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Musculoskeletal Pain in High-G Aircraft Training Programs: A Survey of Student and Instructor Pilots

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Studies note musculoskeletal (MS) symptoms in pilots flying high-G aircraft, impacting mission readiness with concerns for chronic disability. We hypothesized similar prevalence of MS symptoms in student pilots, but we could not find studies that addressed this population. Focused MS strength training and alternative medical treatments would significantly benefit our pilots. Instructor pilots benefitted from osteopathic manipulation at Laughlin Air Force Base, but student pilots were not seen. An aeromedical literature review on pilots' MS issues helped design a survey that was distributed anonymously to T-6, T-38, and T-1 student and instructor pilots at Laughlin Air Force Base, with a response rate of 75.8%. Instructors reported MS pain that interfered with flying and non-flying activities by a 2:1 ratio over students during most training scenarios, similar to literature reports. Both stated alternative therapies were effective. Mission requirements interfered with strength training and therapies. More pilots would report MS issues if they could receive timely and effective therapies without being grounded. Results indicate significant concern for MS issues interfering with flying and need for physical therapy, chiropractic or osteopathic services early in pilot training at training bases, and timely treatment without grounding. Pilots want focused MS strength training by certified trainers and specific time for this training. They are concerned that issues not addressed early with effective therapies will result in chronic disabilities.

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1.0 SUMMARY

Studies note musculoskeletal (MS) symptoms in pilots flying high-G aircraft, impacting mission readiness with concerns for chronic disability. We hypothesized similar prevalence of MS symptoms in student pilots, but we could not find studies that addressed this population. Focused MS strength training and alternative medical treatments would significantly benefit our pilots. Instructor pilots benefitted from osteopathic manipulation at Laughlin Air Force Base, but student pilots were not seen. An aeromedical literature review on pilots' MS issues helped design a survey that was distributed anonymously to T-6, T-38, and T-1 student and instructor pilots at Laughlin Air Force Base, with a response rate of 75.8%. Instructors reported MS pain that interfered with flying and non-flying activities by a 2:1 ratio over students during most training scenarios, similar to literature reports. Both stated alternative therapies were effective. Mission requirements interfered with strength training and therapies. More pilots would report MS issues if they could receive timely and effective therapies without being grounded. Results indicate significant concern for MS issues interfering with flying and need for physical therapy, chiropractic or osteopathic services early in pilot training at training bases, and timely treatment without grounding. Pilots want focused MS strength training by certified trainers and specific time for this training. They are concerned that issues not addressed early with effective therapies will result in chronic disabilities.

2.0 INTRODUCTION

Musculoskeletal (MS) symptoms, especially neck pain (NP), occur at every level of high-performance (HP) aircraft (AC) training with mission readiness impacts and potential long-term disability. The neck is best protected in the neutral position, head directly over the shoulders, and is most vulnerable in the check-6 position, even at lower G-forces. Pilots are also more vulnerable to injury when not in control of the AC [1]. Pilots hesitate to report MS symptoms and do what they can on their own with cockpit techniques and exercise [2]. At the same time, standardized MS training early in pilot training programs and effective alternative therapies are not routinely available to our pilots. Instructor pilots (IPs) were taking advantage of osteopathic manipulation therapy (OMT) services being offered at Laughlin Air Force Base (AFB), TX, and reported utilizing off-base chiropractic services as well. They stated that these therapies alleviated their discomfort and kept them flying. We hypothesized similar prevalence of MS symptoms in student pilots (SPs), but studies have not addressed these issues in Student Undergraduate Pilot Training (SUPT) programs. We felt that focused MS strength training and alternative medical treatments such as chiropractic, OMT, and physical therapy (PT) would provide significant benefits. IPs at Laughlin AFB stated benefits of OMT, but SPs in these same AC did not present for treatment. We questioned if SPs either underreported or simply did not have significant prevalence of MS issues compared to their instructors. We suspected that SPs had MS complaints similar to the IPs and to reports in the literature.

There is a significant concern for MS issues that occurred with the introduction of the enhanced performance high-G aircraft such as the F-15 Eagle, introduced in 1974, and the F-16 Fighting Falcon, introduced in 1979. The F-16 has twice the turning rate and half the turn radius as the previous generation F-4 Phantom II [3].

A survey of 437 U.S. Air Force F-5, F-15, and F-16 pilots was conducted by Vanderbeek in 1988 concerning effects of helmet weight, forward posture, and high-G on the cervical spine

[4]. His survey looked at NP within the prior 12 months to improve recall. His study revealed that 30% of the pilots had NP in the last month, 51% in the prior 3 months, and 64% in the prior year. They reported increased neck injuries with check-6 and head turning under high-G. Medical help was not sought unless injuries stopped flying. Compare this to a study of 129 Japanese F-15 pilots by Hämäläinen et al. in 1995 concerning MS issues experienced when these pilots transitioned from lower-G F-1, F-4, and F-104 AC [1]. Prior to flying the F-15, MS complaints were reported at 30.4% in the F-4, 14.8% in the F-1, and 0% in the F-104. This survey covered pain throughout their careers and revealed 89% of Japanese pilots reported pain with introduction of high-G AC, with NP being most common. MS symptoms were reported in 95% during advanced combat maneuvers (ACM), with check-6 and forward bent posture the most common positions prior to onset of pain. Pain was worse with high-G maneuvers in 50% of the pilots. They noted decreased concentration, lower G-tolerance, and decreased ability to perform target searching, but flew despite the pain due to mission requirements.

The Japan experience highlights what pilots experience as they transition from low-G AC to novel experiences in high-G AC. All pilots are at risk for injuries as they progress through training. The Japan study reviewed literature [3-8] and found high-G neck injuries to include the rare compression fractures, herniated discs, and ligament tears. More common injuries seen are neck strains, with significant impact on mission and lifestyle. Effects on daily lives included a 40% decrease in family and recreation time and needing to rest on days off. The pilots utilized treatments such as acupuncture, moxa cautery, or massage. They felt these therapies were more effective than conventional medical care, but were not covered benefits.

Knudson et al. surveyed 148 U.S. Naval aviators flying the F/A-18 Hornet, capable of over 9 G with a G-onset rate of over 18 G per second, and the A-7 and A-4 [8]. Increased frequency and severity of pain were noted with increasing Gs. The most common position at time of injury was the check-6 position, and 82% of injuries occurred with ACM. Lighter helmets, regular neck exercises, and pre-flight stretching were potential measures to reduce high-G neck injuries [8].

Hämäläinen et al. looked at 12 Finnish pilots exposed to high-G forces and 12 controls not exposed to high-G forces. They stated the same issues with the cervical spine under high-G and during turning movements during ACM, but added x-rays to evaluate for cervical disc degeneration [7]. This study showed that G-load on the cervical spine affected the C3-4 disc more in pilots, whereas the C5-6 disc space is more commonly involved in age-related cervical disc degeneration.

Kang et al. surveyed 1003 pilots from the Republic of Korea Air Force looking at the relationship between aviator NP and exposed G-level [9]. Results showed that monthly duration of G_{max} exposure, flight hours in current aircraft, and body mass index were significantly related to this experience of NP.

Wagstaff et al. evaluated 147 F-16 Royal Norwegian Air Force pilots concerning G-induced NP [10], noting worsening NP with introduction of HP aircraft. The F-16 has a 30-degree inclined seat, which causes forward flexion away from the headrest to scan during maneuvers. There is concern for night vision goggles (NVGs) and helmet-mounted displays increasing helmet weight and increasing neck strain even at lower G levels [10].

Schall looked at cervical spine injuries from high-G forces in the F-15 and F-16 [3]. The cervical spine withstands loads up to 91 kg (200 pounds). At 9 G, loads are 48-65 kg (106-143 pounds), so the cervical spine can tolerate 9-G loads in neutral position. However, when the cervical spine is rotated or bent out of neutral, injuries can occur at only 50% of the

above axial compression loads. Injuries found included compression fractures at C7 and C5, widening of the C6-7 interspinous ligament, herniated disc at C5-6 and C6-7, myofascial pain syndrome, and fracture of the C7 spinous process. Whole-body conditioning with neck training twice a week had a 92% improvement in neck strength. Isolated neck exercises three times a week had a 57% improvement, and no formal training (control group) still showed a 28% improvement [3].

Lange et al. studied NP among Royal Danish Air Force pilots after introduction of the Joint Helmet Mounted Cueing System (JHMCS) and NVGs. JHMCS helps pilots direct (cue) onboard weapons during high-G ACM, but requires looking at the target with head and neck away from the neutral posture while pulling high-G, causing a conflict between the pilots' protected head posture during high-G and moving the head during high-G with the JHMCS system plus the added weight of the NVGs [11].

3.0 METHODS

Based on the clinical experience with the IPs at Laughlin AFB, a literature review of MS issues in HP AC was conducted. An anonymous 32-question paper survey on MS issues was designed based on local concerns as well as concerns noted and surveyed in the reviewed literature. This survey received Institutional Review Board approval as an exempt survey and was supported by the Air Education and Training Command and the 47th Operations Group at Laughlin AFB, TX. We mailed 600 surveys and vetted them through the associate investigator, a T-38 IP, who briefed the potential survey participants prior to the survey distribution to the T-6, T-38, and T-1 SUPT squadrons. Surveys were numbered for statistical analysis tracking and asked about age ranges, IP versus SP, and AC type, but did not ask for any personally identifying information. Survey participants were told to not include any personal information that could identify them and that participation in the survey indicated their consent. Completed surveys were mailed back to the principal investigator by Fed Ex next-day and were secured in locked rooms and cabinets throughout the process. The survey asked about MS symptoms during various training scenarios, training environment to include exercise and cockpit techniques, levels of pain experienced and associated scenarios, overall effects on performance, and any effects on off-duty activities. We asked about medical therapies utilized and tried to discover what was effective, not effective, and what they felt was needed. Finally, we included an essay-type question to provide an opportunity for anecdotal inputs to cover areas not potentially addressed in the prior questions.

4.0 RESULTS

Of the potential 600 surveys, 356 were distributed and 267 were collected, resulting in a 75% response rate of the distributed surveys and a 45% response rate if we considered a potential of 597 participants. There were close to equal representations of SP to IP, with 113 SPs and 137 IPs. The T-6 squadron produced 51 SPs and 75 IPs. The T-38 squadron produced 35 SPs and 32 IPs. The T-1 squadron, initially thought to be our control group, produced 27 SPs and 30 IPs. Summary statistics were calculated for each question. Differences between IP and SP were analyzed across airframes for each question using contingency table analysis. Significant differences in distribution of responses were determined using Pearson's chi-square test. In cases where cell counts were too low to permit the standard chi-square test, the exact option in SAS

was employed and the exact likelihood ratio chi-square test was used. In cases where a range of responses was permitted (0 - 9), the data were grouped into categories of low, moderate, or severe because of low counts in the individual responses. Initially, we intended to classify the T-1 population as the low-G AC control group, hypothesizing that they would have more low back issues and not neck or upper back issues. We found that lower back pain was prevalent in all three populations based on duration of missions. Upper back and neck pain were noted more in the pilots with more hours in high-G AC.

As expected, SPs are younger and IPs are relatively older with 91% of SPs 20-29 years old, 70% of IPs 25-34 years old, and 24% IPs in the 35- to 44-year-old range. There was also the expected increase in total flying hours as pilots aged. The types of AC previously flown were varied and too numerous to report here. IPs reported more pain in general with flying at 68% compared to 48% SPs. Similar reports were also noted between the populations concerning MS pain that got worse during flight, with 30% IPs compared to 25% SPs reporting this issue. The differences become more significant, by a two-to-one ratio, when we asked about pain with G-load, with 48% IPs compared to 23% SPs reporting pain. With this G-load pain, severity levels of 5-10/10 were reported by 63% IPs compared to 29% SPs, again a two-to-one ratio and very concerning.

Considering certain flying training scenarios, we again saw a two-to-one ratio of IP versus SP reports of pain. Pain with check-6 was reported by 48% IPs versus 24% SPs. Pain with ACM was reported by 17% IPs versus 8% SP. Pain during formation flying was reported by 42% IPs versus 21% SPs. Pain occurring when not in control of the AC was reported by 36% IPs versus 16% SPs.

We looked at more subjective factors of pain affecting performance (concentration and flying ability) and safety. Those who reported effects were asked to rate the subjective level of negative effects on a 1-10 Likert scale. Effects of pain on overall performance were reported by 44% IPs versus 27% SPs. For pain specifically limiting concentration, there was not a significant difference, but more IPs reported a 4-6/10 severity level versus SPs, who reported a 3-5/10 severity level. For pain specifically limiting flying ability, again there was no significant difference, but more IPs reported in the 3-5/10 severity level versus SPs reporting in the 2-3/10 severity level. Finally, for pain affecting safety, we saw similar severity scores between IPs and SPs, with 67% IPs versus 57% SPs reporting in the 2-3/10 severity level and 21% IPs versus 28% SP reporting in the 4-5/10 severity level. Overall, IPs reported higher discomfort levels across all three AC types in this study population.

Similar to previous reports in the literature, we saw that 16% IPs versus 7% SPs continued to fly despite pain. Some did have to alter their flying schedule, with 17% IPs versus 5% SPs reporting such consequences. More of our pilot population reported limitations on home life and family time at 52% for our IPs versus 21% SPs.

It is well known in the flying community and in flight medicine, as well as in the literature, that a significant number of pilots do not seek medical help, especially from their flight surgeons. We tried to determine why in this study and included outside resources for medical care such as chiropractic services. Unfortunately, we had limited responses to these questions, with only 18 IPs and 5 SPs answering these questions. We found that 30% IPs and 45% SPs stated they did not need help. Of the remaining respondents, 30% IPs and 30% SPs said services were not available, 35% IPs and 13% SPs stated cost of services as a restriction (assuming off-base services), 29% IPs and 35% SPs stated there was insufficient time in their training, and finally 28% IPs and 32% SPs stated fear of negative evaluation.

Our final survey question was open essay type, asking for additional information that pilots may have felt we missed. For reasons unknown, none of the 51 T-6 SPs provided inputs. From the inputs received, we categorized responses into NP, low back pain (LBP), equipment, formation flying, exercise, chiropractic/osteopathic (OMT) need and use, and PT. Comments were summarized and compared IPs versus SPs across the three AC types. Results are summarized in Tables 1-3.

Table 1. Neck Pain and Low Back Pain Reports

Issue	T-6 IP	T-38 SP	T-38 IP	T-1 SP	T-1 IP
NP	• No ACM • No pulling Gs • Worse w/check-6 • Worse w/clearing w/Gs • D/C third sortie	• Less G and check-6 • Worse w/check-6, rapid head turning • Affects daily life • Not enough done to protect us from NP	• Worse w/Gs, check-6, teaching SP • Sortie stopped • Removed from schedule • Don't talk to flight surgeon due to fear of DNIF/loss of wings	Some NP w/check-6, G-load, hours in cross-country	Helmets, NVGs, craning neck to turn, clear, get into position
LBP	• Long flights in ejection seats • Worse w/G-load if not back in seat	• Long flights in ejection seats • Close air support for hours	*No specific comments*	• More LBP w/ move from T-6 to T-1 and long sorties • Poor back support • Loss of sleep	• Poor seats, long sorties, high ops tempo • Cause sleep problems and skipping activities

Table 2. Equipment and Formation Flying

Issue	T-6 IP	T-38 SP	T-38 IP	T-1 SP	T-1 IP
Equip	• Old poorly padded seats • NVG, helmet weight, esp w/Gs	Old ejection seats on long flights	• Old ejection seats w/sustained Gs • NP w/NVGs so used less than needed	Old seats w/poor back support	Helmets, NVGs, poor seats, poor visibility
Form	• Prefer one side or do add'l turns to avoid NP • Check-6 is a problem • Push on glare shield to turn body	• Prefer one side or more aft to avoid direction of NP • Turn whole body to avoid NP	• Prefer one side or change sides • Prefer to turn one direction to avoid NP	• Problem w/certain positions in close formation • Need to move around in formation	More pain w/ hours looking one direction, craning neck, forward posture esp w/NVGs

Table 3. Exercise, Osteopathic Manipulation Therapy, and Physical Therapy

Issue	T-6 IP	T-38 SP	T-38 IP	T-1 SP	T-1 IP
Exercise	Fear harm due to poor knowledge	• Not sure how to exercise • Need education	• Need SUPT/annual exercise training • Instructor-led gym classes • Flying interferes w/exercise	No time to exercise due to schedule	Need trainers in gym to teach specific exercises
OMT	• Need on-base services • Beneficial, but costly, time away, not covered • Worry about loss of wings	Need on-base services to limit high-G injury and decrease DNIF	• Need on-base services w/o fear of DNIF or negative actions for buy-in • OMT helps	• Need services w/o negative effects on med qualification • Concern of cost, coverage, DNIF/ disqualification	• Need early treatment for minor pain w/o penalty • OMT more effective than injections
PT	• Need education and screening at flight physical • Need on-base PT, back specialist	*No specific comments*	• PT, massage helps • Early interventions not offered	*No specific comments*	Support PT and massage

4.1 Neck Pain

Pilots state that the check-6 position, G-loads, head turning under G-load, helmets, and NVGs cause pain. NP causes sorties to be stopped and pilots to decrease G-loads to below normal expected levels and to decrease their normal head movements. Also, NP is a problem that affects daily life, but they don't report to a flight surgeon due to fear of being grounded, called duties not including flying (DNIF), or ultimately loss of wings.

4.2 Low Back Pain

Pilots state long flights in ejection seats with cross-country flights, close air support, and movement from the T-6 to the T-1 airframe increased their LBP. This LBP was reported to cause loss of sleep. So we see that pilots do not have just NP in these AC; they also have LBP.

4.3 Equipment

Across all AC, old poorly padded seats were cited most commonly as a cause of MS pain, then NVGs and helmets. Pilots admitted to actually decreasing NVG use even in flying scenarios where they were needed. T-1 pilots stated that decreased visibility due to the small windscreens caused them to need to crane their necks to see other AC, with resulting NP. So while we initially thought that our low-G T-1 population would be our NP control group, we found that the T-1 pilots strongly stated that NP should also be considered in their group, not just LBP, and that further research was needed.

4.4 Formation Flying

Across all three AC types, we saw pilots preferring one side of the formation to avoid turning their necks in the painful direction, needing to change their positions in formation when permitted, or turning their whole body to look for traffic to avoid turning their necks. Again, as stated before, the check-6 position in formation was a significant problem.

4.5 Exercise

We found across all AC types that pilots did not know what exercises to do without causing harm, so many would not exercise other than the typical MS training that one would do in any gym. Significant numbers of pilots stated they wanted classes as well as trainers in the gym to show them what to do. While desiring MS training, they also noted that the flying schedule interfered with any potential exercise time. Most exercising had to be done after flying or on days off, which resulted in irregular exercise schedules. One example of training is a 1975 West Point study with specific neck exercises, whole body conditioning, and no formal training as a control group that showed significant improvement with focused training methods. The group who did whole body conditioning plus specific neck exercises showed a 92% improvement in neck strength. Those who did neck exercises only showed a 57% improvement in neck strength. The control group with no formal training still showed a 28% improvement in neck strength [12].

4.6 Chiropractic/Osteopathic Services

Overall pilots wanted on-base services, or approval and coverage for off-base services. Some stated that to have pilot buy-in to engaging medical care, they had to be assured of treatment strategies to address the minor MS pain that occurs in their flying environment without fear of DNIF or loss of wings. Pilots said OMT and chiropractic treatments were effective but costly in terms of money as well as time away from the flying mission.

4.7 Physical Therapy

We had fewer pilots providing comments on this topic, but respondents supported PT and massage as earlier intervention and they also asked for MS training education by the physical therapist.

5.0 DISCUSSION

Musculoskeletal discomfort progresses as pilots transition from low-G to high-G AC and as they progress from basic maneuvers to ACM. Literature reports have stated increased MS complaints as pilots have transitioned to higher performance AC. In our study, more than 50% IPs and SPs have pain and existing pain that gets worse with flying, with 63% IPs and 29% SPs reporting severity levels of 5-10/10, with at least mild concerns for pain limiting concentration, flying ability, and safety. In our survey, pain was reported at a two-to-one ratio IP versus SP with G-load, check-6, ACM, formation flying, and when not in control of the AC. Initially, we thought that the T-1 pilots would serve as a control group for NP, experiencing less NP and more

LBP, but reports revealed that NP was also reported by the T-1 pilots and LBP was reported by the T-6 and T-38 pilots. Pilots continued to fly despite the pain, but some had to alter their flying schedule due to pain. A significant percentage of pilots in both groups stated that their pain affected their lives outside of flying, mainly seen in quality time spent at home and with family. Both IPs and SPs reported similar concerns for safety, with mild concern level at an average of 62% and moderate concern level at an average of 25%. Pilots want access to alternative therapies for minor MS pain without the risk of being grounded or losing their wings. They also want education and training for exercise and time in their training schedules to do MS training.

There were some challenges with this study. While important to us, this was a 32-question paper survey for busy pilots at Laughlin AFB during their Wingman Day, where time was limited with other competing issues. Fortunately, our co-investigator was a current T-38 IP who knew how to motivate pilots to volunteer. Our response rate of 75% of the distributed surveys was good. However, if we consider the total pilot population of 597, our 267 surveys out of this potential total population resulted in a 45% response rate. It is conceivable that those pilots with issues were more likely to respond to this survey, which could skew the data toward more positive results. On the other hand, even with confidentiality assured, it is possible that participants were unwilling to fully admit to problems, thus causing an underreporting of symptoms. Age and experience are confounders. With age and increase in total flying hours comes more MS issues in general. Many of the IPs had flown hundreds of hours in other AC prior to becoming an IP. Age-matched controls such as commercial airline pilots, who were not also Guard or Reserve pilots, would provide better comparisons, but were not part of this study cohort.

6.0 CONCLUSIONS

We must institute MS training at the SP level as well as in the operational levels, similar to the West Point study cited above [12]. This training has to have commander and instructor support and be included in the training syllabi. Specific MS training and classes should also be included for our flight surgeons in our Aerospace Medicine Primary and our Residency in Aerospace Medicine courses. These changes and additional training cannot happen without a coordinated effort of a multidisciplinary group to include PT, Exercise Physiology, Physical Medicine and Rehabilitation, Osteopathic, Chiropractic, Aerospace Medicine Primary, Residency in Aerospace Medicine, and the SUPT, as well as the operational pilots. If we could staff our SUPT and our active flying bases with on-base chiropractic, osteopathic, and PT specialists to treat minor MS complaints and keep our pilots flying, that would be the ideal solution. However, there are not enough of these specialists to staff each base with active flyers, so an alternative approach would be to provide access to these services off base, coordinated by the local flight surgeon and without DNIF.

Results of our survey indicate significant concern for MS issues interfering with flying abilities with need for on-base PT, chiropractic, or osteopathic services at training bases for timely treatment without DNIF. Pilots also wanted focused instruction on MS strength training by certified trainers and physical therapists and time in their training schedules specifically for this training. Finally, they were concerned that MS issues not addressed early, due to stigmas of reporting and lack of availability of effective therapies, are resulting in chronic long-term disabilities that will affect their quality of life both during and after their military flying careers.

It is important to provide appropriate training as well as sufficient and timely access to alternative therapies early in pilot training.

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LIST OF ABBREVIATIONS AND ACRONYMS

AC	aircraft
ACM	advanced combat maneuvers
AFB	Air Force Base
DNIF	duties not including flying
HP	high performance
IP	instructor pilot
JHMCS	Joint Helmet Mounted Cueing System
LBP	low back pain
MS	musculoskeletal
NP	neck pain
NVG	night vision goggles
OMT	osteopathic manipulation therapy
PT	physical therapy
SP	student pilot
SUPT	Student Undergraduate Pilot Training