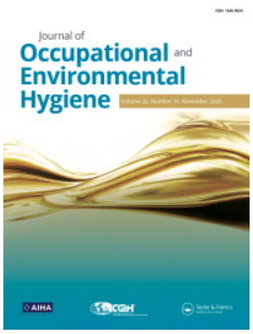

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Evaluating United States Air Force hearing conservation educational materials for compliance, readability, understandability, and actionability

Thomas Dominguez[a], Lucas Pettit[a], Clayton Garner[a], Dirk P. Yamamoto[b], James A. VanDerslice[c], Rodney G. Handy[d], Lisa H. Gren[c], and Darrah K. Sleeth[a]

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ABSTRACT

Noise-induced hearing loss and tinnitus are two of the most prevalent service-connected disabilities of United States military veterans. Educational materials meant for hearing conservation program-eligible Airmen were evaluated from active-duty, continental United States (CONUS) Air Force bases for compliance with US Air Force (USAF), Department of Defense (DoD), and Occupational Safety and Health Administration (OSHA) regulations. Understandability and actionability were assessed using the Patient Education Materials Assessment Tool for Audiovisual Materials (PEMAT-A/V), while readability was assessed with Flesch-Kincaid Grade Level (FKGL). Educational materials were received from 44 of 61 (72%) active-duty, CONUS bases, with 27 bases sending one item and 17 bases sending multiple items, for a total of 67 educational materials, which were evaluated by three evaluators. Educational materials were categorized into one of four types: (A) supervisor's guide to hearing conservation ($n = 21$); (B) new worker hearing conservation training ($n = 20$); (C) two-page hearing conservation program training pamphlet ($n = 14$); and (D) other ($n = 12$). Overall mean compliance was 84% (CI: 63,100) (USAF), 83% (CI: 62,100) (DoD), and 88% (CI: 67,100) (OSHA), respectively. Overall mean understandability was 75% (CI: 63,87) and actionability was 89% (67,100). There was good agreement between the three evaluators for each of the criteria (87-90%). Overall mean readability was grade level 10.68 ± 1.68 on the FKGL scale. For educational materials, 65 of the 67 (97%) were above the recommended 6th-grade reading level, and 62 of the 67 (93%) educational materials were above the average American 8th-grade reading level. This study established compliance, understandability, actionability, and readability scores for educational materials that military service members receive upon entry into the hearing conservation program, gathered from active-duty, CONUS Air Force bases. Using the determined scores, recommendations, such as providing active feedback and condensing information, were given to improve future hearing conservation educational materials.

KEYWORDS

Flesch-Kincaid Grade Level (FKGL); military; noise-induced hearing loss; Patient Education Materials Assessment Tool (PEMAT); regulation; veterans

Introduction

The United States Air Force (USAF) and the Department of Defense (DoD) as a whole have had a problem with occupational noise and hearing loss in United States (US) military service members for generations. The Vietnam Experience Study conducted by the Centers for Disease Control in 1988 compared 7,924 enlisted Army Vietnam veterans against 7,364 non-Vietnam veterans, determined that Vietnam veterans were 40% more likely to have high-frequency hearing loss, and demonstrated a difference in exposures between the military and civilian populations (CDC 1988). The Institute of Medicine found that a US Navy "touch and go" activity by an F4 aircraft had a noise level of 121 dBA; a US Army high-mobility multi-purpose wheeled vehicle (HMMWV), heavy variant at full payload, had a noise level of 100 dBA at crew positions; and M9 9 mm pistols had peak pressure impulse noise levels of 157 dBP when compiling hazardous noise exposure sources during military service from World War II to 2005 (IOM 2005). Baseline audiograms upon entry into the armed services have not been reliably conducted or required

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for the DoD, making it difficult to identify temporary or permanent hearing threshold shifts in service members (IOM 2005). Tinnitus and noise-induced hearing loss (NIHL) were the top two most prevalent service-connected disabilities claimed by US veterans in fiscal year 2020, comprising ~13% of all compensated disabilities (DoVA 2021). According to a 2020 National Health Statistics Report, veterans aged 18 to 44 were over three times more likely to have trouble hearing compared to nonveterans (18.0% vs. 5.3%) (Lucas and Zelaya 2020). Folmer et al. (2011) reported a tinnitus prevalence of 12% in veterans versus the 5% associated with nonveterans (Folmer et al. 2011).

However, solutions such as eliminating the noise source and refining hearing conservation programs (HCP) are actively refined to reduce the risks to service members (IOM 2005; Yankaskas et al. 2017; Moore et al. 2019; Beamer et al. 2020). The US Occupational Safety and Health Administration (OSHA) requires employers to institute a hearing conservation program by 29 Code of Federal Regulation (CFR) 1910.95 Occupational Noise Exposure when occupational noise exposures exceed an action level of 85 dBA over the average of an 8-hr period (CFR 2014). The DoD also has regulations in place to minimize hazardous occupational noise exposure to its servicemembers, specifically in the form of DoD Instruction 6055.12 Hearing Conservation Program, which outlines guidelines for the US Armed Forces to implement (DOD 2019). The USAF meets the DoD Instruction's intent by providing tactical guidance to its Airmen by way of Air Force Instruction (AFI) 48-127 Occupational Noise and Hearing Conservation Program, which specifies directives on how the USAF is to implement hearing conservation programs at each of their bases and identifies topics that Airmen must be educated on regarding hearing conservation (DAF 2022).

Despite the burden of tinnitus and NIHL, there is no service-wide, standardized training protocol for educating servicemembers on the correct placement and use of hearing protection. Implementation of this educational component of the USAF's Hearing Conservation Program is determined locally at each USAF Base, resulting in variation among bases. A general lack of training standardization across the DoD, although offering a degree of autonomy for each of the US Armed Forces, creates the potential for training gaps amongst the separate services (IOM 2005). Best practices can be formally or informally requested or suggested by Major Commands or other entities, but, unless specified elsewhere, each USAF base can address these requirements locally as they see fit. This means that active-duty Airmen may receive differing hearing conservation educational materials that likely still meet OSHA, DoD, and USAF compliance criteria but may not be best suited for a particular Airman.

The importance of educating on how to properly insert hearing protection cannot be overstated. A 2006 study of 301 naval flight deck service members found that, of those who either sometimes (38%) or always (14%) wore their earplugs, only 7% of these personnel inserted them properly (Bjorn et al. 2006). Although annual audiometric testing is effective at finding temporary and permanent hearing threshold shifts, both types of shifts occur after an individual has already experienced the symptoms of acute or chronic hazardous noise exposure. Achieving a greater understanding of what occupationally-exposed service members are taught regarding hearing conservation could help the USAF reduce these threshold shifts from occurring.

Research aims

Because there is variability across base hearing conservation training implementation strategies and significant numbers of veterans are experiencing tinnitus and temporary or permanent threshold shifts due to NIHL, this study aimed to describe hearing conservation educational materials utilized across the USAF, specifically to: (1) determine compliance of hearing conservation educational materials with OSHA, DoD, and USAF regulations; and (2) assess readability, understandability, and actionability of these educational materials to identify potential opportunities for improvement. These four criteria (compliance, understandability, actionability, and readability) were chosen as a multi-pronged approach to evaluate the effectiveness of the educational materials distributed by USAF bases within the continental United States (CONUS) to hearing conservation program-eligible Airmen.

Methods

This research was classified as exempt by the University of Utah's Institutional Review Board, IRB_00161076, on 8 March 2023 and given concurrence by the Department of the Air Force's Component Office of Human Research Protections, FSG20230018, on 15 June 2023 that this was not DoD-supported research involving human subjects. A cross-sectional convenience sample of all active-duty, CONUS USAF bases ($n = 61$) was the target population, while Air National

Guard, Air Force Reserve Command, and overseas bases were excluded from this study.

Data collection

Publicly available phone numbers were sought for Public Health flights (i.e., the USAF Base representatives for the hearing conservation program) within medical treatment facilities to request hearing conservation educational materials for each base. A phased approach was used to request hearing conservation educational materials for all of the bases. The first phase consisted of randomizing the base order and requesting (by telephone) an electronic copy of the educational materials given to workers upon entering the Hearing Conservation Program, conducted between 22 June and 6 July 2023. Bases that could not be reached or did not send their educational materials by email after the first phase were again requested (in the same order as originally sought) during a second phase, conducted between 26 and 28 July 2023. All items were received by 1 August 2023 from facilities that participated.

Evaluation of materials

The educational materials were evaluated independently by three research team members (TD, LP, CG). Educational materials from each base were reviewed in a random order, with the order different for each of the three reviewers. All educational materials were assessed for compliance, then for understandability/actionability, and finally for readability.

Data from the reviews were compiled into a set of data tables using Qualtrics (November 2023, Provo, UT, USA) as the data entry user interface to minimize data entry errors. The educational material review data were recoded using the R Foundation for Statistical Computing (4.1.2 (2021-11-01), Vienna, Austria) via RStudio (2023.09.1 + 494, Boston, MA, USA). Any duplicate or mismatched data entries were identified, clarified, and categorized appropriately in post-analysis. Data were analyzed using SAS (OnDemand for Academics 2024, Cary, NC, USA) and Microsoft (MS) Excel (Microsoft 365, Version 16.80, Redmond, WA, USA), which was also used to generate tables and figures. Table 1 shows a summary of all evaluation criteria.

Compliance

Compliance was assessed using 29 CFR 1910.95, *Occupational Noise Exposure* (published 1 July 2023), DoD Instruction 6055.12 *Hearing Conservation Program* (dated 14 August 2019), and Department of the Air Force Instruction (DAFI) 48-127 *Occupational Noise and Hearing Conservation Program* (certified current 15 September 2022) as guides. Where requirements for hearing conservation training were mentioned in these guides, it was noted and cross-referenced across all three entities (see Table 1). Compliance with hearing conservation training requirements was recorded in a 22-item data entry form that was used to evaluate the educational materials from each of the bases, indicating either agreement or disagreement as to whether each of the educational materials discussed the associated unique and overlapping requirements of the aforementioned guides. Where multiple criteria were contained within a single line item (e.g., on- and off-duty sources of hazardous noise), criteria were split to help identify additional opportunities for improvement.

Understandability & actionability

Hearing conservation educational materials were created, tailored, and provided by preventive medicine personnel, in conjunction with supervisors, within the USAF; therefore, these educational materials were evaluated as patient-focused health education information. A relatively new (2014) and validated tool used to evaluate and compare how understandable and actionable patient educational materials are is the Patient Education Materials Assessment Tool for Audiovisual Materials (PEMAT-A/V) (Shoemaker et al. 2014). The PEMAT-A/V assesses 17 separate criteria on an agree/disagree/not applicable scale, which are then added and divided by the total possible points to arrive at percentages for both understandability and actionability. For example, an evaluator would assess educational material using criteria such as *the material uses illustrations and photographs that are clear and uncluttered*; an evaluator would then indicate *agree*, *disagree*, or *not applicable* (e.g., no visual aids). Developed under contract for the Agency for Healthcare Research and Quality (AHRQ), the PEMAT-A/V specifically assesses content, word choice & style, organization, layout & design, and use of visual aids for understandability while assessing a few key items for actionability. Higher PEMAT-A/V percentages for both understandability and actionability indicate that one educational material is easier to understand and act upon than another. The PEMAT-A/V provides an understandability score and an actionability score, with higher scores generally indicating increased understanding and how encouraged

Table 1. Evaluation criteria for compliance, understandability, and actionability of hearing conservation training materials.

				Regulation		
				USAF[a]	DoD[b]	OSHA[c]
Compliance	Hazardous noise	C1	Effects of (hazardous) noise on hearing	2.12.10.2.1 2.20.13.1	3.7.a.(1)	(k)(3)(i)
		C2	On-duty sources of hazardous noise	2.12.10.2.1		
		C3	Off-duty sources of hazardous noise	2.12.10.2.1		
	Hearing protection devices	C4	Purpose of hearing protection	2.12.10.2.1 2.20.13.1	3.7.a.(2)	(k)(3)(ii)
		C5	Advantages of various HPD types	2.12.10.2.2	3.7.a.(3)	(k)(3)(ii)
		C6	Disadvantages of various HPD types	2.12.10.2.2	3.7.a.(3)	(k)(3)(ii)
		C7	Attenuation of various HPD types	2.12.10.2.2	3.7.a.(3)	(k)(3)(ii)
		C8	Proper selection of HPDs	2.20.13.2	3.7.a.(4)	(k)(3)(ii)
		C9	Proper fitting (or wear) of HPDs	2.12.10.2.3 2.20.13.2	3.7.a.(4)	(k)(3)(ii)
		C10	Proper use of HPDs	2.12.10.2.1 2.12.10.2.3 2.20.13.1 2.20.13.2	3.7.a.(4)	(k)(3)(ii)
		C11	Procedures to report any concerns about the proper fit and use of HPDs		3.7.a.(2)	
		C12	Proper care of HPDs	2.12.10.2.3 2.20.13.2	3.7.a.(4)	(k)(3)(ii)
		C13	Interaction between HPDs interfacing with other personal protective equipment	2.12.10.2.4 2.20.13.3		
	Audiometric testing	C14	Purpose of audiometric testing	2.12.10.2.5 2.20.13.4	3.7.a.(6)	(k)(3)(iii)
		C15	Explanation of audiometric test procedures	2.20.13.4	3.7.a.(7)	(k)(3)(iii)
		C16	Results of audiometric testing	2.20.13.4		
	Administrative	C17	Requirement to wear assigned protective equipment	2.12.10.2.7	3.7.a.(5)	
		C18	Requirement to wear HPDs when exposed to hazardous noise on duty	2.20.13.1		
		C19	Impact of hearing loss on career opportunities and quality of life		3.7.a.(8)	
		C20	Potential for administrative actions that may follow for failure to wear HPDs	2.12.10.2.7	3.7.a.(5)	
		C21	Potential disqualification from current	2.12.10.2.6 2.20.13.1		

(*Continued*)

Table 1. Continued.

				Regulation		
				USAF[a]	DoD[b]	OSHA[c]
			duties as a result of hearing loss			
		C22	Importance of wearing (or recommendation to wear) hearing protection when exposed to hazardous noise off duty	2.12.10.2.1 2.20.13.1	3.7.a.(9)	
Understandability[d]	Content	U1	Makes its purpose completely evident			
	Word choice & style	U2	Uses common, everyday language			
		U3	Medical terms are used only to familiarize audience with the terms. When used, medical terms are defined.			
		U4	Uses the active voice			
	Organization	U5	Breaks or "chunks" information into short sections			
		U6	Sections have informative headers			
		U7	Presents information in a logical sequence			
		U8	Provides a summary			
	Layout & design	U9	Uses visual cues (e.g., arrows, boxes, bullets, bold, larger font, highlighting) to draw attention to key points			
		U10	Text on the screen is easy to read			
		U11	Allows the user to hear the words clearly (e.g., not too fast, not garbled)			
	Use of visual aids	U12	Uses illustrations and photographs that are clear and uncluttered			
		U13	Uses simple tables with short and clear row and column headings			
Actionability[d]		A1	Clearly identifies at least one action the user can take			
		A2	Addresses the user directly when describing actions			
		A3	Breaks down any action into manageable, explicit steps			
		A4	Explains how to use the charts, graphs, tables, or diagrams to take action			

[a]Department of the Air Force Instruction 48-127, *Occupational Noise and Hearing Conservation Program*, certified current 15 September 2022.
[b]Department of Defense Instruction 6055.12, *Hearing Conservation Program*, dated 14 August 2019.
[c]United States Title 29, Code of Federal Regulations, Part 1910, Section 95, *Occupational Noise Exposure*, published 1 July 2023.
[d]PEMAT-A/V.

an Airman would be to take action, respectively. Under the assumption that most educational materials would be MS PowerPoint slides, the PEMAT-A/V was utilized to standardize the data collection.

Responses to the PEMAT-A/V were recorded in a 17-item, standardized data entry form that was used to evaluate 13 understandability and four actionability questions (see Table 1). As recommended by AHRQ, evaluators reviewed the PEMAT-A/V User Guide to familiarize themselves with the tool and referenced it during evaluation to ensure adherence with the guidelines. Questions were presented one at a time to ensure they were answered in the order intended (i.e., no skipping allowed). Scores were calculated using SAS (OnDemand for Academics 2024, Cary, NC, USA). Both understandability and actionability scores were calculated for each educational material by summing each evaluator's number of questions agreed to, dividing by the total possible points (e.g., excluding not applicable questions), and converting to a percentage, respectively.

Readability

Readability refers to how "easy" it is to read a text and is typically conveyed in the US as an educational grade-level equivalent. The Flesch-Kincaid Grade Level (FKGL), originally developed by and for the US Navy (Kincaid et al. 1975), was used for a few important reasons: (1) its utility has been validated in the literature (Albright et al. 1996; Badarudeen and Sabharwal 2008; Bluman et al. 2009; Polishchuk et al. 2012; Eltorai et al. 2014); (2) its output indicates US grade level-equivalent values that can be compared to the American Medical Association's (AMA) recommended reading level of sixth grade (Weiss 2003) and the average US adult reading level of eighth grade (Doak et al. 1995); and (3) reporting of the FKGL is provided in MS Word.

All documents, Adobe PDFs (Adobe Acrobat Pro, 2023.008.20458, San Jose, CA, USA), and MS PowerPoint presentations (Microsoft 365, Version 16.80, Redmond, WA, USA) were exported to Rich Text Format, randomly ordered, and then opened in MS Word (Microsoft 365, Version 16.80, Redmond, WA, USA) to use its built-in FKGL calculator. Rich Text Format was selected as all documents, PDFs, and MS PowerPoint presentations could be converted to that format within their respective program.

Descriptive statistics (mean, standard deviation, and confidence intervals) were calculated for all

quantitative variables. A randomized naming convention was applied post-analysis to ensure base anonymity and to ease result interpretation, specifically: base identification number (1 thru 44), educational material categorical type (A thru D), and an additional identification number if there were multiple educational materials from the same base in the same category (1 thru 2). For example, one of the educational materials may be identified as 20.D2 to signify base 20, an educational material categorical type of (D) Other, and this is the second of two materials sent from base 20.

Results

Educational materials were received from 44 of 61 (72%) active-duty, continental USAF bases, with 27 bases sending one item and 17 bases sending multiple items, for a total of 67 educational materials, likely giving a representative sample. Eight bases (13%) could not be reached despite multiple attempts, six bases (10%) were reached but did not send their materials, two bases (3%) deferred to larger bases, and one base (2%) was not requested due to the USAF having recently become the lead service of the joint base, leading to its unintentional exclusion.

Educational materials were categorized into one of four types: (A) a supervisor's guide to hearing conservation; (B) new worker hearing conservation training; (C) a two-page hearing conservation program training pamphlet; and (D) other. All 67 educational materials were assessed by the three evaluators, leading to a total of 201 assessments for compliance, understandability, and actionability, respectively. Readability was assigned in MS Word for all 67 educational materials by one evaluator for a total of 67 assessments. Table 2 summarizes the results for all bases, further delineated by the educational material type and evaluator. While more variable than educational materials within categories (A), (B), or (C), the (D) other materials were still included and evaluated since bases would have given these materials to Airmen entering the hearing conservation program.

Educational material formats varied primarily by categorical type. Both (A) a supervisor's guide to hearing conservation ($n = 21$) and (B) new worker hearing conservation training ($n = 20$) were multi-slide MS PowerPoint presentations that covered the required regulatory items with headings, subheadings, bulleted information, and figures. The (C) two-page hearing conservation program training pamphlets ($n = 14$) were tri-folds that also covered the required regulatory

Table 2. Mean compliance, understandability, actionability, & readability scores for all bases, by type and evaluator.

		Compliance										Understand-Ability		Actionability		Readability	
		Total		USAF		DoD		OSHA									
(# of Criteria)		(22)		(20)		(18)		(11)				(13)		(4)		Flesh-Kincaid Grade Level	
Educational material type	n	Mean (%)	(CI) (%)	Mean (%)	(CI) (%)	Mean (%)	(CI) (%)	Mean (%)	(CI) (%)			Mean (%)	(CI) (%)	Mean (%)	(CI) (%)	n	Mean ± SD
(A) Supervisor's guide to hearing conservation	63	87	(81,93)	91	(85,97)	90	(84,96)	96	(90,100)			76	(70,82)	84	(61,100)	21	11.96 ± 1.01
Evaluator A	21	89	(82,96)	93	(86,100)	92	(86,98)	97	(89,100)			72	(68,76)	52	(41,63)	21	11.96 ± 1.01
Evaluator B	21	86	(80,92)	92	(87,97)	89	(83,95)	99	(96,100)			83	(79,87)	100	N/A		
Evaluator C	21	85	(81,89)	88	(83,93)	89	(84,94)	91	(88,94)			73	(71,75)	100	N/A		
(B) New worker hearing conservation training	60	92	(88,96)	96	(93,99)	94	(91,97)	99	(95,100)			76	(66,86)	99	(94,100)	20	10.75 ± 1.00
Evaluator A	20	91	(89,93)	95	(93,97)	93	(90,96)	99	(95,100)			63	(60,66)	99	(93,100)	20	10.75 ± 1.00
Evaluator B	20	91	(89,93)	96	(94,98)	94	(93,95)	100	(98,100)			83	(80,86)	100	N/A		
Evaluator C	20	93	(88,98)	97	(92,100)	94	(90,98)	99	(95,100)			82	(80,84)	98	(91,100)		
(C) Two-page hearing conservation program training pamphlet	42	82	(66,98)	81	(65,97)	81	(63,99)	84	(66,100)			81	(70,92)	89	(70,100)	14	9.54 ± 0.96
Evaluator A	14	76	(53,99)	75	(53,97)	79	(54,100)	79	(53,100)			79	(69,89)	93	(66,100)	14	9.54 ± 0.96
Evaluator B	14	89	(78,100)	90	(80,100)	87	(72,100)	86	(73,99)			91	(87,95)	100	N/A		
Evaluator C	14	79	(71,87)	78	(71,85)	78	(69,87)	86	(73,99)			73	(65,81)	75	(67,83)		
(D) Other	36	53	(25,81)	54	(25,83)	55	(26,84)	61	(29,93)			66	(48,84)	79	(49,100)	12	9.68 ± 2.53
Evaluator A	12	55	(26,84)	56	(26,86)	59	(29,89)	63	(31,95)			54	(39,69)	73	(35,100)	12	9.68 ± 2.53
Evaluator B	12	55	(27,83)	58	(28,88)	55	(25,85)	63	(30,96)			78	(61,95)	85	(51,100)		
Evaluator C	12	48	(20,76)	49	(19,79)	50	(21,71)	58	(26,90)			65	(50,80)	79	(66,92)		
Grand total	201	81	(61,100)	84	(63,100)	83	(62,100)	88	(67,100)			75	(63,87)	89	(67,100)	67	10.68 ± 1.68

items but in a concise (1-2 sentence) format, with few headings, some figures, and many underlined subheadings denoting the subject to be covered (e.g., "Effects of Noise on Hearing"). The (D) other educational materials ($n = 12$) varied widely, examples being a 16-slide MS PowerPoint presentation on noise being a hearing hazard, a 4-page noise and hearing protection fact sheet, and a desk reference for hearing conservation monitoring.

Compliance

Overall mean compliance ($n = 201$) for all 67 educational materials, for all three evaluators, for the 22 combined USAF, DoD, and OSHA criteria, was 81 ± 20%. Looking specifically at USAF (20 criteria), DoD (16 criteria), and OSHA (11 criteria) compliance, overall mean compliance ($n = 201$) was 84 ± 21%, 83 ± 21%, and 88 ± 21%, respectively. The compliance items ($n = 201$) most likely to be found in the educational materials by the evaluators were the *effects of (hazardous) noise on hearing* (C1, 97 ± 18%), the *purpose of hearing protection* (C4, 96 ± 20%), and the *proper use of hearing protection devices* (C10, 96 ± 20%). The compliance items ($n = 201$) least likely to be found by the evaluators in the educational materials were *procedures to report concerns about proper fit and use of HPDs* (C11, 27 ± 45%), *on-duty sources of hazardous noise* (C2, 46 ± 50%), and an *explanation of audiometric test procedures* (C15, 67 ± 47%).

When differentiating by educational material categorical type, the (B) new worker hearing conservation training materials ($n = 60$) had the highest overall compliance (92 ± 4%), with a compliance range across the means for the various standards of 94–99% (USAF: 96 ± 3%, DoD: 94 ± 3%, and OSHA: 99 ± 4%). In decreasing overall compliance order, total compliance was 87 ± 6% ($n = 63$, USAF: 91 ± 6%, DoD: 90 ± 6%, and OSHA: 96 ± 6%) for the (A) supervisor's guide to hearing conservation; 82 ± 16% ($n = 42$, USAF: 81 ± 16%, DoD: 81 ± 18%, and OSHA: 84 ± 18%) for the (C) two-page hearing conservation program training pamphlets; and 53 ± 28% ($n = 36$, USAF: 54 ± 29%, DoD: 55 ± 29%, and OSHA: 61 ± 32%) for the (D) other training materials submitted.

Understandability & actionability

Overall mean understandability ($n = 201$) for all 67 educational materials, across all three evaluators and 13 understandability PEMAT-A/V criteria, was 75 ± 12%. The understandability items most likely to be found in the educational materials by the evaluators were: (i) *sections have informative headers* (U6, $n = 185$, 98 ± 15%), (ii) *uses visual cues (e.g., arrows, boxes, bullets, bold, larger font, highlighting) to draw attention to key points* (U9, $n = 201$, 98 ± 16%), and (iii) *presents information in a logical sequence* (U7, $n = 201$, 96 ± 21%). The understandability items least likely to be found by the evaluators in the educational materials were: (i) *provides a summary* (U8, $n = 185$, 7 ± 26%), (ii) *uses the active voice* (U4, $n = 201$, 40 ± 49%), and (iii) *text on the screen is easy to read* (U10, $n = 201$, 44 ± 50%). When differentiating by educational material categorical type, understandability was determined to be highest for the (C) two-page hearing conservation program training pamphlets ($n = 42$, 81 ± 11%), followed by the (A) supervisor's guide to hearing conservation ($n = 63$, 76 ± 6%), the (B) new worker hearing conservation training ($n = 60$, 76 ± 10%), and the (D) other training materials ($n = 36$, 66 ± 18%).

Overall mean actionability ($n = 201$) for all 67 educational materials, across all three evaluators and 4 actionability PEMAT-A/V criteria, was 89 ± 22%. The actionability item most likely to be found in the educational materials by the evaluators was *the material identifies at least one action the user can take* (A1, $n = 201$, 98 ± 16%). The actionability item least likely to be found by the evaluators in the educational materials was *the material addresses the user directly when describing actions* (A2, $n = 201$, 79 ± 41%). When differentiating by educational material categorical type, actionability was highest for the (B) new worker hearing conservation training ($n = 60$, 99 ± 5%), followed by the (C) two-page hearing conservation program training pamphlets ($n = 42$, 89 ± 19%), the (A) supervisor's guide to hearing conservation ($n = 63$, 84 ± 23%), and (D) other training materials ($n = 36$, 79 ± 30%).

Readability

Overall mean readability for all 67 educational materials, reported as FKGL, was 10.68 ± 1.68. When differentiating by educational material categorical type, FKGLs were: 11.96 ± 1.01 for the (A) supervisor's guide to hearing conservation ($n = 21$), 10.75 ± 1.00 for the (B) new worker hearing conservation training ($n = 20$), 9.54 ± 0.96 for the (C) two-page hearing conservation program training pamphlets ($n = 14$), and 9.68 ± 2.53 for (D) other training materials ($n = 12$).

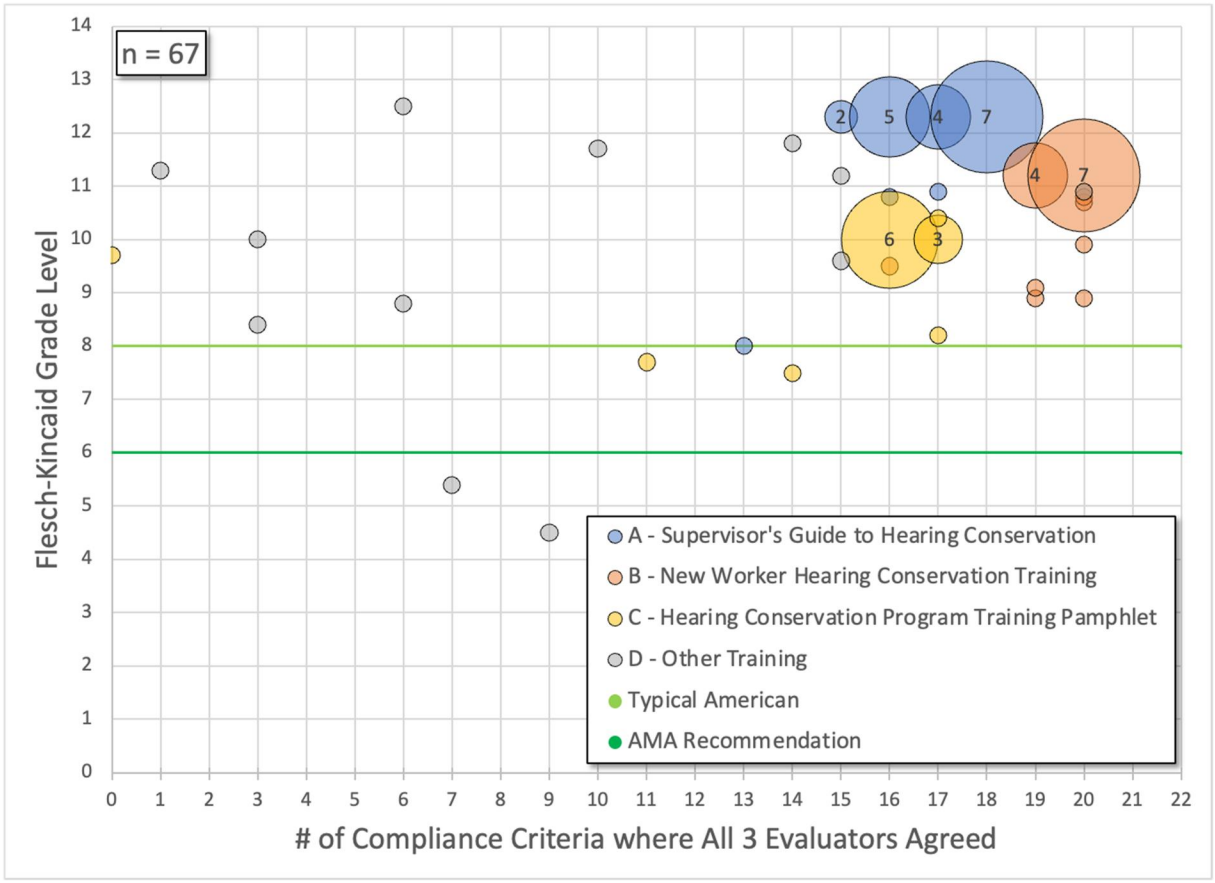

Figure 1. Educational material frequency comparing compliance and Flesch-Kincaid grade level, by category.

Figure 1 compares the FKGL (lower is better) to the total number of compliance criteria where all three evaluators agreed it was met (further right is better) for each of the 67 educational materials. The lower right quadrant is ideal for meeting both compliance and readability metrics, and no materials were located in this quadrant. Colors distinguish educational material type while circle size represents the number of educational materials with the same FKGL and compliance criteria (i.e., number inside the circle represents quantities higher than one). Solid lines indicate both the average American's reading level (8th grade) and the AMA's recommended educational material reading level (6th grade). As shown in Figure 1, 65 of the 67 (97%) educational materials were above the AMA's recommended 6th grade reading level, and 62 of the 67 (93%) educational materials were above the average American's 8th grade reading level. When distinguished by educational material type, clustering was found slightly above (A) 12th grade when 15-to-18 of 22 compliance items were met for the supervisor's guide to hearing conservation, (B) 11th grade but dipped into 9th grade while still meeting 19-to-20 of 22 compliance items for the new worker hearing conservation training, and (C) 10th grade while meeting 16-to-17 of 22 compliance items for the hearing conservation program training pamphlet. There were no distinguishable compliance patterns for (D) other training materials, though readability was generally above 8th grade. Figure 1 also shows the relationship between compliance and readability, with the educational materials demonstrating relatively high compliance but also high FKGL (i.e., lower readability). Ideally, the materials would be in the lower right-hand corner, which represents high compliance and high readability (i.e., lower FKGL).

Variability amongst educational material types

When differentiated by educational material type, overall standard deviation amongst evaluators for total compliance criteria was low for (A) the supervisor's guide to hearing conservation ($n = 63$, $\sigma_A = 6\%$) and (B) the new worker hearing conservation training ($n = 60$, $\sigma_B = 4\%$) but was higher for (C) the two-page hearing conservation program training pamphlet ($n = 42$, $\sigma_C = 16\%$) and (D) other training materials ($n = 36$, $\sigma_D = 28\%$). For understandability, the overall standard deviation for the educational material types was ($\sigma_A = 6\%$, $\sigma_B = 10\%$, $\sigma_C = 11\%$, $\sigma_D = 18\%$) while

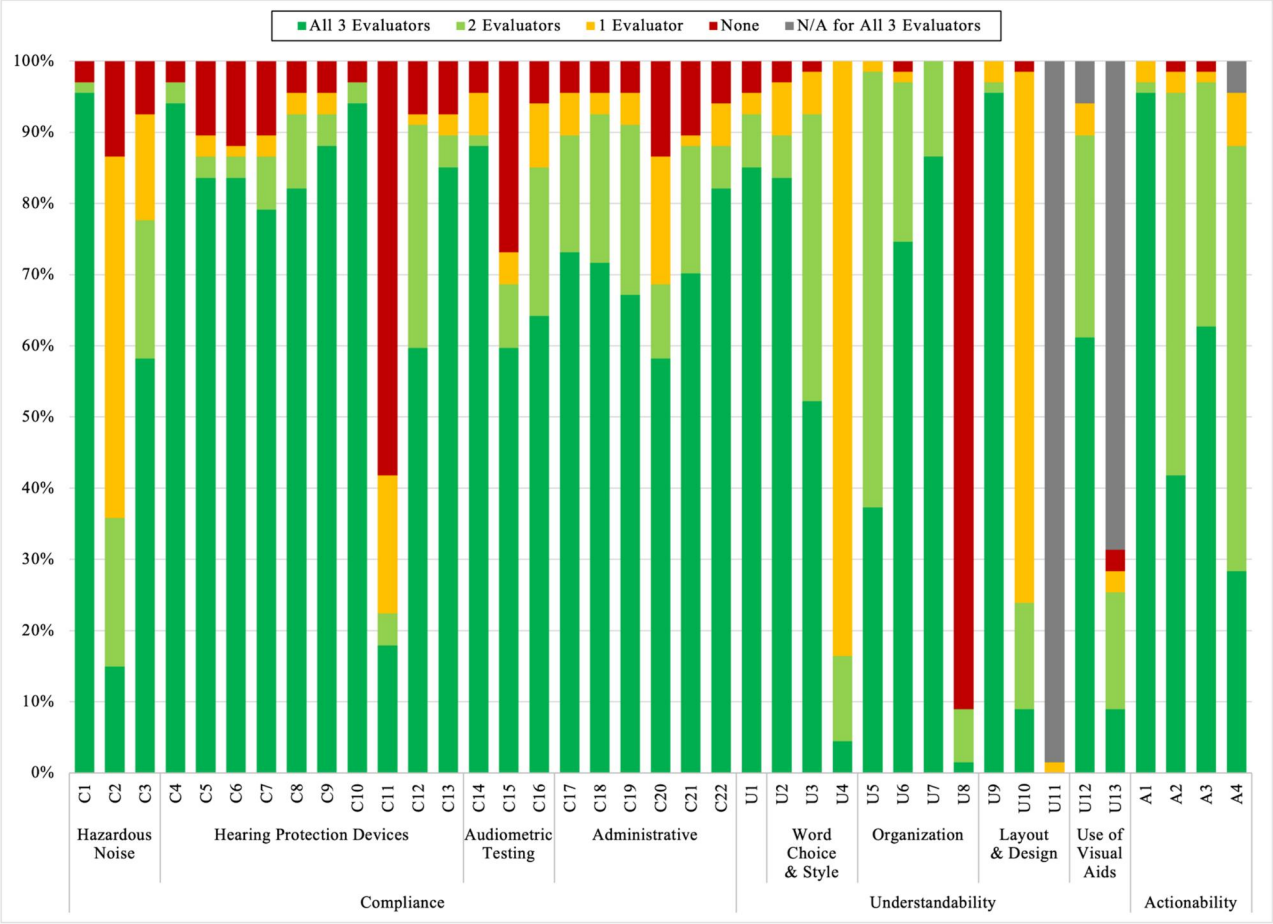

Figure 2. Percentage of total educational materials where evaluators agreed to criteria, $n = 67$.

for actionability it was ($\sigma_A = 23\%$, $\sigma_B = 5\%$, $\sigma_C = 19\%$, $\sigma_D = 30\%$).

Figure 2 indicates the percentage of the 67 educational materials where evaluators agreed to the relevant compliance, understandability, or actionability criterion. A dark green color indicates all three, a light green color indicates any two, an orange color indicates only one, and a red color indicates none of the evaluators agreed to that particular criterion. For 16 of the total 22 compliance criteria that were evaluated, 58 of 67 (87%) of the educational materials had at least two evaluators who believed those criteria were met. Similarly, for 8 of the 13 understandability and all four of the actionability criteria, 60 of 67 (90%) and 59 of 67 (88%) of the educational materials had at least two evaluators who believed those criteria were met, respectively.

Discussion

The USAF (20 criteria) exceeded the number of criteria that the DoD (18 criteria) and OSHA (11 criteria) required. Overall, a majority of the USAF educational materials met a majority of the various evaluated criteria, with results indicating a high measure of compliance, a moderate measure of understandability, and a high measure of actionability.

Compliance

As shown within Table 2 and Figure 1, the (B) new worker hearing conservation training had the highest mean compliance and the least variation among the evaluators when compared to the other educational material types. It is suspected that the amount of content is a considerable contributor to the compliance metric, as (B) new worker hearing conservation training typically had the most content (~39 MS PowerPoint slides) as compared to the (A) supervisor's guide to hearing conservation (~31 MS PowerPoint slides) and the (C) hearing conservation program training pamphlets (2 pages). The (D) other training materials varied considerably in the amount of content (1 to 32 pages). Figure 2 identifies the compliance items with the greatest opportunities for improvement. Educational materials simply stating the

evaluation criteria were generally not considered to be sufficient; however, a single example given for a particular criterion was considered to be compliant.

Of nine DoD compliance line items from the regulation (separated into 16 criteria for this study), two did not have USAF equivalents within the DAFI: (C11) *Procedures to report any concerns about the proper fit and use of HPDs*, a sub-component of a greater line item in the regulation (to include the purpose of hearing protection) and; (C19) *Impact of hearing loss on career opportunities and quality of life*. Interestingly, a majority of the educational materials did not address the former (C11, $n = 201$, $27 \pm 45\%$) but did address the latter DoD compliance item (C19, $n = 201$, $85 \pm 36\%$), visually depicted within Figure 2. It is unclear as to why one would be addressed but not the other.

Understandability & actionability

The (C) two-page hearing conservation program training pamphlets were the most understandable of the educational material types. The lack of a summary (U8) for a vast majority of the educational materials had the greatest negative influence on mean understandability (Figure 2). The (A) supervisor's guide to hearing conservation had the least mean understandability deviation between the evaluators, while the (B) new worker hearing conservation training was the most internally consistent for each evaluator (Table 2).

The (A) new worker hearing conservation training had the greatest mean actionability and the least deviation among the evaluators (Table 2). Actionability had the highest overall mean for its criteria, as compared to Total, OSHA, DoD, and USAF compliance, as well as understandability.

Educational materials collected and evaluated for this study would most likely be reviewed by Airmen electronically, allowing the PEMAT-A/V to be an effective tool to evaluate understandability and actionability. However, using the PEMAT for Printable materials, a 24-item assessment that covers nearly all 17 of the PEMAT-A/V criteria, may be a viable alternative methodology for a future study that could evaluate additional criteria, such as the use of numbers, an emphasis on visual aids, and simplicity.

Readability

Overall mean FKGL ($n = 67$, 10.68 ± 1.68) was higher than the 6th grade reading level recommended by the AMA, as well as the 8th grade reading level of an average American. These held true when differentiating by educational material categorical type as well, with the (A) supervisor's guide to hearing conservation being the highest (11.96) and the (B) two-page hearing conservation program training pamphlets being the lowest (9.54) FKGL. It is believed that the unique, multisyllabic hearing conservation terminology (e.g., audiological) and the lack of sentences due to the bulleted nature of the (A) and (B) educational materials tended to inflate the FKGLs. By comparison, the (C) hearing conservation program training pamphlets were brief (two pages), primarily sentence-based, and generally had the lowest FKGLs (9.54) while maintaining compliance with regulations. As no educational materials were in the "ideal" quadrant within Figure 1, it should be noted that it would be difficult to meet all compliance criteria while also having high readability due to the technical nature of hazardous noise terminology.

Limitations

These assessments do not provide a complete picture of USAF hearing conservation educational materials, as they did not include active-duty laboratories (e.g., Rome), test ranges (e.g., Tonopah), auxiliary fields (e.g., Gila Bend), direct reporting units (e.g., USAF Academy), or joint base installations led by another service despite USAF presence (e.g., Fort Meade). One base was unintentionally excluded due to a recent service-led change that was overlooked. Aside from these exclusions, 61 active-duty CONUS USAF Bases exist, and 60 were approached. We received materials from 44 (72%), likely forming a representative sample. While it is possible that non-responders differed in some systematic way from responders, there was a high level of similarity among the materials received. This is to be expected, as regulations exist that mandate the existence of hearing conservation training and compliance with several standards. Thus, it is unlikely that non-responders were completely out of compliance with these standards. A template was likely used as a starting point for a majority (55 of 67, or 82%, of evaluated educational materials) of the evaluated bases (40 of 44, 91%), with some changes made between them (e.g., changing the base name, conveying information differently, etc.). Since the majority of educational materials were similar in content and format, there is the potential for skewed results toward the means for all evaluated criteria. Educational materials with nearly identical FKGL and

compliance intersections (i.e., groupings) are likely a consequence of the similar educational materials (Figure 2). Some educational materials were more relevant than others in the (D) other training materials category; for example, one may be directly applicable (e.g., training on hearing conservation) while another may be tangentially related (e.g., one-page documentation of hearing conservation topics discussed), leading to high intra- and inter-rater variability for that category (Table 2). The PEMAT-A/V methodology inherently has subjectivity built into it (due to the criteria being assessed), and misclassifications did occur (e.g., marking agree or disagree when it should have been not applicable), likely affecting less than 2% of data. Converting PDFs and MS PowerPoint presentations to Rich Text Format is not ideal and unintentionally breaks sentences apart and potentially introduces artifacts (e.g., symbols instead of letters). Ideally, Microsoft would inherently include FKGL calculations in MS.

PowerPoint as a future capability. The DAFI 48-127 was updated in July 2023, whereas the analysis was based on the September 2022 version; however, changes did not affect the evaluation criteria or conclusions (DAF 2023). The DoD Instruction 6055.12 was updated in November 2023 whereas the analysis was based on the August 2019 version; key differences include the requirement for hearing protection fit testing to be conducted, for personal attenuation ratings (PARs) to be documented, and the addition of an educational requirement that was not assessed in this study: 3.7.a.(10), *an explanation of the quantitative [hearing protector] fit-test and PAR, when required* (DOD 2023). It is believed that since the DAFI has not incorporated this DoD Instruction change, compliance for this item would have been minimal across all educational materials, as this is a new requirement.

Implications

This study established baseline scores for compliance, understandability, actionability, and readability for hearing conservation educational materials across active-duty, continental USAF bases with the intent of improving DoD hearing conservation educational materials as a whole. Actionable recommendations on perceived deficits have been provided below that can potentially improve hearing conservation educational efforts for the USAF in the future.

Evaluating how the USAF currently educates its active-duty Airmen regarding hearing conservation establishes a baseline for potential improvement with future interventions. It also allows for strengths and limitations associated with educational materials to be identified, enabling improvement in training across the USAF. By targeting hearing conservation efforts at the service member level and identifying opportunities for improvement in these training materials for the DoD, the use of personal protective equipment may be positively influenced to reduce the potential for noise-induced hearing loss in active-duty Airmen and future veterans.

Recommendations

United States Air Force

Be concise

The two-page pamphlet can meet all regulatory requirements with minimal changes, has the lowest mean readability, and is much shorter than the other types of educational materials. Condensing the information given to Airmen, perhaps by revising and utilizing the (C) two-page pamphlet rather than (A) and (B) multi-slide presentations, could meet all requirements while keeping attention.

Increase compliance

To increase overall compliance with USAF, DoD, and OSHA regulations, it is recommended that the USAF place particular emphasis on adding the following to their educational materials: (C11) *procedures to report concerns about proper fit and use of hearing protection devices*; (C2) *examples of on-duty sources of hazardous noise* (e.g., flightlines, aircraft, generators, military-specific items, etc.); and an (C15) *explanation of audiometric test procedures*. Ensure DoD Instruction 6055.12 criteria are captured within the latest revision to DAFI 48-127. Additionally, attenuation, although mentioned in qualitative terms, could have been further defined, perhaps with typical noise reduction ranges for formable earplugs, pre-formed (flange) earmolds, and earmuffs. Furthermore, further distinction of the differences among selection, fitting, and use of HPDs is warranted.

Increase understandability and actionability

To considerably increase overall understandability and actionability of these hearing conservation educational materials, it is recommended that the USAF emphasize: (U8) *providing a summary*; (U4) *using the active voice*; (U10) *making text easier to read*; and (A2) *addressing users directly when describing actions*.

Increase readability

Limiting multisyllabic terminology, being brief, using full sentences rather than bullets, and clearly articulating ideas (while still meeting compliance requirements) would all increase readability (i.e., reduce FKGL) as well.

Target unmet criteria

Figure 2, in conjunction with Table 1, clearly outlines what the three evaluators considered to be the least compliant, understandable, and actionable items. Updating these items within the USAF's hearing conservation educational materials could increase personnel retention of the material, potentially leading to a reduction in noise-induced hearing loss in the future.

Incorporate DoD data

Measures of effectiveness are already compiled annually by the DoD Hearing Center of Excellence that indicate hearing threshold shift trends, by service, that are then reviewed by the leaders of each service's respective hearing conservation program (DoDHCE 2021). Including this type of data in educational materials may give service members relevant risk context for NIHL and tinnitus.

Outline responsibilities

Airmen with hazardous noise exposures should have their responsibilities outlined within their initial/annual educational materials, such as those specified in DAFI 48-127, 2.13.

Update rules within the DoD's scope

OSHA regulations alone are not enough to prevent noise-induced hearing loss. Updating relevant USAF regulations is within the service's power and can provide a "best practice" template for the DoD. Requiring the services to consult with experts across the industry or coordinate with the DoD Hearing Center of Excellence may also prove beneficial. This would allow the USAF to draw lessons learned from successful companies with the lowest incidence and prevalence of noise-induced hearing loss. It is recommended that the DoD update its regulations to provide clearer guidance to the services, especially for items such as "impact of hearing loss on career opportunities *and* quality of life" (emphasis added), allowing for service/base compliance to be more readily ascertained.

Give feedback

It may prove advantageous to have the Hearing Conservation Program training include demonstrating the ability to properly insert and fit hearing protection devices (i.e., earplugs and earmuffs), as already required at initial/annual audiograms IAW DAFI 48–127, 2.20.13.2. Adding a feedback mechanism for proper insertion of a hearing protection device into the ear canal, such as the NIOSH QuickFit, that indicates how protected an Airman is from hazardous noise may also prove beneficial (NIOSH 2009).

Occupational hygienists

You can do this too

Any occupational (or industrial) hygienist could apply these same evaluation criteria and methodologies to nearly any educational materials to potentially improve understanding and actionability while meeting your own regulatory-, occupational- or company-specific compliance requirements. Comprehensive overviews for a successful hearing conservation program can also provide clear direction (Rogers et al. 2009).

Require fit testing

Requiring hearing protection fit testing through the use of field-microphone-in-real-ear (F-MIRE) technology to attain personal attenuation ratings to minimize attitude and behavior influences on proper wear of hearing protection may also prove beneficial (Berger et al. 2011). Furthermore, upon entry into the hearing conservation program, fit testing in conjunction with use of a "canal size tool" would identify an individual's ear canal size, allowing them to potentially wear appropriately-sized earplugs for the remainder of their career.

Conclusions

Despite the implementation of a hearing conservation program, the number of veterans with NIHL or tinnitus indicates there are still barriers to effective hearing conservation within the DoD (Beamer et al. 2020). The USAF's hearing conservation educational materials have opportunities for improvement that this study sought to identify, to effectively target how Airmen are trained so that an appreciable impact on noise-induced hearing loss could be made. The majority of the hearing conservation educational materials from the assessed CONUS USAF bases were likely based on templates that require updates to meet all regulatory compliance requirements for the USAF, the DoD, and the OSHA. FKGLs for readability were primarily above the AMA-recommended 8th-grade reading level

and well above the 6th-grade reading level of an average American.

Although exposure to hazardous noise may not be completely preventable, the appropriate use of hearing protection can considerably reduce occupational injuries such as NIHL. Addressing the recommendations made could improve outcomes in Airmen, specifically in how Airmen wear their hearing protection, thereby potentially reducing NIHL and tinnitus incidence in the future.

Future research in this area should include using the same tools (e.g., PEMAT-A/V and FKGL) on updated educational materials to assess the level of improvement. A comparison of these findings with guard, reserve, or overseas USAF bases, or even sister services' (e.g., Army, Navy) educational materials, may identify further improvement opportunities as well. Research into the attitudes and behaviors of Airmen toward the wearing of appropriate hearing protection and the rates of proper insertion and the wearing of personal protective equipment by Airmen after reviewing educational materials would also be prudent.

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Disclosure statement

Thomas Dominguez, Clayton Garner, and Dirk Yamamoto are all active duty members of the United States Air Force. The views expressed within this manuscript are those of the authors and do not necessarily represent the views, position, or policies of the University of Utah, the United States Air Force, the Department of Defense, or the United States government.

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Data availability statement

The data that support the findings of this study are openly available in The Hive: University of Utah Research Data Repository at https://doi.org/10.7278/S50d-9hy0-dbvp.

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