior cruciate ligament (ACL) tears. A 2017 study summarized the shift using the term “preventive biomechanics” and defined it as, “the implementation of biomechanical measures within a standard clinical setting that demonstrate the capacity to diagnose the relative risk and reduce the incidence rate of musculoskeletal injuries before onset" (Hewett & Bates, 2017, p. 2655). The study concluded that a combination of preventive biomechanical screening, training, and treatment measures into an overarching program resulted in a significant reduction in risk of injury. The researchers further concluded that this type of program could be achieved at minimal cost and with a high return on investment (ROI) stemming from the reduced economic burden of sports medicine treatment.

The U.S. military has endeavored to understand the costs of injuries sustained by military personnel and the monetary benefits of preventive medical care. For example, to quantify the cost savings associated with preventive care, the U.S. Army developed the Medical Cost Avoidance Model (MCAM). This tool captures the full spectrum of medical costs associated with various types of injuries. These costs can then be compared to the investment costs required for new preventive forms of medical care to obtain an estimated return on investment for (ROI) for decision makers. MCAM retrieves fatality, injury, and mishap data from the Force Risk Reduction (FR2) tool that compiles over 400 million records and associated cost data which feed back into MCAM's cost component model. We utilized the MCAM model as a framework for the data we obtained in this research. We were not able to access the MCAM model directly, but instead obtained access to the FR2 database from which it pulls data.

Research Objectives/Questions/Hypotheses

With this research, we seek to explore the monetary and non-monetary costs associated with fighter pilot injuries and the potential benefits that the OHWS program offers the

U.S. Air Force. The following questions summarize the information that the study aims to obtain:

1. What are the monetary medical costs to the Air Force associated with neck, spine, and other musculoskeletal injuries in fighter pilots?
2. What reduction in Air Force fighter pilot neck, spine, and other musculoskeletal injuries is necessary for the OHWS program to provide a positive net present value (NPV)?
3. What, if any, additional qualitative benefits does the OHWS program provide the Air Force that affect the NPV?

Methodology Preview

Utilizing the MCAM model as a framework, we collected FR2 data on injury types, physiological injury locations, and their associated medical costs for fighter pilots on OHWS-participating units at twenty-one bases throughout Air Combat Command (ACC), Pacific Air Forces (PACAF), and United States Air Forces in Europe (USAFE). We also collected Centers for Disease Control and Prevention (CDC) data on work loss costs associated with the most common injuries sustained by fighter pilots. We utilized these costs to conduct a NPV analysis for the OHWS program investment. Finally, we incorporated the qualitative benefits of reduced fighter pilot separations from active duty service to further explore the NPV of the OHWS program.

II. Literature Review

Review of Spinal Cord Injury and Treatments

The most common type of injury to the spinal cord is due to compression by force (DeVivo, Go, & Jackson, 2002). This type of injury is normally called a "primary injury." The initial injury leads to a cascade of biological events classified as "secondary injury," which can occur over the course of minutes to weeks, leading to further neurological damage. The onset of a chronic phase follows. This chronic phase can occur days to years after the initial injury. Surgical treatment procedures are available, centering on stabilization and decompression of the spinal cord (Bracken & Holford, 2002), however these approaches are controversial since there is no consensus regarding their true beneficial effects (Silva, Sousa, Reis, & Salgado, 2014).

Sources of Neck and Spinal Injuries in Fighter Pilots

Cervical and lumbar spine disorders are common among fighter pilots. One in two fighter pilots report neck pain and one in three report low back pain (Grossman, Nakdimon, Chapnik, & Levy, 2012). One source of these disorders stems from fighter pilots' need to maintain total environmental awareness while operating their aircraft. Jones (2000) found that neck movements associated with scanning in a high load environment increase the risk of neck injury. In addition to the movements fighter pilots perform under high-g loading, the gear they wear can increase the risk of spinal injury. A one-pound increase in mass can represent up to nine pounds under g-loading.

Lange, Torp-Svendsen, and Toft (2011) explored neck pain in fighter pilots following the introduction of the Joint Helmet Mounted Cuing System (JHMCS). The

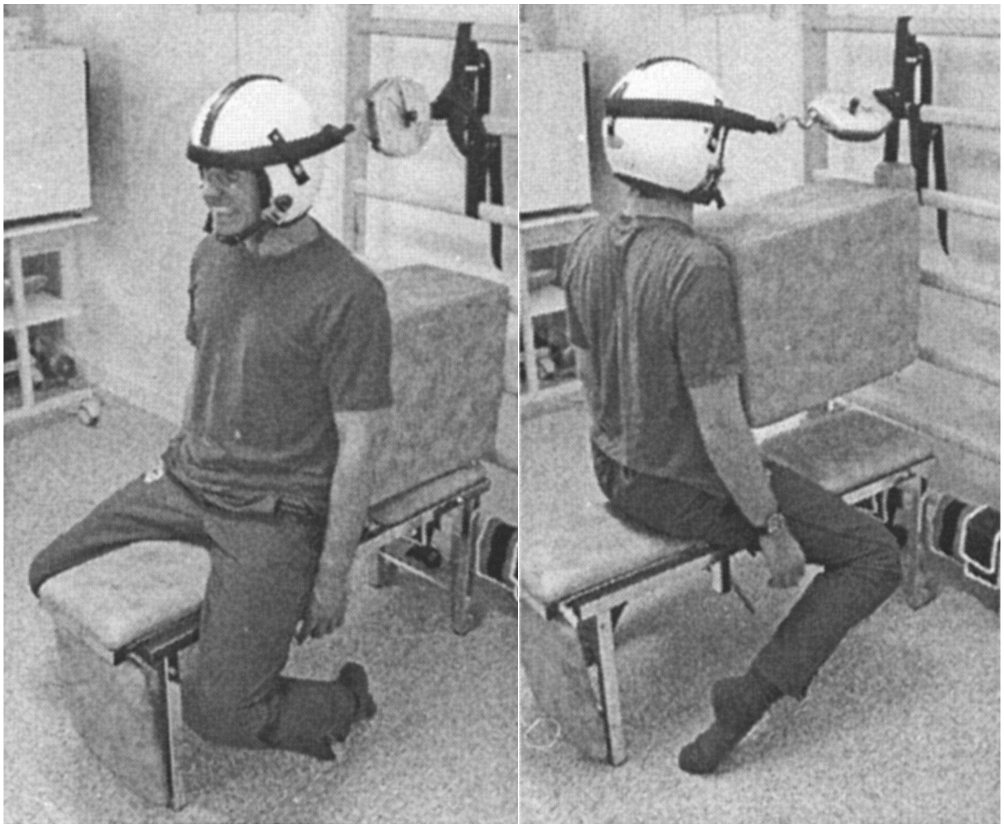
JHMCS provides pilots with the capability to accurately direct, or cue, onboard weapons against enemy aircraft and ground targets while performing high-g maneuvers. In order to direct weapon systems, pilots must look in the direction of the targets. These advancements encourage pilots to move their heads during high-g maneuvers and to do so quickly while the head is out of an anatomically neutral position. Green and Brown (2004) published a study reporting that during air combat maneuvering in a Hawk trainer jet, the aircrew had their head moved away from the neutral position 68% of the time during combat engagements. The 2011 study surveyed 58 F-16 pilots, more than half of whom utilized the JHMCS on a regular basis. With a 100% response rate to the survey, 97% of the pilots experienced neck pain during, or shortly after flight (Lange, Torp-Svendsen, & Toft, 2011).

Prehabilitative Care in Sports

Diving, football, all terrain-vehicle/all terrain-cycling, and snow skiing are among the top sports contributing to spinal cord injuries, according to the American Association of Neurological Surgeons (AANS). Of these, football is perhaps the most applicable analogy with a wealth of injury data. Football-related head injuries are often associated with neck injury during an impact. Neck injuries are typically associated with collisions between players, causing acceleration or deceleration of the head on the neck. One of AANS' tips for spinal cord injury prevention in football is that players receive adequate preconditioning and strengthening of the head and neck muscles (Agarwal, Thakkar, & Than, 2019). Hübscher et. al (2010) found that neuromuscular training, or exercises that train the muscles and nerves to react and communicate, are effective in reducing the incidence of athletic injuries such as sprains, dislocations, and ligament ruptures of the knee, ankle, hands, elbow, and shoulder. The researchers' findings were based on a meta-analysis of seven athletic neuromuscular training programs aimed at injury prevention.

The largest magnitude of muscular contractive forces occur when an external force exceeds that produced by the muscle and the muscle lengthens, producing an eccentric contraction (Katz, 1939). Many have advocated for the use of chronic eccentric exercise for the prevention or rehabilitation of those suffering from musculoskeletal injuries. Dean (1988) suggested that physiological adaption of muscles by way of an eccentric training regimen would decrease the potential for muscle trauma. A 1999 study found that chronic training programs that emphasize eccentric muscle contractions result in strength increases despite having the lowest energy consumption per unit of tension exerted (Lastayo, Reich, Urquhart, Hoppeler, & Lindstedt, 1999). Examples of eccentric muscle contractions can be seen in Figure 2. The photo on the left shows a cervical spine flexor muscle contraction with a subject sitting on a flat bench with his knees bent and arms by his side. The subject's chin was retracted under resistance to induce an eccentric muscle contraction. The photo on the right shows a cervical spine extensor muscle contraction with the subject sitting in the opposite direction with the contraction performed as a neck backward extension.

Figure 2. *Cervical Spine Flexor Muscle Contraction*



Source: Alricsson, M., Harms-Ringdahl, K., Larsson, B., Linder, J., & Werner, S. (2004). Neck Muscle Strength and Endurance in Fighter Pilots: Effects of a Supervised Training Program. *Aviation Space and Environmental Medicine*, 23-28.

U.S. Army Medical Cost Avoidance Model (MCAM)

In today's fiscally constrained environment demonstrating the effectiveness of new programs is a challenging task that relies heavily on providing objective data for use by decision makers. The U.S. Army's Institute of Public Health developed the Medical Cost Avoidance Model (MCAM) to meet the need for a return on investment (ROI) model capable of capturing the full spectrum of medical costs. MCAM is specifically tailored to provide the user with ROI for prevention programs based on the medical costs associated with specific International Classification of Disease, 9th revision (ICD-9) codes. The tool links data from three sources to compute total medical costs: the military health system (MHS) (medical treatment and fatality costs), the Army Military-Civilian Cost System (AMCOS) (personnel costs for lost time), and the U.S. Department of Veterans Affairs (VA) (permanent disability cost). The medical costs in Table 1 are summed to produce the total medical cost (C_t) using the simple equation: $C_t = C_c + C_h + C_l + C_f + C_d$ (Smith, McCoskey, Clasing, & Kluchinsky Jr., 2014).

Table 1. *The MCAM Medical Cost Components, Definitions, and Descriptions*

Cost Component	Definition	Description
C_c	Clinic cost	Outpatient treatment
C_h	Hospital cost	Inpatient treatment
C_l	Lost time cost	Time away from work due to clinic visits, hospital stays, assignment to quarters, convalescent leave, and the limited ability to perform.
C_f	Fatality cost	Insurance and gratuity pay
C_d	Disability cost	VA compensation disability

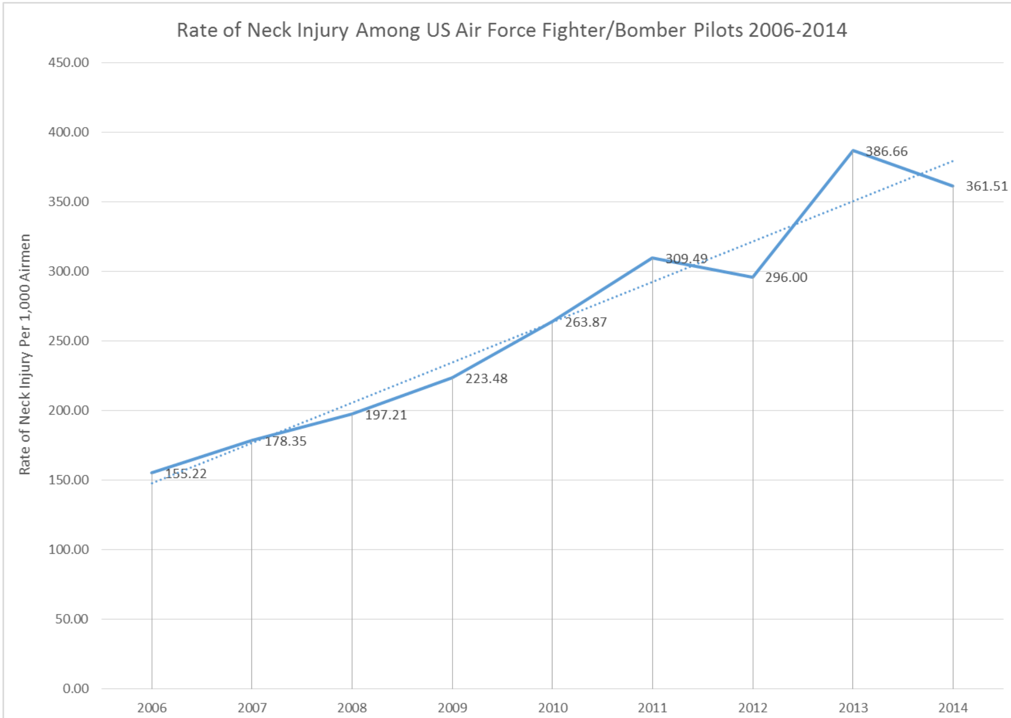
With total medical costs calculated, MCAM's ICD-9 Analysis Tool can be used. First, the user must determine the total cases expected to be avoided through the use of a preventative medicine initiative as well as the number of years the program is expected to be in place; this is information the user should collect separately for input into the model. The tool synthesizes this information to calculate an expected ROI for the program. The ROI value can be compared to the investment costs associated with the program to inform decision makers.

Optimizing the Human Weapon System (OHWS) Program

A Government Accountability Office (GAO) (2018) report on fighter pilot workforce requirements sought to capture initiatives implemented by the Air Force to address reported pilot shortages. Among the initiatives aimed at fighter pilot retention were preventative medical care programs for neck and back injuries. These programs were funded in fiscal year 2017 at one National Guard base and three active duty bases with the potential for increased funding in fiscal year 2020. The Air Force's efforts in 2017 represent a precursor to the current efforts being made to reduce injuries in fighter pilots as part of a multiprong strategy to boost retention.

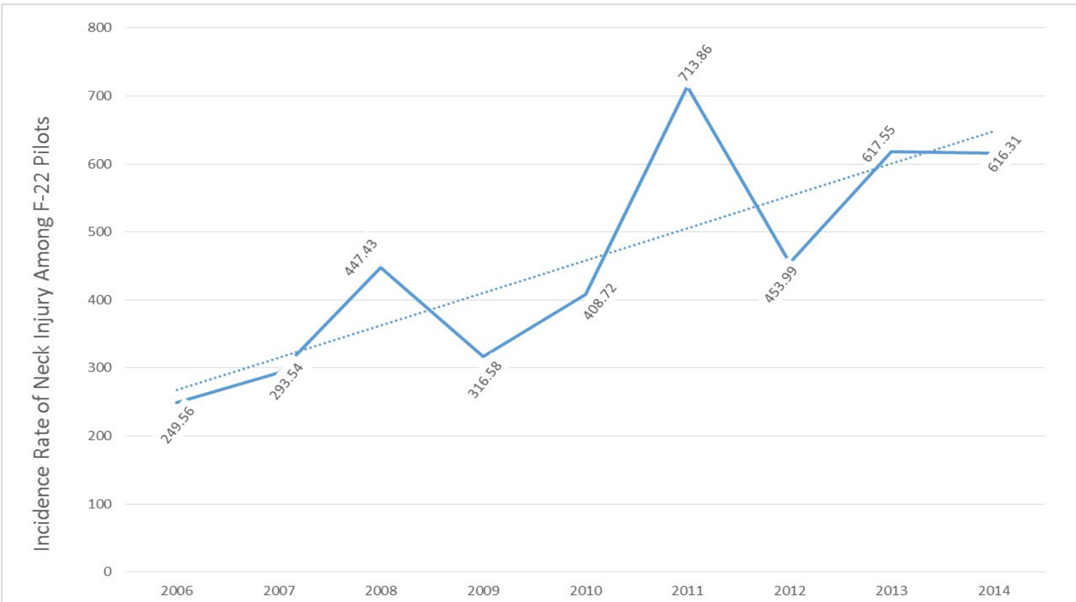
Researchers at the U.S. Air Force School of Aerospace Medicine (USAFSAM) explored neck injury rates in Air Force pilots to assess the need for a program designed to address them. Utilizing the Defense Medical Epidemiology Database (DMED), USAFSAM began by aggregating neck injury rates among U.S. fighter and bomber pilots from 2006 to 2014. ICD-9 codes were used to filter injury data in DMED. Specifically, ICD-9 code 847.0 (a broad category labelled as "Sprain of Neck") was used to gather the desired neck injury data. The aggregate data is depicted graphically in Figure 3.

Figure 3. *Rate of Neck Injury among U.S. Air Force Fighter and Bomber Pilots (2006-2014)*



The DMED data indicated that neck injuries were trending in an upward direction since 2006. This trend may be due in part to the increased maneuverability capabilities of fifth generation fighter aircraft like the F-35. The trend may also be linked to new equipment used by fighter pilots like the JHMCS helmet that places additional strain on pilots' bodies under g-loading. Upon initial analysis, two shortcomings in the data gathered were identified: the combination of fighter and bomber pilots and the utilization of a single ICD-9 code that omitted many other neck pain related codes. To adjust for these factors, a second DMED query was conducted for the same time period of 2006 to 2014. The second query limited the Air Force bases included to Elmendorf, Tyndall, Hickam, Holloman, and Langley Air Force bases in an attempt to limit the results to pilots of fighter airframes. Additionally, 17 ICD-9 codes were added to the query, some of which included: degeneration of cervical intervertebral discs (ICD-9 code 722.4) and intervertebral disc disorder with myelopathy (ICD-9 code 722.7). The results of this second query are displayed graphically in Figure 4.

Figure 4. *Rate of Neck Injury Among U.S. Air Force Fighter and Bomber Pilots (2006-2014) - Truncated Query*



This second query indicates that among fighter pilots, neck injuries were trending in a positive direction since 2006. While the query is indicative of a possible trend in neck injuries it still has a number of shortcomings that could introduce error. The first possibility is the potential of any other fighter airframes utilizing the bases included in the query during the years of 2006 to 2014. Second, the inclusion of 17 additional ICD-9 codes introduces the potential for the introduction of other neck related injuries that are unrelated to flying.

Despite the potential shortcomings of the queries utilized in USAFSAM's research on neck injuries in fighter pilots, the Air Force funded the Optimizing the Human Weapon System (OHWS) program across three commands in the summer of

2020 for a total of $24.90M. The participating commands included Air Combat Command (ACC), Pacific Air Forces (PACAF), and United States Air Forces in Europe (USAFE). The contract includes one base year funded at $6.89M and four option years funded at $18.01M total. The OHWS contract services include physical therapists, strength training coaches, and massage therapists for participating fighter pilot units at twenty-one bases. The goal of the OHWS contract is to increase the physical capacity of fighter aircrew, decrease the rate of injuries, and accelerate return to duty.

III. Methodology

Data Source Overview

Data for this research was obtained from the Force Risk Reduction (FR2) tool. The tool provides comprehensive roll-ups of military injury treatment claims data from military and non-military facilities to provide injury specific cases. FR2 contains seven dashboards that provide users with various categories of information. Data for this research were obtained exclusively from the Military Injury Medical Treatments and Casualties dashboard. This dashboard provides data on costs incurred by the military medical system to treat injuries in military personnel. The Medical Cost Avoidance (MCAM) model discussed in Chapter II was utilized as a framework for the FR2 data. FR2 does not provide lost time cost data for active duty military personnel. For this reason, lost time costs were estimated using Centers for Disease Control and Prevention data discussed later in this chapter.

Data Extraction

Within the Military Injury Medical Treatments and Casualties dashboard, users can filter injury data based on branch of service (Army, Air Force, Marine Corps, Navy, and Other Defense Agencies and Activities), installation, military treatment facility (MTF), major organization, component (Active Duty, Guard, and Reserve). Additionally, users can filter by diagnosis (ergonomic or non-ergonomic). Ergonomic injuries are caused by repetition, poor posture, forceful motion, stationary position, direct pressure, vibration, extreme temperature, noise, and work stress (Occupational Safety and Health

Administration, 2016). Non-ergonomic injuries are those caused by nonrepetitive factors. Orthopedic injuries, like broken bones and joint sprains, fall into the category of non-ergonomic injuries. For the purposes of this research, both ergonomic and non-ergonomic injuries were included in the data. The injury data obtained from FR2 indicates that fighter pilots suffer from both of these injury types.

The method by which data was obtained for this research was informed in part by an organizational map provided by the United States Air Force Schoolhouse of Aerospace Medicine (USAFSAM) shown in Figure 5. The map shows organizations where the Optimizing the Human Weapon System (OHWS) program was implemented. Twenty-one bases were identified as participants in the OHWS program based on the organizational map in Figure 5. Those bases and the local units participating in the program are listed in Table 2. FR2 data was gathered for all participating bases shown in Table 2 with the exception of RAF Lakenheath. FR2 data was not available for this installation during the period examined for this research. If data were available, it would have increased the medical and non-medical injury costs discussed later in this chapter.

Figure 5. *Organizational Map of Units Participating in the OHWS Program*

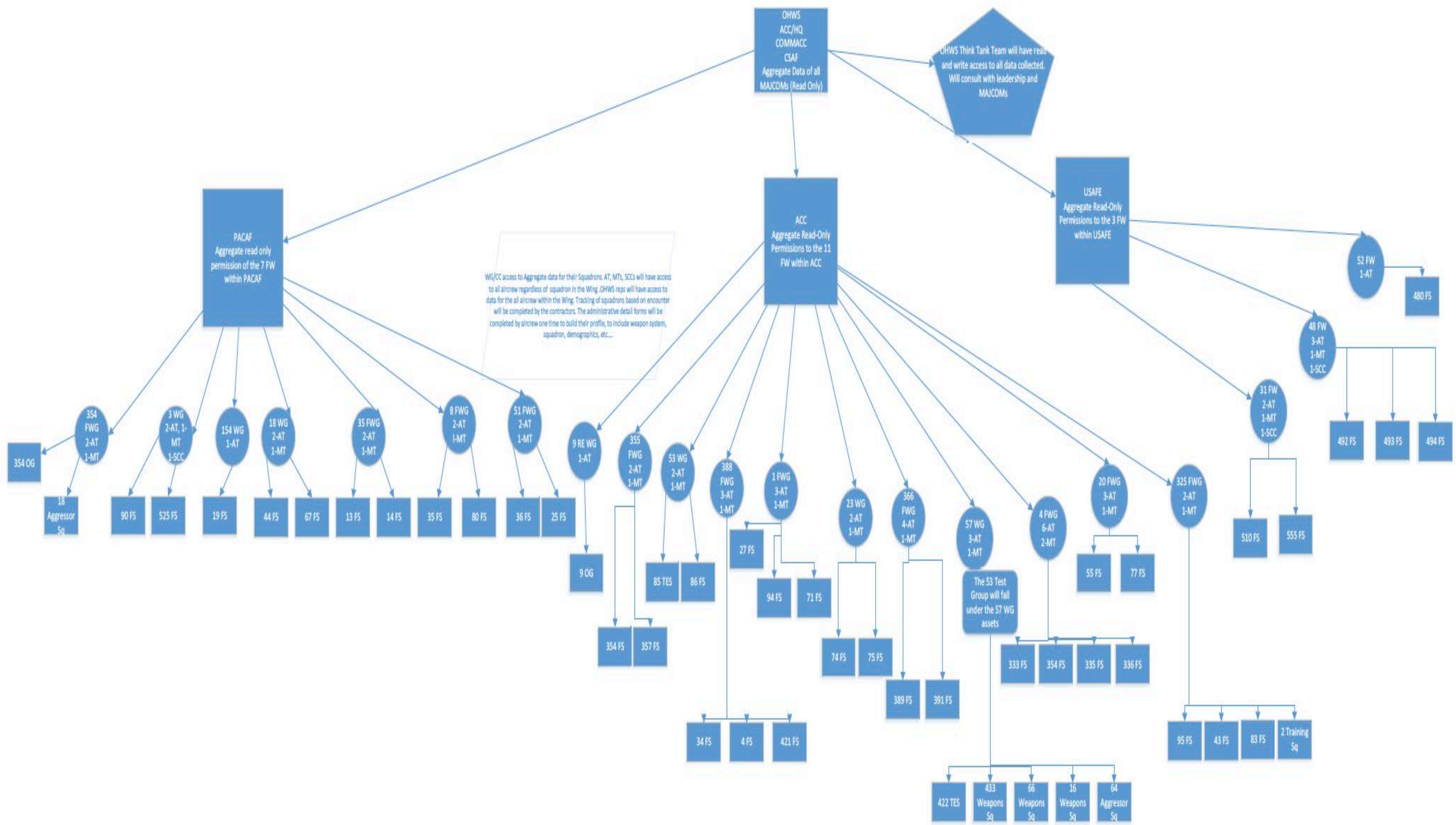


Table 2. *Bases, Units, and Commands Participating in OHWS Program*

<table>
<tr><td>Beale AFB</td><td>9th Operations Group</td><td rowspan="11">ACC</td></tr>
<tr><td>Davis-Monthan AFB</td><td>354th Fighter Squadron, 357th Fighter Squadron</td></tr>
<tr><td>Eglin AFB</td><td>85th Test and Evaluation Squadron, 86th Fighter Squadron</td></tr>
<tr><td>Hill AFB</td><td>4th Fighter Squadron, 34th Fighter Squadron, 421st Fighter Squadron</td></tr>
<tr><td>Joint Base Langley-Eustis</td><td>27th Fighter Squadron, 71st Fighter Squadron, 94th Fighter Squadron</td></tr>
<tr><td>Moody AFB</td><td>74th Fighter Squadron, 75th Fighter Squadron</td></tr>
<tr><td>Mountain Home AFB</td><td>389th Fighter Squadron, 391st Fighter Squadron</td></tr>
<tr><td>Nellis AFB</td><td>422nd Test and Evaluation Squadron, 16th Weapons Squadron, 66th Weapons Squadron, 433rd Weapons Squadron, 64th Aggressors Squadron</td></tr>
<tr><td>Seymour Johnson AFB</td><td>333rd Fighter Squadron, 335th Fighter Squadron, 336th Fighter Squadron</td></tr>
<tr><td>Shaw AFB</td><td>55th Fighter Squadron, 77th Fighter Squadron</td></tr>
<tr><td>Tyndall AFB</td><td>43rd Fighter Squadron, 83rd Fighter Squadron, 95th Fighter Squadron, 2nd Training Squadron</td></tr>
<tr><td>Eielson AFB</td><td>354th Operations Group, 18th Agressor Squadron</td><td rowspan="7">PACAF</td></tr>
<tr><td>JB Elmendorf-Richardson</td><td>90th Fighter Squadron, 525th Fighter Squadron</td></tr>
<tr><td>Hickam AFB</td><td>19th Fighter Squadron</td></tr>
<tr><td>Kadena AB</td><td>44th Fighter Squadron, 67th Fighter Squadron</td></tr>
<tr><td>Misawa AB</td><td>13th Fighter Squadron, 14th Fighter Squadron</td></tr>
<tr><td>Kunsan AB</td><td>35th Fighter Squadron, 80th Fighter Squadron</td></tr>
<tr><td>Osan AB</td><td>25th Fighter Squadron, 36th Fighter Squadron</td></tr>
<tr><td>Aviano AB</td><td>510th Fighter Squadron, 555th Fighter Squadron</td><td rowspan="3">USAFE</td></tr>
<tr><td>RAF Lakenheath</td><td>492nd Fighter Squadron, 493rd Fighter Squadron, 494th Fighter Squadron</td></tr>
<tr><td>Spangdahlem AB</td><td>480th Fighter Squadron</td></tr>
</table>

The FR2 tool's ability to filter injury data to the base-level was utilized to obtain location-specific injury data. In an effort to filter FR2 data in a way that isolated the fighter pilots participating in the OHWS program, the first filter applied to the Military Injury Medical Treatments and Casualties data was the service-level filter for Air Force. Next the component filter was set to active duty to exclude Air Force Reserve pilots. Then one of the Air Force bases in Table 2 (e.g. Beale AFB) was selected. Finally, the occupation filter of "fixed wing fighter/bomber pilot" was selected. This process was repeated for each of the remaining bases participating in the OHWS program for fiscal years 2016 - 2018. These filters ensured that to the greatest extent possible only the fighter pilots participating in the OHWS program comprised the data retrieved from the FR2 tool.

FR2 Medical Data and Costs

With the raw fixed wing fighter pilot data extracted from the FR2 tool, the types of injuries of interest needed to be isolated. This research seeks, in part, to capture the costs of fighter pilots seeking medical care for neck and spine injuries sustained in the cockpit. However, it can be reasonably assumed that if a fighter pilot within an OWHS-participating unit sustained an injury off duty, say a sprained wrist from recreational activities, they would seek medical care from their OHWS caregivers. Injury types extracted from the FR2 data included those related to the neck, spine, and pelvis. Based on the previous assumption, injuries related to pain, strains, and sprains in other regions of the body were captured as well. These injuries and their anatomical locations on the body are listed in Table 3. The anatomical locations were used to filter the raw FR2 injury data to regions of the body where injuries sustained by fighter pilots in the cockpit might originate (e.g. neck, spine, and low back). The anatomical locations also aided in filtering to regions of the body that may be injured during recreational activities (e.g. upper extremities and hip).

Table 3. *Primary Injury Diagnoses - FR2 Data*

Injury Diagnosis	**Anatomical Location**
Pain in hip	Hip
Sprain of hip	Hip
Strain of muscle	Hip
Pain in knee	Lower extremities
Pain in ankle	Lower extremities
Strain of muscle	Lower extremities
Sprain of joint	Lower extremities
Plantar fascial fibromitosis	Lower extremities
Cervicalgia	Neck
Strain of muscle	Neck
Torticollis	Neck
Sprain of joints and ligaments of neck	Neck
Low back pain	Pelvis and lower back
Sprain of lumbar spine	Pelvis and lower back
Sacroiliitis	Pelvis and lower back
Pain in thoracic spine	Spinal cord
Radiculopathy	Spinal cord
Pain in shoulder	Upper extremities
Pain in elbow	Upper extremities
Pain in hand and fingers	Upper extremities
Pain in wrist	Upper extremities
Strain of muscle	Upper extremities
Sprain of joint	Upper extremities
Impingement syndrome	Upper extremities
Cervical disc disorder	Vertebral column
Intervertebral disc displacement	Vertebral column
Cervical disc displacement	Vertebral column
Spinal stenosis	Vertebral column
Intervertebral disc disorder	Vertebral column
Sprain of joints and ligaments of spine	Vertebral column
Thoracic disc disorder	Vertebral column

With the injuries of interest extracted from the FR2 data, the next step in data analysis involved the Medical Cost Avoidance Model (MCAM) discussed in Chapter II. The MCAM model defined five cost types of interest that comprise total military medical costs. The medical services associated with the types of injuries listed in Table 3 are known as outpatient services (i.e. injuries that do not require overnight hospitalization). Using the MCAM model as an analogy, these outpatient costs are represented by the variable C_c, or clinic costs, and comprise a portion of total medical costs, C_t, in the MCAM model. The types of injuries gathered did not contain hospitalization, lost time, disability, or fatality costs. For this reason, only the outpatient portion of total medical costs was analyzed. With clinical costs gathered for the bases participating in the OHWS program, the costs were allocated to each individual base. Table 4 shows total clinical costs for outpatient medical services for fighter pilots by base for fiscal years 2016 - 2018.

Table 4. *Clinical Costs for Outpatient Medical Services by Base - FR2 Data*

		Clinical Costs		
Base	**Command**	**FY2016**	**FY2017**	**FY2018**
Beale AFB	ACC	$ 29,978	$ 31,026	$ 34,617
Davis-Monthan AFB		$ 23,515	$ 21,058	$ 24,028
Eglin AFB		$ 16,605	$ 30,528	$ 35,342
Hill AFB		$ 51,802	$ 25,930	$ 16,824
JB Langley-Eustis		$ 32,530	$ 36,794	$ 57,267
Moody AFB		$ 44,204	$ 14,563	$ 22,664
Mountain Home AFB		$ 25,266	$ 23,362	$ 34,061
Nellis AFB		$ 51,350	$ 44,361	$ 44,246
Seymour Johnson AFB		$ 32,746	$ 22,572	$ 70,083
Shaw AFB		$ 32,172	$ 23,729	$ 19,673
Tyndall AFB		$ 27,597	$ 20,393	$ 25,352
Eielson AFB	PACAF	$ 22,086	$ 6,077	$ 26,428
JB Elmendorf-Richardson		$ 16,246	$ 20,497	$ 35,568
Hickam AFB		$ 5,106	$ 31,283	$ 21,057
Kadena AB		$ 13,036	$ 7,001	$ 4,162
Misawa AB		$ 38,766	$ 10,504	$ 9,523
Kunsan AB		$ 18,461	$ 17,649	$ 21,409
Osan AB		$ 16,750	$ 20,434	$ 45,040
Aviano AB	USAFE	$ 12,219	$ 6,060	$ 13,101
Spangdahlem AB		$ 9,583	$ 6,718	$ 3,434
	ACC Total:	$ 367,770	$ 294,320	$ 384,162
	PACAF Total:	$ 130,454	$ 113,448	$ 163,190
	USAFE Total*:	$ 21,803	$ 12,779	$ 16,536
	Grand Total:	$ 520,028	$ 420,547	$ 563,890

*Note: USAFE total does not include data for RAF Lakenheath

Non-Medical Costs

In addition to the medical costs incurred by military treatment facilities to treat fighter pilots suffering from the injuries listed in Table 3, the costs to the Air Force resulting in these pilots being away from work (e.g. to attend medical appointments or recuperate from injuries) must be considered. The FR2 tool does not contain a metric with which to quantify this cost. However, the Centers for Disease Control and Prevention (CDC) provide a useful metric for these costs, termed work loss costs. Injury cost reports were obtained from the CDC that attribute average work loss costs on a per injury basis based on anatomical locations of injuries and type of injury. The categorization of these costs based on anatomical location aided in pairing the CDC's average work loss cost estimates with the data obtained from FR2. Table 5 summarizes the average work loss cost estimates from the CDC.

Table 5 . *Centers for Disease Control and Prevention (CDC) Injury Costs*

ED Visit and Type of Cost			
Body Region			**Sprains/Strains**
Head and Neck	**Number of Visits**	-	631,020
	Medical Cost	Average	$ 2,538
		Total	$ 1,601,460,000
	Work Loss Cost	Average	$ 5,586
		Total	$ 3,524,833,000
	Combined Cost	Average	$ 8,124
		Total	$ 5,126,293,000
Extremities	**Number of Visits**	-	629,013
	Medical Cost	Average	$ 2,362
		Total	$ 3,368,985,000
	Work Loss Cost	Average	$ 3,872
		Total	$ 5,523,662,000
	Combined Cost	Average	$ 6,234
		Total	$ 8,892,647,000

Source: Centers for Disease Control and Prevention. (2021, January 13).
Data and Statistics (WISQARS): Cost of Injury Reports.
Retrieved from https://wisqars.cdc.gov:8443/costT/ProcessPart1IsEdServlet

The CDC estimates work loss costs resulting from sprains and strains at $5,586 per injury for the head and neck region of the body and $3,872 per injury for the extremities. These average work loss costs are provided from the CDC in base year 2010 dollars, which were converted to BY2020 dollars for use in NPV analysis. For the purposes of this research, the sprain and strain injury type estimated by the CDC is the most appropriate match for the types of injuries gathered from the FR2 database. No instances of the other types of injuries listed in Table 5 were obtained from FR2.

OHWS Contract Considerations

As discussed in Chapter II, the OHWS contract was funded for a total of $24.90M. These dollars fund the program at the twenty-one participating bases for five years. Table 6 breaks down the annual costs of the contract.

Table 6. *OHWS Contract Annual Costs*

	FY2020	FY2021	FY2022	FY2023	FY2024	Total
Setup Costs	$ 2,389,057	$ -	$ -	$ -	$ -	$ 2,389,057
Operating Costs	$ 4,502,452	$ 4,502,452	$ 4,502,452	$ 4,502,452	$ 4,502,452	$ 22,512,262
Total Annual Costs	$ 6,891,510	$ 4,502,452	$ 4,502,452	$ 4,502,452	$ 4,502,452	$ 24,901,320

Source: Federal Procurement Data System. (2021, January 13). Retrieved from Federal Procurement Data System: https://www.fpds.gov/common/jsp/LaunchWebPage.jsp?command=execute&requestid=115051952&version=1.5Link

The total costs for the contract in year one (FY2020) were $6,891,510.44. As shown in Table 6, the annual costs for the four option years of the contract (FY2021 – FY2024) are $4,502,452.48. We assumed that the difference between the year one cost and the annual costs of the four option years constitute setup costs for the contract of $2,389,057.96. These costs were assumed to consist of the purchase of equipment and infrastructure required by the physical therapists, strength training coaches, and massage therapists to perform the services outlined in the contract.

Inflation Considerations

Both the medical and non-medical costs that were gathered for this research occurred in multiple fiscal years. The CDC work loss costs were given in 2010 dollars. The FR2 medical costs were given in 2016, 2017, and 2018 dollars depending on which year the injury of interest occurred in. In order to standardize the costs in preparation for net present value (NPV) analysis, inflation indices were applied. USAF raw inflation indices based on Office of the Secretary of Defense (OSD) raw inflation rates were utilized for this purpose. All costs gathered for the research were inflated to BY2020 dollars. Detailed summaries of the inflated cost figures can be found in chapter IV. In the specific case of the OHWS contract cost data shown in Table 6, the costs in the outyears (FY2021 – FY2024) were deescalated to BY2020 dollars. There is no additional table of these deescalated values, however they were used in place of the Table 6 values for the NPV analysis.

Analysis Way Ahead

Having gathered FR2 medical cost data, CDC work loss cost estimates, and OHWS contract costs, the next step in the research is to conduct a NPV analysis of the OHWS program. In general, the potential medical costs that can be avoided by the services provided to fighter pilots under the OHWS program will represent positive cash flows in the analysis. These costs are comprised of direct monetary reductions in the costs gathered from FR2 as well as decreases in work loss costs associated with the injuries. The annual operating costs to the Air Force of the OHWS program represent negative cash flows in the analysis. We will analyze the NPV of the program under varying levels of assumed injury reduction. These assumptions are explained in additional detail in Chapter IV. Equation (1) shows the NPV model we utilize in our analysis in a general format:

$$\text{OHWS NPV} = -\,OHWS\ Contract\ Setup\ Cost + \sum_{n=1}^{n} Anticipated\ Cost\ Savings\left[\frac{1}{(1+i)^n}\right] - \sum_{n=1}^{n} OHWS\ Operating\ Costs\left[\frac{1}{(1+i)^n}\right] \tag{1}$$

$where$:

$i = discount\ rate$

$n = year\ of\ expenditure/savings$

$\left[\frac{1}{(1+i)^n}\right] = present\ value\ factor$

IV. Analysis and Results

Costs Associated with Fighter Pilot Neck Injuries

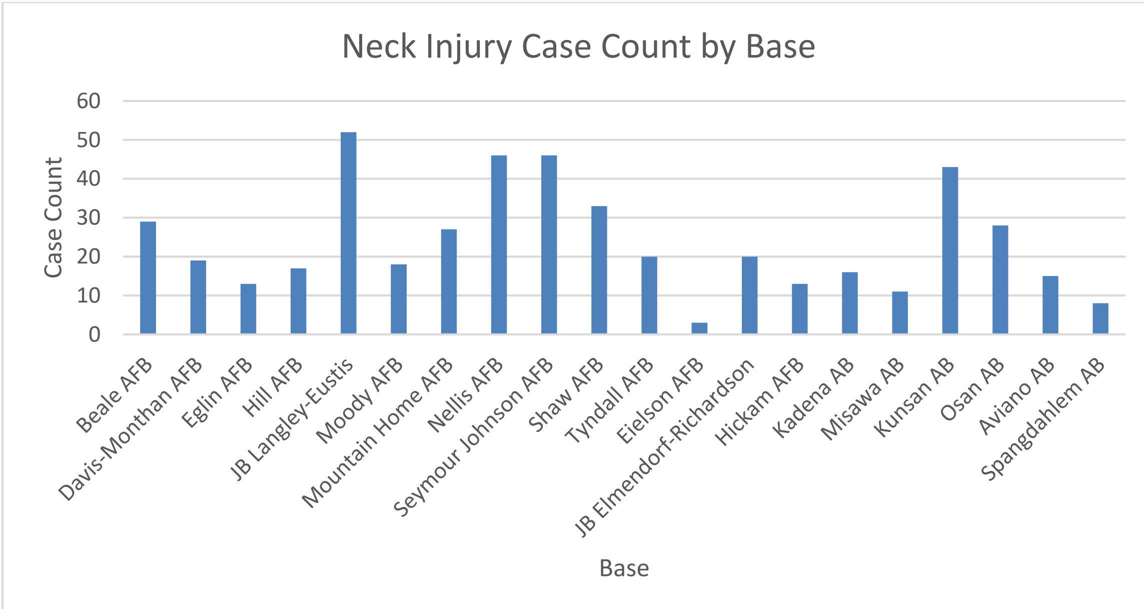
At the outset of this research, based on literature regarding fighter pilot injuries in the cockpit, one goal was to gather cost data on neck injuries. As discussed in Chapter III, cost data consists of medical and non-medical costs. Neck-specific medical cost data was obtained from the FR2 tool and combined with non-medical average work loss cost estimates from the Center for Disease Control and Prevention (CDC). Table 7 summarizes the medical and non-medical costs associated neck injuries faced by the Air Force. These costs pertain to the twenty-one bases participating in the OHWS program which are listed in Table 2. All dollar figures are in BY2020.

Table 7. *Neck-Specific Injury Costs - OHWS Participating Bases*

	Year			
	2016	**2017**	**2018**	**Total**
Medical Costs (BY2020)	$ 71,233	$ 55,296	$ 101,399	$ 227,929
Work Loss Costs (BY2020)	$ 852,378	$ 975,069	$ 826,549	$ 2,653,997
			Grand Total	$ 2,881,927

The injury case counts contributing to the total costs in Table 7 are comprised of neck-specific injury cases from the twenty-one OHWS participating bases gathered from FR2 from 2016 to 2018. Figure 6 shows injury case counts for this three-year period by location.

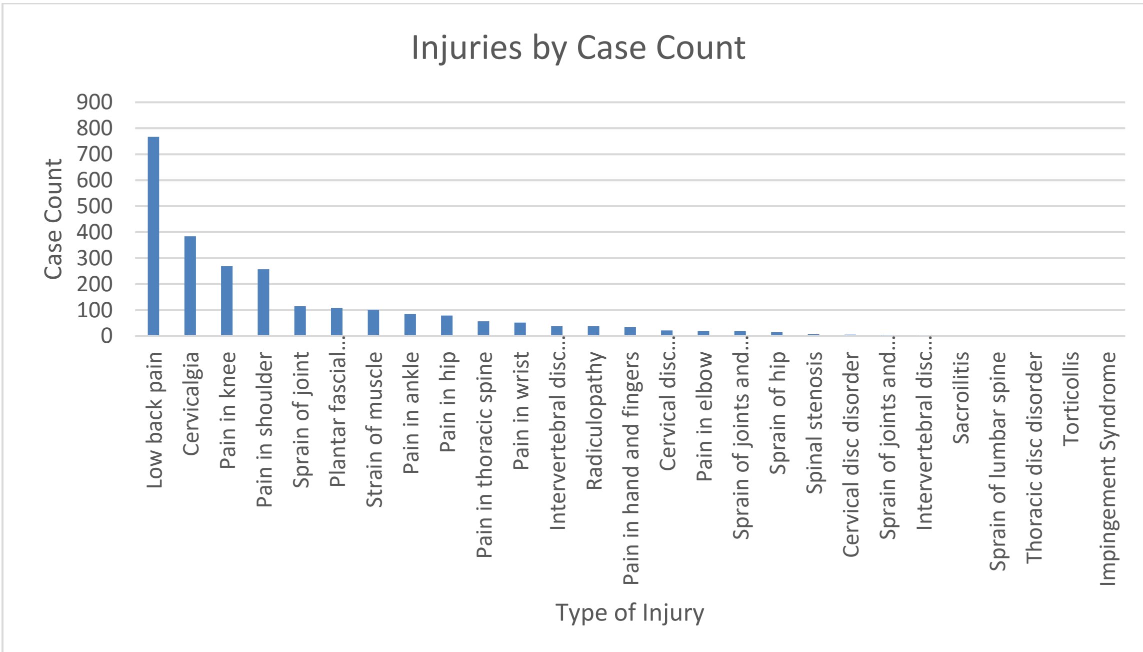
Figure 6. *Neck Injury Case Counts by Base*



The sum of neck injuries occurring at the OHWS participating bases from 2016 – 2018 comprised a total case count of 411 and a total cost of $2.88M (BY2020). While this information does provide a partial response to research question 1, it results in more questions when one considers the annual operating costs of the OHWS contract of $4.5M. We believe that other injury types should be considered when evaluating the OHWS program investment.

We included all injury types listed in Table 3 in the OHWS contract NPV analysis. The main reason for this assumption was that pilots in units falling under the contract can be reasonably expected to visit the physical therapists, strength training coaches, and massage therapists employed under the contract for medical issues such as joint pain, muscle pain, strains, and sprains. Visiting these professionals would likely be preferred by the pilots over visiting their local base hospital because the OHWS personnel work in the squadron alongside the pilots. With all injury types from Table 3 included in the analysis, the injury case count rises to 2,489. Figure 7 shows all of the injury types captured in the FR2 data ranked by case count.

Figure 7. *FR2 Injury Data by Case Count*



Low back pain is the most frequently occurring injury among fighter pilots at the bases for which FR2 data was gathered with 767 cases from 2016 - 2018. Cervicalgia, commonly referred to as neck pain, was the second most frequently occurring injury with 384 cases during the same period. Assorted joint pain injuries comprise the majority of the remaining top ten most frequent injuries.

Having captured a wide range of injuries that fighter pilots commonly suffer from, and that they could be expected to seek treatment for under the OHWS contract, the costs of these injuries were compiled. Table 8 shows total medical and non-medical costs for all injury types captured from FR2 from 2016 – 2018.

Table 8. *Total Injury Costs - OHWS Participating Bases*

	Year			
	2016	**2017**	**2018**	**Total**
Medical Costs (BY 2020)	$ 559,644	$ 446,142	$ 586,729	$ 1,592,516
Work Loss Costs (BY2020)	$ 4,519,631	$ 4,825,553	$ 4,714,237	$ 14,059,422
			Grand Total	$ 15,651,939

Following the inclusion of all injury types listed in Table 3, the total injury case count rises to 2,489 and the total cost rises to $15.65M (BY2020). We believe that the costs shown in Table 8 better reflect those that the OHWS program was put in place to reduce.

Net Present Value (NPV) Analysis

A second goal of this research, following the gathering of data on the costs associated with various injuries in fighter pilots, was to assess the NPV of the OHWS contract. As discovered during analysis directed at the costs associated with injuries, multiple injury types affect fighter pilot health. For this reason, we began analyzing the OHWS contract NPV by incorporating all FR2 case count data gathered on the injury types in Table 3. Cost data on the various injury types pulled from FR2 was used as well, specifically the medical and non-medical costs shown in Table 8. To determine the NPV of the OHWS contract, the cash flows associated with contract, medical, and non-medical costs were incorporated into an NPV analysis.

The current version of the OHWS contract includes an initial one-year period of performance and four subsequent option years. For simplicity's sake, the first NPV analysis was conducted assuming all four option years will be exercised, a five-year period. Negative cash flows are represented by the contract costs shown in Table 6. The $2,389,057.96 of setup costs occur once in year 0 of the analysis, and the annual operating costs of $ 4,502,452.48 occur in the remaining four years.

In the case of the OHWS contract, an increase in the medical care provided by the professionals the contract funds (physical therapists, strength training coaches, and massage therapists) is intended to result in fewer visits to medical care professionals at a base's local medical treatment facility (MTF). Positive cash flows in the NPV analysis are represented by the benefit of cost savings achieved through fewer MTF visits. Specifically, reductions of 10%, 50%, and 90% were analyzed and are represented by reductions of the same magnitude in the total annualized medical and non-medical costs of injuries from Table 8. These values were chosen to provide a wide range of potential NPVs of the OHWS contract. The total medical and non-medical cost over the three-year period from 2016 to 2018 was then annualized. The resulting annualized cost of the OHWS contract is $4,152,752.49.

Finally, an appropriate discount rate was required for the NPV analysis. For this we turned to the Office of Management and Budget's (OMB) Circular A-94 which provides guidance and discount rates for benefit-cost analysis of federal programs. The guidance references two types of discount rates (referenced therein as interest rates). Real interest rates are adjusted to eliminate the anticipated effects of inflation and are appropriate for use with constant dollar benefits and costs analyses. Nominal interest rates reflect expected inflation and are appropriate for use in discounting nominal costs and benefits. All costs and benefits gathered for this research were converted to base year

2020 dollars as discussed in Chapter 3. For this reason, a real discount rate of 7% recommended in OMB Circular A-94 was utilized in the NPV analysis.

The following tables (combined as Table 9) show the annual net cash flows described above as well as the NPV at the end of the OHWS contract five-year period of performance under the assumed 10%, 50%, and 90% MTF visit reductions previously explained.

Table 9. *NPV Analysis of OHWS Contract - Five-Year Period of Performance*

Assume 10% Reduction in MTF Visits							
Year	0	1	2	3	4	5	**NPV**
	$ -2,389,057.96	$ -3,935,985.16	$ -3,859,140.43	$ -3,780,871.29	$ -3,709,278.48	$ -3,636,268.81	$-19,493,916.08

Assume 50% Reduction in MTF Visits							
Year	0	1	2	3	4	5	**NPV**
	$ -2,389,057.96	$ -1,988,560.46	$ -1,911,715.73	$ -1,833,446.60	$ -1,761,853.78	$ -1,688,844.11	$-9,962,163.12

Assume 90% Reduction in MTF Visits							
Year	0	1	2	3	4	5	**NPV**
	$ -2,389,057.96	$ -41,135.76	$ 35,708.97	$ 113,978.10	$ 185,570.92	$ 258,580.59	$-1,977,337.36

As shown in the analysis in Table 9 the NPV of the OHWS contract investment under all three MTF visit reduction assumptions is negative. Cost savings achieved purely through reductions in costs incurred by the military medical system result in a negative NPV, but we cannot fail to consider additional benefits stemming from the implementation of prehabilitative care for fighter pilots.

Additional OHWS Benefits

In addition to the reduction in medical and non-medical costs considered hereto, another key benefit potentially provided by the OHWS program is directly related to pilot training costs and retention. From a budgetary perspective, training Air Force pilots is a demanding process. A 2019 RAND study gathered Air Force Total Ownership Cost (AFTOC) data to quantify the costs of training pilots of various aircraft to basic qualification levels. Table 10 shows the total training costs gathered by the study.

Table 10. *Total Costs of Training Basic Qualified Pilots, by Aircraft (FY2018 Dollars)*

Aircraft	Cost per Pilot
A-10	$ 5,961,000
B-1	$ 7,338,000
B-2	$ 9,891,000
B-52	$ 9,688,000
C-130J	$ 2,474,000
C-17	$ 1,097,000
C-5	$ 1,397,000
F-15C	$ 9,200,000
F-15E	$ 5,580,000
F-16	$ 5,618,000
F-22	$ 10,897,000
F-35	$ 10,167,000
KC-135	$ 1,196,000
RC-135	$ 5,447,000

Source: Mattock, M. G., Asch, B. J., Hosek, J., & Boito, M. (2019). *The Relative Cost-Effectiveness of Retaining Versus Accessing Air Force Pilots.* Santa Monica: RAND.

The average training cost of an Air Force fighter pilot was estimated by calculating the average of A-10, F-15C, F-15E, F-16, F-22, and F-35 training costs from Table 10. The calculated average cost of basic fighter pilot training was $7,903,833.00 in FY2018 dollars. This figure is equivalent to $8,224,592.44 in FY2020 dollars. RAND estimated that this average cost to train a fighter pilot to a basic level of qualification occurred over a five-year period. To incorporate this basic fighter pilot training cost into the NPV analysis the figure was annualized using the same 7% real discount rate from the previous NPV calculations. The resulting annualized basic training cost was $2,005,901.56.

The NPV analysis shown in Table 9 was repeated to include the annualized training cost. With the OHWS program goal of injury reduction in mind, we assumed one form of program success would be reduced fighter pilot separations from active duty service stemming from injuries sustained in the cockpit. We began by conducting NPV analysis with a one-person reduction in separations. The effect on the cash flows would be a one-unit reduction in the basic training costs; in the case of fighter pilots $8,224,592.44 or $2,005,901.56 annualized (in FY2020 dollars). This cost reduction stems from the assumption that the Air Force would have a requirement for one less fighter pilot trainee if an active pilot chose not to separate from active duty service. Under the second most pessimistic 50% MTF visit reduction assumption from the previous NPV analysis, a one-person reduction in active duty separations increases the NPV of the OHWS program investment to $2,772,687.12 from -$1,977,337.36. Table 11 shows the NPV calculations under the same 10%, 50%, and 90% MTF visit reductions from the previous NPV analysis.

Table 11. *NPV Analysis of OHWS Contract - Five-Year Period of Performance with Reduced Separation Cost Savings*

Assume 10% Reduction in MTF Visits and reduced pilot separations (one pilot)							
Year	0	1	2	3	4	5	NPV
	$ -2,389,057.96	$ -965,176.85	$ -939,387.24)	$ -914,497.75	$ -890,462.05	$ -865,854.53	$-5,540,555.26

Assume 50% Reduction in MTF Visits and reduced pilot separations (one pilot)							
Year	0	1	2	3	4	5	NPV
	$ -2,389,057.96	$ 982,247.85	$ 1,008,037.46	$ 1,032,926.95	$ 1,056,962.65	$ 1,081,570.17	$2,772,687.12

Assume 90% Reduction in MTF Visits and reduced pilot separations (one pilot)							
Year	0	1	2	3	4	5	NPV
	$ -2,389,057.96	$ 2,929,672.55	$ 2,955,462.16	$ 2,980,351.65	$ 3,004,387.35	$ 3,028,994.87	$12,509,810.62

With the inclusion of annualized cost savings resulting from a one-person reduction in pilot separations, the NPV of the OHWS program quickly becomes positive from the small reduction of one individual active duty separation. Reductions in separations are likely to stem from pilots receiving care for injuries that otherwise would have caused them to choose or be forced to separate. For the purposes of this research, we chose not to explore the potential for reductions in monetary retirement disability benefits associated with fewer forced medical discharges of fighter pilots. When combined with potential large reductions of MTF visits, the NPV may be as high as $12.06M. Compared with the sample injury data of 2,489 cases, the potential for separation reductions resulting in a far larger NPV is possible. These NPV figures also indicate that even if *more* pilots sought medical care through the OHWS program than in previous years, if fewer chose to separate after receiving specialized care, the program would still provide a large, positive NPV.

V. Research Questions Answered, Conclusions, Policy Recommendations, and Future Research

Research Questions Answered

1. ***What are the monetary medical costs to the Air Force associated with neck, spine, and other musculoskeletal injuries in fighter pilots?***

Our research took into consideration multiple injury types in fighter pilots at the twenty-one OHWS-participating bases, including neck, spine, and other musculoskeletal injuries shown in Table 3. Considering the medical costs for these injuries based on FR2 data, we found in Chapter IV that the total monetary medical costs to the Air Force associated with these injuries between 2016 – 2018 was $1.59M, shown in Table 8. However, this figure fails to consider the non-medical costs associated with fighter pilot injuries; a cost also borne by the Air Force. Utilizing CDC data on work loss costs, the non-medical costs to the Air Force associated with the injuries in Table 3 is $14.06M. The total cost to the Air Force, then is $15.65M from 2016 – 2018.

2. ***What reduction in Air Force fighter pilot neck, spine, and other musculoskeletal injuries is necessary for the OHWS program to provide a positive net present value (NPV)?***

The NPV analysis we conducted in Chapter IV shows, when considering medical and non-medical cost reductions alone, the OHWS contract investment does not achieve a positive NPV during its five-year period of performance under the three assumed injury reduction levels of 10%, 50%, and 90%. The NPV is the least negative under the 90% injury reduction assumption, as expected, at -$1.97M. However, this initial NPV analysis fails to consider additional benefits stemming from the implementation of prehabilitative care for fighter pilots.

3. ***What, if any, additional benefits does the OHWS program provide the Air Force that affect the NPV?***

A key additional benefit potentially provided by the OHWS program is a potential reduction in fighter pilot separations from active duty service. In Chapter IV we computed an average cost to the Air Force to train a single fighter pilot of $8.22M (FY2020 dollars). After incorporating this cost into the NPV analysis of the OHWS contract for its five-year period of performance, a one-person reduction in active duty separations results in a positive NPV of $2.77M under the 50% injury reduction assumption. When one considers the FR2 data containing 2,489 injury cases, the potential for separation reductions resulting in larger positive NPVs becomes clear. In fact, the calculated NPV figures indicate that even if *more* pilots sought medical care through the OHWS program, if fewer chose, or were forced to separate after receiving care, the program would still provide a large, positive NPV. The $8.22M average cost benefit achieved by preventing a single pilot separation would offset an increase up to that amount in new, additional medical care expenses.

Net Present Value (NPV) Final Thoughts

The NPV calculations used to form the basis of the NPV analysis for the OHWS program show that a positive NPV can be achieved through reductions in fighter pilot visits to military treatment facilities (MTFs) and separations from active duty service. A final figure of interest offered by the Force Risk Reduction (FR2) tool is personnel populations. For a given installation, system users can obtain personnel counts by occupation. For each base in Table 2 the fighter pilot personnel counts were collected for the three-year period of 2016 – 2018. The average of the personnel counts for the three-year period were calculated for each base, and those averages were summed to achieve a total average fighter pilot personnel count for the OHWS program. The average annual population of fighter pilots who could be positively affected by the OHWS program where it is currently implemented is 1,786. Bearing this in mind, the feasibility of a one pilot reduction in active duty separations fits squarely in the realm of possibility. Pilots who received medical care through the OHWS program may experience reductions in injuries that would otherwise cause them to choose or be forced to separate from the Air Force. With a population as large as this, a reduction of greater than one active duty separation could certainly be achieved.

We wanted to take the NPV analysis one step further to find the breakeven point of the OHWS program's NPV; the point at which reductions in MTF visits and active duty separations result in a NPV of $0. Any additional costs savings or monetary benefits beyond the breakeven point represent positive returns on investment. Assuming a one-person reduction in active duty separations, a 28.97% reduction in MTF visits achieves the breakeven point of $0 for the OHWS program's NPV. This highlights a key insight achieved by the research. With sufficient reductions in active duty separations, medical and non-medical costs associated with fighter pilots utilizing OHWS program services (i.e. physical therapy and strength training) could rise without resulting in a negative NPV for the program. The result would be more pilots receiving tailored medical care that may drive down separations from active duty service for the reasons previously discussed relating to reductions in injuries that would otherwise result in pilots separating. To further explore the NPV of the OHWS program within an environment with no medical cost savings, we conducted the NPV analysis a second time assuming no reduction in medical costs to find the breakeven point of the program solely based on the benefit of reduced pilot separations. Under the assumption of no medical cost reductions, the breakeven point occurs at a 2.72-person reduction in pilot separations from active duty over the five-year period of performance of the OHWS contract.

Policy Recommendations

Based on the potentially high NPV associated with the OHWS contract, the program may be scalable within the pilot career field. It can be reasonably assumed that pilots of non-fighter aircraft also suffer from neck, spine, and other musculoskeletal injuries. For this reason, as well as the previously discussed benefits of reduced pilot separations, the program could be used to provide prehabilitative care to many other Air Force pilots. In addition to scaling the program to other types of pilots, personnel under other Air Force specialty codes (AFSCs) may benefit from the type of medical care offered through the OHWS program. Cyber personnel, who perform the majority of their work on computers, may experience reductions in stress and strain injuries associated with maintaining a seated posture for extended periods of time. Other operational AFSCs, like special forces personnel, who must meet demanding physical job requirements may benefit from the OHWS program as well. The costly training pipelines associated with these AFSCs offer the same non-monetary benefits as in the fighter pilot community that result in positive NPVs with small reductions in active duty separations.

Recommendations for Future Research

This research has implications for academics and practitioners in the areas of preventative care, aerospace medicine, and cost benefit healthcare models. Future research could improve on this research by clarifying the role of retention, and validating our preliminary cost benefit estimates with actuals from the OHWS program. With the OHWS contract currently in its first one-year period of performance, the program's effects on injury reduction and pilot retention are unknown. Following multiple years of program performance, future research that captures FR2 injury data can compare the case counts, injury types, and costs to the figures presented in this research. The results of such a comparison may indicate if injuries increase or decrease and also may determine root causes of the change. An NPV analysis can also be conducted to explore the mission and monetary benefits the OHWS program does or does not provide in its future years of performance.

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14. ABSTRACT
Air Force fighter pilots face risks associated with neck and spine injuries sustained while operating fighter aircraft. Studies from the flying and medical communities indicate that muscle-strengthening prehabilitative care may decrease the risk of flying related injuries in high performance aircraft pilots. For this reason, the U.S. Air Force provided $24.9M to implement the Optimizing the Human Weapon System (OHWS) program. The program provides physical therapy and strength training to fighter pilots in participating units at twenty-one Air Force bases with the intent of reducing injury rates and time out of the cockpit. From a healthcare perspective there is interest in the effectiveness of the program in injury reduction. From a funding perspective there is interest in the potential for a positive net present value (NPV) of the OHWS investment. This research utilizes injury data obtained from the Force Risk Reduction (FR2) tool to analyze injury rates, injury types, physiological injury locations, as well as medical and non-medical injury costs to form an NPV estimate for the OHWS program. The research finds that the OHWS program provides a NPV of $12.5M assuming the potential effects on injury reduction and fighter pilot separations from active duty service that the

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