Differing Presentation and Functional Correlates of Cervical Spine Degenerative Changes in Military Fighter Pilots: Association with the Loading Environment

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I. INTRODUCTION

Pilots of military fighter aircraft are regularly exposed to high accelerations during basic fighter manoeuvres (BFM) training, which act in the vertical axis, i.e., Gz, along the seated occupant and lead to compressive stresses on the cervical spine [1-2]. Repeated exposure to these forces during flight training exercises over the course of years is thought to contribute to accelerated degenerative changes in spinal tissues. Compounding the problem is that pilots experience these loads while wearing military helmets, which increases the effective head mass and loads on the spine, and often with the head-neck in non-neutral positions [3], which changes the load sharing between spinal components and can add a pre-stress to spinal tissues. This abnormal and repetitive cervical spine loading is hypothesized to contribute to a high prevalence of neck pain in the fighter pilot community [1][4-5].

II. METHODS

The Medical College of Wisconsin, USA, Military Aircrew Neck and Back Pain study was designed to characterise the natural history of neck and back pain in pilots and aircrew of military fixed wing fighter aircraft and rotary wing aircraft. The study includes flight history and detailed pain questionnaires to characterise the type and severity of neck and back pain symptoms, functional assessments to characterise functional changes associated with flight-related pain, supine and upright magnetic resonance imaging (MRI) scans to quantify structural degeneration of the spine and acute/chronic physiological changes, and blood/serum biomarker assessments to quantify stress and inflammatory response to flight training activities. Baseline assessments are conducted annually during times of reduced flight training activity and flight training assessments (3x per year) are conducted the day before and immediately following flight training activities. The study initiated in the autumn of 2024 and has completed all Year 1 baseline assessments, and the first Year 1 flight exposure assessment. Supine and upright MRI scans were used to determine structural changes in the spine associated with degeneration, advanced MRI sequences were used to identify physiological changes linked to flight training activities, and functional assessments included neck range of motion (ROM), neck strength, and postural stability.

III. INITIAL FINDINGS

All study procedures were approved by the Institutional Review Board (IRB) at the Medical College of Wisconsin. A total of 20 5th Gen fighter pilots (18M/2F) from the Wisconsin Air National Guard were consented and enrolled in the study. Subjects had a mean age of 38.7 years (range: 28-49), mean total military flight time of 2,191 hours (400-3,500), and an average annual flight time of 155 hours/year (83-200). All 20 pilots operated 4th Gen fighters prior to transitioning to the 5th Gen fighter in early 2024. During the baseline pain assessment, 55% of pilots (n=11) reported moderate-to-severe pain in the previous four weeks and 60% (n=12) reported neck disability index (NDI) scores indicative of mild neck disability. Eighty percent (n=16) described a pain course indicative of chronic pain and 60% indicated pain flare-ups both during and after flight training. All pilots indicated that BFM and Air Combat Maneuvers (ACM) worsened their neck pain.

Baseline MRI scans revealed a unique pattern of cervical spine degenerative changes compared to civilians, characterised by more advanced degenerative changes at cranial levels (C2/3 and C3/4) compared to the middle-

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and caudal cervical spine. For example, mean intervertebral disc degeneration as graded using Pfirrmann scores was greatest at the C2/3 and C3/4 spinal levels (Figure 1). Ultra-short echo time (UTE) sequences also revealed evidence of endplate calcification that was also most common at upper cervical vertebrae.

Enrolled pilots also demonstrated flight-related functional changes that were more evident for pilots that reported flight-related neck pain (Figure 2). Specifically, pilots demonstrated reduced post-flight training neck range of motion (ROM) in extension, lateral bending, and axial rotation when compared to the same measurements obtained the day prior to the flight training exercise. These ROM reductions were greater for pilots that reported flight-related neck pain and were significantly greater ($p<0.05$) in axial rotation.

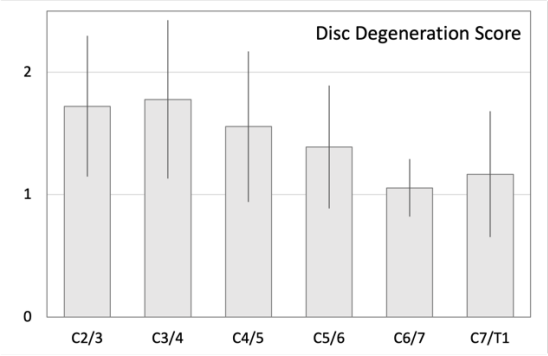

Fig. 1. Cervical spine intervertebral disc degenerative changes were most evident at upper cervical spine levels.

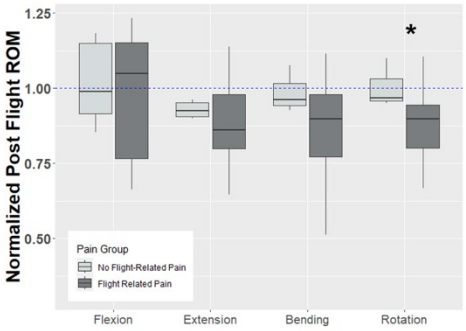

Fig. 2. Pilots demonstrated reduced neck ROM following flight training activities.

IV. DISCUSSION

Preliminary data presented in this manuscript represent novel findings regarding the character of pain symptoms, the profile of cervical spine intervertebral disc and facet joint degenerative changes, and functional consequences of neck pain in a population of 5th Gen pilots from the Wisconsin Air National Guard. Although the study sample represents a somewhat limited population (n=20), degenerative changes in the cervical spine appear to occur in an accelerated manner and with unique presentation compared to the civilian population [6]. Most interesting is the preponderance of disc- and endplate-related changes in the upper cervical spine that are likely attributable to the unique and severe loading environment experienced by military fighter pilots. Post flight training questionnaires revealed that pilots experienced between 6 and 9 peak g's during the previous flight training exercise, which lasted a median of 90 minutes. That type of flight training, occurring over an average of 155 flight hours per year clearly represents a significant accumulating biomechanical load. Much of that load is experienced with the cervical spine in non-neutral orientations, such as the *check-six* position where the pilot has axially rotated the cervical spine to monitor opponent movements to the rear of their aircraft. Accelerated cervical spine degeneration at upper cervical spine levels can then be explained by a majority of axial rotation occurring in the upper cervical spine due to the atlanto-axial joint. Post-flight functional changes support this finding by demonstrating the largest reductions in neck ROM between pilots with and without flight-related pain to be in axial rotation. These preliminary results provide a unique insight into flight-related neck pain in fighter pilots likely associated with accumulating biomechanical load on the cervical spine during repeated flight training exercises over the course of a pilot's career. Repeated baseline and flight-training assessments yet to be completed for this study will further explore these progressive changes across three consecutive years.

IV. DISCLOSURE

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