Skin Pathology Prevalence in Deployed Fighter Aircrew Using Custom Molded Hearing Protection

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INTRODUCTION: During a deployment of a fighter unit, aircrew began to exhibit ear discomfort and episodes of auricular irritation and ulceration. All affected were using the Attenuating Custom Communications Earpiece System (ACCES). Discomfort was previously discussed in the literature, but neither the prevalence of discomfort nor the occurrence of skin ulcerations had been previously described.

METHODS: An anonymous paper questionnaire was used with three fighter squadrons while deployed in 2019. A total of 59 aircrew in the F-15C/E and F-16 airframes participated; aircrew not using ACCES were excluded.

RESULTS: Response rate was 57.3%, spread evenly among airframes, with 78% being pilots. A majority of respondents (79.7%) stated they had ACCES problems in the deployed setting. Among those noting problems in the deployed setting, 89% reported ear discomfort and a smaller portion reported skin redness, erosion, and bleeding.

DISCUSSION: This study was able to provide a small sample estimate of the prevalence of ear problems among fighter aircrew ACCES users while deployed. This sample exhibited an increase in prevalence of ear discomfort during the deployment. It also showed pathological features absent in home-station flying, such as skin redness and erosion. However, the sample size and study design prevented risk factor characterization, confounder control, or causal inference. While ACCES may contribute to these problems, other confounders such as air characteristics, recall bias, aircrew motivation to report problems, and baseline dermatologic pathology could not be excluded. This data should serve as a baseline for larger studies, which are better equipped for confounder control and assessment of other potential risk factors.

KEYWORDS: dermatitis, noise reduction, high performance aviation, operational medicine.

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Hearing protection is vital in military aviation, especially in the fighter jet community, due to repeated exposure to high intensity noise. Modern fighter jet cockpits can have sustained sound levels between 115–120 dB, with exterior airflow, avionics cooling systems, and environmental control/cabin pressurization systems being the primary noise sources.[10] Prolonged exposure to noise at these levels is well known to cause sensorineural hearing loss (SNHL). This presents a significant burden of disease in the fighter aviator community, with one study finding a mean incidence rate of SNHL of 19.56 new cases per 1000 persons per yr between 1997 and 2011.[9]

While advances in airplane design have produced louder cockpits, the need for the pilot to communicate clearly, sometimes simultaneously with several agencies, has increased exponentially. The modern battlespace requires rapid and frequent information sharing and direction between multiple control agencies, ground troops, wingmen, flight leads, and mission commanders.[5] Clear communication is essential to exchanging tactical information and ensuring safety of flight. One survey of pilots reported that 18% had experienced a potentially dangerous event caused by problems with radio communication, with high levels of background noise as a commonly cited contributor.[6]

In previous generations of aircraft, pilots relied solely on the hearing protection built into their helmets: an ear-cupping

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mold integrated into the flight helmet with a speaker present in the center. With the advent of noisier cockpits, dual hearing protection became necessary as some air forces noted that in-ear canal noise levels could be as high as 91 dB in modern fighter aircraft when relying on helmet-only hearing protection.[4,7] Initially, aircrew relied upon foam ear plugs, but this carried the trade-off of impaired ability to hear communications from the helmet's built-in speakers. This led to the development of in-ear hearing protection devices that incorporated speakers to allow for communications sound to bypass hearing protection systems and be clearly heard by the aircrew member. These communication ear plug (CEP) systems can be either foam-based, which have a universal fit, or custom-molded (m-CEP), usually using a silicone-based compound tailored to the individual user. These systems offer hearing protection with the added benefit of providing clear transmission of communications sounds that are better understood by aviators.[5,7,12]

Recognizing the need for better hearing protection coupled with improved communications fidelity, the US Air Force Research Laboratory (AFRL) teamed with Westone Laboratories, Inc. to develop the Attenuating Custom Communications Earpiece System (ACCES). The ACCES m-CEPs were first deployed with the F-22 community in 2005 and have since been made available and widely adopted throughout USAF fighter aircrews.[8] Aircrew using m-CEP systems have reported satisfaction with the level of hearing protection and ability to understand radio communications, which was reinforced in a Finnish Air Force study that found that 93% of users would recommend the system to others[6], as well as another that found that 85% of users reported improved speech intelligibility.[7]

Shortly after the adoption of m-CEPs, problems were noted with these systems. Specifically for ACCES, a survey conducted in 2008 of F-22 and F-15C pilots noted that while only 18% of users preferred foam ear plugs over ACCES, 78% of users reported discomfort when using ACCES.[3] A survey of Finnish F/A-18 pilots noted 42.2% reporting outer ear discomfort.[7] Discomfort and even "hot spots" from ACCES earplugs are not unknown to the manufacturer and are, in fact, documented in the user manual. When discomfort occurs, the ACCES m-CEP can be ground or shaped to achieve a better fit. If that is ineffective, new molds can be made in an attempt to achieve a more comfortable fit.[1] Despite these issues, positive experiences have been noted in other studies which have shown a 90% satisfaction rate, and adoption of these systems continues beyond the USAF to other air forces around the world.[7,11]

Increased relative discomfort due to static mechanical pressure of molded hearing protection systems when compared to foam systems has been previously documented.[2] What has not been previously studied is the specific effect of using molded systems during long-duration sorties that can be typical of a combat mission. In this study, we seek to examine aircrew experiences and reports of discomfort when compared to their use at home versus when flying in a deployed environment.

METHODS

Upon noticing several aircrew presenting to a deployed clinic with ear pain complaints attributed to ACCES during a deployment in 2019, a questionnaire was designed to better assess the magnitude of the problem. This questionnaire was administered to aircrew flying the F-15C, F-15E, and F-16CJ in the southwest Asia deployed environment. Institutional review board (IRB) oversight was considered by the 711th Human Performance Wing at Wright-Patterson AFB, OH; however, this study was determined to be exempt from IRB oversight under exemptions for operational equipment testing and evaluation. Further approval was obtained from the US Central Command Surgeon to conduct this study in the area of his operational oversight.

Questionnaire

Over a period of 4 wk, a paper-based questionnaire was distributed to pilots and weapons system officers (WSO) of 3 different USAF squadrons while still in the deployed environment. Completed questionnaires were placed in a container left in the aircrew working area to allow for anonymous completion of the study. The first part of the questionnaire obtained basic aircrew demographics, including position, age, total flying hours or years, and level of flying responsibility. Gender was not ascertained due to concerns about the ability to maintain confidentiality. To date, females are underrepresented in aviation, with a substantial magnification of that demographic disparity in the fighter jet community. Of the airframes included in this questionnaire, there are only a total of 31 females in pilot or WSO positions, representing 1.87% of the entire community.[13] Given the total number of respondents, the authors did not feel they could adequately maintain confidentiality if gender data were collected.

Demographic data was followed by questions that probed the experience with the ACCES system while at home station, prior to deployment. Questions included: years of ACCES use; home average sortie length and frequency; frequency of ACCES wear; presence of ACCES problems; and if they had ever stopped wearing ACCES. The final portion of the questionnaire readdressed the same questions regarding ACCES experience at home, but now in the deployed environment. Aircrew that experienced problems with ACCES in the deployed environment were then asked further questions about the nature and duration of the problem, as well as if it led to discontinuation of ACCES wear. If ACCES wear was terminated, additional questions were asked regarding the duration of wear avoidance and the time for problems to resolve. Aircrew that continued to wear ACCES despite problems were asked to elaborate as to why they had made that decision. Questionnaire responder demographics are described in **Table I** and **Table II**.

Statistical Analysis

Data analysis was conducted utilizing Microsoft Excel 2016 (Redmond, WA) and Stata BE version 17.0 (College Station, TX). Aircrew who did not report using the ACCES system were

Table I. Study Demographics.

DEMOGRAPHIC	AVERAGE	STANDARD DEVIATION	LOWER RANGE	UPPER RANGE
Age	31.6	5.18	24	45
Years aircrew experience	7.79	4.94	1	19
Total career flying hours	1380	777	300	3000

excluded from the study. To assess potential confounders, aircrew were further broken down by age (29 yr and under, 30–39 yr, 40 yr and greater), number of total flying hours (less than 1000 h, 1000–1999 h, 2000 h and greater) and total years of ACCES use (less than 3 yr, 3–7.9 yr, 8 yr and greater). Respondents were considered to be reporting problems with their ACCES system if they reported pain, discomfort, skin redness, bleeding, skin erosion, or other symptoms on any of the home or deployed questions. They were also specifically asked if they had stopped using their ACCES system and, if so, what symptom had caused them to discontinue wear in both the home and deployed questions.

RESULTS

In all, 59 aircrew participated in the study (57.3% response rate). Aircrew ages were not normally distributed (right skewed), ranging from 24 to 45 yr old with an average age of 31.6 yr (SD = 5.2) and median age of 30 yr. Also, career aircrew flying hours were not normally distributed (right skewed), ranging from 300 to 3000 h with an average of 1380 h (SD = 777) and a median of 1200 h. A positive linear relationship between age and flying hours was observed (R = 0.852). Among respondents, 78% (N = 46) were pilots and 22% (N = 13) were WSOs. Aircrew were fairly evenly divided between all three aircraft types with 32.2% (N = 19) flying the F-15C, 45.8% (N = 27) the F-15E, and 22.0% (N = 13) the F-16CJ.

Sortie length when at the home-base environment, which is dominated by training missions, was reported to average 1.69 h (SD = 0.67). This is contrasted with the deployed average sortie length of 5.89 h (SD = 0.36), which represents a 4.2-h increase (95% CI 4.00–4.40) in sortie duration ($P < 0.0001$). Sortie frequency did not increase by a statistically significant margin, averaging 3.12 sorties per wk (SD = 0.53) at home and 3.31 sorties per wk (SD = 0.36) while deployed.

Baseline problems at home station with ACCES were reported in 39% of aircrew. Affected aircrew noted that ear discomfort was the most prevalent problem (87% of respondents who noted problems). In the deployed environment, the number of aircrew reporting problems increased to 79.7%, an absolute increase of 40.7% (95% CI 24.6–56.8%, $P < 0.0001$). Again, ear discomfort was most frequently cited by aircrew (89% of respondents that noted problems). Skin redness and pain increased in prevalence, and skin erosion and bleeding, which did not garner any responses in the home station affected population, appeared on responses while deployed (N = 17). It is worth noting that among aircrew who experienced adverse symptomology associated with ACCES, 44.7% experienced problems both at home and while deployed, while 55.3% only reported symptoms while deployed, though these differences are not statistically significant (P = 0.076). In addition, no statistically significant differences in symptom-reporting were evident between the three squadrons or when pilots were compared to WSOs.

Presumably because of these problems, aircrew reported an 18.6% absolute increase (95% CI 6.38–30.8%, P = 0.004) in ACCES wear stoppage between the home and deployed environment (5.1–23.7%, respectively). Reasons for stopping use in the deployed environment were mostly due to ear discomfort and pain. There were only 3 individuals that reported stopping wear at home station, however all noted ear discomfort and pain as the reason for stopping.

Among those who stopped ACCES while deployed, 6 noted skin damage. Regardless, of the 47 participants that reported ACCES problems, 87% continued to wear them despite these problems. ACCES wear being essential to hear and communicate via the radio was the primary reason to continue use.

Table II. Aircrew Characteristics and History Data.

AIRCREW DATA	*N**	PERCENT
Airframe		
F-15C	19	32.2
F-15E	27	45.8
F-16C	13	22.0
Aircrew Position		
Pilot	46	78.0
WSO	13	22.0
Experience Rating		
Wingman	20	33.9
2 Flight Lead	6	10.2
4 Flight Lead	14	23.7
Instructor Pilot	19	32.2
ACCES History		
Molds previously redone	7	11.9
Previously used for long duration missions	55	93.2

*N = 59.

DISCUSSION

Lack of normal distribution in age and flying hours is expected due to the U.S. military career progression system. Increasing years of military experience are constrained by competitive promotion to the next rank and competition with the civilian aerospace sector, which offers advantages in both pay and lifestyle. Therefore, any survey-based study of U.S. military aviators would be expected to produce a similar distribution of age and experience.

The magnitude of the contribution of age and flying hours to ear pain is difficult to ascertain from this study; larger studies will need to be conducted to better quantify the scale of that effect. Another confounder could be recall bias, which could possibly be exacerbated by the fact that aircrew had heard stories of ear pain from ACCES from other members of their squadron. Finally,

aircrew could have been motivated to over-report problems to draw attention to a perceived problem and push the USAF to procure more advanced hearing protection systems in the future.

Despite these confounders, this study was the first to show the magnitude of this problem in the deployed environment. Further studies will be needed to increase the statistical power of the conclusion that increased duration of ACCES wear is linked to ear pain and ear skin pathology.

Flight surgeons briefing their squadrons prior to deployment should make their aircrew aware of this issue and discuss possible mitigation strategies, including periodic avoidance of wearing ACCES and increased spacing of sorties. Aircrew should be informed that while they may not have experienced problems at their home station, they may experience them when in theater. However, with discontinuation of wear, it is suggested that the ear will heal, and they can resume wear of the ACCES system.

Additionally, operational units should consider bringing equipment for ACCES modification on deployment or when operating from locations where long duration missions are anticipated. This equipment can be used by Aircrew Flight Equipment (AFE) shops to adjust molds based on aircrew ear symptoms. Flight surgeons should also bring materials needed to recast molds if modification attempts are unsuccessful. Even though it would take several weeks until new molds arrived, possible future problems might be avoided.

While deployment is not, based on this study, a confirmed risk factor for ACCES related problems, initial impressions are that increased mission duration and less than optimal device fitting may be contributing factors. Further study is needed to fully determine the broad prevalence of this problem and potential risk factors that could predict its occurrence.

The number of participants and timing of the survey did not allow for adequate statistical power and proper epidemiological design to assess for risk factors. Ideally, such studies would follow multiple units with data collected before, during, and after deployment. Additionally, given the critical nature of communications in operational settings, further study seems reasonable—not only to address prevalence, but to identify risk management measures which could reduce adverse outcomes.

In conclusion, in a small prevalence study of aircrew wearing the ACCES hearing protection system in a deployed environment and flying long-duration missions, an increase in ear discomfort complaints was noted. Additionally, there were sporadic reports of skin erosions and wear discontinuation. Further studies will be needed to better characterize this issue.

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