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BACK PAIN AND ITS CONSEQUENCES AMONG POLISH AIR FORCE PILOTS FLYING HIGH PERFORMANCE AIRCRAFTS

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Abstract
Objectives: Back pain in Air Force fast jet pilots has been studied by several air forces and found to be relatively common. The objective of the study was to determine the prevalence and degree of the pain intensity in the cervical, thoracic and lumbar spine, subjective risk factors and their effect on the pilots' performance while flying high maneuver aircrafts and the consequences for cognitive deficiencies. **Material and Methods:** The study was designed as a retrospective, anonymous questionnaire survey, collecting data on the age, aircraft type, flying hours, pain characteristics, physical activity, etc. The study was participated by 94 pilots aged 28–45 years (mean age: 35.9±3.3 years), actively flying fast jet aircrafts Su-22, Mig-29 and F-16. The estimates regarding the level of the subjective back pain were established using visual analogue scales (VAS). **Results:** The values of the Cochran and Cox T-test for heterogeneous variances are as follows: for the total number of flying hours: F = 2.53, p = 0.0145, for the pilot's age: F = 3.15, p = 0.003, and for the BMI factor F = 2.73, p = 0.008. **Conclusions:** Our questionnaire survey showed a significant problem regarding spinal conditions in high performance aircraft pilots. The determination of the risk factors may lead to solving this problem and help eliminate the effect of the unfavorable environment on piloting jet aircrafts. Experiencing back pain during the flight might influence the mission performance and flight safety. The costs of pilots education are enormous and inability to fly, or even disability, leads to considerable economic loss. More research on specific prevention strategies is warranted in order to improve the in-flight working environment of fighter pilots.

Key words:
Back pain, Risk factors, Attention, Concentration and perceptual disturbance, High performance aircrafts pilots, Jet pilots

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INTRODUCTION

The prevailing cervical and low back pain is a common disorder in the modern society due to, among other things, changes in the body posture [1], non-ergonomic habits [2], certain occupational exposures such as physical workload (repeated heavy lifting) [3,4]. High performance pilots experience similar problems to the general population, but they are additionally exposed to the increased risk of flight stressors (i.e., flight acceleration and ejection training). On the other hand, they were very thoroughly – medically and psychologically – selected before and during the professional military training. These determinants constitute a scientifically interesting question: do the above-mentioned disadvantages of the military aviation service influence the severity of the cervical and low back pain and its consequences on the physical and psychological state also during a flight?

Neck pain and low back pain are often reported by military helicopter pilots and fighter pilots [5,6]. Fighter pilots frequently experience such pain and injuries due to high G(z) loading [7].

OBJECTIVES OF THE STUDY

The objective of the study was to determine:

1. Prevalence and degree of the pain intensity in the cervical, thoracic and lumbar spine.
2. Subjective risk factors and their effect on the pilots' performance while flying high maneuver aircrafts.
3. Consequences for cognitive deficiencies.

MATERIAL AND METHODS

The examined group included 94 pilots, i.e. the significant majority of the Polish Air Force pilots flying high performance aircrafts. In Poland, we currently have 48 F-16, 31 Mig-29, and 48 Su-22 aircrafts.

After the research program had been approved by the Ethics Committee at the Polish Military Institute of Aviation Medicine (PMIAM), each participant was thoroughly familiarized with the methodology of the research. No one refused to participate in it. The study was conducted at PMIAM in the years 2011–2013 with the participation of a group of pilots attending the basic training in the area of aviation medicine.

The pilots were aged 28–45 (mean age: 35.9±3.3 years), their body mass index (BMI) ranged from 21.63 to 33.91 (mean BMI: 26.9±3.0). All pilots were actively flying fast jet aircrafts Su-22, Mig-29 and F-16 (Su-22: 28 pilots, Mig-29: 34 pilots and F-16: 32 pilots). The questionnaire applied in this study comprised 5 groups of questions:

1. Anthropometric data and the total and annual flight loading.
2. Pain location and intensity (VAS scale 0–10).
3. Subjective causes of pain.
4. Pain effect on the pilots' performance.
5. Pilots' participation in prophylactic or therapeutic exercises.

Based on the obtained results, the authors divided the subjects into 2 groups. Group 1 consisted of 56 pilots (59.57% of 94 subjects), aged between 32 and 45 years (mean age: 37.2±2.6 years) complaining of back pain. The body mass index in this group was 22.92–33.91 (mean: 27.3±3.0). Group 2 included 38 pilots (41.43% of the total sample), aged 28–45 years (mean age: 33.8±3.4 years) who did not report back pain. The BMI in this group was 21.63–32.28 (mean: 26.3±2.8).

Statistical analysis

The StatSoft Statistica v. 6.0 statistics package was used. Firstly, the obtained results were analyzed with the statistical significance test for independent samples. Then, the values of the Cochran and Cox T-test for heterogeneous variances were used, and an analysis with the non-parametric Mann-Whitney test was conducted.

The analysis of the interaction between the independent variables (predictors interactive effect) was performed using the two-factor logistic regression model with the backward stepwise (likelihood ratio) elimination method.

RESULTS

During the first stage of the study, the obtained results (Table 1) were analyzed with the statistical significance test for independent samples, taking into account the following parameters compared between the 2 groups: the total annual number of flying hours, the total number of flying hours, pilot's age and BMI.

The values of the Cochran and Cox T-test for heterogeneous variances are as follows: for the total number of flying hours: F = 2.53, p = 0.0145 (Figure 1a), for the pilot's age: F = 3.15 p = 0.003 (Figure 1b), for the BMI factor F = 2.73, p = 0.008 (Figure 1c). This means that pilots with back pain were significantly older, had a significantly higher body mass index and had a significantly greater total number of flown hour than pilots without such symptoms.

During the next stage of the study, the other obtained results were analyzed statistically with the non-parametric Mann-Whitney test, taking the following parameters into account (just as in the previous analysis): the number of hours flown annually, the total number of flown hours, pilot's age and BMI. The analysis was performed together for all the examined subjects. In order to demonstrate the significance effect of each risk factor for different types of seats, the analysis of back pain was performed also separately for each type of aircraft.

The results of the analysis are shown in Table 2.

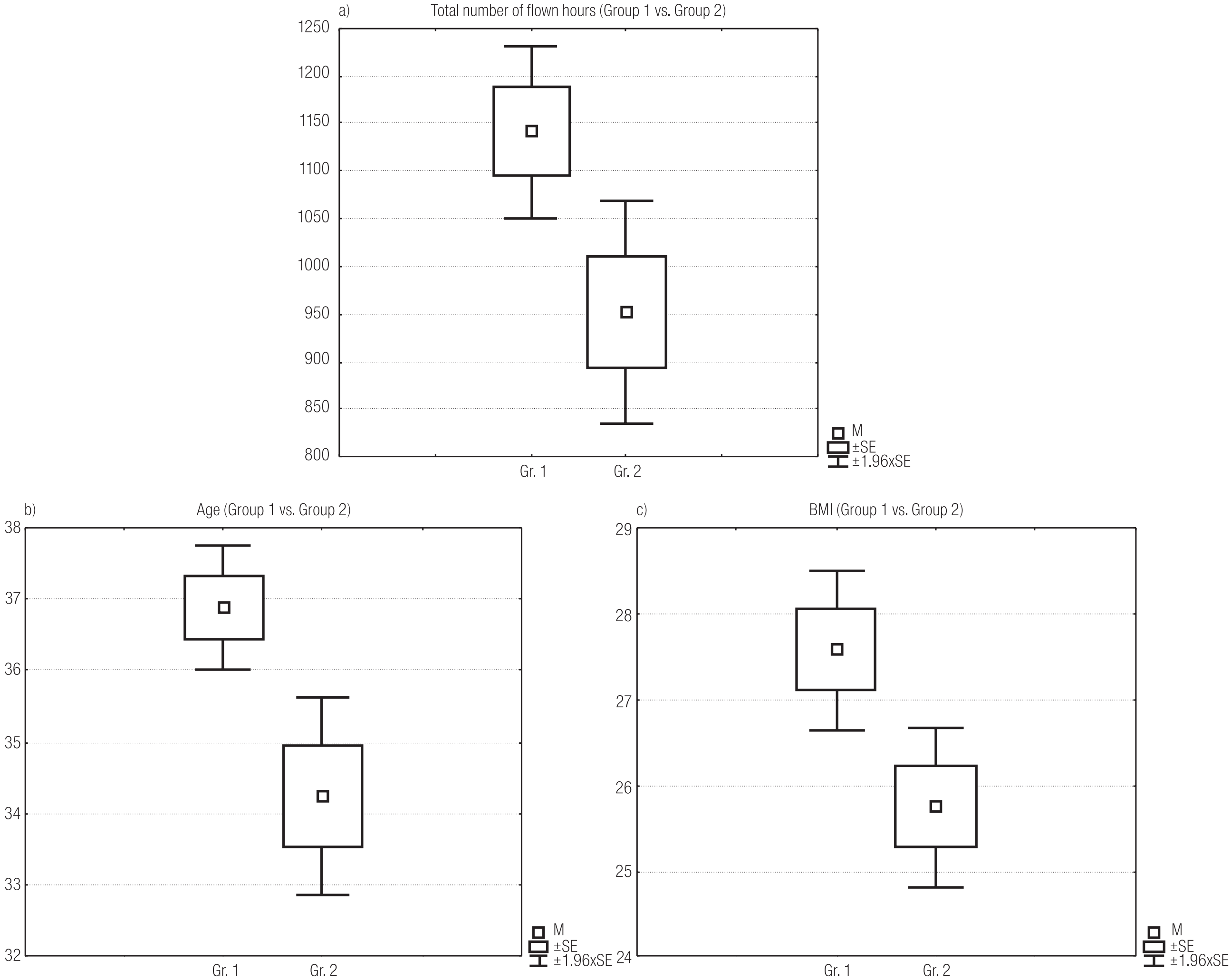
Among the F-16 pilots, only the age factor significantly differentiated Group 1 and 2. In the analysis of the location of mild pain and intense pain for this type of aircraft, no significant correlation was noted. Most probably this is related to, among other things, the fact that this particular group of pilots (F-16) is subjected to rigorous testing and periodic selection also as regards the conditions of the spine.

The authors suspect that one of the reasons for back pain is uncomfortable sitting posture. The analyzed aircrafts differ as regards the seat equipment. In ACES II ejection seat (F-16), pilots have lumbar support, a much more comfortable posture, and more possibility to move without restriction compared to K-36D (Su-22) and K-36M (Mig-29) seats. In these seats, pilots maintain a flexed posture, which predisposes the intervertebral disc to protrude. The frequency of back pain in F-16 pilots was slightly lower than in Su-22 and Mig-29 pilots and it depended only on the total number of flown hours. As shown in Table 2, the results for F-16 pilots indicate statistically significant differences in terms of age for most of the analyzed factors of pain.

Table 1. Characteristics of the study groups

Analyzed parameters	Group 1 (N = 56)		Group 2 (N = 38)	
	M	SD	M	SD
Age (years)	36.9*	2.9	33.8	25.7
Body mass index	27.6*	3.1	26.3	2.3
Annual flown hours (n)	106.9	42.7	99.8	46.0
Total flown hours (n)	1 141.4*	297.6	951.7	289.9

Group 1 – high maneuver aircrafts pilots suffering from back pain; Group 2 – pilots without back pain.
M – mean value in the group; SD – standard deviation.
* Differences statistically significant at $p < 0.05$.



M – mean; SE – standard error.

Fig. 1. Intergroup differences in terms of a) total number of flown hours, b) pilot's age and (c) pilot's body mass index

The results obtained by the authors indicate that 21% of pilots suffered from mild neck pain, and 38% of pilots suffered from severe neck pain. We noted a significant correlation of back pain with uncomfortable posture in 43% of the subjects, and with head loading with equipment in 31% of the pilots. For the intensity of the flight maneuver and head movement, there was no significant effect observed on back pain.

The analysis of the interaction between the independent variables (total number of flown hours, the pilot's age and BMI) for dichotomous dependent variables did not reveal interactions between these explanatory predictors. No statistical significance in the predictors interaction (pairs, each of each), means that the relationship between the predictor and the factors concerning back pain, does not proceed in a different manner for the different levels of the second predictor.

Pain during flight

In 43% of the surveyed pilots, pain appeared after 30 minutes of flight, and 14% of the remaining subjects reported the occurrence of the symptoms after an hour from

Table 2. Selected factors concerning back pain in Group 1 (reporting pain)

Analyzed parameters	Pilots – total (N = 56) (%)	Statistically significant differences		
		Su-22 (N = 17)	Mig-29 (N = 21)	F-16 (N = 18)
Pain intensity in the VAS scale				
1–5 (mild)	76	p(flight) = 0.001	p(BMI) = 0.011	p(age) = 0.025
6–10 (severe)	24	p(age) = 0.004 p(BMI) = 0.001		
Location of the mild back pain (VAS scale 1–5)				
cervical spine	21	ns	p(BMI) = 0.003	ns
thoracic spine	31*	p(flight) = 0.019 p(BMI) = 0.033	p(age) = 0.033	p(BMI) = 0.009
lumbar spine	81*	ns	p(flight) = 0.038 p(BMI) = 0.038	p(age) = 0.009
Location of the severe back pain (VAS scale 6–10)				
cervical spine	38	p(flight) = 0.001	p(BMI) = 0.001	ns
thoracic spine	31*	p(BMI) = 0.001		ns
lumbar spine	67***	ns	p(flight) = 0.013 p(age) = 0.013	ns
Prevalence				
rarely	71	p(flight) = 0.019	p(flight) = 0.013	p(flight) = 0.005
frequently	29	p(BMI) = 0.0335	p(BMI) = 0.001	
Pain onset				
during the flight	43*	p(flight) = 0.001	p(flight) = 0.001	p(flight) = 0.014
after the flight	57*	p(age) = 0.029 p(BMI) = 0.001	p(age) = 0.016 p(BMI) = 0.005	p(age) = 0.022
Cause of back pain				
uncomfortable posture	43***	p(flight) = 0.001	p(BMI) = 0.001	ns
intensive flight maneuver	38	p(BMI) = 0.001	p(BMI) = 0.002	p(age) = 0.033
head loading	31**	ns	ns	ns
Head movement	10	ns	ns	ns

VAS – visual analogue scale; BMI – body mass index.
* Statistically significant differences vs. the total number of flown hours at $p < 0.05$.
** Statistically significant differences vs. age at $p < 0.05$.
*** Statistically significant differences vs. the BMI factor at $p < 0.05$.
ns – statistically not significant.

the take-off. It is worth noting that a number of pilots, as many as 38% of the group reporting pain, felt it only after the flight, or during a long break between the flights. Experiencing pain during the flight and after its completion was reported respectively by 43% and 57% of the pilots. Those pilots have statistically significantly higher total

Table 3. Prophylactic activities of pilots reporting back pain (Group 1)

Type of exercises	Pilots (N = 56) (%)
Strengthening-stabilizing exercises	26*
Enhancing physical fitness	33
Physiotherapy	4

* Statistically significant differences in relation to the total number of flown hours at $p < 0.05$ ($p = 0.0157$).

number of flown hours ($p < 0.05$), compared to the pilots who did not complain about these problems. For 19% of the respondents reporting pain, its presence was associated with the head movements only during the flight, which in relation to the total number of flown hours significantly differentiated the pilots, at $p = 0.002$.

Treatment

None of the pilots used pain relievers. In individual cases, they used specialized periodic treatments, relaxing massage and stretching of the muscles of the spine (massage). Only 26% of the pilots applied strengthening-stabilizing exercises, and specific physiotherapies were used by 4% of the subjects. The authors found only statistically significant differences concerning the strengthening-stabilizing exercises in relation to the total number of flown hours at $p < 0.05$. This means that those pilots who trained, had significantly higher flying experience. There were no significant differences for age or BMI (Table 3).

Concentration of attention and perception of the environment

Four pilots reported adverse effects of pain on the level of concentration as well as hindered observation of flight instruments in the cockpit and weakened perception of the external environment during the flight. One of the surveyed pilots reported pain-related difficulties in piloting the aircraft, which finally caused him to abort the flight.

Ejection training

Each of the respondents participated in the ejecting training with the use of the UTKZ simulator. The number of training ejections ranged from 1 to 5 (mean: 1.9±1.5). None of the pilots ejected during the procedure of emergency exit during real flight conditions.

DISCUSSION

Main findings

The split into groups concerning the pilots who reported back pain and those who did not have such a problem may be due to the number of hours spent in the air. It is a factor statistically differentiating the analyzed groups of pilots.
Almost 60% of high performance aircrafts pilots complained of back pain, mostly in the lumbar spine, and then in the thoracic spine.
The risk factors included: the overall number of flown hours, age and BMI. The available literature indicates that back pain can be a major distraction during the flight, but also after completing the tasks in the air [8]. In our study, four pilots reported severe pain and its consequences in the form of attention disturbances and cognitive functions impairment concerning the visual control of the flight instruments' indications. Although this regards a relatively small number of the analyzed pilots, the problem of back pain and its consequences requires constant monitoring and may be related to the level of flight safety. One of the pilots indicated that he had had to give up continuing the flight, because he had estimated that back pain had prevented him from carrying out his operational tasks in a safe manner.

Prevalence

Grossman et al. attempted to define the epidemiologic characteristics of back pain in the military pilots of the Israeli Air Force. They evaluated 566 aviators of various aircrafts (fighter, attack helicopter, utility helicopter, and transport and cargo aircrafts). As many as 64.02% of fighter pilots reported back pain, and 47.2% felt pain in the cervical spine [6].

Risk factors

Wagstaff et al. studied the incidence, characteristics, causative factors, as well as the operational impact of neck pain on the pilots' performance by a retrospective anonymous questionnaire survey. They suggested that new technologies, such as night-vision goggles or helmet-mounted displays that increase the helmet's weight, add a higher strain to the neck, especially when a pilot acts in moderate G environments. The "checking six" position was the most common posture at the time of the injury [9]. Kikukawa reported that 44 pilots, out of 115, stated that their symptoms adversely affected the flight performance, and 50 pilots confirmed that their condition negatively impacted their daily life [10].

Tucker et al. found that the in-flight neck pain was very positively associated with the flown hours. The authors' own results confirmed these findings. The total number of hours flown was a significant risk factor for back pain [11]. In 2008, De Loose et al. determined the self-reported 1-year prevalence of neck pain among 90 male pilots. They also compared individual, work-related and flight-related, characteristics in F-16 pilots with and without neck pain. The neck pain prevalence equaled 18.9% and correlated with high force demands, sitting for a long time, holding the neck in a flexed position, and being physically tired [12].

Pilot's tasks

It is not possible to determine the daily or weekly activity of the pilots. The flight schedule depends on the annual training program and changes its intensity depending on special activities. Higher intensity is related to the participation in missions, training under traverses and exercises outside the country. The hourly load flights indicator in a calendar year is the only objective parameter available to evaluate the tasks performed in the air. In accordance with the applicable rules, the number of flown hours is considered as the basis for payment of financial charges and redeeming work (tasks) in difficult conditions. Every flight on the aircraft (Su-22, Mig-29 and F-16) is associated with acceleration (mainly in the vertical axis of the body). Its value, duration and frequency is dependent on the task performed. Thus, the number of flown hours is only an indicator that describes the professional activity of pilots.

Low back pain

Hämäläinen evaluated the effect of high G-forces on lumbar spine with the use of a questionnaire. The aim of the study was to determine whether high G-force exposure caused work-related thoraco-lumbar spine pain in fighter pilots. The study analyzed subjective responses of 320 fighter pilots and 283 non-flying controls. The conclusion was that pilots were between 1.5 and 3.5 times more likely to experience thoraco-lumbar pain than non-pilots. This risk increases with the number of hours flown during high accelerations. These findings were confirmed by our study [13].

Petren-Mallmin and Linder tried to establish the factors for low back pain analyzing MRI of the cervical spine. They concluded that high performance aircraft pilots are at increased risk of premature development of degenerative disc disorders, similar to that of the aging population [14].

Prevention

Hämäläinen et al. (1999) recommended that student fighter pilots should undergo conventional X-ray and MRI tests in order to screen out and reject candidates with a congenitally narrow spinal canal. In the opinion of these authors, such imaging methods might be useful in fighter pilots' periodic medical check-ups performed in order to reveal the acquired degenerative spinal stenosis [15].

For this reason, the Polish Air Force implemented thorough screening of the candidates for high performance aircraft pilots. Rąpała et al. evaluated 89 MRI scans of the whole spine. The authors found degeneration in 25.84% of the examined intervertebral discs, mainly on the L4L5 and L5-S1 levels [16]. Disc degeneration can be asymptomatic [17,18].

Sovelius et al. demonstrated that individually adjusted fighter pilots lumbar support lowered the strain of the neck and back muscles measured by the maximal voluntary contraction during combat flights [7].

The physical capacity of pilots and the characteristics of their physical training are important for the interpretation of the results. Every soldier (including pilots) is obliged to participate in physical education activities twice a week for 45 min. The forms of physical activity (running, swimming, weight training) are dependent on the training base and the individual needs and preferences. In the survey, we asked whether the training conducted in a military unit is sufficient in pain prevention. Only 10% of the pilots from the pain group answered the question positively. This indicates that the training for these pilots should be designed individually according to the existing problems. In fact, data on the physical capacity of pilots could provide valuable information for the interpretation of the results. Unfortunately, no surveys have included such questions. The authors received information about the pilots physical fitness. However, since the surveys were anonymous, the authors were not able to properly attribute the data to physical training or to the occurrence of back pain.

Treatment

According to Kikukawa, Japanese pilots preferred oriental therapeutic methods (acupuncture, moxa cautery, and finger-pressure massage) for back pain treatment [10]. A small percentage of Polish pilots used physiotherapy.

CONCLUSIONS

1. Our questionnaire survey showed a significant problem regarding spinal conditions in high performance aircrafts pilots.
2. The determination of the risk factors may lead to solving this problem and help eliminate the effect of the unfavorable environment on piloting jet aircrafts. It is worth mentioning that among the analyzed risk factors of back pain occurrence we can only affect BMI. It is therefore necessary to point out the desirability of addressing the problem of normalization of body weight among pilots.
3. Experiencing back pain during the flight might influence the mission performance and flight safety. The costs of pilots education are enormous and inability to fly, or even disability, leads to considerable economic loss.
4. More research on specific prevention strategies is warranted in order to improve the in-flight working environment of fighter pilots.

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