Doi:10.47572/muskutd.991961

Spinal Pain and Predisposing Factors in Flight Personnel

Uçuş Personelinde Omurga Ağrıları ve Predispozan Faktörler

Halil İbrahim IŞIKLI[1], Erdinç ERCAN[2]

[1]Sağlık Bilimleri Üniversitesi, Sultan 2. Abdülhamid Han Eğitim ve Araştırma Hastanesi, Sualtı ve Hiperbarik Tıp Kliniği, İstanbul
[2]Sağlık Bilimleri Üniversitesi, Hava ve Uzay Hekimliği Anabilim Dalı, Ankara

Öz
Bu çalışmada, omurga ağrılarının uçuş personelinde görülme sıklığının ve uçuş ortamında buna neden olabilecek predispozan faktörlerin belirlenmesi amaçlanmıştır. Kesitsel planlanan bu çalışma, 2012-2019 tarihleri arasında yapıldı. Katılımcılara, demografik özelliklerinin, kullanmış oldukları hava taşıtı tipinin, uçuş saatlerinin, gece görüş gözlüğü (GGG) kullanma durumlarının, fiziksel aktivite durumlarının ve omurga ağrılarının sorgulandığı anket formu uygulanmıştır. Çalışmaya, 22-52 (29.93±5.2) yaş arası 475 katılımcı dahil edilmiştir. Uçucu personelde boyun ağrısı sıklığı %5.89 (n=28), bel ağrı sıklığı %9.89 (n=47) olarak bulunmuştur. Bel ve boyun ağrılarına; yaş, hava taşıtının tipi, toplam uçuş saatleri, GGG kullanma durumları, düzenli fiziksel aktivite ve boyun egzersizi yapma gibi faktörlerin etki ettiği bulunmuştur. Bel ağrısı skorları ile yaş ve toplam uçuş saatleri arasında pozitif yönde düşük korelasyon (sırasıyla, r=0,134, r=0,177, p<0.05); düzenli fiziksel aktivite ile ise negatif yönde yüksek korelasyon saptanmıştır (r=-0,635, p<0.05). Erkek katılımcılarda bel ağrısı skorlarının helikopter pilotlarında yüksek olduğu (p<0.05) bulunmuştur. Bel ağrısı skorlarının 30-39 yaş arası, 3000 saat ve üzerinde uçuş saati olan ve GGG kullanan uçuş personelinde yüksek olduğu (p<0.05) tespit edilmiştir. Ayrıca, düzenli fiziksel aktivitede bulunanlarda bel ağrısı skorlarının düşük olduğu (p<0.05) saptanmıştır. Çalışmamızda boyun ağrısı sıklığının, boyun egzersizi yapmayanlarda da yüksek olduğu tespit edilmiştir (p<0.05). Çalışmamızda yaşın, uçulan hava aracı tipinin, toplam uçuş süresinin ve GGG kullanımının bel boyun ağrılarına etki ettiği, düzenli fiziksel aktivitelerde bulunulmasının bel-boyun ağrılarını azalttığı gösterilmiştir. Kişi ve yaşa özgü doğru fiziksel aktivite ve bel-boyun egzersizlerinin yapılması, omurga geometrisine ekstra yük bindiren her türlü ekipman kullanımında ergonomik kurallara riayet edilmesinin uçuş personelinin bel ve boyun ağrılarının önlenebilmesi ve azaltılabilmesinde yardımcı olacağı değerlendirilmektedir.
Anahtar Kelimeler: Bel Ağrısı, Boyun Ağrısı, Uçuş Personeli

Abstract
In this study, it was aimed to determine the frequency of spine pain in the flight personnel and predisposing factors that may cause spine pain in-flight environment. This study was planned in cross-sectional design and conducted between 2012 and 2019. A questionnaire form was performed to examine the demographic features, the type of aircraft, the flight times, the use of night vision goggles (NVG), the physical activity and the spine pain. 475 subjects aged between 22 and 52 (29.93±5.2) participated in this study. Neck pain was 5.89% (n=28) and waist pain was 9.89% (n=47). Low correlation was found between low back pain scores with age and total flight times (r=0.134, r=0.177, p<0.05). There was a negative correlation with back pain scores and regular physical activity (r=-0.635, r=p<0.05). Low back pain scores in male participants were found to be higher in helicopter pilots, and 30-39 years old group, 3000 hours or more flight hours group and NVG group (p<0.05). Additionally, low back pain scores were found to be low (p<0.05) in those with regular physical activity. Neck pain was found to be higher in aircrew who did not perform neck exercise (p<0.05). In our study, it was determined that age, aircraft type and total flight time, NVG usage affects back and neck pain, and regular physical activities reduce spine pain. Performing back and neck exercises tailored to the person and compliance with ergonomic rules in the use of all kinds of equipment that puts extra load on the spine may prevent and reduce back and neck pain.
Keywords: Aircrew, Back Pain, Neck Pain

Introduction

The spine is divided into cervical, thoracic, lumbar, sacral, and coccygeal regions and consists of 33 vertebrae. The morphology of the vertebrae in each region varies according to their functions. While the cervical region vertebrae are structured in a way that move the head freely to allow us to be aware environmental alterations; thoracic vertebrae are less mobile to protect intrathoracic structures (1). Neck pain is an ache in the posterior part of the neck between the occiput and C7 vertebra. Pain-sensitive structures in the neck; vertebral bones, cervical ligaments, radixes, articular facet joints and capsules, dura and neck muscles surrounding the spinal cord (1). Low back pain is a common symptom seen as a pain or muscle tension in the region from the lower costal border to the upper level of the inferior gluteal folds. This symptom is sometimes accompanied by radiating lower extremity pain.

Pilots are affected by many environmental factors while performing their duties. It has been evaluated that acceleration (G) forces, vibration, and ergonomic problems had effects on spinal (back-neck) pain (2). It has also been reported that there was a correlation between low back pain symptomatology and total flight hours (3).

The gravitational force of the Earth creates an acceleration of 1G (9.81 m/s^2), and this force affects everything on earth and its perimeter. So, human beings have adapted to live in a 1G environment. However, when performing flight maneuvers often

	ORCID No
Halil İbrahim IŞIKLI	0000-0002-3872-0631
Erdinç ERCAN	0000-0002-4478-7031

Başvuru Tarihi / Received: 07.09.2021
Kabul Tarihi / Accepted : 03.03.2022

Adres / Correspondence : Halil İbrahim IŞIKLI
Sağlık Bilimleri Üniversitesi, Sultan 2. Abdülhamid Han Eğitim ve Araştırma Hastanesi, Sualtı ve Hiperbarik Tıp Kliniği, İstanbul
e-posta / e-mail : drhalilibrahim.isikli@gmail.com

greater forces are exposed. For example, if a pilot accelerates at 88.29 m/s^2 on the vertical axis during aerobatic maneuver, he or she is exposed to 9G acceleration, and his weight increases to nine folds. The physical effects of G-forces are also causing movement restriction. A pilot operating under this force cannot get up from the chair, cannot raise his/her head, and cannot move his/her hand or arm easily. Prolonged exposure to G forces may cause muscle fatigue, soft tissue damage, and neck pain (4).

Vibration, another predisposing factor for low back and neck pain. Movement of engine pistons and propeller blades, oscillations in airplane body caused by turbulence are examples of vibrations in aviation. Vibration can be transmitted to the body, usually by direct contact with a vibrating structure, or through air. Vibration affects many systems in humans' body and may cause back and neck pain in the neuromuscular system. Long-term exposure to whole-body vibration can cause spinal degeneration and low back pain (5).

Aircraft type is the most determinant factor for amplitude and duration of G forces, and vibration. Significant morbidity is seen even in a moderately maneuverable trainer aircraft. Flight attendants or passengers who do not have direct control of the aircraft have a risk of injury due to unexpected maneuvers (4).

The most common neck complaints in aviation are muscle pain and muscle tension. More serious injuries such as fractures, ligament ruptures, nerve compression, and intervertebral disc injuries have also been reported (6).

The aim of our study is, to examine the relationship between demographic data and etiological causes of low back and neck pain of flight personnel and to determine the predisposing factors.

Material and Method

It is a descriptive, cross-sectional, single-center, survey study. A total of 475 flight personnel, including 464 male and 11 female flight personnel accepted to participate in this study.

This study is a survey study, and the participants were asked about the demographics, type of aircraft, total flight hours, the use of night vision goggles (NVG), sports and exercise status, and low back and neck pain. It has been accepted that jet (high performance) aircraft can produce high acceleration, while other aircraft can produce low acceleration. "Quebec Low Back Pain Disability Scale and Oswestry Disability Scale" were used for back pain assessment. "Neck Pain and Disability Scale" was used for neck pain assessment.

The Quebec Low Back Pain Disability Scale was developed in 1995. In the Quebec Low Back Pain Disability Scale, the patients were asked 20 questions about his daily activities and told to mark the appropriate option, ranging from 0 (not at all difficult) to 5 (unable to do). The total score ranges from 0 to 100 points, with a higher score indicating higher pain. The Turkish version, validity and reliability study of the Quebec Low Back Pain Disability Scale was performed in 2009 (7).

The Oswestry Disability Scale is a 10-item questionnaire used to assess low back pain. It consists of pain intensity, personal care, lifting, walking, sitting, standing, sleep, social life, and travel. Patients are asked to mark the item that best fits their situation. The options are scored as A:0, B:1, C:2, D:3, E:4, F:5. The total score ranges from 0 to 50. The score is calculated as a percentage [(Score/50) X 100]. High scores indicate low functionality (0-20%: minimal disability, 20-40%: moderate disability, 40-60% severe disability, 60-80%: disability, 80-100%: confined to bed). The validity and reliability of the Turkish version was demonstrated in 2004 and scale can detect 31 functional limitations associated with low back pain (8).

The Neck Pain and Disability Index is a functional assessment form developed by Wheeler et al., and Turkish validity and reliability study was conducted in 2004 by Biçer et al. The questions are of the nature of investigating the relationship of neck pain severity and pain with professional life, recreational activities, social and functional status related to life, and emotional factors. The scoring of each question ranges from 0 to 5. High scores indicate severe disability (9).

The data obtained from the study were collected in the Microsoft Excel program and the "IBM SPSS for Windows" program was used for analysis. Descriptive statistics were evaluated as "Mean ± Standard Deviation" for continuous variables and "Percentage" for categorical variables. Group distributions were evaluated by "Kolmogorov Smirnov Test". The significance of the difference between subgroups that did not show normal distribution was investigated using non-parametric tests. Whether there is a relationship between the parameters were evaluated with the "Spearman Correlation Test". Analyzes between discrete variables were evaluated with the "Chi-Square or Fisher Exact Test".

In the statistical evaluation, the significance level was accepted as 0.05. Kruskal Wallis Test was used in subgroup analyzes where 3 or more groups were compared, and as a POST HOC Test, "Mann Whitney U Test" was applied for the values found to be unequal in the Kruskal Wallis Test ($p<0.05$). In the 3-variable groups, the $p=0.05$ value was divided by 3 and the significance level was accepted as $p=0.017$. In the 4-variable groups, since there were 6 comparison groups in pairs, the $p=0.05$ value was divided by 6 and the significance level was accepted as $p=0.008$.

All stages of the study were carried out according to the principles of the Declaration of Helsinki. Written consent was obtained by the volunteers informing them that, they were free to participate in the research, and they could leave the research at any time. There would be no invasive intervention, and the data obtained would be used only for scientific purposes. For the study, ethical approval was obtained with the decision number 2011/313 of the Osmangazi University Ethics Committee.

Results

Of the 475 flight personnel participating in the study, 97.68% (n=464) were male and 2.32% (n=11) were female. The mean age of the males was 29.93±5.2 years, the average height was 178.06±5.3 cm, the average weight was 79.56±8.6 kg, and the average BMI was calculated as 25.06±2.2 kg/m^2. The mean age of the women was 32.36±3.1 years, the mean height was 169.91±4.3 cm, the mean weight was 60.45±7.5 kg, and the mean BMI was 20.86±1.5 kg/m^2.

4.3% (n=20) of the male pilots were in the training category. 11.6% (n=54), 65.7% (n=305) and 18.3% (n=85) of the male pilots were in helicopters, in jet, and in cargo planes categories respectively. 36.3% (n=4) of the female pilots were in the helicopter category, 27.2% (n=3) of them in the jet category, 36.3% (n=4) of them in the cargo plane category.

In our study, 9.89% (n=47) of the 475 flight personnel had low back pain and 5.89% (n=28) had neck pain. All the female participants stated that low back pain does not pose a significant problem in their daily lives; while 2.6% (n=12) of male participants stated that low back pain limited daily life to certain degrees (mild, moderate, severe).

In our study, Spearman's correlation analyzes were performed between low back/neck pain and possible causes. In female participants, a negative moderate to strong correlation was found between low back pain (Oswestry Score) and aerobic exercise frequency (p=0.05, r=-0.708); and between back pain (Quebec score) and regular exercise (p=0.049, r=- 0.635)]. In male participants, there was a very low positive correlation between low back pain (Oswestry Score) and age (p=0.05, r=0.134), and low back pain (Oswestry Score) and total flight time (p<0.001; r= 0.177).

No statistically significant correlation was found between neck pain disability score and age, height, weight, total flight hours, flight hours using helmet-mounted flight equipment (HGG), regular sports, aerobic and anaerobic exercise frequency, and flight category in male and female participants (p>0.05).

There was no statistically significant difference between low back pain and neck pain scores according to gender subgroups (p>0.05). Because the number of the female pilots were insufficient, the factors affecting the low back and neck pain could not be evaluated in female participants subgroup.

The relationship between low back pain and aircraft category was evaluated in male flight personnel. The frequency of low back pain was 9.4% (n=5) in helicopter pilots, 5% (n=1) in training aircraft pilots, 2.4% (n=2) in cargo aircraft pilots, and 1.3% among jet pilots. A statistically significant difference was found between the frequencies of low back pain and aircraft types (p=0.008). Subgroup analyses showed that the frequencies of low back pain were found to be significantly higher in helicopter pilots than in jet pilots (p=0.005) (Figure 1).

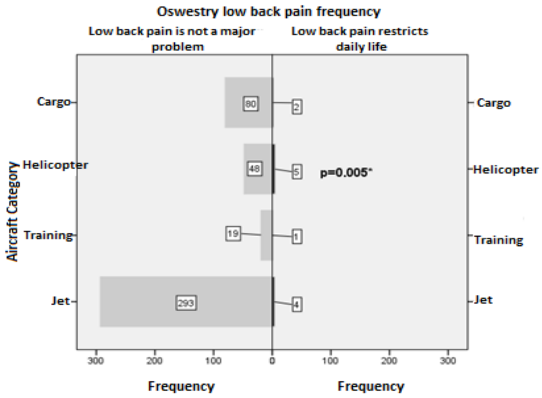

Figure 1. The relationship between low back pain and airplane category in male participants *FisherExact Test used (p<0.05).

Effectiveness of neck exercises on neck pain complaints was investigated in male participants. The frequency of neck pain was higher in those who did not do neck exercises (p=0.031). In addition, there was a statistically significant increase in the group with mild neck pain compared to the group without neck pain (p=0.009) (Figure 2).

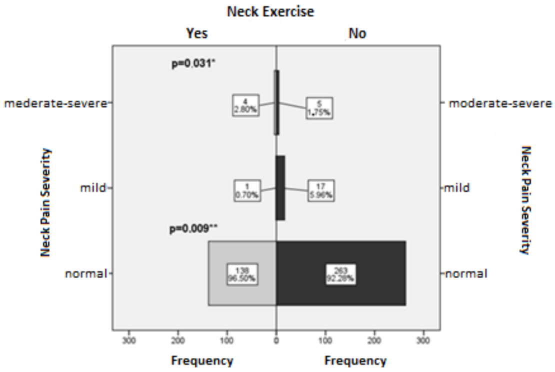

Figure 2. The relationship between neck pain frequencies and neck exercise status in male participants. * Chi-square test was used in 3-comparison (p=0.031). ** FisherExact Test was used to compare Normal and Mild Neck pain groups (p=0.009).

In our study, the effects of age and sports on low back pain were examined. Accordingly, it was found that the severity of low back pain (Oswestry score) increased with aging in male participants (p=0.011), and statistically significant difference was found between the 20-29 age group and the 30-39 age group (p=0.005) (Table 1). In addition, it was determined that low back pain (Oswestry score) decreased (p=0.031) in male participants who were doing sports and statistically significant difference was found between the non-sports group and the regular sports group (p=0.013) (Table 1).

In our study, the relationship between exercise and low back pain was investigated. In male participants, low back pain was found to be low in both scales in exercise groups, and the Oswestry low back pain score was found to be statistically significant (p=0.029) (Table 2). In addition, the relationship between the use of NVG and low back pain was investigated, and it was observed that the low back pain score on both scales was high (p>0.05) in NVG using groups in male participants and Oswestry low back pain scores were found to be statistically significant (p=0.038) (Table 2).

In our study, the effect of aircraft type and total flight hours on low back pain was examined. It was shown that low back pain (Oswestry score) affected by aircraft type in male participants (p=0.025). The back pain detected in helicopter pilots was higher than that of other pilots and statistically significant difference was found between helicopter and jet pilots (p=0.003) (Table 3). In addition, it was determined that higher low back pain (Oswestry score) was seen in male pilots who had higher flight hours (p=0.014) and statistically significant difference was found between "1000 and lower" and "3000 and higher" flight hours group (p=0.007) (Table 3).

Discussion

In our study, the frequency of low back pain was found 9.89% and the frequency of neck pain was detected 5.89% in flight personnel. Age, type of aircraft, total flight time, and use of NVG were found to be associated with low back and neck pain. It has been determined that regular physical activity has a reducing effect on low back and neck pain.

70-85% of people experience low back pain at some point in their life. While the annual prevalence of low back pain ranges from 15% to 45%, the point prevalence is 30% on average (10). In a study to determine the prevalence of low back pain in Turkey, 4990 people were screened; The lifetime prevalence of low back pain was 44.1%, the 1-year prevalence was 34%, and the point prevalence was 19.7% (11). Neck pain is the second most common musculoskeletal disease after low back pain. It has been reported that Japanese Air Defense Force F-15 pilots reported flight-related cervical muscle pain at a rate of 89% (12). It has been reported that the frequency of neck pain among Swedish high-performance fighter pilots varies between 29-37% (13). Contrast to the literature lower frequency of low back pain (9.89%) and neck pain (5.89%) was found in our study.

Two main factors associated with neck and low back pain in flight personnel: Whole body vibration (vibration) and G forces. Prolonged exposure to vibration and insufficient rest between sorties can lead to muscle fatigue and increased loading on the spine (2). High acceleration forces, unexpected high-speed flight maneuvers, head movements during these maneuvers in fighter pilots and high vibration that occurs during flight activities can cause damage to the cervical and lumbar spine (14).

In the study conducted by Aydoğ et al. in 732 pilot and 202 non-pilot control groups, age was found as the most important factor in cervical and lumbar changes (15). In our study, when we grouped flight personnel according to age groups, we found a statistically significant low correlation between age and low back pain in male participants. We also found that low back pain increased with age and Oswestry low back pain scores were higher and statistically significant in the 30-39 age group compared to the 20-29 age group. We think that aircraft personnel are exposed to the aviation environment cumulatively with aging, and this might cause more symptoms.

A study was conducted by Grossman A. et al. by filling out a series of questionnaires in terms of neck and low back pain in 566 flight personnel and investigating the low back and neck pain of pilots flying in different aircraft types. Participants were divided into four aircraft categories as fighter aircrafts, attack helicopters, utility helicopters and cargo planes in their study. The frequency of low back pain was found to be higher in attack helicopter pilots compared to jet and cargo pilots (2). We investigated the relationship between back pain and aircraft type in our study. In male pilots, we found a statistically significant difference in back pain frequencies among aircraft types. When the aircraft types were evaluated as paired groups, the frequency of low back pain of helicopter pilots were significantly higher than jet pilots. In addition, the low back pain score of helicopter pilots was found to be higher than the other aircraft pilots, and statistically significant difference was found between helicopter pilots and jet pilots.

Aircraft-induced vibration has been reported to be one of the predisposing factors in spinal pain (5). It is considered that vibration is higher in helicopters, and therefore, spinal pain is more common in helicopter pilots than in other types of aircraft pilots. Helmet-mounted NVG equipment increases the mechanical load on the neck and shifts the center of mass forward and upward relative to the axis of cervical spine. The usage of helmets and night vision goggles under high acceleration forces may cause neck pain arising from muscle structures (2). NVG, oxygen support equipment and helmet-integrated control systems may increase the rotational and

Table 1. The effect of age groups and sports status on low back pain scores in male participants.

Low Back Pain	Age group (years)	n	Mean±SD	p	p
Oswestry Scale	20-29	241	3.20±6.0	0.011*	0.005 **
	30-39	191	4.45±5.9		
	40-65	14	2.43±5.2		
	Total	446			
Low Back Pain	Sports group	n	Mean ±SD	p	p
Oswestry Scale	Doing sports regularly	270	3.23±5.7	0.031*	0.013 **
	Not doing sports	57	5.51±7.2		
	Doing sports	125	4.06±5.9		
	Total	452			

** Kruskal Wallis Test was used (p<0.05). ** Mann-Whitney U Test used (p<0.017). SD: Standard deviation*

Table 2. The relationship between low back pain scores and exercise status and using Night Vision Goggles (NVG) in male participants.

Low Back Pain	Exercise	n	Mean ±SD	p
Oswestry Scale	Yes	395	3.49±5.8	0.029*
	No	57	5.51±7.2	
	Total	452		
Quebec Scale	Yes	368	3.05±6.4	0.746
	No	50	3.34±7.2	
	Total	418		
Low Back Pain	NVG	n	Mean ±SD	p
Oswestry Scale	Yes	94	5.13±7.8	0.038*
	No	334	3.34±5.3	
	Total	428		
Quebec Scale	Yes	94	7.03±10.9	0.381
	No	334	5.67±9.5	
	Total	428		

**Mann-Whitney U Test used (p<0.05). NVG: Night Vision Goggles, SD: Standard Deviation*

Table 3. The effect of aircraft type and total flight time on low back pain scores in male participants.

		n	Mean ±SD	p	p
Aircraft Type	Jet	297	3.24±5.1	0.025*	0.003 **
	Helicopter	53	7.19±9.4		
	Training	20	3.50±6.2		
	Cargo	82	3.41±5.3		
	Total	452			
		n	Mean ±SD	p	p
Hour of Flight	0-999	186	2.89±5.4	0.014*	0.007 **
	>3000	39	4.82±5.5		
	1000-1999	98	4.21±6.6		
	2000-2999	96	4.52±5.9		
	Total	419			

** Kruskal Wallis Test was used (p<0.05). ** Mann-Whitney U Test used (p<0.008). SD: Standard deviation*

bending torque of the head and thus may cause cervical injury (15, 16). In our study, we questioned whether the usage of NVG led to spinal pain in flight personnel or not. Although the neck pain score was higher in the group of using NVG in our study, it was not statistically significant. In addition, it was revealed in our study that the Oswestry low back pain scores of flight personnel using NVG were significantly high. We think that the extra weight that occurs with the usage of a NVG mounted helmet causes pathological changes in the muscle and connective tissue supporting the vertebrae, and ultimately reveals the symptomatology of pain over the years.

In a study conducted by Orsello et al. on 554 helicopter pilots, they reported that no significant correlation was found between total flight hours and helicopter type and low back pain scores (17). Haugli et al. evaluated the relationship between low back pain and flight time in commercial airline pilots; they found the frequency of neck and low back pain were higher and statistically significant in pilots flying long distance (18). In addition, it has been reported that there was a relationship between low back pain symptomatology and total flight hours (3). In our study, a positive correlation was found between the Oswestry low back pain scores and the total flight times, and it was found that the participants in flight time over 3000 hours group had higher low back pain scores. The changes take place in spine physiology are directly proportional to the amplitude and the duration of exposure to these physical factors in aviation. For this reason, it has been shown that low back pain increases with the flight time increments in our study.

Several authors in aviation medicine have suggested that neck-strengthening exercises may be necessary for fighter pilots. Performing neck-specific strength and endurance exercises can significantly increase neck muscle strength when compared to whole-body or aerobic exercises. In addition, certain neck exercise programs have been shown to increase neck muscle strength and reduce neck pain (19). The results of our study also support the results of the published literature. In our study, statistically significant negative correlation was found between low back pain score and frequency of aerobic exercise in female participants. In addition, a good negative correlation was found between the low back pain score and regular sports in female participants. In male participants, it was revealed that the low back pain scores were higher in those who did not do regular sports, and there was an increase in the severity of neck pain in those who did not do neck exercises. We think that doing regular exercise and performing appropriate neck exercises will be effective in reducing spinal pain in flight personnel.

In conclusion, low back and neck pain is particularly important in pilots. Low back and neck pain causes loss of workdays and disruption of flight duties. It should not be forgotten that spinal pain that occurs in the pilot during the flight may have consequences that may lead to the cancellation of the task, depending on its severity. Especially occurrence of this pain during critical phases of the flight (landing or take-off) can lead to catastrophic consequences.

Aviation personnel undergo regular medical examinations at the beginning and along of their careers. In case of deterioration in health, pilot may not be allowed to continue their carrier temporarily or permanently. For this reason, aviation personnel give great importance to their health. They stay away harmful environmental factors such as cigarettes and alcohol to protect their health, do exercise regularly, and be careful of their diet and weight gain. We have detected lower rates of spinal pain in our study. This may have been caused by aviation personnel's attention to their health and taking preventive measures. In addition, due to fear of carrier loss, the frequency or severity of pain may have been reported at a lower rate in our study.

It was seen that low back pain scores were lower in those who was doing sports regularly. For this reason, we recommend doing individually tailored, appropriate and balanced aerobic and anaerobic sports together. To prevent back and neck pain, we consider that it is very important to comply with ergonomic rules and all kinds of equipment that puts extra load on the spine geometry must be counter balanced.

Ethics Committee Approval: Ethical approval was obtained with the decision number 2011/313 of the Osmangazi University Ethics Committee.

References

1. Middleditch A, Oliver J. Functional anatomy of the spine. Oxford: Elsevier Health Sciences; 2005.
2. Grossman A, Nakdimon I, Chapnik L, Levy Y. Back symptoms in aviators flying different aircraft. Aviat Space Environ Med .2012;83:702–5.
3. Pelham TW, White H, Holt LE, Lee SW. The etiology of low back pain in military helicopter aviators: prevention and treatment. Work. 2005;24(2):101–10.
4. Benson AJ., Scott JR. Effects of long duration acceleration, Ernsting's Aviation Medicine, 5 Edition, Edward Arnold Ltd, New York, 2016, 131-56.
5. Wilder DG, Pope MH. Epidemiological and etiological aspects of low back pain in vibration environments-an update. Clin Biomech (Bristol, Avon). 1996;11(2):61–73.
6. Alricsson M, Harms-Ringhdal K, Larsson B, Linder J, Werner S. Neck muscle strength and endurance in fighter pilots: effects of a supervised training program. Aviat Space Environ Med. 2004;75:23–8.
7. Alkan Melikoglu M, Kocabas H, Sezer I, Bilgilisoy M, Tuncer T. Validation of the Turkish version of the Quebec back pain disability scale for patients with low back pain. Spine (Phila Pa 1976). 2009;34(6):219-24.
8. Yakut E, Duger T, Oksuz C, et al. Validation of the Turkish version of the Oswestry Disability Index for patients with low back pain. Spine. 2004;29:581–5.
9. Bicer A, Yazici A, Camdeviren H, Erdoğan C. Assessment of pain and disability in patients with chronic neck pain: reliability and validity of the Turkish version of the neck pain and disability scale. Disabil Rehabil. 2004; 26: 959-62.
10. Anderson GBJ. Epidemiological features of chronic low-backpain. Lancet. 1999;354:581-5.
11. Öksuz E. Prevalance, risk factors and preference-based health states of low back pain in a turkish population. Spine. 2006: 31 (25); 968-72.
12. Kikukawa A, Tachibana S, Yagura S. G-related musculoskeletal spine symptoms in Japan Air Self Defense

Doi:10.47572/muskutd.991961

Force F-15 pilots. Aviat Space Environ Med. 1994;65:269–72.
13. Alricsson M, Harms Ringdahl K, Linder J, et al. Mobility, muscular strength, and endurance in the cervical spine in Swedish Air Force Pilots. Aviat Space Environ Med. 2001;72:336–42.
14. Hendriksen IJM, Holewin M. Degenerative changes of the spine of fighter pilots of the Royal Netherlands Air Force (RNLAF). Aviat Space Environ Med. 1999;70:1057-63.
15. Aydoğ ST, Türbedar E, Demirel AH, Tetik O. Cervical and lumbar spinal changes diagnosed in four view radiographs of 732 military pilots. Aviat Space Environ Med. 2004;75:154–7.
16. Hamalainen O, Vanharanta H, Kuusela T. Degeneration of cervical intervertebral disks in fighter pilots frequently exposed to high Gz forces. Aviat Space Environ Med 1993;64:692–6.
17. Orsello CA, Philipps AS, Rice GM. Heightand in-flight low back pain association among military helicopter pilots. Aviat Space Environ Med. 201384:32–7.
18. Haugli L, Skogstad A, Hellesoy OH. Health, sleep, and mood perceptions reported by airline crews flying short and long hauls. Aviat Space Environ Med. 1994;65(1):27-34.
19. Ylinen J, Takala E-P, Kautiainen H, et al. Effect of long-term neck muscle training on pressure pain threshold: a randomized controlled trial. Eur J Pain. 2005;9:673–81.