Prevalence of Work Related Musculoskeletal Disorders Among Egyptian Fighter Pilots :A cross-Section Study

Mahinour M Osama[1], Neveen A. Abdel Raoof[2] , Amira Hussin Draz[2]

[1] Department of Basic Sciences /Faculty of Physical Therapy/ Badr University.

[2] Department of Basic Sciences /Faculty of Physical Therapy/ Cairo University.

ABSTRACT

Background: Fighter pilots are known to be prone to have work related musculoskeletal disorders (WMSDs) where they are exposing to high gravitational forces and high accelerations during the flight with their aircrafts but its prevalence among Egyptians fighter pilots has not been reported. **Objective of the study** was to investigate the prevalence of work related musculoskeletal disorders in different body parts among Egyptian fighter pilots. **Methods:** Ninety fighter pilots were involved in this research; they were recruited from different Egyptian airbases to assess musculoskeletal disorders. An ethical approval and informed consent were collected from them. The participants were asked to answer Cornell Musculoskeletal Discomfort Questionnaire (CMDQ). **Results**: The prevalence of WMSDs of the study group for different body regions was reported that the lower back (77.77%) was the most affected part, neck (61%), hip/Buttocks (51.1%) and upper back (43.33%). Lowest prevalence of WMSDs was reported for left upper arm (8.9%) and left wrist and knees (10%). No WMSDs were reported for forearm, legs and foot. **Conclusion:** There was a high prevalence of work related musculoskeletal disorders among Egyptian fighter pilots, Mostly in lower back, neck, hip/buttocks disorders and upper back disorders, consequently. The prevalence of WMSDs among fighter pilots in Egypt is near to values reported for the counterparts around the world.

Keywords: Cornell questionnaire**,** Fighter pilots; G-forces; prevalence; work related musculoskeletal disorders

INTRODUCTION

Musculoskeletal disorders (MSDs) include a wide range of inflammatory and degenerative conditions affecting the muscles, tendons, ligaments, joints and peripheral nerves. These include clinical conditions such as tendon inflammation and related syndromes (tenosynovitis, bursitis), nerve compression disorders (carpal tunnel syndrome, sciatica) and osteoarthritis as well as less related conditions such as myalgia, low back pain and other regional pain syndromes not attributable to known pathology.1 Work related musculoskeletal disorders (WMSDs) are cumulative disorders resulting from repeated exposure to loads from high to low intensities over a long period of time during work day routine. The symptoms may vary from discomfort and pain to decreased body function and disability2. Common and high risk factors of work related musculoskeletal disorders (WMSDs) are awkward postures, prolonged static work, repetitive movements, forceful exertions, forceful contraction, contact stress and vibration.3,4 Low back pain (LBP), neck pain and other musculoskeletal disorders (MSDs) are the leading causes of years lived with disability (YLDs).5

Military pilots are exposed during the flight to high accelerations with using the aircraft where air combat engagements consist of multiple repetitive excursions to high Gravitational force z axis levels (Gz) where Gz is a gravitational force that is applied to the vertical axis of the body of the military pilots.6 Where main predisposing factors are high G-forces have been suggested as an underlying factor.7

High G-forces, frequent turning and tilting of the head and neck as well as the weights of the helmet and oxygen equipment increase the stresses allows the cervical spine of pilots to be susceptible to injuries.8 It has been reported that the main risk factor of musculoskeletal disorders in fighter pilots is the Gravity induced muscle pain and other symptoms of muscles, tendons and ligaments which support cervical, thoracic, and lumbar vertebrae under G stress. The frequent exposure to high + Gz inertial force acts from head to feet may cause not only acute neck or back pain, but also disc degeneration.9 Postural pain may be produced due to flexed body posture of pilots for prolonged flight time. They have no possibility to change their posture until the flight has ended.10 Where the fighter cockpit has limited space, the placement of controls, ejection seat requirements and the position of the backrest of an ejection seat more upright than recommended may stress the low back structures.11,12

Neck pain in fighter pilots has been studied by several air forces and found to be most common risk factor.13 There is an unambiguous factor called check six position which is full rotation to look behind the aircraft. Many authors cite this position as being vulnerable to pain and injury.9 Therefore, in aircrew, this issue became an aeromedical concern

with the potential for major health problems.14

Two major factors associated with neck and back pain in aviators are whole body vibration (WBV) and acceleration (+Gz) forces where prolonged exposure to whole body vibration (WBV) may lead to muscle fatigue and increased loading on the bony structures of the spine. 7 Though, military pilots have the strongest association with low back pain among occupational groups where seating is a requirement for more than half a workday.15 Moreover, radiologically about 15–50% of fighter pilots showed cervical and 10–50% lumbar disc degeneration.16 So, the purpose of the study was to investigate the prevalence of work related musculoskeletal disorders among Egyptian fighter pilots .

MATERIALS AND METHODS

Study design

A cross-sectional study design was used to investigate the prevalence of work related musculoskeletal disorders among Egyptian fighter pilots at the period of March 2019 to December 2019. This study was approved by the Ethical Committee of the Faculty of Physical Therapy; Cairo University.

Participants

Ninety asymptomatic male subjects participated in the study. They were randomly selected from different air bases in Egypt. Subjects were included if their age ranged between 22 and 45, working in Egypt, and their experience with different years of working at least 1 year to have annual flown hours.

The exclusion criteria for participants were: history of musculoskeletal abnormalities due to other causes than work related (i.e. traumatic, cervical or lumber, shoulder, hip, knee and ankle problems) or previous surgical interventions.

Measurement procedures

Ninety copies of the questionnaire were given randomly to fighter pilots who work in different air bases in Egypt. Aim of the study was explained for the participants .They were asked to answer the questionnaire honestly. Consent form was agreed by the participants before starting the study. Participants were asked whether they have or have had troubles in the indicated areas during the last work week. Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) which is a valid, reliable, a self-reported questionnaire to assess musculoskeletal disorders was used in this study. 17-20

The questionnaire had two parts, part one collected the participant's personal characteristics that included general questions about age, weight and height and collected information about risk factors associated with fighter’s work. Part two collected participant’s information including musculoskeletal complaints. The questionnaire divided human body into 20 parts neck, shoulder (right and left), upper back, lower back, forearms (right and left), wrist (right and left),

hips/buttocks, thighs (right and left), knees (right and left), lower legs (right and left) and feet (right and left). Participants were asked if they had any musculoskeletal disorders over the last work week which has made a trouble or prevented their normal activity. The questionnaire also included a body map diagram clearly marked.19,20

The scoring system of the questionnaire and analysis of the obtained scores were carried out as follows:

Scoring of Cornell Musculoskeletal Discomfort Questionnaires: For duration (Frequency):

Never = 0 1-2 times last week = 1.5 3-4 times last week = 3.5 Once every day = 5 Several times a day = 10 For discomfort:

Slightly uncomfortable = 1 Moderately uncomfortable = 2 Very uncomfortable = 3, For interference: Not at all =1 Slightly interfered =2 Substantially interfered =3

The results of the questionnaire are determined by way of multiplying both the scores for levels of discomfort and interference with the frequency scores stated above.20

The discomfort score helps to determine the level of seriousness in discomfort, ranging from mild and moderate to severe.

Results

Ninety Male Egyptian Fighter Pilots participated in this study. The mean ± SD age and BMI of the study group was 33.57 ± 6.82 years and 25.51 ± 2.12 kg/m² respectively. Their working years ranged from 2 to 25 years, working hours/day ranged from 1 to 5 hours/day, working hours/week from 3 to 20 hours/week, annual flying hours from 50 to 800 hours/ year and total flown hours from 110 to 3700 hours (Table 1).

Table 1. physical characteristics of fighter pilots in this study

	$\overline{X}$ ±SD	Minimum	Maximum
Age (years)	33.57 ± 6.82	22	45
Weight (kg)	78.44 ± 8.88	65	100
Height (cm	175.17 ± 5.42	166	187
BMI (kg/m²)	25.51 ± 2.12	21.31	29.86
Working years	14.16 ± 7.01	2	25
Working hours/day	2.15 ± 0.91	1	5
Working hours/week	8.28 ± 3.55	3	20
Annual flying hours	139.77 ± 119.72	50	800
Total flown hours	1406.68 ± 898.92	110	3700

$\overline{X}$ **, Mean; SD: Standard deviation**

Prevalence of WMSDs among participants

The prevalence of WMDs of the study group for different body regions was reported in table (2). The highest prevalence was for lower back 70 (77.77%), neck 55 (61%), hip/Buttocks 46 (51.1%) and upper back 39 (43.33%). Lowest prevalence of WMSDs was reported for left upper arm 8 (8.9%) and left wrist and knees 9 (10%). No WMSDs were reported for forearm, legs and foot.

Table 2. Prevalence of WMSDs of the study group.

	Prevalence (%)	95% CI
Neck	55 (61%)	50.78- 70.53%
Upper back	39 (43.33%)	33.57-53.63%
Lower back	70 (77.77%)	68.15-85.12%.
Right shoulder	30 (33.33%)	24.45- 43.57%
Left shoulder	22 (24.44%)	16.73-34.24%
Right upper arm	12 (13.33%)	7.79- 21.87%

Left upper arm	8 (8.9%)	4.57-16.57%
Right forearm	0 (0%)	0- 4.09%
Left forearm	0 (0%)	0- 4.09%
Right wrist	19 (21.11%)	13.95- 30.63%
Left wrist	9 (10%)	5.35-17.92%
Hip/Buttocks	46 (51.1%)	40.95- 61.17%
Right thigh	14 (15.55%)	9.49- 24.43%
Left thigh	14 (15.55%)	9.49- 24.43%
Right knee	9 (10%)	5.35-17.92%
Left knee	9 (10%)	5.35-17.92%
Right lower leg	0 (0%)	0- 4.09%
Left lower leg	0 (0%)	0- 4.09%
Right foot	0 (0%)	0- 4.09%
Left foot	0 (0%)	0- 4.09%

CI: Confidence interval

- <u>Perception of discomfort:</u>

The results of Cornell questionnaire showed that the highest frequency of discomfort, several times every day, was reported for lower back 28 (31%), followed by the neck in 14 (15.56%) and hip/buttock in 13 (14.5%). High level of discomfort was reported for lower back in 39 (43.33%) subjects, hip/buttock in 30 (33.33%) subjects and neck in 20 (22.22%). Substantially interfered with work was reported for lower back in 50 (55.55%) subjects, hip/buttock in 18 (20%) subjects and upper back in 11 (12.22%), while the neck discomfort was reported as slightly interfered with work in 55 (61.11%) subjects. (Table 3).

The table represents three questions titles:

How often did you encounter aches, pain and/or discomfort when you were last at work?

How uncomfortable were you when you encountered such aches, pain and/or discomfort?

If you have experienced these aches, pain and/or discomfort, did you also experience any form of interference in your work?

Duration of pain had 5 components:

- Never
- 1-2 times last week
- 3-4 times last week
- Once everyday
- Several times a day

Discomfort had 3 components:

- Slightly uncomfortable
- Moderately uncomfortable
- Very uncomfortable

Interference had 3 components:

- Not at all
- Slightly interfered
- Substantially interfered

Total discomfort score was obtained by multiplying the above frequency score by the discomfort score by the interference score as mentioned before. The maximum score can be obtained is 90 and the minimum is 0.

The score thus obtained was classified as

- 0 No
- 1-30 Mild
- 30-60 Moderate
- 60-90 Severe

And here, mean of total discomfort score was calculated and the missing value was for the frequency score then it was used as a zero in multiplying i.e. all combinations of frequency, discomfort and interference become 0 and has no significance.(Table 3).

Table 3. Frequency of discomfort, severity of discomfort and level at which the discomfort interfered with work in the study group:

	During the last work week how often did you experience ache, pain, discomfort in:					If you experience ache, pain, discomfort, how uncomfortable was this?			If you experience ache, pain, discomfort, did this interfere with your ability to work?			Total discomfort score
	Never	1-2 times last week	3-4 times last week	Once every day	Several times every day	Slightly un-comfortable	Moderately un-comfortable	Very un-comfortable	Not at all	slightly interfered	substantially interfered	
Neck	**35**	**18**	**11**	**12**	**14**	**8**	**27**	**20**	**0**	**55**	**0**	**11.48**
Upper back	**51**	**21**	**6**	**0**	**12**	**10**	**17**	**12**	**2**	**26**	**11**	**15.79**
Lower back	**20**	**19**	**9**	**14**	**28**	**6**	**25**	**39**	**17**	**3**	**50**	**23.38**
Right shoulder	**60**	**22**	**0**	**٤**	**4**	**18**	**6**	**6**	**0**	**22**	**8**	**7.9**
Left shoulder	**68**	**18**	**0**	**0**	**4**	**14**	**4**	**4**	**5**	**15**	**2**	**9.95**
Right upper arm	**78**	**8**	**4**	**0**	**0**	**3**	**9**	**0**	**3**	**9**	**0**	**11.42**
Left upper arm	**82**	**8**	**0**	**0**	**0**	**1**	**8**	**7**	**2**	**6**	**0**	**2.44**

Right forearm	**90**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-**
Left forearm	**90**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-**
Right wrist	**71**	**6**	**2**	**7**	**4**	**5**	**8**	**6**	**14**	**5**	**0**	**4.68**
Left wrist	**81**	**9**	**0**	**0**	**0**	**4**	**5**	**0**	**1**	**7**	**1**	**4.5**
Hip/Buttocks	**44**	**14**	**8**	**11**	**13**	**8**	**8**	**30**	**8**	**20**	**18**	**12.24**
Right thigh	**76**	**4**	**4**	**0**	**6**	**0**	**6**	**8**	**3**	**11**	**0**	**13.5**
Left thigh	**76**	**6**	**4**	**0**	**4**	**0**	**6**	**8**	**0**	**14**	**0**	**12.71**
Right knee	**81**	**0**	**2**	**0**	**7**	**3**	**6**	**0**	**2**	**7**	**0**	**16.39**
Left knee	**81**	**2**	**0**	**0**	**7**	**3**	**6**	**0**	**2**	**7**	**0**	**15.28**
Right lower leg	**90**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-**
Left lower leg	**90**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-**
Right foot	**90**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-**
Left foot	**90**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**-**

DISCUSSION

The present study was designed to assess the prevalence of work related musculoskeletal disorders (WMSDs) among the Egyptian fighter pilots. There was a gap in the research field regarding the military aviation sector in the Middle East including Egypt. The present study reported that a high prevalence of lower back disorders (77.77%) in Egyptian fighter pilots followed by a high prevalence in the neck disorders (61%), Hip/buttocks (51.1%) and upper back disorders (43.33%). It's important to mention that all military pilots are exposed to high G-forces, tilting, rolling, high excursions, high accelerations and uncomfortable postures in limited size cockpits during flights.21 This allowed the prevalence of pain areas among different pilots are near to each other where there were studies and a systematic review and meta-analysis showed no differences in the prevalence of cervical or lumbar pain between fighter pilots and helicopter pilots. However, pilots exposed to high G-forces more frequently sought medical care than pilots exposed to low G-forces.7,13,22 One study compared back ache (BA) in fighter pilots and helicopter pilots showed that fighter pilots had significantly more chronic pain, longer lasting pain, pain requiring bed rest, and radiating pain to the leg.23

In this study lower back was the most affected part of the spine with percentage (77.77%). This was near to the reported prevalence among airline pilots in Colombia (71.1%) 24, initial survey reported back pain in navy helicopter aircrew (72%) 25 , and higher than an incidence reported in another study about back symptoms in aviators (64.02%) 6 , and in Israel aviation among fighter pilots (64.02%).7 Less than a study of pilots in Poland (92%).26 The high prevalence in this

study may be a reflection of the conditions under which fighters are exposed among military aviation sector. Fighter pilots may expose to the old fashioned designed cockpits and uncomfortable seats. Some of them may also not express about their pain when they exposed to a medical issue like back pain because of fear of stopping their career.27 Kikukawa et al. (1995) reported that the reasons why most of pilots didn't stop flying inspite of having the symptoms were surveyed. The most common causes were pilot didn't think the symptoms would influence flight performance or someone else would have to do extra duty for him if he didn't fly or he didn't want to lose his chance, and he was a member of a flying team for an important competition. Some of these reasons indicated that our fighter pilots are flying in a stressful, competitive, and hard busy working environment.28

The high prevalence in the lower back may be related to the flexed posture during the flying and fighter's cockpit dimensions which is limited in space, the placement of controls and ejection seat requirements .The position of the backrest of an ejection seat more upright than recommended may stress the low back structures .11 Military pilots have the strongest association with low back pain among occupational groups where seating is a requirement for more than half a workday. And from main risk factors that the military pilots are exposed all the time during flying that affect lower back ,the whole body vibration (WBV) and acceleration gravitational forces (+Gz) that may lead to muscle fatigue and put huge loading on the lower bony structures of the spine.7,15 Whole body vibration has been associated with Low back pain , sciatic pain, and degenerative change in the spinal structures including lumbar intervertebral disc disorders.29

The present study showed high prevalence of neck region among fighter pilots (61%) which was similar to a study in US reported minor neck injuries in (61%) of operational F-16 pilots 30 and which was higher than a study in Belgium (42.2%) 31 , and US was (56.6%).32 In the world literature over years, the neck pain prevalence rate in fighter pilots varies widely this could be related to the differences in the method of reporting neck pain, the differences in type of missions, newer or older equipment available, head loading ,night vision goggles (NVG) and the adopted style of flying during the years of working. Besides, differences in type of aircraft have an effect on the occurrence of neck injury.30

The lowest prevalence of WMSDs in spine among fighter pilots was found in the upper back (43.33%), this results were too close to an initial survey for back disorders in helicopter aircrew midback prevalence was (42%) 25 , and higher than a Poland study which reported thoracic pain (36%).26 These findings correlates to the twisting positions under G-forces the fighter pilots are exposed during flying which mainly affect the spine with different percentages. It was found that 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

twisted position of head and upper back, the muscles capability to protect the structures of the spine is the lowest, where considerable muscle strength and muscle endurance are needed. 27 So, some pilots felt severe pain just after flight. A study in japan reported that the second most common WMSDs in fighter pilots was the upper back pain because of the "checking six position". 9,31 . Multiple authors cited that the check six position as being vulnerable to pain and injury 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.28

The prevalence of the right shoulder (33.33%) was higher than left shoulder (24.44%) in our study which is higher than a prevalence study conducted on navy aircrew for both shoulders' pain (19%).25 Right upper arm prevalence (13.33%) was also higher than left arm (8.9%) and the right wrist (21.11%) higher than left wrist (9%). Right forearm and left forearm had no prevalence in our study. Those findings may correlate to the controlling unit of the cockpit and engine arm that needs fighter to use his dominant hand which most common is the right hand in most of population. Those findings related to the prevalence of the upper limb work related musculoskeletal disorders.

As for the lower limbs, the hips/buttocks were the most affected area (51.1%), with a lesser prevalence that appeared in the right and left thighs (15.55%). The prevalence in the right and left knees was (10%).

There was no prevalence in the right and left lower legs and in the right and left feet. Those findings may correlate to the long time flying with flexed posture position of hip and knees that cannot be changed until the flight has ended .One study reported that back ache in fighter pilots had significantly, longer lasting pain , and radiating pain to the leg.23

According to Cornell questionnaire, the results indicated the frequency of discomfort, severity of discomfort and interference with work are shown in table 3.

The result of this study which indicate high prevalence of work related musculoskeletal disorders are due to nature of hard work being performed by fighter pilot who may contribute to stress in many anatomical areas such as high G forces, high accelerations and combats, whole body vibrations , head loading rolls and turns.

Within the limitations of this study which were the difference in physical ability between fighters. Furthermore, the study also relied on self-reported data, and pilots may not have recalled all incidents of work related musculoskeletal disorders. It was concluded that There was a high prevalence of work related musculoskeletal disorders among Egyptian fighter pilots, Mostly in lower back, neck, hip/buttocks disorders and upper back disorders, consequently. The prevalence of WMSDs among fighter pilots in Egypt is near to values reported for the counterparts around the world.

Clinical Implementations

The findings of the current study provides weight into the prediction of work related musculoskeletal disorders among Egyptian fighter pilots and paves the way for the prevention of work related musculoskeletal disorders as health care professionals for better work environment.

References

1. Punnett, L., & Wegman, D. H. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. *Journal of electromyography and kinesiology.*, 2004, *14*(1);13-23.
2. Pinder, A., L. Yeomans, S. Heuvel, B. Blatter, M. Verjans, K. Muylaert, V. de Broeck, M. A. Buffet, and N. Nevala. *Work-related musculoskeletal disorders: Back to work report*. European Agency for Safety and Health at Work, 2007.
3. Choobineh, A., Tabatabaei, S. H., Mokhtarzadeh, A., & Salehi, M. Musculoskeletal problems among workers of an Iranian rubber factory. *Journal of occupational health.*,2007, *49*(5); 418-423.
4. Long, M. H., Johnston, V., & Bogossian, F. Work-related upper quadrant musculoskeletal disorders in midwives, nurses and physicians: A systematic review of risk factors and functional consequences. *Applied ergonomics*., 2012, *43*(3);455-467.
5. Vos, T., Flaxman, A. D., Naghavi, M., Lozano, R., Michaud, C., Ezzati, M., ... & Abraham, J. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *The lancet.*, 2012,*380*(9859);2163-2196.
6. Newman, D. G., & Callister, R. Analysis of the Gz environment during air combat maneuvering in the F/A-18 fighter aircraft. *Aviation, space, and environmental medicine.*, 1999, *70*(4); 310-315.
7. Grossman, A., Nakdimon, I., Chapnik, L., & Levy, Y. Back symptoms in aviators flying different aircraft. *Aviation, space, and environmental medicine.*, 2012, *83*(7); 702-705.
8. Mathys, R., & Ferguson, S. J. Simulation of the effects of different pilot helmets on neck loading during air combat. *Journal of biomechanic* ., 2012, *45*(14);2362-2367.
9. Coakwell, M. R., Bloswick, D. S., & Moser, R. High-risk head and neck movements at high G and interventions to reduce associated neck injury. *Aviation, space, and environmental medicine.*, 2004,*75*(1); 68-80.
10. Cunningham, L. K., Docherty, S., & Tyler, A. W. Prevalence of low back pain (LBP) in rotary wing aviation pilots. *Aviation, space, and environmental medicine.*, 2010, *81*(8); 774-778.
11. Harrison, D. D., Harrison, S. O., Croft, A. C., Harrison, D. E., & Troyanovich, S. J. Sitting biomechanics part I: review of the literature. *Journal of manipulative and physiological therapeutics.*, 1999, *22*(9); 594-609.

12. Shiri, R., Frilander, H., Sainio, M., Karvala, K., Sovelius, R., Vehmas, T., & Viikari-Juntura, E. Cervical and lumbar pain and radiological degeneration among fighter pilots: a systematic review and meta-analysis. *Occup Environ Med.*, 2015, *72*(2); 145-150.
13. Wagstaff, A. S., Jahr, K. I., & Rodskier, S. + Gz-induced spinal symptoms in fighter pilots: operational and individual associated factors. *Aviation, space, and environmental medicine.*, 2012, *83*(11); 1092-1096.
14. Thuresson, M., Äng, B., Linder, J., & Harms-Ringdahl, K. Mechanical load and EMG activity in the neck induced by different head-worn equipment and neck postures. *International Journal of Industrial Ergonomics.*, 2005, *35*(1); 13-18.
15. Lis, A. M., Black, K. M., Korn, H., & Nordin, M. Association between sitting and occupational LBP. *European Spine Journal.*, 2007,*16*(2); 283-298.
16. Landau, D. A., Chapnick, L., Yoffe, N., Azaria, B., Goldstein, L., & Atar, E. Cervical and lumbar MRI findings in aviators as a function of aircraft type. *Aviation, space, and environmental medicine.*, 2006, *77*(11); 1158-1161..
17. Afifehzadeh-Kashani, H., Choobineh, A., Bakand, S., Gohari, M. R., Abbastabar, H., & Moshtaghi, P. Validity and reliability of farsi version of Cornell Musculoskeletal Discomfort Questionnaire (CMDQ)., 2011.
18. Shariat, A., Tamrin, S. B. M., Arumugam, M., & Ramasamy, R. The bahasa melayu version of cornell musculoskeletal discomfort questionnaire (CMDQ): reliability and validity study in Malaysia. *Work.*, 2016, *54*(1); 171-178.
19. Kreuzfeld, S., Seibt, R., Kumar, M., Rieger, A., & Stoll, R. German version of the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ): translation and validation. *Journal of Occupational Medicine and Toxicology.*, 2016, *11* (1); 13.
20. Erdinc, O., Hot, K., & Ozkaya, M. Turkish version of the Cornell Musculoskeletal Discomfort Questionnaire: cross-cultural adaptation and validation. *Work.*, 2011, *39*(3); 251-260.
21. Newman, D. G. + GZ-induced neck injuries in Royal Australian Air Force fighter pilots. *Aviation, space, and environmental medicine.*, 1997, *68*(6); 520-524..
22. Shiri, R., Frilander, H., Sainio, M., Karvala, K., Sovelius, R., Vehmas, T., & Viikari-Juntura, E. Cervical and lumbar pain and radiological degeneration among fighter pilots: a systematic review and meta-analysis. *Occup Environ Med.*, 2015, *72*(2); 145-150.
23. Thomae, M. K., Porteous, J. E., Brock, J. R., Allen, G. D., & Heller, R. F. Back pain in Australian military helicopter pilots: a preliminary study. *Aviation, space, and environmental medicine.*, 1998, *69*(5); 468-473.

24. Fajardo Rodriguez, H. A., & Ortiz Mayorga, V. A. Characterization of low back pain in pilots and maintenance technicians on a commercial airline. *Aerospace medicine and human performance.*, 2016, *87*(9) ; 795-799.
25. Sheard, S. C., Pethybridge, R. J., Wright, J. M., & McMillan, G. H. Back pain in aircrew--an initial survey. *Aviation, space, and environmental medicine.*, 1996, *67*(5); 474-477.
26. Truszczyńska, A., Lewkowicz, R., Truszczyński, O., Rąpała, K., & Wojtkowiak, M. Back pain in Polish military helicopter pilots. *International journal of occupational medicine and environmental health.*, 2012, *25*(3); 258-264.
27. Hämäläinen, O., & Vanharanta, H. E. I. K. K. I. Effect of Gz forces and head movements on cervical erector spinae muscle strain. *Aviation, space, and environmental medicine.*, 1992, *63*(8); 709-716.
28. Kikukawa, A., Tachibana, S., & Yagura, S. G-related musculoskeletal spine symptoms in Japan Air Self Defense Force F-15 pilots. *Aviation, space, and environmental medicine.*, 1995, *66*(3); 269-272.
29. Bovenzi, M., & Hulshof, C. T. J. An updated review of epidemiologic studies on the relationship between exposure to whole-body vibration and low back pain (1986–1997). *International archives of occupational and environmental health.*, 1999, *72*(6); 351-365.
30. Vanderbeek, R. D. Period prevalence of acute neck injury in US Air Force pilots exposed to high G forces. *Aviation, space, and environmental medicine.*, 1998, *59*(12); 1176-1180.
31. De Loose, V., Van den Oord, M., Burnotte, F., Van Tiggelen, D., Stevens, V., Cagnie, B., ... & Danneels, L. Individual, work-, and flight-related issues in F-16 pilots reporting neck pain. *Aviation, space, and environmental medicine.*, 2008, *79*(8); 779-783.
32. Albano, J. J., & Stanford, J. B. Prevention of minor neck injuries in F-16 pilots. *Aviation, space, and environmental medicine.*, 1998, *69*(12); 1193-1199.