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The Noise Outcomes in Servicemembers Epidemiology (NOISE) Study: Exploring Risk Factors for Tinnitus and Hearing Loss in Veterans and Service Members

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Disclaimer

- The content of this work does not necessarily represent the views of the Department of Veterans Affairs, the Department of Defense, or the United States Government.

Learner Outcomes

- As a result of this course, participants will be able to:
  1) Describe potential risk factors for tinnitus and hearing loss by individuals who have served in the military.
  2) Describe a new self-report instrument to screen for tinnitus.
  3) Describe a new self-report questionnaire for capturing noise and solvent exposures by individuals who have served in the military.

Why Tinnitus and Hearing Loss?

- In Fiscal Year (FY) 2016, tinnitus and hearing loss, respectively, were the top two service-connected conditions for which Veterans received compensation[1]
- So far in this FY, the VA has spent > $180 million dollars on hearing aids and accessories[2]
- As an illustrative example, Tufts et al. (2010) estimated that the lifetime costs associated with noise-induced hearing loss for a machinist on a Navy aircraft carrier was $13,472[3]

Our Newest Veterans

- Theodoroff, S., Lewis, M.S., Folmer, R., Henry, J., Carlson, K. 2015. Hearing impairment and tinnitus: prevalence, risk factors, and outcomes in US service members and veterans deployed to the Iraq and Afghanistan wars. *Epidemiol Rev,* 37(1), 1-15[4].
- Tinnitus: 31%
- Hearing Loss: Up to 27%

Active-Duty Military

- Bothersome tinnitus is associated with problematic sleep[5]
- Tinnitus also has been associated with anxiety, depression, and post-traumatic stress disorder[5-8]
- Yankaskas (2013) provides an overview of how both tinnitus and hearing loss can impact job performance in the military by active-duty personnel[9]
- Hearing loss can impact ability to complete job tasks[10] and operational effectiveness[11, 12]

Noise Exposure[13, 45]

- Impulse noise (e.g., weapon fire)[14-15]
- Continuous noise[16]
- Intermittent noise[16]
- Exposure may depend on location, job duty, and military branch[17-24]
- Temporary threshold shift versus permanent threshold shift[17, 25, 26]
- Greater prevalence of hearing loss in those that do not use hearing protection devices (HPD) versus those that do[13, 27-28]
- Tinnitus[29, 30]

Hidden Hearing Loss

- Can there be damage that occurs as a result of noise exposure that does not show up on the pure-tone audiogram?
- Animal studies have shown exposure to continuous loud noise may result in cochlear synaptopathy[11, 31-33]
- Bramhall et al. (2017) found that among young individuals who had audiograms WNL those with high levels of military noise exposure and/or firearm use had reduced ABR wave I amplitudes in comparison to those with less noise exposure[34]

Chemical/Solvent Exposure[35, 45]

- Toluene
- Carbon disulfide
- Styrene
- Xylene
- N-hexane
- Lead
- Cadmium
- Organophosphates
- *Jet Fuel*

Fuente and McPherson (2007)[36] suggest exposure may also cause abnormal performance on tests of central auditory function.

Blast Exposure[37-39]

- Joseph et al. (2016) reviewed audiometric data for Soldiers having had a deployment-related injury:
  - Tinnitus: 14%
  - Hearing Loss: 39%
- Dougherty et al. (2013) reported that blast-related ear injuries were:
  - Less common in those that use HPDs
  - More commonly occurring from improvised explosive devices, in Marines, and in younger Soldiers

Central Auditory Processing

- Subjects who were exposed to at least one high-intensity blast versus control subjects were compared on performance of behavioral tests of central auditory processing[40-41]
- Subjects with blast-exposure history were more likely to perform abnormally on these tests[40-41]
- Differences between subject groups persisted even after time had passed since the blast (to potentially allow for recovery of function) [41]

Traumatic Brain Injury (TBI)

- Gallun, F., Papesh, M., & Lewis, M.S. (2017)[43] reviewed studies regarding hearing complaints in individuals following TBI:
  - Peripheral auditory injuries
  - Self-reported problems with hearing
  - Deficits on tests of central auditory function
  - Abnormal electrophysiology
- Tsao et al. (2010)[42] reported that 48% of those with history of one military-related concussion had tinnitus (vs. 23% without concussion history and 9% without blast exposure or history of concussion)

Lawson et al. (2016)[10] show military occupation matters, with infantry experiencing the highest rates of head/brain and auditory injuries.

Other Causative Factors[4,35, 44, 45]

- Age
- Gender
- Race/ethnicity
- Genetics
- Nutrition
- Smoking
- Alcohol
- Dual-sensory loss
- Cardiovascular disease
- Pre-existing hearing loss
- Diabetes
- Cholesterol
- Cerebrovascular disease
- Ototoxic medications
- Otitis media
- Mental health
- Migraine
- High blood pressure

The NOISE Study[45]

- **Aim #1:** "Provide data elucidating: (1) the prevalence and incidence of tinnitus and hearing loss; (2) associations between tinnitus and hearing loss and military noise exposure; (3) associations between these disorders and other common comorbidities; (4) impacts of these disorders on function; (5) disability and clinical care burden to DoD/VA healthcare systems; and (6) factors affecting the severity of these conditions."

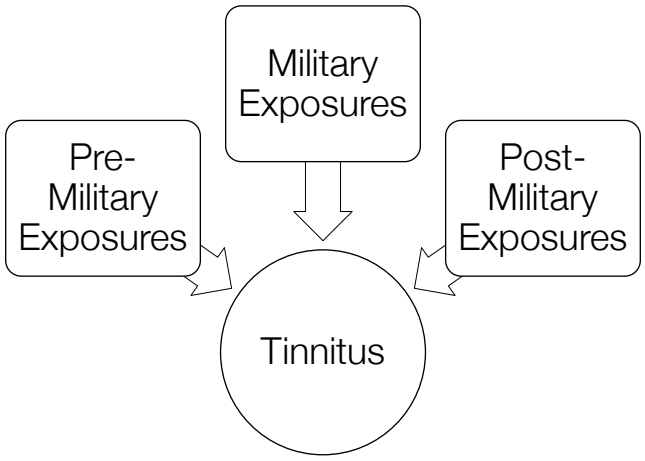
The NOISE Study[45]

- **Aim #2:** "Provide the platform to better understand the relationships between military noise exposure, other important exposures, and the natural history of hearing loss or tinnitus that may develop."

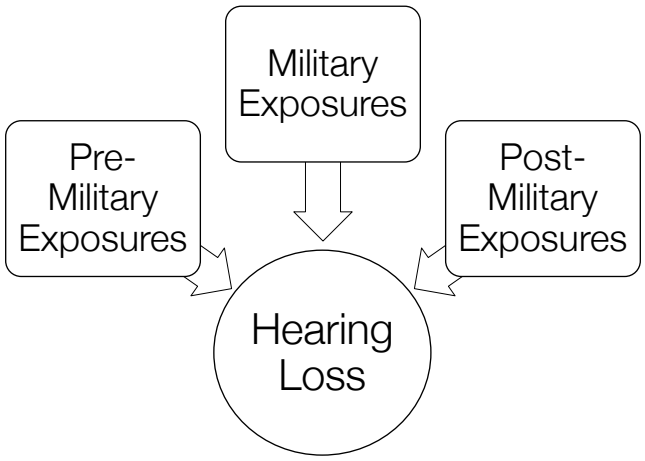
Study Subjects

- Two study sites:
  - VA RR&D NCRAR
    - Must have been separated or discharged from active-duty military service or the National Guard within approximately the last 2.5 years
  - DoD HCE
    - Active Duty Service Members, National Guard, Reserve, and TRICARE eligible recipients (within approximately 2.5 years of separation)

Creating a Causal Model



Creating a Causal Model



Tinnitus Screener[46]

- Original version: 4 questions
  - Tinnitus: present versus absent (or transient ear noise) - “lasting more than 2-3 minutes”
  - Tinnitus categories:
    - Constant
    - Intermittent - “come and go on its own”
    - Temporary - “caused by a recent event”
  - 96% accuracy

Tinnitus Screener[46]

- Current version: 6 questions
- Needed it to be self-administered when our subjects completed their yearly questionnaires
- Additional changes:
  - Adds a new tinnitus category: occasional
    - "Daily or weekly basis" versus "monthly or yearly basis"
  - Differentiates acute versus chronic ("at least 6 months")

Tinnitus Screener[46]

- Henry, J., Griest, S., Austin, D., Helt, W., Gordon, J., Thielman, E., Theodoroff, S., Lewis, M.S., Blankenship, C., Zaugg, T., Carlson, K. 2016. Tinnitus Screener: results from the first 100 participants in an epidemiology study. *Am J Audiol,* 25,153-160.
- Available on the VA RR&D NCRAR website
  - Clinician version (to be completed interview style with the patient)
  - Patient version (to be done on own)

Assessment of Tinnitus

- Tinnitus Screener
- Tinnitus Evaluation System:[47]
  - Pitch match
  - Loudness match
  - Minimum masking level
- Tinnitus Functional Index[48-49]
- Tinnitus and Hearing Survey[45-51]
- Tinnitus History Questionnaire[52]

Assessment of Hearing

- Comprehensive audiometric evaluation:
  - Otoscopy
  - Air-conduction thresholds (including extended high-frequency audiometry)
  - Bone-conduction thresholds
  - Speech reception threshold
  - Word recognition (CID W-22 word lists)
- Immittance audiometry:
  - Tympanometry
  - Acoustic reflex thresholds

Additional Test Measures

- Dichotic Digits Test (Musiek version)[53]
- SPeech Recognition In Noise Test (SPRINT)[54]
- Distortion-product otoacoustic emissions
- Hearing Handicap Inventory for Adults (HHIA)[55-56]
- Speech, Spatial and Qualities of Hearing scale (12-item version)[57]
- Hearing History Questionnaire

Lifetime Exposure to Noise and Solvents Questionnaire (LENS-Q)

- 18-page self-report questionnaire that queries exposure to loud noise and to chemicals/solvents in three settings:
  - Non-military occupational
  - Military-occupational
  - Recreational/non-occupational
- Collect details regarding:
  - Length of exposure
  - How often exposed
  - Use of protective gear/hearing protection

Lifetime Exposure to Noise and Solvents Questionnaire (LENS-Q)

- Bramhall, N., Konrad-Martin, D., McMillan, G., Griest, S. 2017. Auditory Brainstem Response Altered in Humans With Noise Exposure Despite Normal Outer Hair Cell Function. *Ear Hear*, 38, e1-e12.[34]
- Gordon, J., Griest, S., Thielman, E., Carlson, K., Helt, W., et al. 2017. Audiologic characteristics in a sample of recently-separated military Veterans: The Noise Outcomes in Servicemembers Epidemiology Study (NOISE Study). *Hear Res*, 349, 21-30.[57]

- Sample questionnaire shown in classroom

Exploration of Other Exposures and/or Causative Factors

- Demographic Questionnaire
- Medical History Questionnaire[59-60]
- Hearing History Questionnaire
- Tinnitus History Questionnaire
- Blast and Traumatic Brain Injury Questionnaire[61]

Other Questionnaires

- Epworth Sleepiness Scale (ESS)[62]
- Hospital Anxiety and Depression Scale (HADS)[63]
- Primary-Care – Post-Traumatic Stress Disorder (PC-PTSD) Screen[64-65]
- World Health Organization Disability Assessment Schedule (WHODAS) 2.0[66]
- Cost of Tinnitus Questionnaire[67-68]
- Cost of Hearing Loss Questionnaire[67-68]

Longitudinal Epidemiological Investigation

- Questionnaires are completed annually
- Audiometric evaluation completed every 5 years
- With continued funding, the plan is to follow our initial cohort of subjects for as long as 20-25 years

Current Status (as of June 12, 2018)

- **Project Initiation Date:** October 1, 2013 (first grant)
- **Current enrollment (NCRAR):** 450
- **Current enrollment (HCE):** 165

Publications to Date

- Theodoroff, S., Lewis, M.S., Folmer, R., Henry, J., Carlson, K. 2015. Hearing impairment and tinnitus: prevalence, risk factors, and outcomes in US service members and veterans deployed to the Iraq and Afghanistan wars. *Epidemiol Rev,* 37(1), 1-15.
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- Brungart, D., Walden, B., Cord, M., Phatak, S., Theodoroff, S., et al. 2017. Development and validation of the Speech Reception in Noise (SPRINT) Test. *Hear Res,* 349, 90-97.
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Gordon, J., Griest, S., Thielman, E., Carlson, K., Helt, W., Blankenship, C., Lewis, M., Austin, D., Theodoroff, S., Henry, J. 2017. Audiologic characteristics in a sample of recently-separated military Veterans: The Noise Outcomes in Servicemembers Epidemiology Study (NOISE Study). *Hear Res*, 349,21-30.

- N=100
- VA RR&D NCRAR subjects only
- Majority had pure-tone air-conduction hearing thresholds within normal limits (≤20 dB HL) at the conventional audiometric test frequencies
- Those with hearing loss reported significantly more exposure to loud noise
- Majority had tinnitus

Updated Data (N=429)

	Mean (SD), range
Age (in years)	34.0 (8.9), 19-61
Gender	n (%)
Male	344 (80.2%)
Female	85 (19.8%)

Griest, S., Blankenship, C., Melgoza, R., Henry, J. 2018, February. Risk factors associated with tinnitus and hearing loss in current and recently separated service members across military branches. 2018 *National Hearing Conservation Association Annual Conference*. Orlando, FL.

Noise Exposure

Military Occupational	Non-Military Occupational	Non-Occupational/ Recreational
mean (SD), range	mean (SD), range	mean (SD), range
439.4 (423.3), 3.5-2949.3	53.3 (102.3), 0-714.8	833.7 (598.3), 0-2932

Exposures

Blast Wave Exposure	n (%)
No	264 (61.8%)
Yes	163 (38.2%)
Military TBI	n (%)
No	323 (75.5%)
Yes	105 (24.5%)
Military Solvent	n (%)
No	141 (32.9%)
Yes	287 (67.1%)

Military Occupational Solvent Exposures

Solvent	n (%)
Burn Pits	194 (45.3%)
Carbon Monoxide	104 (24.3%)
Welding Fumes	47 (11%)
Lead	47 (11%)
Ethyl Benzene	27 (6.3%)
Toluene	13 (3%)

Most commonly reported solvent exposures; exposures <3% not reported

Tinnitus

	n (%)
No Tinnitus	156 (36.4%)
Temporary or Occasional Tinnitus	26 (6.1%)
Intermittent Tinnitus	75 (17.5%)
Constant Tinnitus	171 (40%)

Hearing Loss

	Low Frequency Pure-Tone Average (.25-2 kHz)	High Frequency Pure-Tone Average (3-8 kHz)	Extended High Frequency Pure-Tone Average (9-16 kHz)
	n (%)	n (%)	n (%)
No Hearing Loss (≤20 dB HL)	363 (84.8%)	325 (75.9%)	252 (60.3%)
Hearing Loss (>20 dB HL)	65 (15.2%)	103 (24.1%)	166 (39.7%)

Identifying Potential Risk Factors

- After controlling for age and gender, military TBI and military solvent exposure were significantly associated with:
  - Tinnitus
  - Low-frequency hearing loss
  - Extended high-frequency hearing loss
- After controlling for age and gender, military TBI was significantly associated with:
  - High-frequency hearing loss

Model considered age, gender, military TBI, blast-wave exposure, military solvent exposure, military noise exposure, and non-occupational noise exposure

Theodoroff SM, Griest SE, Carlson KF, Gallun F, Blankenship C, Henry JA. Preliminary findings on the prevalence of decreased sound tolerance in Veterans with traumatic brain injury. Poster presented at the Association for Research in Otolaryngology 41st MidWinter Meeting, San Diego CA, Feb 9-14, 2018.

- N=312 Veteran subjects
- Those subjects who had moderate or severe TBI (military or non-military related) were 2.5 times more likely to report hyperacusis than those Veterans without any history of TBI

Exposure by Military Branch

- A statistically significant association was found between *military branch and solvent exposure*, with the greatest percentage of subjects having reported military solvent exposure by those who served in the Army and the smallest percentage reported by those who served in the Air Force
- A statistically significant difference was not noted between military branches in terms of exposure to loud noise

Examining the Impact of Military Occupational Specialty (MOS) Code

- N=299 subjects from NCRAR
- Majority had tinnitus
- Majority had hearing within normal limits (≤ 20 dB HL) for the low-frequency PTA and high-frequency PTA
- Extended high-frequency PTA not analyzed

Blankenship, C., Reavis, K., Griest, S., Thielman, E., Lewis, M.S., Henry, J. 2018, April. Do certain military occupational codes have a higher prevalence for hearing loss and tinnitus? *Collaborative Auditory and Vestibular Research Network (CAVRN) Conference,* Dayton, OH.

Military Occupational Specialty (MOS) Code

- MOS codes from the LENS-Q were categorized into 9 occupational categories
- Low numbers in each category precluded statistical analyses
- The greatest percentage of individuals with intermittent or chronic tinnitus was reported by those in:
  - *Combat operations*
  - *Infantry*

MOS Code and Hearing Loss

- *Electrical/mechanical equipment repair personnel* had the greatest percentage of subjects with *low-frequency HL*, followed by *motor vehicle operators*
- The greatest percentage of subjects with *high-frequency HL* (in order) was:
  - Medical care and treatment personnel
  - Electrical/mechanical equipment repair personnel
  - Aircraft personnel
- *Electrical/mechanical equipment repair personnel* and those who worked with *aircraft* also reported the highest amount of loud noise exposure related to their position

Summary

- More than half of our sample experience tinnitus that is chronic or intermittent (57.5%)
- The majority of our sample have hearing that is within normal limits for the low-frequency PTA, high-frequency PTA, and extended high-frequency PTA
- The prevalence for hearing within normal limits drops (i.e., becomes less) with increasing audiometric frequency

Summary

- There is a statistically significant relationship between both tinnitus and hearing loss, independently, with military TBI and military solvent exposure
- TBI severity is significantly associated with hyperacusis
- There is a statistically significant association between military solvent exposure and military branch, but not noise exposure
- Hearing loss and noise exposure appear to be higher in certain job categories, while tinnitus appears to be more prevalent in others

Limitations

- Small N
- Convenience sample
- Predominately male
- Predominately Army and Air Force sample
- Solvent exposure did not account for time or use of personal protective equipment; number of TBI and/or blast exposures were not analyzed
- Only evaluated one occupational category for each subject
- Only analyzed some of our potential risk factors
- Cross-sectional data versus longitudinal data

Hearing Conservation Efforts

- Pre-enlistment assessment of auditory function[22]
- Source noise reduction[69-70]
- Hearing protection devices[71-74]
- Hearing conservation education[68-73]
- Pharmaceutical interventions[14, 75]
- Dietary interventions[76]

Potential Future Considerations[77-78]

Questions?

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