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ORIGINAL ARTICLE

LONG-TERM HEALTH EFFECTS EJECTION FROM AIRCRAFT IN MILITARY PILOTS

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Introduction: In military aviation, pilots have to perform complex tasks under variable environmental conditions, at different times of the day, during complex military missions; this can cause emergency events. Such emergency events may necessitate emergency ejection. However, because of deficits of time and attention as well as because of difficult conditions of ejection, pilots often have inadequate positions before ejection. This can lead to various bodily injuries, leading further to acute and long-term consequences for the pilots' psychophysical state. The main aim of the study was to analyze injuries related to emergency ejection in military pilots and to evaluate potential long-term health consequences of emergency ejection.

Methods: We included all pilots of the Polish Air Force who performed successful emergency ejections between 1985 and 2007. In this period, 36 pilots performed emergency ejections, including one pilots who had two ejections. We analyzed the gathered data with respect to medical and legal aspects.

Results: We put forward the three following hypotheses: 1) emergency ejections have a negative impact on pilots' health; 2) the health condition of pilots is getting worse with an increasing number of flight hours; 3) the health condition of pilots is getting worse with increasing age.

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Discussion: Despite the advancement of aviation technologies, it is impossible to avoid all emergency situations that can lead to emergency ejections. The increasing role played by new technical and informational solutions limits the role of human factor in the process of ejection, which remains the major cause of aviation disasters. A number of solutions applied in the construction of the ejection seats are in place to reduce the risk of death and injuries. Aviation health care analyzes every case of emergency ejection with regard to its health consequences to the pilot, mechanisms of injury, effectiveness of emergency systems, hospital procedures and the scheme of action for medicolegal personnel who decides on the fate of the pilot.

Conclusions: Based on the investigations, we report the following findings:

- mild injuries incurred during ejection or injuries that were not recognized within several hours after ejection resulted in pilots being unfit for military service in the long-term,
- severe injuries with accompanying psychological disorders led immediately to discontinuation of military service,
- moderate injuries of the vertebral column in the long-term caused pain syndromes related to overload,
- subjective evaluation of pilots' own health after ejection was related to the degree of injury and pain.

Keywords: emergency event, emergency ejection, health effects, inadequate positions, pilots psychophysical state

INTRODUCTION

In supersonic and infrasonic aircraft, pilots need to perform emergency ejections in unpredictable situations or due to aircraft malfunction [28,54]. The decision to eject has to be made instantly and automatically. Hesitation in making decisions and errors in performing ejections can lead to a disaster. Despite the advancement of ejection devices, pilots have fear of ejection from an aircraft [1,2,15,30,49]. On-ground, practice ejections in the Air Force Academy in Deblin (WSOSP) have not been popular among students because of large g-forces (ca. 10-13 G). Although practice ejections help get used to the conditions of ejection, they promote degenerative changes in the vertebral column. Currently, there are safe on-ground, pneumatic facilities for learning the skills of successful emergency ejection. According to the current curriculum, every student of WSOSP has to perform four practice ejections in on-ground devices. It need to be emphasized that flight simulators are currently widely used in military aviation with the assessment of factors that modify the tolerance of flight environment [4,8,45,49,50,51,52,53].

Emergency ejection in military aviation

In the studied period, i.e. between 1989 and 2009, there were 37 instances of emergency ejections in military aviation. One of the pilots performed two emergency ejections. During this period, 29 pilots died in aircraft with ejection seats because of aviation disasters. Therefore, it is an important task of the military health service to decrease the number of deadly accidents and to comprehensively analyze and monitor health status of pilots after emergency ejections, especially with respect to further military service.

Based on medical and aviation protocols, it was shown that pilots incur various injuries during emergency ejections. This is due to many causes (level of experience, flight conditions, health status, psychophysical dispositions, ejection device etc.). An important role is played by physical and psychological characteristics. One should start from a proper selection of candidates for WSOSP. Currently, magnetic resonance imaging can assess in detail the structure of vertebrae, ligaments, intervertebral discs and vertebral canal. Due to comprehensive psychological evaluations performed in WSOSP and in the Military Institute of Aviation Medicine (MIAM), the selected candidates have adequate psychological traits for being military pilots. The character of aviation changes, pilots perform flights in conflict zones, during practices with NATO members carried out in order to prepare them for combat interventions. In 2011, it was declared that pilots have to be examined by a psychologist with at least 5 years of experience and an MA degree (Journal of Laws, 8th January 19, 2011 Pos. 96; Decree of the Minister of National Defense, 23.12.2010 r.).

Medicolegal issues in the case of pilots who performed emergency ejections

The medicolegal regulations with regard to Polish Air Force pilots who performed emergency ejections were determined by Head of the Military Committee of Air Forces in the "Scheme of assessing the ability to perform air force military service of pilots who performed emergency ejections" (internal organizational documents, 2005).

Emergency ejection is a stressful event for military pilots and it can also cause various bodily injuries. Therefore, after medical treatment, pilots who performed emergency ejections need to undergo the following examinations:

- x-ray of the vertebral column after one year and then every 5 years,
- magnetic resonance imaging of the vertebral column in cases with vertebral trauma or vertebral pain after one year and then every 5 years,
- control examinations of organs and bodily systems that were injured during emergency ejection after one year and then depending on the symptoms,
- psychological assessment with comprehensive conclusions with regard to pilots' state (psychological state, assessment of suitability for a given position in future).

It is worth to get acquainted with medicolegal regulations in other NATO countries, in which it is emphasized that in order to be suitable to pilot a new generation aircraft, one has to be in a good physical condition. Pilots need to meet the highest health standards and therefore physicians who evaluate them need to use all available investigations and diagnostic methods. Physicians need to be experienced in their given fields of medicine as well as in the field of aviation medicine. This is to detect pathologies and direct personnel to tasks that can be performed with a given health status.

Currently, there are works carried out in order to unify regulations in all NATO countries. Therefore, STANAGI that relate to medical procedures with respect to exchangeability of aviation personnel within NATO countries need to be translated into Polish circumstances. In order for these regulations to apply in the Polish circumstances, they have to be adjusted to Polish social, health and financial conditions. Currently, each NATO country has its own regulations that need to fulfill strict diagnostic and medical criteria. Regulations that are created for the Polish Air Force take into account NATO recommendations and characteristics of our aviation [17,43].

Assumptions, aims of the study and study questions

In military aviation, pilots have to perform complex tasks under variable environmental conditions, at different times of the day, during complex military missions; this can cause emergency events. Such emergency events may necessitate emergency ejections. Because of time deficits and difficult conditions of ejection, pilots often have inadequate positions for ejection, and high speeds and/or changing weather conditions (e.g. wind) during parachuting increase the risk of bodily injuries and psychological trauma. This can have both short-term and long-term effects on the psychophysical state of the pilots, potentially leading to a lower health category. Therefore, it seems important to assess both short-term and long-term effects of emergency ejections on the psychophysical state of injured pilots.

In the studies performed so far, the detailed, long-term consequences of emergency ejection on the health status of pilots have not been investigated. Therefore, we wanted to perform a study in order to evaluate cognitive and practical aspects of long-term health effects of emergency ejections. Because of a low number of the studied pilots who performed successful ejections, we primarily carried out a case series study. We also performed a comparative analysis with a randomly selected group of military pilots who had never performed emergency ejections.

Aim

The main aim of the study was to analyze injuries associated with emergency ejections in military pilots and to evaluate potential long-term effects of emergency ejections on the health status of pilots. Practical aims focused on medicolegal aspects and on potential prophylactic recommendations and recommendations for health assessment.

We posed the following research questions:

1. What injuries are incurred after emergency ejections?
2. What is the process of treatment, rehabilitation and medicolegal regulations after emergency ejections?
3. What is the long-term effect of emergency ejections of health status (somatic and psychological) of military pilots?
4. What are the medicolegal regulations for military pilots who quit military service?

Study material

We included all pilots of the Polish Air Force who performed successful emergency ejections between 1985 and 2007. In this period, 36 pilots performed emergency ejections, including one pilot who had two ejections. Emergency ejections were performed from the following aircraft types: turboprop PZL Orlik aircraft (130 [3 times]; infrasonic LIM aircraft (2, [1 x]; LIM aircraft – (6 [1x]); TS aircraft – (11 Iskra [3x]); supersonic MIG aircraft – (21 [15x]); MIG aircraft – (23 [1x]); SU aircraft – (20 [3x]); SU aircraft– 22 [4x], AM-X – an aircraft of the Italian Air Force [1x].

For a comparative analysis with military pilots who performed emergency ejections and were still in military service, we gathered a control group of 45 pilots matched for age and flight experience (e.g. aircraft type) based on an analysis of medical charts. In total, we analyzed 80 cases, of whom 36 cases performed emergency ejections and were the experimental group. The remaining 45 pilots, who had never performed emergency ejections, were included in the control group.

Upon our request, we obtained permission from the Head of the Military Institute of Aviation Medicine in Warsaw, Poland to get access to military and medical files of the cases.

The gathered data were analyzed with respect to medical and medicolegal aspects; we did not disclose personal details, including initials, of the studied subjects. Guided interviews were carried out during routine examinations after obtaining consent from the pilots; the data gathered in this way were also anonymous.

Characteristics of the control and experimental groups

The preliminary analysis, based on the values of margins, found that the dependent variable (occurrence of diseases and health defects) was considerably dispersed. Many of the recorded diseases and ailments were found only once. Because such dispersion rendered the data inadequate for analysis, we included for further analysis only those diseases that were most frequent and that were potentially related to emergency ejections. They included:

- abnormal vertebral curvature, healed fractures and inborn defects of the vertebral column, as listed in § 34 pkt. 1-6 (attached in appendix no. 1) – 40% of subjects,
- chronic pain syndromes, radicular pain, pain related to nerve plexuses, chronic diseases and long-term consequences of trauma of the peripheral nervous system, as listed in § 63 pkt. 1-3 of the above-mentioned appendix – 32.5% of subjects,
- anxiety disorders that insignificantly disturb adaptation skills and maladaptation reactions, as listed in § 67 pkt. 2 i § 68 pkt. 1 of the above-mentioned appendix – 10% of subjects.

A preliminary analysis of the total flight hours (performed because of emergency ejections) showed a very large dispersion of this feature in both groups (experimental and control groups). The difference in total flight hours between the groups was statistically significant ($p < 0.0001$); the difference was in favor of the control group.

Because of the large dispersion of total flight hours, we performed cluster analysis with the k method in order to create 3 clusters. Based on this, the studied subjects were divided into the three following categories:

1. Pilots with a low number of flight hours - 329 – 1350 hours (mean of 1014.03 hours) 33 subjects (41.25%).
2. Pilots with a moderate number of flight hours - 1400 - 2243 hours (mean of 1764.55 hours) 31 subjects (38.75%).
3. Pilots with a large number of flight hours - 2335 - 3250 hours (mean of 2890.00 hours) 16 subjects (20%).

Because in cluster analysis the distances between the centers of clusters are maximized, such a categorized variable was used for further analysis, as this reduced the dispersion of data.

Because such a categorization decreased the amount of information (i.e. transition to a nominal level of analysis), we had to verify our hypotheses on the relationship between the number of diseases and ailments and independent variables. Therefore, we had to group subjects according to the number of reported symptoms. Those pilots who did not have any symptoms were classified as healthy; those with 1-2 symptoms as subjects having endangered health; those with 3 or more symptoms as having a health problem. We found the following distribution of the variable:

- healthy pilots (no symptoms) - 35.0% (28 subjects),
- pilots with endangered health (1-2 symptoms) - 26.3% (21 subjects),
- pilots with health problems (3-10 symptoms) - 38.8% (31 subjects).

Categorization of pilots according to age was also carried out with cluster analysis with k-means, with an imposed condition of 3 clusters. The pilots were classified into three age groups; Group I (up to 39 years of age) – 25% of subjects; Group II (40 49 years of age) – 51.25%, Group III (over 50 year of age) – 23.75% of subjects. The mean age and stand-

ard deviation show that this variable had a low dispersion in the above-described age groups.

With such categorized variables, we analyzed their distributions with two variables in contingency tables and the following independent variables – emergency ejection, total flight hours and age of subjects. We analyzed the distributions of variables with percentage profiles, statistical significance and strength of association measured with coefficients dedicated for nominal and ordinal variables.

METHODS

Chart review

Initially, we analyzed the medical and military charts of the subjects, which included:

- personal details,
- medical history,
- military-medical opinion, aviation psychological profile after emergency ejection and before quitting military service or the most recent one in case of pilots who were still in service,
- description of reported symptoms after emergency ejection,
- evaluation of health condition on the day of injury (specialist consults and results of diagnostic studies),
- psychological assessment performed immediately after emergency ejection,
- routine assessment chart with notes of the examining physicians,
- opinions of the Medicolegal Committees,
- consults of military aviation physicians.

In the second stage, we analyzed the current legal regulations that pertain to the Polish Air Forces:

- Journal of Laws and Decrees of the Minister of National Defense,
- "Flight safety instructions of the Polish Air Force for military aviation and the air traffic service",
- "Scheme of conduct for deciding on one's ability to continue military service in the Air Forces after emergency ejection" issued by the Head of the WKLSP.

In the third stage, we performed guided interviews with 10 pilots who performed emergency ejections. They were randomly selected out of 36 pilots from the experimental group. The interview included the six following evaluation criteria: Assessment of health condition before emergency ejection; Assessment of health condition after emergency ejection; Assessment of current health condition; Assessment of health care after emergency ejection; Assessment of health care in the subsequent years after emergency ejection; Assessment of psychological care after emergency ejection.

A significant problem of the ex post factum analysis was the lack of full radiological documentation that was recorded immediately after emergency ejections. The available radiological examinations came from the subsequent years after emergency ejections; these examinations were performed as part of routine examinations of pilots.

Based on the preliminary psychological evaluation, psychological trauma was more pronounced than physical trauma in some pilots. The descriptions of psychological conditions of pilots immediately after emergency ejections were very condensed, which made it difficult to gain a thorough insight into the mental sphere of the pilots.

In the fourth stage, we performed a case-series study (with the use of data from the first stage of analysis) and described 36 instances of emergency ejections with a special emphasis put on the health condition of the pilots. The analysis of health condition included the period immediately after emergency ejections and the subsequent years of service in the Air Forces (routine examinations carried out by aviation-medical committees).

Statistical analysis and methods of statistical reasoning

Study hypotheses:

1. Emergency ejection negatively influences health condition of pilots:
   - with regard to neurological disease,
   - with regard to the skeletomuscular system,
   - with regard to trauma of the vertebral column.
2. Health condition of pilots decreases with increasing number of flight hours.
3. Health condition deteriorates with the age of pilots.

Taking into account the studied issue, the aim of the work and the posed research questions and hypotheses (regarding statistical reasoning), we employed a modified experimental scheme. Because of ethical and material issues, we could not perform a typical experiment that would fulfil the following theoretical assumptions:

- manipulation of the independent variable – i.e. emergency ejection,
- controlling for the influence on the remaining variables that could have a significant impact on health – i.e. the main dependent variables,
- randomization – i.e. a random assignment of subjects to experimental and control groups.

Therefore, we used a quasi-experimental design [6]. In the control group, we included randomly selected pilots matched for age and flight experience who did not have any life-threatening events (n = 45).

Because of that, the study was carried out in an ex post factum model (in its confirmatory form) [6], whereby, based on the gathered data, we tested the hypothesis that traumatic events (i.e. emergency ejection) negatively impact the health condition of pilots.

The key independent variable was the occurrence of emergency ejection. Moreover, we also gathered data that characterized the included subjects such as age, number of flight hours and type of most frequently used aircraft, as these variable could also influence the health of pilots. Health condition of pilots was the dependent variable, and it was measured with the number of diseases and ailments found in the studied pilots. Based on a preliminary analysis of health charts, there were 69 variables that described the health condition of pilots. These variables were categorized according to a classification included in the list of diseases and ailments used for the assessment of physical and psychological suitability for military service as part of the flying personnel, on-ground personnel and engineering service (appendix no. 3, Decree of the Minister of National Defense from May 10th 2004; i.e. on the assessing suitability for military service and on the military medical committees).

We analyzed the gathered data with IBM SPSS statistical software (version 19). We paid special attention when exploring the gathered data in the studied groups with statistical methods. For comparisons, we used the Mann-Whitney test for independent groups and Kruskal-Wallis test for more than two independent groups. In the case of nominal variables presented in contingency tables, we used the chi-squared test for assessing independence. For assessing the strength of association, we used nonparametric statistics suitable for nominal variables. Statistical significance was considered at $p \leq 0.05$.

RESULTS

Assessment of health status of pilots – emergency ejection and health status of studied pilots

Based on the analysis, emergency ejection was not significantly associated with pathological changes in the vertebral column (Tab. 1).

Based on the analysis of distributions of the emergency ejections and chronic pain syndromes, it can be concluded that emergency ejections were not significantly associated with chronic pain syndromes. In contrast, based on the percentage profiles, such an association was found, i.e. chronic pain syndromes were more frequent in the group of pilots who performed emergency ejections (Tab. 2).

Tab. 1. Emergency ejection and occurrence of changes in the vertebral column (comparative data).

Group		Vertebral changes		In total
		Absent	Present	
Experimental	n	22	13	35
	%	62.9%	37.1%	100.0%
Control	n	29	16	45
	%	64.4%	35.6%	100,0%
In total	n	51	29	80
	%	63.8%	36.3%	100.0%

Person's chi-square = 0.021 p = 0.884
Phi Φ = 0.016 p = 0.884

Tab. 2. Emergency ejections and prevalence of chronic pain syndromes (comparative data).

Group		Chronic radicular and nerve pain syndromes		In total
		Absent	Present	
Experimental	n	21	14	35
	%	60.0%	40.0%	100.0%
Control	n	33	12	45
	%	73.3%	26.7%	100.0%
In total	n	54	26	80
	%	67.5%	32.5%	100.0%

Pearson's chi-square = 1.595 p = 0.207
Phi Φ = 0.141 p = 0.207

Based on the analysis of distributions of the emergency ejections and anxiety disorders, it can be concluded that emergency ejections were not significantly associated with anxiety disorders. Based on percentage profiles (only 10% prevalence – 8 subjects), anxiety disorders are two times more frequent in the group of pilots who performed emergency ejections (Tab. 3).

Tab. 3. Emergency ejection and prevalence of anxiety disorders (comparative data).

Group		Anxiety disorders and maladaptive reactions		In total
		Absent	Present	
Experimental	n	30	5	35
	%	85.7%	14.3%	100.0%
Control	n	42	3	45
	%	93.3%	6.7%	100.0%
In total	n	72	8	80
	%	90.0%	10.0%	100.0%

Pearson's chi-square = 1.270 p = 0.260
Phi Φ = 0.126 p = 0.260

With a relatively frequent occurrence of vertebral abnormalities in the studied pilots, age does

not predict their occurrence. The distributions are not significantly different (Tab. 4).

Based on percentage profiles, pain syndromes were much more frequent in pilots older than 50 years. The distributions are nor significantly different (Tab. 5).

Percentage profiles indicate a slight tendency for anxiety disorders and maladaptive reactions to occur more frequently in pilots up to the age of 49 years. The distributions are not significantly different (Tab. 6).

Tab. 4. Age of studied pilots and occurrence of vertebral abnormalities.

Age		Vertebral abnormalities		In total
		Absent	Present	
28-39 years	n	13	7	20
	%	65.0%	35.0%	100.0%
40-49 years	n	26	15	41
	%	63.4%	36.6%	100.0%
50-58 years	n	12	7	19
	%	63.2%	36.8%	100.0%
In total	n	51	29	80
	%	63.8%	36.3%	100.0%

Pearson's chi-square = 0.018 p = 0.991
Phi Φ = 0.015 p = 0.991

Tab. 5. Age and prevalence of chronic pain syndromes.

Age		Chronic pain and nervous syndromes		In total
		Absent	Present	
28-39 years	n	14	6	20
	%	70.0%	30.0%	100.0%
40-49 years	n	29	12	41
	%	70.7%	29.3%	100.0%
50-58 years	n	11	8	19
	%	57.9%	42.1%	100.0%
In total	n	54	26	80
	%	67.5%	32.5%	100.0%

Pearson's chi-square = 1.051 p = 0.591
Phi Φ = 0.115 p = 0.591

Tab. 6. Age and prevalence of anxiety disorders and maladaptive situational reactions.

Age		Anxiety disorders and maladaptive reactions		In total
		Absent	Present	
28-39 years	n	18	2	20
	%	90.0%	10.0%	100.0%
40-49 years	n	36	5	41
	%	87.8%	12.2%	100.0%
50-58 years	n	18	1	19
	%	94.7%	5.3%	100.0%
In total	n	72	8	80
	%	90.0%	10.0%	100.0%

Pearson's chi-square = 0.693 p = 0.707
Phi Φ = 0.093 p = 0.707

Number of flight hours and health condition of studied pilots

Based on percentage profiles, vertebral abnormalities tend to occur more frequently in pilots with a low number of flight hours. The distributions are not significantly different (Tab. 7).

Tab. 7. Number of flight hours and occurrence of vertebral lesions.

Number of flight hours		Vertebral lesions		In total
		Absent	Present	
Low	n	18	15	33
	%	54.5%	45.5%	100.0%
Moderate	n	22	9	31
	%	71.0%	29.0%	100.0%
High	n	11	5	16
	%	68.8%	31.3%	100.0%
In total	n	51	29	80
	%	63.8%	36.3%	100.0%

Pearson's chi-square = 2.082 p = 0.353
Phi Φ = 0.161 p = 0.353

Number of flight hours does not have a significant influence on the occurrence of chronic pain syndromes. The distributions are not significantly different (Tab. 8).

Tab. 8. Number of flight hours and occurrence of chronic pain syndromes.

Number of flight hours		Chronic pain syndromes		In total
		Absent	Present	
Low	n	21	12	33
	%	63.6%	36.4%	100.0%
Moderate	n	23	8	31
	%	74.2%	25.8%	100.0%
High	n	10	6	16
	%	62.5%	37.5%	100.0%
In total	n	54	26	80
	%	67.5%	32.5%	100.0%

Pearson's chi-square = 1.040 p = 0.595
Phi Φ = 0.114 p = 0.595

Tab. 9. Number of flight hours and occurrence of anxiety disorders and maladaptive reactions.

Number of flight hours		Anxiety disorders and maladaptive reactions		In total
		Absent	Present	
Low	n	27	6	33
	%	81.8%	18.2%	100.0%
Moderate	n	30	1	31
	%	96.8%	3.2%	100.0%
High	n	15	1	16
	%	93.8%	6.3%	100.0%
In total	n	72	8	80
	%	90.0%	10.0%	100.0%

Pearson's chi-square = 4.285 p = 0.117
Phi Φ = 0.231 p = 0.117

Based on percentage profiles, anxiety disorders and maladaptive reactions tend to occur more frequently in pilots with a low number of flight hours. The distributions are not significantly different (Tab. 9).

Age and health status of studied pilots

The level of health status impairment was measured with the number of diseases as follows; pilots with degree I of health impairment were those with 1-2 diseases; pilots with degree II health impairment were those with 3 or more diseases and ailments. The distributions of health impairments between different degrees of health impairment are significantly different. Moreover, a statistically significant Kendall's tau-c coefficient (0.32) indicates a relatively moderate strength of association between the variables presented in Table 10.

Tab. 10. Emergency ejection and health impairment (comparative data).

Group		Health impairment			In total
		Healthy	Degree I impairment	Degree II impairment	
Experimental	n	21	2	12	35
	%	60.0%	5.7%	34.3%	100.0%
Control	n	7	19	19	45
	%	15.6%	42.2%	42.2%	100.0%
In total	n	28	21	31	80
	%	35.0%	26.3%	38.8%	100.0%

Pearson's chi-square = 21.427 p = 0.000
Kendall's Tau-c = 0.316 p = 0.010

Based on data distribution in the experimental group, pilots who performed emergency ejections had good health, as in 60% of them no health deficit was present; 5.5% of pilots had 1-2 diseases; 34.5% had three or more diseases. This suggests that emergency ejection can favor the degree II health impairment.

As regard the control group, 84.4% of these pilots had some degree of health impairment; 42.2% of them had 1-2 diseases and 3 or more diseases, respectively. Based on the data presented in Table 14 emergency ejection does not have any influence on the health status of pilots. However, it should be kept in mind, as mentioned above, that emergency ejection can favor degree II health impairment. The data in Table 11 confirmed that health deteriorates with age; the strength of this association is weak, but statistically significant (Kendall's tau-c=0.272).

Based on percentage profiles, there is an association between the number of flight hours and health impairment. This is especially clear in the group of healthy pilots, in whom the proportion of pilots without health impairment radically decreases with an increasing number of flight hours. The distributions are not significantly different (Tab. 12).

Based on the data presented in Table 13, emergency ejection occurs more frequently in the two groups of younger pilots. The majority of pilots who performed emergency ejections (51.4%) are 40-49 years old and 37.1% have 28-39 years. This might suggest an association between experience and emergency ejection. This association is statistically significant (Tab. 13).

Tab. 11. Age and degree of health impairment.

Age		Health impairment			In total
		Healthy	Degree I impairment	Degree II impairment	
28-39 years	n	11	3	6	20
	%	55.0%	15.0%	30.0%	100.0%
40-49 years	n	15	13	13	41
	%	36.6%	31.7%	31.7%	100.0%
50-58 years	n	2	5	12	19
	%	10.5%	26.3%	63.2%	100.0%
In total	n	28	21	31	80
	%	35.0%	26.3%	38.8%	100.0%

Pearson's chi-square = 10.837 p = 0.028
Kendall's Tau-c = 0.272 p = 0.003

Tab. 12. Number of flight hours and health impairment.

Number of flight hours		Health impairment			In total
		Healthy	Degree I impairment	Degree II impairment	
Low	n	15	5	13	33
	%	45.5%	15.2%	39.4%	100.0%
Moderate	n	10	10	11	31
	%	32.3%	32.3%	35.5%	100.0%
High	n	3	6	7	16
	%	18.8%	37.5%	43.8%	100.0%
In total	n	28	21	31	80
	%	35.0%	26.3%	38.8%	100.0%

Pearson's chi-square = 5.243 p = 0.263
Kendall's Tau-c = 0.256 p = 0.272

Tab. 13. Emergency ejection and age of studied pilots (comparative data).

Group		Age categories			In total
		28-39 years	40-49 years	50-58 years	
Experimental	n	13	18	4	35
	%	37.1%	51.4%	11.4%	100.0%
Control	n	7	23	15	45
	%	15.6%	51.1%	33.3%	100.0%
In total	n	20	41	19	80
	%	25.0%	51.3%	23.8%	100.0%

Pearson's chi-square = 7.648 p = 0.022
Phi Φ = 0.309 p = 0.022

Tab. 14. Emergency ejection and number of flight hours (comparative data).

Group		Number of flight hours			In total
		Low	Moderate	High	
Experimental	n	19	13	3	35
	%	54.3%	37.1%	8.6%	100.0%
Control	n	14	18	13	45
	%	31.1%	40.0%	28.9%	100.0%
In total	n	33	31	16	80
	%	41.3%	38.8%	20.0%	100.0%

Pearson's chi-square = 6.668 p = 0.036
Phi Φ = 0.289 p = 0.036

Based on Table 14, emergency ejection is performed more frequently by pilots with lower numbers of flight hours. This relationship is statistically significant.

DISCUSSION

Despite the advancement of aviation technologies, it is impossible to avoid all emergency situations that can lead to emergency ejections [3,5,7,10,16,18,28,31-35,37,44,47,48]. The increasing role played by new technical and informational solutions limits the role of human factor in the process of ejection, which remains the major cause of aviation disasters [22,23,38,42]. A number of solutions applied in the construction of the ejection seats are in place to reduce the risk of death and injuries. Aviation health care analyzes every case of emergency ejection with regard to its health consequences to the pilot, mechanisms of injury, effectiveness of emergency systems, hospital procedures and the scheme of action for medicolegal personnel who decides on the fate of the pilot [9,21,24].

The process of selecting candidates for military aviation needs to take into account not only the physical state but also the psychological condition [14,19,20,22,25,26,29,53]. Emergency ejection is a consequence of a quick decision that is not preceded by a detailed analysis of the current situation. Moreover, this can be further interfered by the necessity to communicate with air traffic management. This burden as well as fear of one's own life and of the aircraft negatively influence the pilots' psychological state. There are emotional reactions that impact on further occupational and personal activities of pilots. Based on a number of studies and observations, people are in a state of strong emotional arousal in situations that endanger their lives [11-15,36,41]; the actions of people are then imprecise, and reaction times are prolonged, which is very negative with regard to emergency ejection because of the decreased time available to prepare a proper body position and set off the ejection seat.

As regards the training of the of high-altitude rescue systems, it includes the requirement to get acquainted with technical details of ejection seats and proper safety conditions; moreover, psychological training and on-ground practice ejections with the UTKZ device and the MK-11 simulator are obligatory. The aim of the on-ground practice ejections is to use the device quickly and to learn to accept the fact that ejection devices are reliable and safe. Pilots learn the proper positioning that reduces the impact of large g-forces. However, it is certain that the psychological condition of pilots is the key factor that modifies their reactions.

Currently, pilots meet with psychologists only during routine examinations. A system of psychological help that could minimize the negative impact of emergency ejections on personal and professional life has not been organized. Among pilots who have severe bodily injuries or experience emotional or somatization disorders, the most frequent problems include alcoholism [11], reduction of occupational activity (reduction of flight groups), cessation of flying, sleep disorders and increased defense mechanisms. The job of the many psychologists of the MIAM is limited only to standard tests and studies. We are lacking in training and talks carried out in the military units (carried out only recently) and referring to operational risks and the role of the human factor in aviation events. During these trainings, pilots are prepared theoretically for situations that could astonish them in the air.

The bodily injuries that are incurred during emergency ejection are often due to safety mechanisms implemented in the seats and additional equipment of the pilot. The quality of these injuries influences the way of treatment and consequently the time of recovery and return to aviation service. Based on a developed medicolegal scheme, after discharge from hospital, pilots can be referred to a sanatorium. However, since the military health service was incorporated in the National Health Fund services, there are difficulties with finding placements in sanatoria (pilots are qualified according to the same criteria as patients covered by the services of the NHF).

Military Committee of Air Forces and Military Medicolegal Committees decide on a 30-day unfitness for aviation service in order to make it possible for pilots to recover with the help of local health care institutions. However, often, this is not done in the right way in the institutions covered by the NHF.

Based on the case series study presented herein, mild injuries that were incurred after emergency ejections or injuries that were not recognized immediately after ejection led to unfitness for military service in the long-term. Severe injuries (including psychological trauma) immediately led to cessation of aviation service in spite of treatment. Moderate injuries (mainly vertebral injuries) led to overload pain syndromes. The crucial period in which symptoms are revealed by the pilots is the time before cessation of service or periods in which the flight group has to be decreased because of "professional" reasons. Under such circumstances, pilots often admit to having symptoms during routine examinations and undergo more detailed diagnostic investigations. Pilots who are at the beginning of their career tend not to report the above-mentioned symptoms. It could be inferred that experienced pilots with a high number of flight hours tend to incur a larger number of injuries (both physical and psychological); however, the motivation for further military service probably plays here a greater role [29,39,41].

Guided interviews

A subjective evaluation of pilots' own health after emergency ejections was dependent on the degree of incurred injuries, intensity of pain and stressful situations related to treatment; it ranged between 1 and 10 points and was obviously the greatest in pilots who did not incur any injuries. Health care services were assessed the best by pilots who incurred the greatest injuries and required long-term health care or surgery. The assessment of psychological care was high (9-10 points in the majority of pilots). The studied pilots underlined the professionalism of psychologists and the necessity of psychological support. In direct talks, pilots also suggested that psychological support should be provided to their families.

Taking into account the possibility of dissimulation and "clinically silent" diseases [27], in the case of pilots who performed emergency ejections, the medicolegal committees (WKLSP and WKLL) extended the diagnostic procedures. Regardless of the presence of pain, pilots undergo an x-ray of the vertebral column every 5 years. In pilots who report pain, relevant diagnostic studies and specialist medical consults are performed during routine examinations. In difficult medicolegal cases, the committees ask for the opinions of the national consultants. This enables proper decision-making with respect to the fate of the pilot and his potential health impairment.

Interestingly, Kozlowski [27] found that, immediately after ejection or during hospitalization, pilots did not report any symptoms, but imaging studies show early degenerative changes in the vertebral column. After 48-72 hours, pain in the vertebral area tended to increase but was transient. This suggests a stretching injury of the ligaments and muscles. The above-mentioned injuries were classified as clinically silent. In my opinion, they did not have any influence on the career of pilots and it can be suspected that routine examinations performed after many years were similar as in the case of average pilots who never performed emergency ejections. This can also explain the results presented herein, whereby pilots who performed emergency ejections usually hade degree II health impairment.

Health status assessment – characteristics of injuries

Based on the research presented herein, emergency ejections were not significantly associated with vertebral changes. However, based on percentage profiles, chronic pain syndromes are more frequent among pilots who performed emergency ejections.

In the group of pilots who performed emergency ejections, 60% of cases did not have any health deficit, which indicates a relatively good health condition. Interestingly, 5.7% had 1-2 diseases and 34.5% had 3 or more diseases. This can suggest that emergency ejections can favor degree II health impairment.

As regards the control group, degree I or degree II health impairment was present in 84.4% of pilots. This indicates that emergency ejection does not have any influence on the health condition of pilots; at the same time, emergency ejections can favor degree II health impairment. Therefore, these pilots require constant monitoring of their psychophysical state; moreover, they need prophylactic treatment (physical therapy after flights, treatment in sanatoria, health leaves, etc.).

According to Kozlowski [27], who studied injuries in pilots who performed emergency ejections in a 26-year period (1980-2005), "the largest group of injuries was constituted by mild injuries (47%), primarily in the lower and upper extremities. Mild injuries had a local character and did not have any influence on the careers of pilots. Severe injuries had the greatest impact on pilot's careers. Sever injuries constituted 23% of all injuries, and 75% of them were found in the vertebral column (43% - injuries of the intervertebral discs, 27% - vertebral fractures in the thoracic and lumbar segment (Th-

L), 12% - injuries of ligaments with vertebral instability). The vertebral bodies Th6, Th8 and Th9 were fractured most commonly. Th6 and Th8 fractures were parts of multilevel fractures, whereas Th9 fractures were usually isolated. Fractures of the shoulder and injuries of the muscular-tendinous unit (biceps and Achilles tendon) constituted 5% of severe injuries; 4% of severe injuries were constituted by fractures of the extremities and 2% by fractures of the pelvis and injuries of knee ligaments".

It was found that emergency ejections were performed by younger pilots; the majority had 40-49 years, and 37.1% had 28-39 years. This can suggest a specific relationship between experience and emergency ejections (this relationship was statistically significant).

It was also found that emergency ejections are more frequent in pilots with a lower number of flight hours. This relationship was statistically significant. Similarly, according to Kozlowski [27], the largest number of emergency ejections was found among pilots aged 25-30 years who had 500-1000 of flight hours (they used the zero-zero ejection seats).

In our own research, we found the occurrence of emotional reactions described as posttraumatic stress disorder (different intensities) in pilots [18,23,40,43].

CONCLUSIONS

1. Based on the research presented herein, both mild and severe injuries related to emergency ejection led to unfitness for military service in the long-term. The pilots' subjective evaluation of their own health status was dependent on the degree of injury.
2. Moderate injuries, mainly injuries of the vertebral column, led to overload pain syndromes in the long-term.
3. Based on the analysis of distributions of variables, pilots who performed emergency ejections had a relatively good health condition; 60% did not have any health deficit, and in the control group, 84.4% of pilots had health impairment.
4. Severity of injuries has an influence on the way of treatment and consequently on the time of recovery and return to aviation service. The developed medicolegal scheme recommends further care in sanatoria after hospitalization.

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