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Military aviation and vision. The impact of aerodynamic force on vision

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HIGHLIGHTS
Exposure to aerodynamic forces can lead to various vision problems.

ABSTRACT
The state of health and vision plays a crucial role in the effective and safe performance of duties by military pilots. Working in the air and exposure to aerodynamic stress can lead to various vision problems, which can be both temporary and permanent. Symptoms of dry eye syndrome, susceptibility to cataracts, and macular degeneration are more common among pilots than in the general population. Additionally, flights in hyperbaric chambers and significant aerodynamic stress can induce various ocular symptoms, such as corneal swelling, flashes in the eyes, or visual field disturbances, which can temporarily affect vision. Although most of these symptoms are reversible, there is a need for more scientific research on ophthalmic issues related to the work of military pilots to better understand these issues and develop appropriate prevention strategies. In the context of military operations, maintaining healthy vision is a key factor in the success of missions.

Key words: military aviation, aerodynamic force, aerospace medicine, flight safety, pilots' visual

INTRODUCTION

Military aviation plays a key role in modern military operations, providing mobility, fire support, and strategic advantage. However, working in an aviation environment comes with numerous challenges, including health and physical fitness risks for pilots [1]. One of the most significant factors affecting the effectiveness of aviation operations is the health and psychophysical fitness of aviation personnel, especially vision health [2]. Vision standards for military pilots were established as early as the 1920s, based on the visual systems of aircraft from that period. Despite significant advancements in aviation technology, these standards have changed little [3]. Vision plays a crucial role in executing aviation tasks, where quick reaction and precise environmental perception are key to operational safety and effectiveness [4]. However, the aviation environment, with its specific conditions, can negatively affect pilots' visual abilities, leading to various visual field disorders and other vision-related health issues [5].

The purpose of this study is to precisely determine the impact of aviation on vision, with particular emphasis on military pilots and problems related to visual field disorders. A review of the scientific literature in this area will allow us to delve into the essential aspects of aviation personnel's eye health and identify the risks and challenges that may arise in the context of their work.

METHODOLOGY

A thorough review of medical literature was conducted to understand the effects of aviation on vision, particularly concerning military pilots and visual field problems. This review involved a detailed analysis of relevant scientific publications to fully understand the issue. The first step was utilizing databases, primarily the renowned PubMed database, providing access to a rich collection of publications in medicine, ophthalmology, and eye surgery. The search was conducted using defined keywords such as "military aviation," "aerodynamic overload," "visual field disorders," "aviation medicine," "pilot vision," and others, tailored to aviation specifics. In the selection process, titles and abstracts of articles were reviewed to assess their relevance to the study topic. The next step was a thorough review of selected publications to extract critical information and findings on the impact of aviation on vision. The collected data was analysed and synthesized, identifying and selecting articles for further analysis. Information in the selected publications regarding various techniques, research results, action effectiveness, safety aspects, and other significant aviation-related topics was carefully synthesized and compared, allowing the identification of the most valuable insights.

VISUAL IMPAIRMENT DURING FLIGHT

Visual efficiency plays a crucial role in aviation operations, especially for military pilots. Quick reactions and signal recognition are essential for mission success and personnel safety. Studies conducted at various pilot experience levels have shown the impact of experience on reaction time and situational awareness, favouring pilots with longer service [6]. It turns out that the majority of accidents caused by visual perception and image processing impairments among pilots are attributed to visual illusions [7]. An additional challenge of airborne work is night vision, which can distort perception [8]. Another critical issue is the growing fatigue experienced by pilots during flights, which also leads to fatal aviation accidents [9, 10]. Attention has also been given to the use of lasers as a distraction during military air missions. An analysis of 21 cases involving military pilots revealed that none suffered permanent vision damage despite exposure to various types of laser beams [11]. The use of UVA and UVB protective shields is recommended, as pilots are particularly vulnerable to UV radiation. There is evidence of an increased risk of cataracts and maculopathy in individuals exposed to ultraviolet radiation [12]. Modern technology allows for eye movement tracking in pilots during flights; these movements change with increasing fatigue, and the accuracy of such studies reaches 93.55% [13]. There is a lack of research on the effects of aging on pilots' vision. According to isolated reports, it is similar to the general population: sensitivity to contrast, dynamic acuity, recovery from glare, low-light functioning, and information processing all deteriorate with age [14].

OTHER CAUSES OF VISION IMPAIRMENT IN MILITARY PILOTS

In 2018, a case was described for the first time involving a 41-year-old pilot who experienced vision changes while performing manoeuvres in a fighter aircraft. He was diagnosed with non-arteritic anterior ischemic optic neuropathy, a rare condition among pilots. Studies suggested that high-G manoeuvres may have triggered the episode in this patient and could be a risk factor for this condition in pilots [15]. Another factor that can impair vision and pilots' response time during flight is the occurrence of dry eye syndrome (DES). DES is related to age, the number of weekly flights, average flight hours, and flight altitude. As many as 72.3% of pilots report experiencing DES symptoms during flights, with 5.4% experiencing daily symptoms unrelated to flight conditions [16]. Another study found that 95% of aircraft crews experience tear film instability and discomfort during flights, particularly those who wear contact lenses or smoke cigarettes. Due to abnormal humidity and gas concentrations in the aircraft, conjunctivitis and DES are more common among crew members [17]. Military pilots are more prone to age-related macular degeneration (AMD) than the general population [18], which can lead to vision loss and force a career or position change. Another threat to vision and flight safety is lens opacity. Even early changes in transparency can cause glare, fog, and colour perception changes [19]. Pilots develop cataracts earlier than the general population [20]. However, after cataract surgery, pilots regain full visual acuity and can safely continue their work [21].

THE IMPACT OF G-FORCE ON VISION

During flights, fighter pilots are exposed to high G-forces along the +Gz axis (gravitational force acting on the body's vertical axis), which can lead to impaired blood flow to the brain. Loss of consciousness occurs when acceleration forces prevent sufficient blood supply to the brain, which may manifest as a loss of peripheral vision, up to total blindness [22]. A study was conducted to determine the effect of G-forces on pilot orientation in the tilt plane and compare pilot reactions during actual flight. Eight pilots were tested under both conditions using similar acceleration profiles. Results showed that despite inter-individual variability, group mean and individual response characteristics were similar under both conditions [23]. Unwanted symptoms persist in 5% of pilots for more than a day, making it difficult for them to function and continue working. Symptoms include visual flickering, photopsia, balance disturbances, and impaired visual-motor coordination [24]. A case was described of an S-70A-9 Blackhawk helicopter pilot who experienced significant, reversible vision impairment due to G-force (+2.5 Gz), likely caused by fatigue and dehydration, highlighting the risks in tactical helicopter operations [25]. It has been proven that G-forces ranging from +3 Gz to +4 Gz can cause partial blindness in relaxed individuals in good condition. Total blindness typically occurs between +4 Gz and +4.5 Gz [26]. Another study found that the effects of G-force on the body begin with blurred vision, followed by grey-out, and eventually total blindness. These symptoms are reversible once G-forces are reduced [27]. In a survey of 325 jet pilots, 95.7% reported experiencing episodes of blindness during flight [28]. Among 65 fighter pilots, 98% reported experiencing at least one visual disturbance under high-G conditions [29]. Experiments using +6 Gz observed temporary decreases in visual acuity, increased anterior chamber depth, and pupil dilation. These changes persisted for 15–30 min after the force ceased [30]. With +9 Gz, decreases in visual acuity, corneal thickening, anterior chamber deepening, and pupil dilation were observed [31]. A meta-analysis of 5 studies showed an average increase in corneal thickness of 13.4 μm after 12-hour high-altitude exposure or its equivalent in a hyperbaric chamber [32]. Preventing vision loss and consciousness at high G-forces in aircrew requires awareness of risks and training to recognize symptoms and correctly perform anti-G manoeuvres. Additionally, proper equipment use and conditional training to increase G-force tolerance are essential [22]. G-force exposure can also result in optic disc swelling. In one case, after a fighter jet flight, visual acuity decreased to 20/25, and retinal haemorrhages and congestion were observed, along with changes in the visual field. Vision improved after hyperbaric oxygen therapy [33]. Experiments simulating conditions at 7620 m showed visual field disturbances in pilots, affecting about 5% of subjects, and these defects were temporary [34].

CONCLUSIONS

Modern systems and technologies provide tools to enhance pilots' visual perception, but continuous research and adaptation to changing operational conditions are key to maintaining the highest safety standards in military aviation. This study can contribute to a better understanding of the complex impact of aviation on vision and the development of strategies to minimize risks associated with health issues in this field.

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