A Preliminary Analysis of the Costs and Benefits of Physical Therapy and Strength Training for Fighter Pilots

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BACKGROUND: Occupational hazards facing high performance aircraft pilots ("fighter" pilots) can cause injury, time lost from flying, and voluntary or involuntary career termination. The high cost of training and retaining fighter pilots has spurred interest in the cost effectiveness of preventative and rehabilitative health solutions.

METHODS: We investigated the potential cost effectiveness of a 5-yr, $24.9M U.S. preventative health program using equivalent annual worth (EAW) analysis. The program benefits were assessed with a combination of actual and estimated medical cost data and projected pilot retention improvement rates. Sensitivity analysis of variables such as discount rate, medical cost avoidance, and pilot retention improvement rate was conducted.

RESULTS: Annualized costs of approximately $5M U.S. were used as the basis of comparison for annualized benefits. A medical cost database was searched to find expected annual direct medical (outpatient) costs related to injury of roughly $531K U.S. for the pilots covered by the program. Using Centers for Disease Control recommendations, approximately $4.7M U.S. was estimated to be the annual work loss cost. The program would presumably reduce a significant portion of these annual costs, but not all. Assuming various proportions of reduced costs by the program, the EAW was found to be consistently negative. However, when pilot retention improvement is included, EAW is positive using conservative assumptions.

DISCUSSION: While outpatient and work loss costs will unlikely be completely covered by preventative health programs in this context, a minor improvement in pilot retention (about 1–3 additional retentions per year) produces a net positive annual benefit.

KEYWORDS: fighter aircrew, preventive health program, rehabilitative health solutions, cost benefit analysis, economic analysis.

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Occupational hazards facing high performance military aircraft pilots ("fighter" pilots) can cause injuries, time lost from flying, and, in extreme cases, voluntary or involuntary career termination.[5,9,10] Because of the high cost associated with fully training fighter pilots (estimates range from $3M to $11M, depending upon airframe),[11,15] military organizations such as the North Atlantic Treaty Organization (NATO)[12] and the U.S. Air Force (USAF) are highly interested in mitigating those hazards. Days lost from flying can cause mission readiness issues and costly training delays. Additionally, when pilots leave the cockpit for health reasons earlier than a "natural" progression rate (e.g., promotion, retirement), a replacement must be recruited and trained.

Risks of acute and chronic cervical spine injury are of particular interest and concern. Studies have shown that the offensive and defensive maneuvering required of fighter pilots increases the risks associated with neck and spine injuries.[7,8] Maintaining situational awareness in this environment by turning the head

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during high stress maneuvers requires withstanding pressure many times the normal force of gravity ("g" force). The use of night vision goggles and helmet mounted cueing systems (e.g., the Joint Helmet Mounted Cueing System) has been found to exacerbate neck pain.[10] A recent meta-analysis found the prevalence of neck pain in the fighter pilot community (~50%) to be about 10 times the prevalence in the greater population (~5%).[13]

The high cost of recruiting, training, and retaining these pilots has spurred interest in the cost effectiveness of preventative and rehabilitative health solutions.[11,14] Exercise interventions are widely accepted as the primary rehabilitative treatment modality for chronic musculoskeletal pain in general.[3] Additionally, studies have provided preliminary evidence that rigorous strength training may reduce cervical injury rate and severity in fighter and helicopter pilots.[1,2] In other words, there is evidence that preventative or "prehabilitative" exercise programs can reduce pilot injuries. However, the cost effectiveness of such programs has not been rigorously analyzed. This study is a preliminary attempt to address this gap in the literature by examining the cost effectiveness of a new program launched by the USAF.

In 2017, the USAF held a Dedicated Aircrew Retention Team Summit (sponsored by the Aircrew Crisis Task Force). The summit identified 44 recommendations to aid the Air Force with retention challenges.[15] Many of those recommendations have already been implemented, including "preventative medical care for back and neck injuries." Implementation of the 5-yr, $24.9M Optimizing the Human Weapon System (OHWS) program started with four bases and was then expanded in 2020 across three commands: Air Combat Command, Pacific Air Forces, and U.S. Air Forces in Europe.[6] The OHWS program is designed to meet the unique physical needs of Air Force fighter pilots through a comprehensive "prehabilitative" physical training program that employs focused strength and conditioning, physical therapy, and athletic training.[6]

METHODS

Data Sources and Modeling Framework

The Medical Cost Avoidance Model (MCAM), developed by the U.S. Army's Institute of Public Health, provides a useful model for capturing medical costs for U.S. military personnel. Specifically, the medical costs are summed to produce total medical cost (C_t) using this simple equation (variables summarized in **Table I**):[14]

$$C_t = C_c + C_h + C_l + C_f + C_d$$

MCAM is specifically tailored to capture return on investment for prevention programs based on medical costs associated with specific International Classification of Disease, 9th Revision codes. Direct access to MCAM data was unavailable at the time of the study; however, the primary database it uses to obtain medical and treatment costs [the Force Risk Reduction Tool (FR2)] was available.

Much of the data for this research were obtained from the Military Injury Medical Treatments and Casualties dashboard provided by the FR2 tool, managed by the Office of the Under Secretary of Defense for Personnel and Readiness. The tool provides comprehensive roll-ups of military injury treatment claims data from military and nonmilitary facilities, including costs incurred by the military medical system to treat injuries in military personnel. The Force Risk Reduction tool is a wide-ranging database with over 400,000 records, numerous dashboards, and extensive filtering capabilities.

Table I. 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

Inclusion/Exclusion Criteria

First, we filtered FR2's Military Injury Medical Treatments and Casualties dashboard for branch of service, installation, and military treatment facility. A total of 21 bases participated in the OHWS program, and FR2 data were available for 20. Each available installation was filtered by component and occupation. The component filter was set to "active duty" to exclude the reserve component. Additionally, the occupation filter was set to "fixed wing fighter/bomber pilot." Using these filters ensured to the greatest extent possible only the fighter pilots eligible for the OHWS program comprised the data retrieved from the tool. Bomber pilots were excluded from the data by default; the 20 bases for which data were collected were fighter bases (i.e., those bases did not have a bomber pilot population).

For the purposes of this research, both ergonomic injuries (e.g., caused by repeated motion, vibration, noise, etc.) and nonergonomic injuries (e.g., orthopedic) were included in the data. Anatomical locations of injuries we included in the data were upper extremities, lower extremities, neck, hip, spinal cord, pelvis and lower back, and the vertebral column. The list of included injury diagnoses is shown in **Table II**. It was not possible to distinguish between occupational injury (cockpit related) and off-duty injury (e.g., sports injury). The OWHS program is also not limited to the treatment of occupational injury, therefore the use of the filtered FR2 data set was appropriate for this research. However, due to the nature of the data, no isolated analysis was possible for occupational injuries.

Ultimately, the filtered data consisted of outpatient information (equivalent to C_c in the MCAM). It did not contain inpatient treatment costs, C_H, which presumably were not extensive for typical musculoskeletal injuries, so we excluded this variable in our calculations. Lost time cost, C_l, fatality cost, C_f, and disability cost, C_d, were also not included. Although fatality cost

Table II. Primary Injury Diagnoses: FR2 Data.

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

is high when it occurs, we assumed it was a rare occurrence and excluded it. For this research, we made the very conservative assumption that the OHWS program would not reduce disability cost (e.g., Veteran's Affairs disability) and excluded it as a variable. However, we believe an expected reduction in disability cost is a reasonable hypothesis for future researchers to explore. Because lost time costs were not included in FR2, we estimated them using Centers for Disease Control and Prevention (CDC) Cost of Injury Reports statistics.[4] Injury work reports were obtained from the CDC that attribute average work loss costs on a per-injury basis based on anatomical location and type of injury.

Equivalent Annual Worth Analysis

We investigated the potential cost effectiveness of the OHWS preventative health program using equivalent annual worth (EAW). The most straightforward part of the analysis is the cost of the program, approximately $2.4M in setup costs and annual operating costs of $4.5M for 5 yr. In general, the potential medical costs that can be avoided due to the services provided to fighter pilots under the OWHS program will represent positive cash flows in the analysis ("benefits"). These benefits would come in the form of direct reductions in medical care costs and associated indirect reductions in work loss costs. Another potentially quite large contribution to cost avoidance would be any reduction of voluntary or involuntary career termination caused by the program. While it is difficult to obtain precise estimates for any of these cost avoidance variables, conducting sensitivity analysis with a wide range of assumptions, from optimistic to extremely conservative, allows for meaningful interpretation of the results. For instance, if the expected annual worth of the OHWS program is positive under extremely conservative assumptions, it likely has a positive return on investment.

Other aspects of EAW analysis include the choice of the discount rate and the treatment of inflation. Generally, interest rates used in government cost benefit analysis calculations come from the Office of Management and Budget Circular A-94. Although interest rates in recent years have been quite low, we chose 0–8% as a reasonable range for the discount rate for this study. All data used in the EAW analysis was either inflated to Base Year 2020 dollars or, in the case of the outyears of the contract, deescalated to Base Year 2020 dollars. Inflation indices used for this purpose were obtained from the Office of the Secretary of Defense raw inflation rates.

An EAW is obtained by calculating the net present value (NPV) and then annualizing that value with an annuity factor. Specifically, we calculated our EAW values using the following formulas:

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

$$where: i = discount\ rate,$$
$$n = year\ of\ \frac{expenditure}{savings},$$
$$\left[\frac{1}{(1+i)^n}\right] = present\ value\ factor$$

$$\mathbf{OHWS\ EAW} = \mathit{OHWS\ NPV}\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right]$$

$$where: i = discount\ rate,$$
$$n = year\ of\ \frac{expenditure}{savings},$$
$$\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] = annual\ annuity\ factor$$

RESULTS

Benefits

We analyzed 2489 total injury cases over a 3-yr period prior to the start of the OHWS program (2016–2018) at the 20 participating bases for which data were available. Among these cases, the most common injuries were low back pain, with 767 cases, and neck pain, with 384 cases. The "Benefits" section of **Table III** summarizes total outpatient and work loss costs associated with these injury cases. The outpatient costs were obtained from the FR2 database. Work loss cost estimates were derived from CDC per-injury cost figures based on the anatomical location of each injury.[4] For the 2489 injury cases that we observed, the total outpatient and work loss costs were ~$5.2M annually. For our EAW analysis, this figure represents the status quo value for health care costs without the OHWS program. It also represents the maximum outpatient and work loss cost savings ("benefits") the OHWS program could achieve, assuming the OHWS program completely supplanted all musculoskeletal injury related health care visits.

An additional benefit we considered was the potential cost savings derived from an improvement in pilot retention attributable to the OHWS program. Although this benefit is not part of the MCAM model, the cost of training new fighter pilots is so high, this should not be ignored. According to a RAND study, the total cost of training basic qualified fighter pilots over 5 yr ranged from $5.6M to $10.9M (FY2018 dollars), depending on airframe.[11] We calculated the average cost of training one fighter pilot to be about $8.22M over 5 yr (FY2020 dollars), shown in annualized terms in the "Benefits" section of Table III.

Costs

The "Cost" side of our EAW analysis is the annualized monetary costs needed to fund the OHWS program—primarily the contract costs, but also the anticipated work loss cost. For work loss costs, we considered two extreme possibilities (very pessimistic, very optimistic). At one extreme, we considered that work loss costs could be essentially the same (a "wash" cost) as they were prior to the new program (Table III). At the other extreme, we considered the possibility that the OHWS program may eliminate outpatient and work loss costs entirely (**Table IV**). Neither of these extremes is likely to occur, but they do encompass the entire range of possibilities. Sensitivity analysis labels in Table III (Best Case, Optimistic, Moderate, Pessimistic, Worst Case) correspond to different assumptions about the proportion of outpatient costs replaced by the OHWS program (100%, 90%, 50%, 10%, 0%). The corresponding sensitivity analysis labels in Table IV correspond to different assumptions about the proportion of outpatient and work loss costs supplanted and potentially reduced by the OHWS program. These values were chosen to provide a wide range of potential EAWs for the OHWS program (from extremely optimistic to extremely pessimistic).

Equivalent Annual Worth

EAW is defined as the expected annual benefit minus the expected annual cost. We considered discount rates between 0% and 8%, in 2% increments, encompassing all plausible scenarios. Under the "wash" cost assumption for work loss costs, and without considering pilot retention changes, the EAW was consistently negative (between –$4.5M and –$5.1M per year). When work loss costs were assumed to be partially to completely eliminated by the OHWS program, the OHWS program achieved a positive EAW for the "Best Case" (between $100K and $237K per year), but was negative for all other levels (between –$300K and –$5.1M per year).

Breakeven Analysis

The "Breakeven" sections of Tables III and IV provide the improvement in pilot retention required for the EAW to equal $0. For instance, when work loss costs are a wash and a 50% reduction in outpatient costs (the "Moderate" case) is considered at a 2% discount rate, a 2.67 improvement in pilot retention achieves breakeven for the program (see Table III). The equivalent scenario in Table IV (2% EAW, Moderate) requires a 1.35 improvement in pilot retention to achieve breakeven. Under the most conservative assumptions, the highest

Table III. Equivalent Annual Worth Summary Table (OHWS Replaces Up to 100% of Outpatient Costs; 0% of Work Loss Costs).

SUMMARY	EAW 0%	EAW 2%	EAW 4%	EAW 6%	EAW 8%
Benefits (B)					
Outpatient	$530,838	$530,665	$530,506	$530,360	$530,228
Work Loss (WL) is considered a wash cost					
1 Pilot Training Year	$1,644,000	$1,778,821	$1,958,698	$2,194,246	$2,500,156
Costs (C)					
OHWS Contract	$ 4,980,263	$ 5,009,310	$ 5,039,099	$ 5,069,606	$ 5,100,807
Net (B – C)					
Best Case 100%	$(4,449,425)	$(4,478,645)	$(4,508,593)	$(4,539,245)	$(4,570,579)
Optimistic 90%	$(4,502,509)	$(4,531,712)	$(4,561,644)	$(4,592,281)	$(4,623,602)
Moderate 50%	$(4,714,844)	$(4,743,978)	$(4,773,846)	$(4,804,425)	$(4,835,693)
Pessimistic 10%	$(4,927,180)	$(4,956,244)	$(4,986,048)	$(5,016,569)	$(5,047,784)
Worst Case 0%	$(4,980,263)	$(5,009,311)	$(5,039,099)	$(5,069,606)	$(5,100,807)
Breakeven*					
Best Case	2.71	2.52	2.30	2.07	1.83
Optimistic	2.74	2.55	2.33	2.09	1.85
Moderate	2.87	2.67	2.44	2.19	1.93
Pessimistic	3.00	2.79	2.55	2.29	2.02
Worst Case	3.03	2.82	2.57	2.31	2.04

OHWS: Optimizing the Human Weapon System; EAW: equivalent annual worth.
*Represents the improvement in pilot retention (# pilots) required for EAW to equal $0.

Table IV. Equivalent Annual Worth Summary Table (OHWS Replaces Up to 100% of Outpatient and Work Loss Costs).

SUMMARY	EAW 0%	EAW 2%	EAW 4%	EAW 6%	EAW 8%
Benefits (B)					
Outpatient	$530,838	$530,665	$530,506	$530,360	$530,228
Work Loss (WL)	$4,686,474	$4,685,180	$4,683,894	$4,682,617	$4,681,349
Total	$5,217,312	$5,215,845	$5,214,401	$5,212,978	$5,211,577
1 Pilot Training Year	$1,644,000	$1,778,821	$1,958,698	$2,194,246	$2,500,156
Costs (C)					
OHWS Contract	$4,980,263	$5,009,310	$5,039,099	$5,069,606	$5,100,807
Net (B – C)					
Best Case 100%	$237,048	$206,535	$175,302	$143,372	$110,770
Optimistic 90%	$(284,683)	$(315,050)	$(346,139)	$(377,926)	$(410,388)
Moderate 50%	$(2,371,607)	$(2,401,388)	$(2,431,899)	$(2,463,117)	$(2,495,018)
Pessimistic 10%	$(4,458,532)	$(4,487,726)	$(4,517,659)	$(4,548,308)	$(4,579,649)
Worst Case 0%	$(4,980,263)	$(5,009,311)	$(5,039,099)	$(5,069,606)	$(5,100,807)
Breakeven*					
Best Case	–	–	–	–	–
Optimistic	0.17	0.18	0.18	0.17	0.16
Moderate	1.44	1.35	1.24	1.12	1.00
Pessimistic	2.71	2.52	2.31	2.07	1.83
Worst Case	3.03	2.82	2.57	2.31	2.04

OHWS: Optimizing the Human Weapon System; EAW: equivalent annual worth.
*Represents the required improvement in pilot retention (# pilots) required for EAW to equal $0.

breakeven ratio was 3.03. In other words, if the program indirectly or directly causes three additional pilots to continue flying for the USAF (than would have otherwise), OHWS pays for itself.

DISCUSSION

The implications of this preliminary study are promising for preventative medicine programs such as OHWS. Of course, there are many other variables that impact pilot retention, such as airline hiring practices, deployment fatigue, etc., but if preventative medicine programs have even a minor impact, they could be sound investments.[11,15,16] Certainly, the long-term health of fighter pilots is valuable regardless of its cost effectiveness, but finding efficient ways to achieve this goal is worth pursuing for policymakers.

While we have attempted to capture estimates of direct effects from the OHWS program (reductions in visits, less work loss time), it is interesting to consider possible indirect effects. Would having convenient access to health care (located in the squadrons) improve morale? Would pilots get the message from leadership (and by extension, the USAF) that their wellbeing matters? Could this have an impact on variables such as "intentions to stay in the USAF" or "organizational commitment"? This psychological information could perhaps be captured with surveys and interviews, and we recommend future research in this area.

There were many limitations to this study. First, data were available for only 20 of the 21 OHWS-participating bases. Therefore, it is likely that our comparison costs were underestimated. Second, pilot separation data that includes reasons for separation (e.g., to work for an airline, because of extended deployments, or because of chronic neck pain) were unavailable.[16] If this information were available, this study could have made reasonable estimates of likely effects from the OHWS program instead of attempting to encompass the entire range of possibilities. Reasons for separation gathered from exit interviews or other means would be invaluable information for researchers and policymakers. It is possible that this information is tracked by the USAF, but unsystematically and in disparate locations. We recommend the data be systematically gathered, cleared of any identifying, health-related information, and processed to avoid any potential security concerns. Then it should be made available to researchers and policymakers. An additional limitation is that we did not include any estimates for disability costs, fatality costs, or inpatient costs. Disability costs, in particular, may be extensive and preventative medicine programs such as OHWS may very well reduce them. According to a Government Accountability Office report, the average Veterans Administration disability compensation for Department of Defense personnel was about $13K per year as of 2013.[17] Considering that pilots are officers, it is likely the disability compensation is higher for them. Future researchers should attempt to quantify preventative health program effects on disability.

The results of the current study indicate that from an EAW standpoint, preventative health programs such as OHWS have the potential to pay for themselves. Every circumstance is unique, but the MCAM framework appears to be a useful starting point for researchers, program managers, and decision makers to model the potential cost savings of a program.[14] In addition, factors outside the model may play an outsized role in capturing true benefits (as pilot retention improvement did in this study). While a positive EAW is a worthwhile objective, we caution against its use as a milestone or decision hurdle that must be achieved for program approval. Preventative health programs may have intangible benefits that are difficult to quantify in monetary terms. The intrinsic worth of such programs may be far more important than cost considerations.

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