Exercise Regimen for Mitigation of Neck Pain in Military Aircrew and Support Personnel

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INTRODUCTION: Operators of rotary wing aircraft and high-performance jet aircraft often face musculoskeletal pain and cervical spine injury risks due to flight-related factors, including heavy vibrational and g-loading, abrupt head maneuvering, and a large number of flight hours. This study explores the use of a portable lightweight resistance band exercise device (PLED) to strengthen and stretch neck musculature, potentially mitigating these risks.

METHODS: A multi-aircraft study building on an initial pilot study of 10 high-performance jet aircraft aviators involved both active-duty aviators and civilians. Over 6 wk, subjects engaged in targeted PLED-based exercises. Baseline and endpoint measurements were obtained. Quantitative measurements assessed range of motion (ROM) and endurance, while Visual Analog Scale reports tracked pain. A total of 47 subjects consented, with 26 completing the protocol. There were 21 subjects who were either lost to follow-up or withdrew due to scheduling conflicts.

RESULTS: Analysis of this interventional study showed significant ROM improvement, increased muscular endurance, and reductions in pain magnitude. Subjects reported improvements in flexibility, strength, stiffness, and pain relief. Active-duty aviators noted improved ROM, quicker postflight recovery, and reduced in-flight pain.

DISCUSSION: This collaborative Department of Defense-academia-Department of Veterans Affairs research highlights the effectiveness of regular PLED-based cervical musculature exercises in enhancing ROM and endurance. While promising, further research with larger datasets is needed to support definitive recommendations. Moreover, the study's findings may benefit a broad population engaging in activities that stress the cervical spine and surrounding musculature.

KEYWORDS: aviation, exercise, neck pain, high performance jet aircraft, rotary wing aircraft.

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Since 1909, U.S. military aviation has evolved to counter increasingly sophisticated adversaries.[11] Accordingly, aviation technology continues to advance with the development of faster, more agile, and more technologically advanced aircraft. Yet, while airframes are engineered to withstand forces introduced by more advanced flight profiles, the human body cannot be similarly engineered. With training and anti-G equipment, most military aviators can withstand brief acceleration exposures up to +9 Gz, whereas the ultimate load factor of some modern airframes exceeds this limit.[4] Therefore, the human body remains a limiting factor in certain flight maneuvers and environments.

As a result of consistently pushing the envelope of what is humanly feasible, operators of high performance jet aircraft (HPJA) and rotary wing aircraft (RWA) are exposed to a myriad of musculoskeletal (MSK) injury risks. These risks are broadly divided into six main categories: environmental (acceleration, vibration); human factors (age, sex, anthropometry, etc.); body-borne equipment [night vision goggles (NVGs)]; helmet-mounted displays (counterweights, etc.); aircrew behaviors

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(positions, postures); aircraft workspace (instrument and control layout); and organization (mission type and length, aircraft type).[6] Current helmet-mounted systems require pilots to turn their heads during maneuvering to use the full range of helmet-mounted display capabilities, thus setting the stage for conflict between mission lethality and the health and safety of the pilots.[10] With the documented association between these helmets and neck pain, continued development of next-generation helmet-mounted targeting technology may further contribute to the development of neck pain.

Although neck pain is not unique to aviation, or even the military as a whole, there is a uniquely greater risk in military aviation units, with some studies finding far higher reported rates of MSK disorders in military aircrews compared to deployed ground soldiers, particularly in the upper body and neck.[21] One survey of Austrian police and rescue helicopter operators reported the 12-mo prevalence of neck pain to be 67.3% for pilots and 45.3% for crewmembers.[17] A survey of Royal Australian Air Force fast jet pilots showed a 95% prevalence of neck pain either during or after flight, with an average pain level of 5.5 on a 10-point scale while flying and 5.0 after flying; further, because of this neck pain, 42% of those respondents were classified as medically unfit for flying at some point in their careers, though most were only deemed unfit for less than a week.[15] Indeed, in one study of civilian flights, 45% of aircrew and flight attendants report experiencing work-related neck pain.[13] While significant imaging-based differences in the rate of degenerative changes to the cervical spine between aviators and nonflying personnel have not been found, a clinical difference has been noted.[9,12,20]

Higher muscular fitness scores and aerobic capacity in flying personnel are associated with fewer disabilities.[18] While high-G pilots exhibit higher aerobic capacity and muscular fitness scores, the incidence of self-reported MSK pain in this population is still greater than that of their nonaviator colleagues, suggesting that general muscular fitness is insufficient to combat neck pain.[18] One study of commercial helicopter pilots specifically demonstrated the improved success of targeted exercises in reducing sick days compared to a general fitness routine for low back pain.[2]

There have been many attempts to remedy neck pain in aircrew. In a Royal Australian Air Force survey, 43 of 78 fast jet aircrew seeking treatment for their neck pain reported using physiotherapy, chiropractic treatment, exercise/stretching, massage, and over-the-counter medications, with varying opinions on effectiveness.[15] Of note, about 30% of those respondents also listed medication as the least effective form of treatment for neck pain, second only to physiotherapy, raising concern that pharmacological intervention alone was insufficient to address this problem.

One case study in 2015 of a commercial helicopter pilot with over 2 yr of intermittent nonradicular chronic neck pain and limited range of motion (ROM) reported "significant recovery" and improved ROM after treatment with cervical and upper thoracic spinal manipulation and mobilization therapy and a 5-wk exercise therapy regimen.[1] This regimen included seven cervical and pectoral muscle stretching sessions followed by a few weeks of isometric exercises two to three times a week. Another case study involving a U.S. Marine Corps F/A-18 pilot with chronic sortie-associated neck pain also revealed resolution of neck pain and stiffness using a combination of cervical manipulation therapy and standing isometric neck exercises.[8]

The Royal Danish Air Force engaged in a randomized controlled trial involving 31 helicopter pilots and 38 aircrew to test the efficacy of the Neck Flex, a head harness with progressive resistance bands, measuring changes in reported neck and shoulder pain over time using the Standardized Nordic musculoskeletal questionnaire and Pressure Pain Threshold.[14] Subjects in this study were randomly assigned to an exercise group and a control group. Exercises included flexion, extension, lateral flexion, and rotation with the head harness, as well as deep cervical flexor and extensor exercises while supine. However, this regimen did not lead to statistically significant reductions in neck pain among the participating aviators compared to control.[14] Another randomized control trial in the Swedish Air Force with a similar regimen showed a statistically significant 60% reduction in 3-mo neck pain prevalence and a 42% reduction in neck pain at 12 mo with a 77% regimen compliance rate among helicopter pilots.[3] In addition, a recent U.S. Army Aeromedical Research Laboratory report displayed statistically significant increases in cervical ROM after a 6-wk exercise protocol with a progressive resistance band system in a small population of active-duty RWA aviators.[16] Aside from exercise-based strengthening regimens, cervical traction, when used three times a week with 20–25 lb. traction force in F-15C pilots, resulted in a decrease in the rate of postflight neck pain and an increase in cervical rotation ROM, pointing to the possibility of spinal compression itself as a cause of the pain.[5]

A pilot study at our institution in 2010 demonstrated the feasibility of the exercise regimen. A total of 10 fixed-wing HPJA (F/A-18) U.S. Navy pilots (all men) consented and enrolled in a demonstration of a novel 6-wk cervical muscle exercise regimen with the portable lightweight exercise device (PLED) (**Fig. 1**). Exercises included neck flexion, extension, lateral bending, and rotation. Baseline and postintervention quantitative data for ROM and muscular endurance (repetitions) were recorded and analyzed for changes. Increases in neck muscular endurance and range of motion were noted across all of the above-noted motions except neck extension, which saw no change. Investigators did not administer questionnaires or gather subjective data in the pilot study.

The study reported here was created to address the magnitude and frequency of neck pain while engaging in a 6-wk

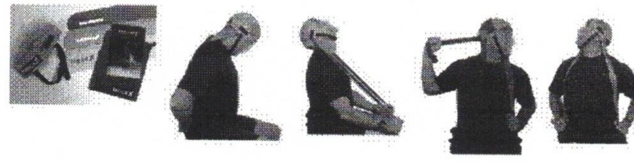

Fig. 1. Portable Lightweight Exercise Device (PLED)[Neck-X™] employed during exercise training.

exercise regimen to target limitations in cervical range of motion and neck muscular endurance. Another study aim was to add neck pain prevalence data from active-duty aviators to the literature. Interim results have previously been reported.[19] These results represent the conclusion of the study

METHODS

Subjects

All subjects underwent an informed consent briefing. No subject was denied standard medical care due to participation in this study. This Department of Defense (DoD)-supported research study falls under the Protection of Human Subjects and Adherence to Ethical Standards per DoD Instruction 3216.02 and received institutional review board approval (#NAWCAD.2015.0004-CR). Recruitment for the study took place between November 2015 and June 2021. Subjects were a combination of DoD military personnel gathered from various bases and units, including pilots and nonpilot aircrew, as well as civilians recruited from academic sites. All underwent a baseline medical fitness screening and completed occupation, pain, and fitness program questionnaires. Inclusion criteria for military subjects required ages 18–45 and the ability to pass a medical fitness screening. Civilian subjects had no age restrictions and had to be cleared by a trained practitioner to engage in physical therapy. For military personnel, exclusion criteria were a history of previous neck surgery, neurological symptoms, severe back pain, participation in a neck training or treatment regimen over the previous 12 mo, or current pregnancy. For civilians, exclusion criteria were current pregnancy or those disqualified by a trained practitioner who deemed them unfit for physical therapy.

Subjects were able to request cessation in program participation at any time. If a subject withdrew, they were recorded as withdrawn and they would not be continued in data collection. All screening and exercise assessments were completed in established medical offices with trained personnel.

Procedure

In this study, subjects engaged in the same 6-wk exercise regimen using the PLED. The PLED used in this study was the Neck-X™ system.[22] This device is composed of a soft, elastic cap with resistance bands fed through bitemporal straps over the top of the head. Each end of the resistance band is then held in the hands of the user for positioning and resistance level (Fig. 1). Primary endpoints were changes in endurance and ROM in the neck. For this study, the working definition of ROM is the angular difference between the neutral position of the cervical spine and the position of maximal subject movement in each anatomical plane; for muscular endurance is the number of exercise repetitions completed before fatigue; and for fatigue is the inability to complete a repetition without recruiting accessory muscles. Secondary endpoints were reduction in neck pain magnitude and frequency, reported weekly as pain scores with the commonly used Visual Analog Scale (VAS),[23] the number of neck pain episodes experienced, and subjective changes in neck strength, flexibility, and stiffness.

Baseline anthropometric measurements included height, weight, head circumference, head width, neck circumference at the midcervical spine, base neck circumference (including trapezius musculature), sitting height, and overall neck length. A commercially available goniometry instrument assessed baseline cervical ROM in neck flexion, extension, left and right side bending, and left and right neck rotation. Subjects completed a weekly log to record their performance of exercise, manipulation history, nonwork-related incidents associated with neck/spinal pain, flight hours with and without night vision goggles, subjective level of maximum and average pain, number of neck pain episodes experienced, and any treatment received, including over-the-counter analgesia. After the program, subjects evaluated the ease of use and their subjective view of the PLED's effectiveness for improvement in flexibility, neck muscle strength, neck stiffness, and relief from neck pain.

Investigators were trained by clinicians and physical therapists to perform the prescribed exercises with the Neck-X™, measure cervical ROM, and grade appropriate repetitions for each exercise. Subsequently, the investigators' ability to accurately perform the above tasks was verified by the clinicians and physical therapists during a mock subject encounter. Trained investigators carried out baseline ROM and endurance assessments following a series of stretches to warm up the neck musculature. These stretches included neck retraction, neck extension with small rotations, neck side bending, neck rotation, and neck flexion (**Appendix A**, found online at https://doi.org/10.3357/amhp.6288sd.2025). For lateral bending, with the subject in the neutral anatomical position, the fulcrum of the goniometer was placed in the midline at the base of the neck with the stationary arm in a vertical position in line with the cervical spine, pointing to the vertex of the head. Once the subject was at the apex of their lateral bend, the moving arm was pointed toward the vertex of the head. The subject's recorded ROM was the measured angular distance between the goniometer's moving arm and stationary arm. The same technique was performed for right and left rotation with the fulcrum being placed at the vertex of the head, the stationary arm pointed toward the tip of the nose in the axial plane, and the moving arm pointed at the tip of the nose once at the apex of the movement. Finally, for flexion and extension, the fulcrum was placed at the tragus, the stationary arm was pointed toward the tip of the nose in the sagittal plane, and the moving arm was pointed at the tip of the nose once at the apex of the movement. Endurance testing using the PLED included each subject performing neck flexion, extension, lateral bending, and rotation exercises using the highest resistance band until fatigued.

For this study, specific exercises were selected by clinicians and physical therapists to strengthen target muscles surrounding the cervical spine, improve muscular endurance, and enhance ROM around the cervical joints. The exercises were selected from the instruction manual included on the Neck-X™ website and in the device packaging.[22] These included neck flexion, extension, lateral bending, and rotation. Each exercise was performed in 2 sets of 10 repetitions, with 3 s of pull to the maximum range of motion and a brief pause at the apex, followed by 3 s of engaged resistance back to neutral (**Fig. 1**). Each exercise session at home was estimated to be about 30 min in length.

An investigator trained subjects to perform the aforementioned exercises in person. Investigators demonstrated each exercise and then verbally and visually verified participants' understanding of and proper performance of the exercises. Investigators scheduled follow-up with subjects at week 3 to verify appropriate understanding and performance of the exercises, with more frequent follow-up available if either the subject or investigator deemed it necessary. After using the highest resistance band (purple) for baseline testing, all subjects began their at-home exercises with the lowest (yellow) resistance band and performed exercises 5 d/wk. After each week, the subjects moved to the medium band level and then high resistance (green and purple, respectively). If a subject experienced pain, excessive fatigue, etc., they would remain on the current band level for another week. After using the highest resistance band (purple band) for a week, the exercise regimen increased to 2 sets of 15 repetitions per exercise for the remainder of the program. The complete regimen can be found in **Appendix B**, (found online at https://doi.org/10.3357/amhp.6288sd.2025).

Following the completion of the 6-wk regimen, investigators measured the subjects' ROM and muscular endurance with the same technique and equipment as the baseline testing mentioned above. These results were then aggregated for statistical analysis compared to the baseline measurements. All subjects' intake questionnaires and weekly surveys were aggregated for further analysis.

Statistical Analysis

Subject ROM, endurance, and subjective measures were compared between the baseline and 6-wk follow-up visits. Nonparametric statistical testing using the Wilcoxon signed-rank test was used to analyze quantitative study variables such as ROM and endurance. The decision to use nonparametric testing followed a Shapiro-Wilk test demonstrating our data was not normally distributed. Subjective measures were reported using descriptive statistics, with pain scores (**Appendix C**, found online at https://doi.org/10.3357/amhp.6288sd.2025) compared using a Student's *t*-test. The authors determined there to be a benefit to comparing the results of this study with that of the pilot study performed prior due to the population difference. The active-duty population studied in the pilot study were all HPJA operators, while 12 out of 14 active-duty flying subjects examined in this study were RWA operators. The comparison of response to intervention between these two groups is an important question to introduce due to the difference in environmental and occupational risks of the different flight profiles between groups.

RESULTS

A total of 47 subjects consented to the study. Of those, 8 subjects withdrew from the study and 13 subjects were lost to follow-up, with 26 subjects presenting for a 6-wk follow-up. Of these, 10 subjects filled out all weekly surveys, limiting the data set for pain scores over time, while 3 subjects did not report their demographic information. Of the subjects, 33 were active-duty aviators, with 14 completing the protocol. A total of 14 subjects were civilians, with 12 completing the protocol and 2 lost to follow-up. Subjects who completed the protocol were predominantly men (22 men vs. 4 women). The mean age was 38.5 yr and the mean BMI was 27.94. **Table I** contains subject demographic characteristics.

Our intake questionnaire gathered information including airframes, night vision goggle usage, previous treatments, how neck pain has previously affected missions, etc. (**Table II**, **Table III**, and **Table IV**). Of the DoD subjects, 12 were pilots, with the majority operating rotary-wing aircraft. One was a crew chief and one was a weapons safety officer for the EA-18G.

Table I. Total Cohort Demographics ($N = 26$).

VARIABLE	VALUE
Age, yr	38.5 (14.14)
Sex	
Men	22 (84.6%)
Women	4 (15.4%)
BMI	27.94 (7.87)
Active-Duty Military	14 (53.8%)
Civilians	12 (46.2%)
Experiencing Recurrent Neck Pain at Start of Study	16 (61.5%)

Variables presented as mean (SD) or N (% of the sample) where appropriate.

Table II. Frequency of Aircraft Experience and Average Number of Flight Hours per Aviator.

AIRCRAFT	NO. OF SUBJECTS ASSOCIATED	AVERAGE NO. OF FLIGHT HOURS
"Single Engine Piston"	1	380.00
AH-1 variants	1	2040.00
C-150	1	30.00
CH-46E	2	1177.50
CH-47	1	115.00
E/A-18G	1	818.00
E/A-6G	1	1183.00
F-15D	1	2.00
F-16D	1	7.00
F/A-18	10	No questionnaire (pilot study)
HH-60H	1	2.70
MH-60 variants	2	139.50
MV-22B	2	307.00
P-3	1	34.70
SH-60B	2	1739.50
T-34C	3	103.33
TH-57 variants	3	123.33
TH-67	4	25.00
UH-1Y	1	320.00
UH-60 variants	1	33.75

Variables presented as the total number of respondents and the average number of flight hours accrued. Many subjects were associated with multiple airframes.

Table III. Helmet and NVG Use ($N = 14$).

EQUIPMENT USED	NO. OF RESPONDENTS WITH HISTORICAL USE
HGU-56/P	3
HGU-67/P	1
HGU-84/2P	1
HGU-84/6P	2
HGU-84/8P	2
HGU-68(V)/P	1
NVG use	10

Variables presented as the total number of respondents. Some subjects reported use with multiple night vision goggles (NVGs).

Table IV. Average Flight Hours With and Without NVGs ($N = 14$).

RESPONSE MEASURE	AVERAGE NO. OF HOURS PER AVIATOR
Average Total Flight Hours	1005.84 (1019.96)
Average Total NVG Hours	270.17 (228.98)
Average Total NVG Hours (last 45 d)	4.82 (8.83)

Variables presented as mean (SD).
NVG: night vision goggles.

Table V. Prevalence of Neck Pain in Active-Duty Flight Crew in Different Scenarios ($N = 14$).

QUESTION	YES	NO
During the last 6 mo, have you experienced neck pain UNRELATED to flying?	10	4
During the last 6 mo, have you experienced neck pain RELATED to flying?	6	8
During the past 6 mo, have you had significant neck pain DURING flight?	5	9
During the last 6 mo, have you had significant neck pain AFTER flight?	6	8
During the last 6 mo, have you had significant neck pain during flight that was related to equipment other than head-mounted systems?	2	12
Are there any flight maneuvers that consistently cause neck pain?	3	11
During the past 6 mo, have you sought treatment for the occurrence of any flight-related significant neck pain?	3	11
Have you ever been grounded as a result of flight-related neck pain?	1	13
Have you ever acted to minimize or avoid flight-related neck pain?	2	12
Used night vision goggles (NVGs)?	10	4

Variables presented as the total number of respondents.

The 10 subjects with previous NVG use had a wide range of reported NVG flight hours. The most commonly used words to describe subjects' neck pain were "stiffness" and "dull ache." **Table V** shows the prevalence of neck pain among DoD personnel based on our questionnaire. Those who stated certain maneuvers caused pain pointed to prolonged NVG use, Basic fighter maneuvers, lookout duties, shipboard landings, instructor duties, and flying with the night vision cueing and display helmet as inciting events. When subjects were asked overall what they most associated with their pain, five answered "NVGs or helmets", two indicated instructor status, and one blamed infrequent flying. Duration of flight-related pain episodes ranged from as short as less than 2 h to as long as 1–4 d after flight (**Table VI**). **Table VII** lists data regarding the severity of pain episodes. Of those who reported regular pain episodes related to flight, 2 reported 1–3 episodes a week, 5 reported 4–10 episodes a week, and 1 reported >10 episodes a week.

Table VI. Self-Reported Duration of Pain During the Worst and Typical Episodes During the Previous 6 Months ($N = 14$).

OUTCOME MEASURE	WORST EPISODE	TYPICAL EPISODE
N/A	6	6
<2 h after flight	0	2
2–11 h after flight	2	1
12–24 h after flight	3	3
1–4 d after flight	2	1
5+ d after flight	0	0
No response	1	1

Variables presented as the total number of respondents.

After 6 wk of exercise using the PLED, mean ROM significantly increased in all domains: left rotation (+19.26°, $P < 0.001$), right rotation (+15.97°, $P < 0.001$), left lateral bend (+11.61°, $P < 0.001$), right lateral bend (+9.57°, $P < 0.001$), flexion (+15.18°, $P < 0.001$), and extension (+19.08°, $P < 0.001$) (**Table VIII**). Endurance also significantly increased in all domains after 6 wk of exercise: left rotation (+20.91 repetitions, $P < 0.001$), right rotation (+22.61, $P < 0.001$), left lateral bend (+24.37, $P < 0.001$), right lateral bend (+23.79, $P < 0.001$), flexion (+26.76, $P < 0.001$), and extension (+24.98, $P < 0.001$) (**Table IX**).

Investigators also followed the magnitude and frequency of neck pain episodes among subjects. At baseline, 16 subjects reported experiencing neck pain, with an average magnitude of 5.13 points on the VAS and an average frequency of 5.46 episodes a week. Of those, two reported an increase in magnitude of pain and three reported increased frequency at varying points during the study, though all reported overall decreased magnitude and frequency from baseline at the end of the 6-wk period. For the subjects with neck pain at baseline, the averages in magnitude and frequency of pain episodes at 6 wk were 1.81 and 2.00, respectively. Of the 10 subjects who did not have neck pain at baseline, 3 reported the development of isolated episodes of neck pain, though none stated that they had any pain

Table VII. Severity of Neck Pain Episodes in Department of Defense Flight Crew ($N = 14$).

OUTCOME MEASURE	MILD	MODERATE	SEVERE	VERY SEVERE	N/A
Severity of pain for the worst episode of pain experienced during the last 6 mo DURING flight	4	3	0	0	7
Severity of pain for the worst episode of pain experienced during the last 6 mo AFTER flight	3	5	0	0	6
Severity of pain for the typical episode of pain experienced during the last 6 mo DURING flight	4	3	0	0	7
Severity of pain for the typical episode of pain experienced during the last 6 mo AFTER flight	3	5	0	0	6

Variables presented as the total number of respondents.

Table VIII. ROM Analysis, Pre- and Post-Intervention ($N = 26$).

VARIABLE	BASELINE	6-wk FOLLOW-UP	*P*-VALUE
Rotation, left	57.86 (13.55)	74.65 (9.42)	< 0.001*
Rotation, right	58.94 (16.71)	74.90 (10.79)	< 0.001*
Lateral, left	32.40 (10.63)	43.05 (9.72)	< 0.001*
Lateral, right	30.34 (11.23)	40.11 (10.68)	< 0.001*
Flexion	32.13 (17.30)	42.32 (18.38)	< 0.001*
Extension	41.38 (16.61)	56.02 (15.81)	< 0.001*

Variables presented as mean (SD), in degrees.

Table IX. Endurance Analysis, Pre- and Post-Intervention ($N = 26$).

VARIABLE	BASELINE	6-wk FOLLOW-UP	*P*-VALUE
Rotation, left	20.08 (17.46)	42.13 (21.87)	< 0.001*
Rotation, right	18.50 (17.23)	43.79 (20.11)	< 0.001*
Lateral, left	24.25 (24.16)	49.88 (34.25)	< 0.001*
Lateral, right	23.79 (23.85)	50.21 (31.67)	< 0.001*
Flexion	23.96 (21.88)	53.29 (26.28)	< 0.001*
Extension	25.71 (23.15)	51.46 (29.95)	< 0.001*

Variables presented as mean (SD), reported as the number of repetitions before fatigue.

by the end of the regimen. The average magnitude of the worst pain episodes decreased by 3.32 points on the VAS pain scale ($P < 0.05$), and the average frequency of episodes decreased by 3.46 episodes per week; however, the decrease in frequency was not statistically significant. No subjects reported overall increases in the magnitude or frequency of pain episodes upon completion of the regimen. Additionally, two subjects reported a reduction in over-the-counter pain medication usage; however, there was not enough data to create a meaningful analysis.

Subjects noted changes in flexibility, strength, stiffness, and relief from pain at the end of the 6-wk program. A total of 23 subjects had complete records of the postintervention survey. Of those, 21 reported at least slight improvement in neck flexibility, 22 in neck muscle strength, 18 in neck stiffness, and 13 in neck pain (**Table X**). No subjects reported worsening pain, flexibility, strength, or stiffness.

With multiple categories of airframes in today's military force, it is necessary to compare the response to treatment between fixed and rotary-wing aviators. DoD recruitment for the full protocol included one fixed-wing aviator with experience with multiple airframes; however, this aviator was not able to follow up for data collection. There were 12 rotary-wing aviators who completed the protocol. **Table XI** compares quantitative response-to-intervention between the 10 fixed-wing aviators (pilot study) and 12 rotary-wing aviators. The exercise regimen in both the pilot study and full protocol were

Table X. Subjective Outcomes on Post-Intervention Follow-Up ($N = 26$, 3 Subjects Did Not Respond).

OUTCOME MEASURE	VASTLY IMPROVED	SLIGHTLY IMPROVED	SAME	WORSENED
Neck flexibility	6	15	2	0
Neck muscle strength	6	16	1	0
Neck stiffness	6	12	5	0
Neck pain	4	9	10	0

Variables presented as the total number of respondents.

Table XI. Comparison of RWA ($N = 12$) and HPJA ($N = 10$) Aviators: Performance Changes Post-Intervention.

	MUSCULAR ENDURANCE		CERVICAL ROM	
VARIABLE	RWA	HPJA	RWA	HPJA
Rotation	+133.35%	+17.00%	+32.81%	+8.00%
Lateral	+78.38%	+10.00%	+40.66%	+7.00%
Flexion	+73.47%	+9.00%	+55.23%	+5.00%
Extension	+72.60%	+12.00%	+34.13%	+0.00%

RWA: rotary wing aircraft; HPJA: high performance jet aircraft; ROM: range of motion. Variables presented as percent change from baseline.

the same despite the difference in study type. Qualitative data, including pain prevalence and intensity, are not compared due to the lack of a questionnaire in the pilot study.

No subjects reported severe adverse effects from using the PLED, nor did anyone need to seek outside emergency medical care related to participating in the study protocol. In final feedback at the end of the 6-wk regimen, five subjects who completed the protocol stated that they were unsatisfied with the size of the cap, stating that it was too small and uncomfortable at times. One subject reported nausea from using the device due to its constricting nature. No other adverse events were reported.

Subjectively, our small sample population provided valuable occupational history and critiques for aircraft design, medical access, and PLED design. The most common complaint among aviators was the weight and cumbersomeness of NVG systems, especially battery and electronics weight. When asked which maneuvers and equipment caused the most pain, most respondents responded with concurrent NVG use with basic and combat maneuvers. Typical helmet use during daytime sorties was also blamed. This suggests that reduction in weight and improvement of the ergonomics of the helmet and helmet-mounted systems are other important interventions for future studies to address. Further, critiques included complaints about the one-size-fits-all seats that are installed on many aircraft, contributing to discomfort in pilots, claiming they do not have the proper proportions for a comfortable fit. One pilot also recommended immediate access to a physical therapist on the flight line after sorties to receive manipulations for pain management, similar to other flying units that have already begun this integration.[7]

DISCUSSION

While limited in scope, this study has a few strengths. The sample population included subjects with varying degrees of exposure in the number of hours and variations in airframes flown. We also gathered subjective reports on the prevalence and incidence of neck pain rather than just objective measures of range of motion and muscular endurance.

There are several limitations to this study. First, the study population was not entirely active-duty military aviators. Second, we attempted to expand on previous studies to create a clear and easy neck strengthening regimen for flight crews; however, limitations in the size of the study prevent isolated recommendations for implementation at this time. Part of the difficulty in obtaining data from subjects on active-duty aviation service is the unpredictable demands of said service. High operational tempo hindered the subjects' follow-up, as many aircrew were deployed or on extended temporary duty missions before the 6-wk follow-up. While the study originally intended to follow these subjects for longer than 6 wk, this high operational tempo of active duty also meant that longer follow-up was sporadic. Therefore, extended follow-up was not required for inclusion in the analysis. Third, another potential factor in low recruitment could be the belief by some aviators that reporting any symptoms may lead to a review of their flying status with potential disqualification. Fourth, the original intention of this study was to include a control group; however, low recruitment numbers led to a change in the study design and, thus, there is no control group against which to compare subject performance. Fifth, our quantitative analyses for ROM and muscular endurance only used data from the 26 subjects who completed the study, potentially introducing bias in the results. While our low enrollment of women is a limitation, other recent studies had similar issues and struggled to enroll any subjects, regardless of sex.[16] Further, compliance with weekly neck pain surveys was low. Many subjects did not complete the requisite survey documentation per the protocol schedule. Many subjects claimed they "forgot" to complete the survey.

Despite the difficulty in obtaining data on these subjects, the portability of the PLED introduced flexibility in training and strengthening that the subjects applauded. The device is easily folded down to travel in any type of bag, typically a standard helmet bag, and is lightweight enough not to introduce a noticeable burden when traveling. Therefore, although data collection was difficult on these active-duty subjects, the intervention can be completed "on the go" and taken with the aviator to any location. In addition, this regimen requires less than an hour a day to perform a universal routine that could fit in with all schedules, especially the demanding nature of military aviator flying regimens.

While not specifically tested in this protocol, our regimen could apply to civilian aviation and aerospace operators, including spaceflight crew and participants. Though the same high-G environment and burden of tactical equipment do not translate to civilian crews, our exercises still have the potential to show benefits in these populations. However, large-scale studies are needed for more definite conclusions.

Subject feedback illuminated a few design suggestions to make the PLED more comfortable. For example, 12 subjects complained about the tight fit of the cap or that their head was measured between the regular and large caps. While the operation of the PLED depends on the cap remaining immobile on the head, more comfortable security features and a more progressive size scale may lead to increased user satisfaction, increased compliance, and better results. Another point of feedback arose surrounding the progression of resistance as subjects moved through the protocol. To add more resistance using the same band, the subjects were required to anchor their hands along the band closer to the cap. However, five subjects said the lack of indicators on the band for different resistance levels led to inconsistencies in the resistance they applied at home. They suggested the company add markings on the band to help users remain more consistent in their exercises rather than guessing where they previously held the band.

Further studies with the inclusion of PLEDs, e.g., Neck-X(™) or similar devices, should be conducted on a larger scale, perhaps fleet-wide, to gain more data on the operational factors influencing neck pain in aviators and expand on the strength and flexibility benefit of this regimen shown in this small study. These further studies should refer to the design of this trial and others to avoid the limitations we experienced with subject recruitment and compliance.

In conclusion, in this study, a 6-wk home exercise program using a lightweight, portable resistance band neck muscle strengthening device increased mean cervical ROM, increased muscular endurance, and reduced the magnitude of neck pain episodes in our subject pool who completed the protocol and reported for follow-up. These outcomes point to an easy, on-the-go solution for total-force use to potentially reduce the effect of MSK disorders of the neck and time spent disqualified for flight status, thus improving the reliability and longevity of military aviators.

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APPENDIX A. WARM-UP PROCEDURES

Prior to and after neck muscle endurance assessments, subjects will perform stretching exercises to warm-up and cool-down their neck muscles from exertions. These stretches include (12), but are not limited to, such exercises as:

1. Head retraction: Sit or stand with good posture; tuck chin down and in; place both hands on the chin retract head backward as far as possible without tilting head up; maintain for a few seconds, relax and repeat 5-6 times. If using the Neck-X, do 10 reps (3 s of pull to maximum range of motion, slight pause at neutral, and followed by 3 s of engaged resistance for a total of slightly more than 6 s per repetition).
2. Neck extension: Sit or stand with good posture; tuck chin down and in; lift chin up and tilt head backward without allowing the head to move forward; with head tilted back as far as possible, repeatedly turn nose 2 cm to right and left while attempting to move the head farther backward for a few seconds; relax and repeat 5-6 times. If using the Neck-X, do 10 reps (3 s of pull to maximum range of motion, slight pause at neutral, and followed by 3 s of engaged resistance for a total of slightly more than 6 s per repetition).
3. Neck side-bending: Sit or stand with good posture; tuck chin down and in; place hand over top of the head and gently but firmly pull head sideways and hold for a few seconds; relax and repeat 5-6 times; repeat for other side. If using the Neck-X, do 5 reps on the left; then repeat for the right side. (3 s of pull to maximum range of motion, slight pause at neutral, and followed by 3 s of engaged resistance for a total of slightly more than 6 s per repetition. Come to neutral end position after movement to the left/right sides).
4. Neck rotation: Sit or stand with good posture; tuck chin down and in; place one hand on the chin and the other behind the head and gently but firmly push head into rotation; hold in maximum rotation for a few seconds; relax and repeat 5-6 times; repeat for other side. If using the Neck-X, do 5 reps on the left; then repeat for the right side. (3 s of pull to maximum range of motion, slight pause at neutral, and followed by 3 s of engaged resistance for a total of slightly more than 6 s per repetition. Come to neutral end position after movement
5. Neck flexion: Sit and drop head forward and let it rest with the chin as close to the chest as possible; place hands behind the head and interlock fingers; gently but firmly pull head onto chest and hold for a few seconds; relax and repeat 2-3 times. If using the Neck-X, do 10 reps × 2 sets (3 s of pull to maximum range of motion, slight pause at neutral, and followed by 3 s of engaged resistance for a total of slightly more than 6 s per repetition)

APPENDIX B. NECK-X EXERCISES AND SEQUENCE

Exercises

i. Neck Extension: 10 reps × 2 sets
ii. Side Bending: Left – 10 reps × 2 sets Right – 10 reps × 2 sets
iii. Neck Rotation: Left – 10 reps × 2 sets Right – 10 reps × 2 sets
iv. Neck Flexion: 10 reps × 2 sets
v. All exercises, except for Side Bending and Neck Rotation, are performed with 3 s of pull to maximum range of motion, slight pause at neutral, and followed by 3 s of engaged resistance for a total of slightly more than 6 s per repetition. Side Bending and Neck Rotation exercises should come to neutral end position after movement to the left/right sides.

Exercise Sequence

i. All participants begin with the yellow (lowest) resistance band
ii. Regimen is to be performed 5 d/week
iii. At the end of each week, participants proceed to the next band level (green, followed by purple). Note: If the participant feels pain, excessive fatigue, etc., then an additional week is spent on the current resistance band.
iv. After the week of exercises using the purple band, each subsequent week's regimen (weeks 4-6) will include 2 sets of *15 reps* of each exercise with the purple band since range of motion and strength have been developed in the preceding weeks.

APPENDIX C. PAIN SCORE SCALE

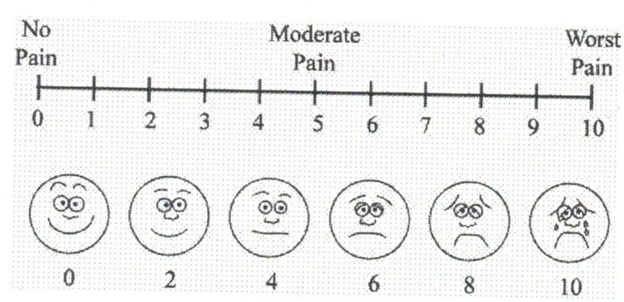

Fig. C1. VAS pain scale.