G-Related Musculoskeletal Spine Symptoms in Japan Air Self Defense Force F-15 Pilots

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The introduction of the F-15 Eagle to the Japan Air Self Defense Force (JASDF) in the early 1980's seemed to increase musculoskeletal problems of the spinal column among pilots. The neck is the body part most vulnerable to high-G force injuries, and serious cases of neck injury have been reported. We surveyed 129 F-15 pilots from different air bases by means of a questionnaire. The occurrence rate of musculoskeletal problems in different types of aircraft was analyzed according to the pilots' flying experience. Of the surveyed pilots, 115 (89.1%) reported muscle pains related to flying. Of those who experienced pain, each averaged 7.6 events, 95% of which occurred in the F-15. Of these 115, 30% experienced pain in the F-4 and 15% in the F-1. The "checking six" position was the most common posture at the time of injury, followed by "forward bend." Of the 115 pilots, 44 stated that their symptoms adversely affected flight duty performance, and 50 pilots stated that their symptoms adversely affected daily life. The effectiveness of muscle training as a preventive measure was supported by 62%. Some oriental therapeutic methods (acupuncture, moxa cautery, and finger-pressure massage) were preferred by pilots for pain treatment.

G-related problems of the spinal column still exist as a major medical concern in JASDF.
instructor pilots. The questions were designed to include numerous factors which might be related to G-induced muscle pain and other symptoms. The "G-induced muscle pain and other symptoms" were defined to be the pain and other symptoms of muscles, tendons, and ligaments which support cervical, thoracic, and lumbar vertebrae under G stress. Factors surveyed include: pilot's age, flight experience, flight hours of the past month, muscle pain prior to flight training, G-induced muscle pain and its frequency, type of aircraft flown, type of mission when pain occurs, body position at injury, limitations of performance, and influence on daily life. The questionnaires were anonymous so that no aeromedical action would be taken on any pilots from this survey.

RESULTS AND DISCUSSION

The average age of the 129 F-15 pilots surveyed was 32.9 ± 4.9 years (range 24-47). The average total flying hours were 2,361.0 ± 1,290.8 (range 410-6,300). The average flying hours in their current aircraft (F-15) were 657.2 ± 419.2 (range 10-1,500). They also had experience of flying in different types of fighter aircraft before transition to F-15, as indicated in Table I. The relationship between muscle pains and type of aircraft flown was surveyed according to their experience of flying different aircraft. Their average flying hours in the preceding 1 month was about 23 h (range 3-40), and they averaged two sorties per day. Older pilots (instructor or operation-ready status) flew more often than younger pilots (training-ready status) because of the shortage of instructors.

Of the 129 pilots surveyed, 115 (89.1%) reported muscle pains related to flying, while only 14 (10.9%) reported no pain. At the time of entrance to flight training, only 10 (7.8%) had any complaints of the musculoskeletal system, while most of them (92.2%) reported no problems (Fig. 1). At the time of the survey, the most common complaint was neck pain, while prior to flight training, back pain was the most common complaint. Each pilot experienced an average of 7.6 episodes of acute muscle pain, with 30% of the pilots experiencing more than 10 episodes. It took about 8 d for recovery from each episode of acute pain. Due to continuing symptoms 16 pilots were removed from the flying mission for an extended period of time.

According to a similar survey by USAF (11), 83 (51.3%) out of 162 F-15 pilots had some type of neck injury, which is relatively lower than our data. The difference seems to be due to two factors: 1) the period of survey—USAF limited the time frame for injury to the preceding 3-month period, while we included any episode in the past; and 2) the range of injury—USAF limited the injury to the neck, while we included all muscles which support the vertebrae.

Table I. Flying hours of pilots with different aircraft before transition to F-15.

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Flying Hours</th>
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<tr>
<td>F-4</td>
<td>1221.5 ± 554.4 h (32 ~ 2600 h)</td>
</tr>
<tr>
<td>F-104</td>
<td>1014.4 ± 415.8 h (170 ~ 2000 h)</td>
</tr>
<tr>
<td>F-1</td>
<td>271.3 ± 345.5 h (20 ~ 1500 h)</td>
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Fig. 1. Percentages of pilots reporting muscle pain on different occasions. Shaded squares = Yes; Solid squares = No.

Fig. 2 shows prevalence ratios of muscles pains and type of aircraft flown. Some pilots reported muscle pain related to flying in F-4 (30.4%) and F-1 (14.8%) at least once, while 109 (94.8%) pilots reported pain in F-15. No pilot reported pain in F-104. The data support a hypothesis that injuries of the vertebral column (mainly neck) is more prevalent in the F-15 than in the less G-capable aircraft. This tendency is consistent with the results of other reports (7,11). The type of mission at the time of injury was predominantly air-to-air combat maneuvers (94.9%), followed by air-to-air gunnery (32.9%) (overlap answer was allowed). Table II shows the pilot's posture at the time of injury. "Checking six" (looking back over the shoulder) was the most common posture that caused...
pain, followed by a ‘‘forward bend’’ posture which is necessary for manipulating instruments.

Twisted positions of the head have been commonly reported as a risk factor for acute neck pain during high +Gz maneuvers (7,11). When the pilot’s head is in a twisted position, the forces to be resisted are even higher than in the neutral position, because the +Gz forces will be acting on longer lever arms. In this position, the muscles’ capacity to protect the structures of the cervical spine is the lowest, where considerable muscle strength and muscle endurance are needed (3). Some pilots noticed severe pain just after flight. The neck was the most common part of body that was injured regardless of posture. Upper back pain was the second most common at “checking six,” while lower back pain was the second most common in the “forward bend” posture. This indicates that other parts of the body were also twisted during maneuvers, and susceptible to injury in tactical flight maneuvers.

There were 64 (49.6%) pilots who reported chronic muscle pains that became prominent during high-G maneuvers. Only 16 of the 64 pilots were grounded for any period of time for symptoms of muscle pain. This indicates that most pilots continue to fly in spite of some symptoms. The reasons why they didn’t stop flying in spite of having the symptoms were surveyed. The most common answers were: 1) I didn’t think the symptoms would influence flight performance (41 pilots); 2) someone else would have to do extra duty for me if I didn’t fly (40 pilots); 3) I didn’t want to lose my chance; 4) I could fly if I limited maneuvers within low G load. Some of these reasons (2–4) indicate that our fighter pilots are flying in a stressful, competitive, and busy working environment.

To the question whether the chronic or continuing symptoms influence their flying or not, 44 pilots answered affirmatively. Of these pilots, 30 answered that the symptoms limited their flying ability, especially for target searching, 20 reported that they couldn’t concentrate on the mission, and 14 answered that they couldn’t perform high-G maneuvers (one pilot reported more than one answer). Although there were no serious reports which directly influenced flying safety, it is clear that these symptoms decrease a pilot’s capability, concentration, and G-tolerance. Impairment of concentration in flight may result in mistakes that lead to a mishap!

How the chronic symptoms influenced the daily private life of the pilots was also surveyed. Fifty pilots admitted that symptoms adversely effected their daily life. Breakdown of their answers were: 1) I want to take more days off to alleviate the symptoms (n = 29); 2) I lay down at home all day long on holidays (n = 26); 3) I have lost my desire to play sports that I participated in in the past (n = 26); 4) I don’t feel like going out or playing with the family; and 5) I often ask for muscle massages from my family members. Pilots, especially fighter pilots, originally tend to be active and energetic, both on the job and in their private life. However, this survey has made it clear that they are forced to spend their private time passively due to the symptoms which are related to high-G stress of modern high performance aircraft.

Concerning the treatment of the symptoms, 55 (42.6%) pilots reported having received oriental medicine including acupuncture, moxa cautery, and muscle massage. Most of them reported that these oriental treatments were more effective than ordinary orthopedic therapy. They complained that doctors (both flight surgeons and civilian orthopedists) couldn’t resolve their problems. There were 121 (93.8%) pilots who considered the G-related symptoms as “an occupational disease,” and many were concerned over continuation of the symptoms even after retirement. This survey has shown that prevalence of G-related muscle pains and other symptoms among our F-15 pilots is very high. Cumulative effects of repeated exposures to G-stress may result in chronic symptoms which may have an adverse influence not only on their flight performance but also on their daily private life. According to Hamalainen et al., fighter pilots frequently exposed to high +Gz forces had a more frequent and more serious degeneration of the cervical intervertebral disks than the controls. They cautioned that frequent exposure to high +Gz forces may cause premature disk degeneration (6). Some oriental medical therapy seems to be more effective and favored by pilots than orthodox western style medical therapy.

Countermeasures

Several countermeasures to relieve musculoskeletal spin symptoms have been undertaken. Future countermeasures have also been discussed, which may reduce spin symptoms in our pilots exposed to high Gz force. Screening programs for fighter pilot candidates, consisting of 12 X-ray films of vertebral columns, have been performed since 1980. Some candidates with abnormalities such as spondylosis, spondylolisthesis, and spina bifida occulta were rejected through this screening process. However, X-ray examination is not sufficient for detection of soft tissue abnormalities, such as disc herniation. We are planning to introduce Magnetic Resonance Imaging to improve screening programs in the future.

General muscle conditioning is considered important for maintaining G tolerance (9,12). Effectiveness of muscle training as a protective measure was also supported by 80 (62.0%) pilots in this survey. JASDF provided new muscle training machines in all tactical bases several years ago. However, there are some problems which hamper the effective use of the equipment, including: 1) pilots are too busy to do muscle training
regularly; 2) experienced training instructors are not available on all bases; and 3) training facilities are located far from pilots’ offices on some bases. JASDF Aeromedical Laboratory continues efforts to foster training instructors and encourage pilots in muscle conditioning by sending supervisors to local bases.

Treatment is important to prevent the symptoms from becoming chronic. Oriental medical methods (acupuncture, moxa cautery, and finger-pressure massage) have been proven to be more effective in some cases. However, these oriental treatments are not fully covered by the health insurance, which means pilots have to pay for the treatments on their own. We are now studying the possibility of authorizing the therapy in order to officially cover these expenses. We have also started a training program for licensed physical therapists.

Efforts to make a quality lightweight helmet have been ongoing. Hämäläinen commented that improvement of helmet ergonomics can be beneficial for reducing high +Gz-related neck pain, based on his study of the relation between helmet weight and neck muscle strain (2). The current type of helmet (FHG-2: 960–980 g), introduced in 1987, is more comfortable and less burdensome under G loading than the previous one. However, the potential exists for developing a lighter-weight helmet with new lighter materials in the future. Some pilots attributed the muscle pains to maladjustment of their bodies to the cockpit of the F-15, which was originally developed for USAF pilots. Reforms of cockpit arrangement might be necessary if this is the case.

Difficult working conditions of fighter pilots became clear through this survey. Although these problems are not purely medical, flight surgeons who are responsible for the good mental and physical conditions of aircrew should be involved. Therefore, we will discuss measures to improve the working conditions of fighter aircrew with individuals in charge of training and personnel.

CONCLUSIONS

This survey shows that G-related problems of the spinal column (most of which are muscle pains) exist as a major medical concern in the JASDF fighter pilot community. The symptoms influence not only the pilots’ flight performance but also their daily private life. Their demanding working conditions prevent them from taking days off to alleviate the symptoms. Some pilots are even afraid that their symptoms may become chronic and influence their future career.

Several countermeasures were discussed. General muscle conditioning seems to be very effective for preventing injury. This fact was supported by 62% of the pilots surveyed. JASDF Aeromedical Laboratory has been promoting this program by teaching student pilots and sending instructors to each base. However, the muscle training program at each base is not fully performed for several reasons: no time for muscle training, no experienced instructor, bad location of training facility, etc. Concerning treatment, some oriental therapeutic methods were supported by pilots as effective. We are now trying to authorize these methods for treatment of some symptoms.

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REFERENCES