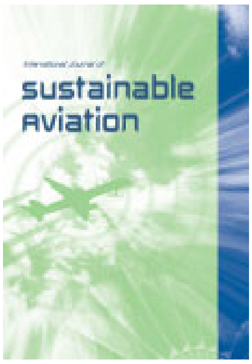

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Analysis of the pilots' decisions to eject in F-16 fighter aircraft accidents in Turkey

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Analysis of the pilots' decisions to eject in F-16 fighter aircraft accidents in Turkey

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Abstract: The aim of this study is to do a descriptive and statistical analysis of pilots' decisions to eject during F-16 fighter aircraft accidents in Turkey and evaluate the ejection decisions of pilots by comparing the findings to those presented by similar studies conducted in other countries. A total of 32 F-16 accidents were included in the study. Thirty-five pilots were involved in 32 accidents and 12 of these pilots lost their lives because they did not/did not manage to actuate the ejection system, and two pilots died despite the actuation of the ejection system. Despite the limited access to the available data because official accident investigation reports contain confidential information, the study is significant in that it is the first study dealing with Turkish pilots' decisions to actuate the ejection system and the consequences of these decisions and it contributes to the sustainability of Turkish fighter aircraft pilots' safety culture.

Keywords: aviation medicine; decision making; ejection system; human factors; Turkey.

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1 Introduction

Military flights have different rules and practices from civil flights. One of these practices, maybe the most important one, is leaving the aircraft when it is inevitable. This practice involves leaving the aircraft with an ejection seat after it is activated with a handle. In today's aircrafts, the ejection process automatically progresses once the ejection system is activated. Therefore, the most important issue to consider in relation to 'ejection' is pilot's decision to activate the system rather than the technology behind it (Callaghan and Irwin, 2001; McCarthy, 1988; Sandstedt, 1989; Visuri and Aho, 1992; Williams, 1993). Most of the deaths following an ejection are the result of delayed decisions of pilots (Callaghan and Irwin, 2001; Jenkins, 1991). 'Delayed ejection decision' is defined as "the death or injury due to the delay in decisions to eject as stated in the accident report" or, according to a broader definition, "to eject under 2000 feet in a controlled flight and under 10.000 feet in an uncontrolled flight" (Nakamura, 2007).

In aviation terms, decision making is defined by Federal Aviation Administration as a systematic approach to the mental process employed by pilots in order to carry out the best action in a consistent way according to certain conditions (Hunter, 2003). Fischer et al. (1995), in a more brief and concise way, defines it a "the mental process employed by pilots to make decisions".

Ejections are divided into three categories according to the time that passes between the emergency situation and ejection: immediate ejection (0–5 seconds), rapid ejection (6–30 seconds) and slow ejection (longer than 30 seconds) (Moreno et al., 1999).

Ejections are examined under three categories according to the level of 'control'. When an emergency situation occurs at high altitude, the pilot takes a necessary corrective action. It is called 'controlled ejection' when the pilot fails and has to decide to eject at a suitable altitude, at a suitable speed and in an area far away from people and suitable for parachute landing, and ejects by taking a suitable position. If an emergency situation develops at a relatively lower altitude, the pilot may lose the control of the aircraft. However, if there is still enough time to eject, 'semi-controlled ejection' occurs. Called semi-controlled ejections, such ejections might result in serious injuries or death. In case of ejections at very low altitudes or situations when there is very little time before the crash, the pilot might use this short time to solve the problem or to avoid crowds or he just freezes. These ejections, which are called 'uncontrolled ejection', are highly likely to result in death even if the pilot manages to eject (Chub et al., 1967).

1.1 Situations affecting decisions to eject

Ejection seat technology, the altitude where emergency situation occurs, the reason of this emergency situation and post ejection investigation process are the factors affecting pilots' decisions to eject (Callaghan and Irwin, 2001).

Since some of the ejection seats used in the past were known to tumble after the ejections, pilots tended to delay their decisions to eject until the last moment. In addition, the development of ejection seats allowing the ejection at 0 feet and 0 knot speeds, which is called zero-zero capacity as the latest technology, misleads pilots by leading to overconfidence and misinterpretation of the situation (Callaghan and Irwin, 2001).

During emergency situations at low altitudes, pilots tend to try to land the aircraft since they are afraid of getting injured, which naturally results in certain delays in decisions to eject (Callaghan and Irwin, 2001).

Pilots might decide to eject during serious and sudden emergency situations such as bird strike more easily than gradually developing emergency situations. If the reason of decision to eject is a technical problem, pilots might generally delay ejection until the aircraft stalls or they lose the control. If the pilots completely lose the control of the aircraft, it is more likely that ejection will take place within a certain safe time (Callaghan and Irwin, 2001; Moreno et al., 1999). Pilots' decisions are often delayed during the emergency situations caused by the pilot's error because they try harder to save the aircraft. The presence of many people that might be harmed in the area where the aircraft is flying can also affect pilots' decision to eject (Callaghan and Irwin, 2001; Sandstedt, 1989).

Costs and benefits of ejection also affect pilots' decision. Each pilot has a strong desire to save his/her aircraft. The main reason of their desire is to save the country's property. Another reason is the possibility of a success story by saving the aircraft from a difficult situation. In fact, the pilot is likely to disobey some commands while trying to do this. Although the altitude required for an ejection during an uncontrolled flight is exceeded, he tries to save the aircraft (Callaghan and Irwin, 2001).

All aircraft accidents, regardless of the presence of ejection or not, are subject to official investigation. If this investigation report reveals that the ejection was carried out inappropriately, some orders were not obeyed and the emergency situation could have been managed in a different way, the pilot might lose his job, which also might cause delays in his decisions. There is a remarkable difference between a senior and unexperienced pilot in terms of pressure they are exposed to after an ejection because the senior pilot will be more knowledgeable and more prepared against criticisms. The studies conducted in a simulator environment showed that experience is not a factor affecting decisions to eject; however, experienced pilots are more decisive about ejection (Callaghan and Irwin, 2001). Some studies reported that it is easier to make decisions to eject in two-seat aircrafts due to the confidence of supporting each other against possible criticisms. On the other hand, decisions to eject might be delayed in two-seat aircrafts because one pilot has to wait for the other pilot to actuate the ejection system (Callaghan and Irwin, 2001; Newman, 2013), which clearly shows the importance of human factors in aviation. Gerbert and Kemler (1986) found that the correlation ratio between low levels of experience and pilot errors as 11.7%. In addition, McFadden (1997) classified the factors affecting accidents and incidents due to pilot errors into two main categories. The factors in the first category were determined as personal factors: age, experience (total hours of flight), exposure to risk (the most recent hours of flight), health (e.g., alcohol use), personality traits and gender. This study also found that some factors such as age, experience, gender, personality traits and alcohol use are related to accidents caused by pilot errors. It also showed that accident rate gets lower when pilots are older. The studies focusing on the correlation between experiences (total hours of flight) and accidents due to pilot error report that there are fewer accidents as hours of flight increase (Golaszewski, 1983; McFadden, 1993).

In addition to above mentioned issues, pilots trust their aircrafts, so they may not want to leave this safe environment and end up in a place where they do not know what will happen. Therefore, it is known that pilots who receive parachute training give decisions to eject more easily. Another advantage of getting parachute training is lower risk of injury during landing (Hepper, 2006; Moreno et al., 1999; Visuri and Aho, 1992).

Decisions to eject are generally given in vague situations, in which reasons (what is the emergency situation and its consequences) and the consequences of the pilot's decision are not clear. However, it is often necessary to make the decision to eject in a very short time. Therefore, accuracy of decision might be sacrificed for immediacy of this decision. Decision to eject provokes considerable stress on individuals. This situation is a factor causing a delay in making a correct and suitable decision to eject. Pilots' decision to eject is quite challenging and complex, which also includes many more factors. Military pilots who fly in a challenging and dangerous zone should also consider the possibility of ending up in an enemy zone while making their decisions in addition to negative consequences of the emergency situation. Fischer et al. (1995) claim that risk and time pressure might restrain such a decision process due to the necessity to give an immediate reaction no matter whether this emergency situation is clearly identified or not.

The literature review revealed that the number of research articles focusing on decisions to eject and death-injury data after the ejection in the world is quite limited. The number of pilots who ejected, the years and death-injury data are presented in Table 1 (Sandstedt, 1989; Visuri and Aho, 1992; Nakamura, 2007; Biesernans and Vandenboach, 1992; Epstein et al., 2020; Gheorghiu and Boscoıanu, 2015; Milanov, 1996; Newman, 1995; Rowe and Brooks, 1984; Campbell, 2003; Werner, 1999). Major injury refers to the following situations in an accident: a hospital stays longer than 5 days after the ejection, loss of consciousness for more than 5 minutes, broken bones (except nose and fingers), dislocated joints, internal organ injury, third-degree burn or more than 5% second-degree burn (McCarthy, 1988; Nakamura, 2007; Werner, 1999).

Table 1 The number of ejecting pilots, the years, death-injury data and countries in literature

Country	*Years*	*Total ejected pilots*	*Death*		*Major injuries*	
			Number	*Rate (%)*	*Number*	*Rate (%)*
Japan	1956–2004	138	32	23.19	13	9.42
USA	1949–2002	5446	959	17.61	-	-
Bulgaria	1953–1993	60	10	16.67	14	23.33
Belgium	1970–1990	64	10	15.63	21	32.81
Spain	1979–1995	48	7	14.58	25	52.08
Romania	1952–2014	87	9	10.34	-	-
Sweden	1967–1987	91	9	9.89	4	4.40
Australia	1951–1992	84	7	8.33	42	50
Canada	1972–1982	77	5	6.49	8	10.39
Finland	1958–1991	17	1	5.88	5	29.41
Israel	1990–2019	37	2	5.41	7	18.92
Germany	1981–1997	85	2	2.35	30	35.29

This study aims to evaluate Turkish pilots' decisions to eject by comparing the findings of similar studies in other countries through descriptive statistical analysis regarding Turkish F-16 fighter aircraft pilots' decisions to eject.

In the next section, the methodology of this study is explained on how data collection of F-16 fighter aircrafts and statistical analysis for the number of pilots who decide to actuate ejection are performed. In the following sections, the results of the study, discussion and conclusions are presented.

2 Method

2.1 Data collection

The study was carried out by analysing the data obtained from a website which publishes the most comprehensive database about F-16 fighter aircrafts (https://www.f-16.net/aircraft-database/F-16/mishaps-and-accidents/airforce/TuAF/) as an open resource. 'F-16 accident investigation data' submitted between 1987, when Turkish Army started to use F-16 fighter aircrafts, and May 2021 were analysed by accessing them from the website's database. The accident list prepared according to the information presented in these reports were confirmed by the news accessed via national press, internet search engines and goklerdeyiz.net website (http://www.goklerdeyiz.net/gecmisten-gunumuze-turk-hava-kuvvetlerine-ait-f-16-ucak-kazalari/), which publishes aviation-related news. The necessary permissions were taken from the administrators of the websites to use the available data for the purposes of this study. The names of the martyr pilots were confirmed by the data obtained from the Aviation Martyrs' Album (Hava Kuvvetleri Personel Başkanlığı, 1999) published by Turkish Air Force.

Only the accidents involving aircrafts flown by Turkish pilots were included in the analysis. The accidents involving the aircrafts flown by foreign pilots, although they occur in Turkey, the accidents involving aircrafts other than F-16 fighter aircrafts and the accidents that do not result in ejection and death (sliding off the runway during landing and fires at air docks, etc.) were all excluded from the analysis.

2.2 Data file

The accidents were grouped according to the following criteria: whether the pilot ejected or not, whether the pilot survived or not and the time of the accident.

2.3 Statistical analysis

SPSS 24.0 was used for the statistical analyses. Descriptive analysis was done for the number of pilots who lost their lives in aircraft accidents and the related ratios. The confidence level was calculated by using the formula below in order to compare the ratio of Turkish pilots who *did not / did not manage to* make decisions to eject to those found in the previous studies and determine whether there are significant differences when compared to the findings of these studies (Ozdemir, 2005).

$$95\% \text{ confidence interval} = \mathrm{p} \pm 1.96\sqrt{(\mathrm{p}(1-\mathrm{p}))/n}$$

Here, ‘n’ is the number of pilots who are involved the accident and ‘p’ is the ratio of pilots who *did not / did not manage to* make decisions to eject.

The same formula was also used to compare the ratio of Turkish pilots who died although they decided to eject. In this version of the formula, ‘n’ is the number of pilots who decided to eject and ‘p’ is the ratio of pilots who died although they decided to eject.

Odds ratio was used to compare the following two variables: whether the accidents occurred at night or in the daytime, and decisions to eject in these accidents.

3 Results

The first F-16 fighter aircrafts arrived in Turkey in 1987 and the first F-16 aircraft accident occurred in 1991, since when a total of 34 F-16 aircraft accidents have been reported in Turkey. One of these accidents was sliding off the runway after landing and another one was an accident on the ground, so these two accidents were excluded from the analysis and 32 accidents were analysed within the scope of this study. Of these 32 accidents, 29 occurred in one-seat aircrafts and 3 in two-seat aircrafts and 35 pilots were involved in these accidents. The first F-16 accidents occurred in 1991 and the last one in 2018 and the pilots actuated the ejection system in 21 accidents. 12 pilots died in 11 accidents, in which they *did not/did not manage to* actuate the ejection system and two pilots died in 21 accidents in which the pilots actuated the ejection system. In summary, 35 pilots were involved in 32 accidents and 14 pilots (40%) lost their lives. The number of pilots and deaths in F-16 accidents is given in Table 2.

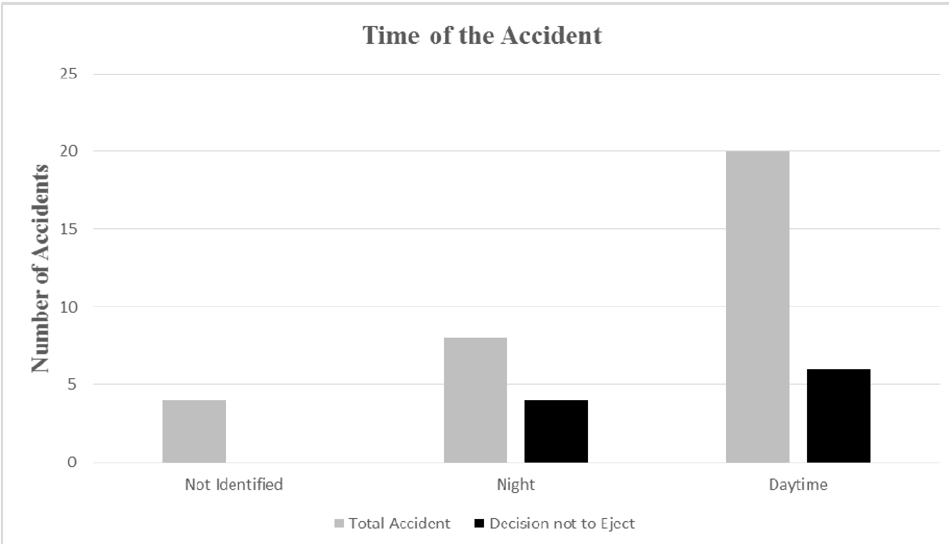
Table 2 The number of pilots and deaths in F-16 accidents

Decision to eject	*Number of accident*	*Number of pilots*	*Number of death*
Yes	21	23	2
No	11	12	12
Total	32	35	14

12 pilots lost their lives because they *did not/did not manage to* actuate the ejection system in 32 accidents in which 35 pilots were involved. The confidence interval calculated for the pilots who *did not / did not manage to* make decision to eject (34.29%) was found to be between 19% and 50%. In other words, if the data reported in other similar studies are lower than 19%, this implies that the ratio of decisions to eject is considerably high in Turkey and if these data are higher than 50%, it means the ratio in Turkey is considerably low.

Of the 23 pilots involved in 21 accidents where the pilots actuated the ejection system, two pilots lost their lives (8.70%). The confidence level calculated for the pilots who died despite actuating the ejection system was found to be between 0% and 20.12%. In other words, if the data reported in other similar studies are higher than 20.12%, this implies that the ratio of death in accidents in which pilots actuated the ejection system is considerably low in Turkey.

Figure 1 Time of the accidents and the number of the accidents whose the pilots *did not/did not manage to* actuate the ejection system



The researchers could not identify the time of accident in 4 of the total 32 accidents. 8 of 28 accidents (28.6%) occurred at night and 20 (71.4%) in the daytime. In 4 of the 8 accidents (50%) that occurred at night, the pilots *did not / did not manage to* actuate the ejection system, while this ratio is 30% (6 accidents out of 20) for the accidents that occurred in the daytime. The ratio of daytime accidents to night accidents was found to be 62 times higher according to odds analysis. In addition, the ratio of the pilots who *did not/did not manage to* actuate the ejection system at night to those who *did not/did not manage to* actuate the ejection system in the daytime was found to be 2.33 according to odds analysis. The number of accidents according to the time is shown in Figure 1.

4 Discussion

The death rate in Turkey in 21 accidents in which 23 pilots were involved was determined as 8.7%, which is lower than the data of 7 countries out of 12 as presented in Table 1. Unfortunately, this study could not reveal the number of pilots with major injury due to the lack of patient files although there are some data stating that pilots survived or were hospitalised. A comparison of the total number of pilots who ejected (6257) and the number of the pilots who died after the ejection (1055) reveals that the number of Turkish pilots who died after the ejection is lower than the overall average (11.16%). However, only the death rate of Japan (23.19%) is significantly higher than 20.12%, which is the 95% confidence level for the death ratio in Turkey after the ejection. No significant differences were found for the ratios of other 11 countries. Therefore, although Turkish pilots' death rate after ejection is low, this ratio is not significantly different from the data of the other countries except Japan (Nakamura, 2007).

It is possible to obtain more accurate results by evaluating the death rate in all the accidents in addition to the death ratio of the pilots regardless of the actuation the ejection system. The literature review revealed that there are not enough related studies to make a comparison. In a study conducted in England, 313 pilots involved in aircraft accidents were analysed and it was found that 76 (24.28%) pilots did not actuate the ejection system. Majority of the accidents were identified as controlled flight into terrain (CFIT) or accidents of collision in the air (Lewis, 2006). Another study conducted in Sweden, 121 pilots involved in aircraft accidents were analysed and it was found that 30 (24.79%) pilots did not actuate the ejection system (Sandtstedt, 1989). Similarly, 12 pilots (34.29%) in Turkey died in 32 F-16 fighter aircraft accidents involving 35 pilots because they *did not / did not manage to* actuate the ejection system. This ratio is higher than those of England and Sweden. However, no significant difference was determined since the ratios of other countries are between 19% and 50%, which is 95% confidence interval.

71.8% of the F-16 accidents in Turkey occurred in the daytime, which is 2.5 times higher than those that occurred at night. However, when this ratio is statistically interpreted, it is found that the possibility of accidents in the daytime is 62 times higher than at night, which can be explained by considerably higher number of flights in the daytime. Just like this significant difference between night and daytime in terms of the possibility of accidents, the possibility of deciding to eject in the daytime is 2.5 times higher than at night. The low number of decisions to eject at night might result from spatial disorientation due to limited vision and CFIT as reported by a study conducted in England. Pilots may have problems in evaluate some negative situations or fail to notice an abnormal situation due to spatial disorientation (Poisson and Miller, 2014).

5 Conclusions

The most important limitation of the study is that the official accident investigation reports cannot be examined. Since these reports are classified as ‘confidential’, they are not accessible via open sources. Although this study does not report a detailed evaluation about the reasons of these accidents, it contributes to the literature as the first academic study dealing with Turkish pilots’ decisions to eject and consequences of these decisions.

According to the lessons taken from the previous accidents, pilots should be taught to try certain solutions to emergency situations before they actuate the ejection system but also how to activate this system immediately when it is necessary. In addition, they should be told that countries need well-trained pilots as much as they need aircrafts since there is an increasing demand for qualified human resource in aviation industry. We should always keep in mind that if ejection is inevitable despite efforts to solve emergency situations, ejection is quite a safe way and, in fact, what is unsafe is a delayed decision to eject.

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