Military Operational Medicine Research Program (MOMRP)

Hearing Injury Prevention and Protection Research

International State-of-the-Science Meeting on Blast-Induced Tinnitus

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Mission and Key Focus Areas

Develop effective medical countermeasures against combat and operational stressors to maximize Warrior health, performance and fitness.

Science

INJURY
Injury Prevention and Reduction

THREATS
- Acoustic Trauma
- Blast Overpressure
- Blunt Head and Body Trauma
- Traumatic Brain Injury
- Face, Eye and Spinal Cord Injury
- Musculoskeletal Injury
- Toxic Gas Inhalation
- Laser Eye Injury

PSYCH
Psychological Health and Resilience

THREATS
- PTSD/Other Anxiety Disorders
- Suicide Behavior
- Concussion (mTBI)
- Alcohol/Other Drug Use Problems
- Co-occurring Mental Disorders
- Access/Retention in Behavioral Health Care
- Family Transitions and Well-being

PHYSIO
Physiological Health

THREATS
- Malnutrition
- Dehydration
- Sustained Fatiguing Work (Physical/Mental)
- Sleep Deficit & Circadian Desynchrony
- Distributed/Continuous Operations
- Dietary Supplements

ENVIRO
Environmental Health and Protection

THREATS
- Toxic Industrial Chemicals and Materials
- Dust and Air Pollution
- Altitude and Hypoxia
- Cold Stress
- Heat Stress
- Protective Equipment/ Clothing

Soldier

Injury Prevention and Reduction

Develop and provide the biomedical basis for countermeasures that prevent and mitigate Warrior injury.

THREATS

- Acoustic Trauma
- Blast Overpressure
- Blunt Head and Body Trauma
- Traumatic Brain Injury
- Face, Eye and Spinal Cord Injury
- Musculoskeletal Injury
- Toxic Gas Inhalation
- Laser Eye Injury

"Combat is inherently brutal and difficult, and it impacts humans in different ways. We have made significant improvements in the identification and treatment for PTSD and mild TBI, but we must aggressively work research, prevention and treatment of these injuries and encourage Soldiers and their Families to seek treatment."

— Gen. George Casey Jr., Chief of Staff of the Army

ST 4-02.501 ARMY HEARING LOSS, HQ DOA, 1 February 2008
Hearing and Military Operations

The purpose of the Army Hearing Program is to prevent **Noise-Induced Hearing Loss (NIHL)** in Soldiers and to ensure their maximum combat effectiveness. Hearing is a critical sensor used by Soldiers that increases their survivability and lethality.

COMMUNICATING ON THE BATTLEFIELD

- Verbal communications-Human hearing is required to complete communications.
- Studies have shown that the ability to accomplish a unit's mission is directly proportional to its ability to communicate effectively.
- Soldier hearing must be protected from damage caused by hazardous impact and sustained noise without compromising the ability to hear.

IMPACT OF HEARING LOSS

- Hearing loss is an invisible injury.
- Sound is often the first source of information a Soldier has before direct contact with the enemy.
- Noise-induced hearing loss is a tactical risk and threatens both individual and unit combat effectiveness.
- High-frequency hearing loss such as the signature of weapons and vehicles is devastating to military operations.
- Ability to distinguish sounds of different weapons, both friendly and enemy, is a combat-critical skill.

Medical Surveillance Monthly Report (MSMR), June 2011, Vol.18, No.6

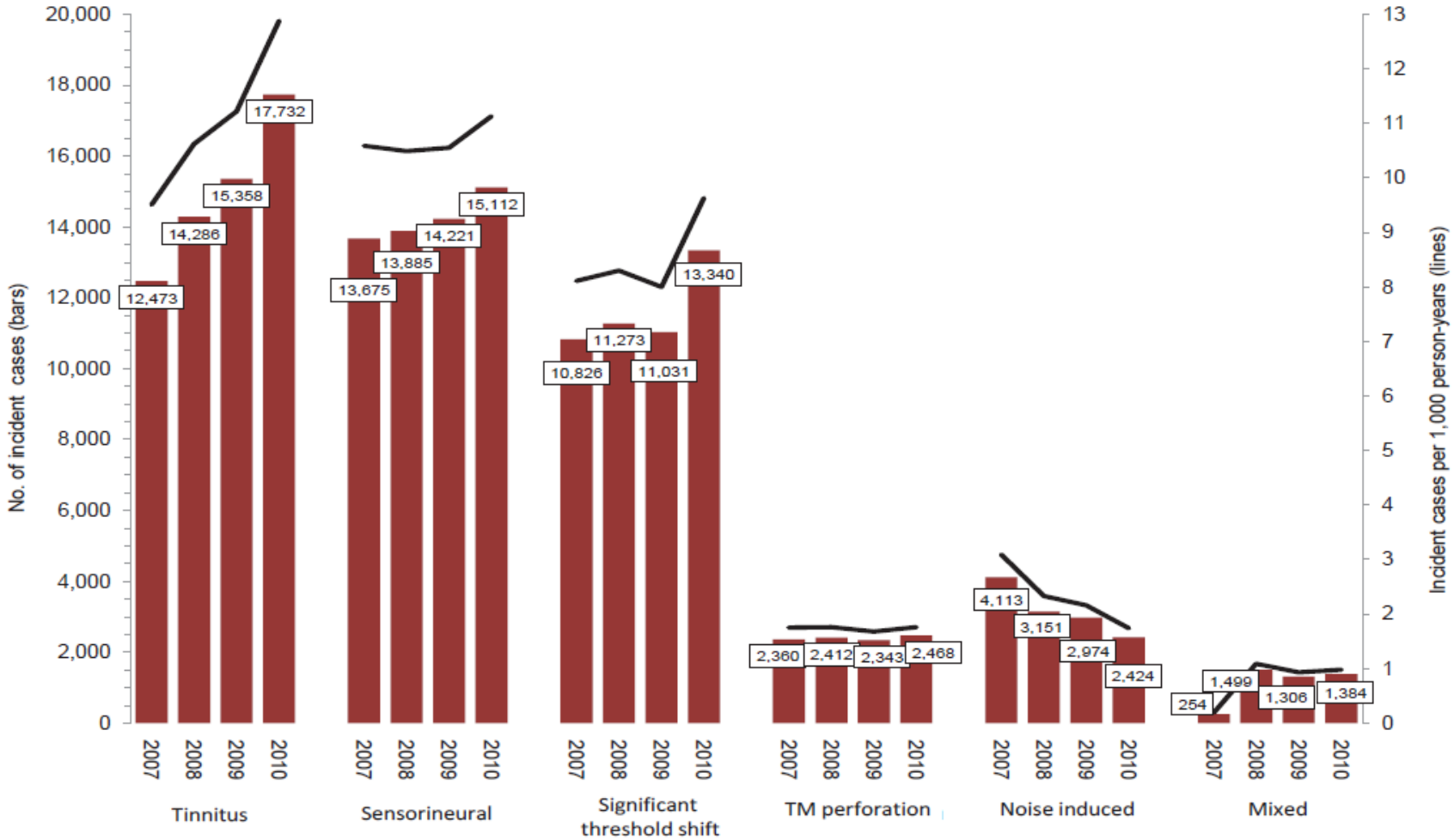
Noise-Induced Hearing Injuries, Active Component, U.S. Armed Forces, 2007-2010

The surveillance period was 1 January 2007 to 31 December 2010. The surveillance population included all individuals who served in an active component of the Army, Navy, Air Force or Marine Corps any time during the four-year surveillance period.

Most frequently diagnosed indicators of noise-induced hearing injuries (NIHI) were tinnitus, sensorineural hearing loss, and significant threshold shift. On average, there were nearly 15,000 new tinnitus cases diagnosed each year (mean, per year: 14,962). From the first to the fourth year, annual numbers and rates of tinnitus increased by 42 percent and 35 percent, respectively.

Medical Surveillance Monthly Report (MSMR), June 2011, Vol.18, No.6

Figure 1. Annual numbers and incidence rates of noise-induced hearing injuries, active component, U.S. Armed Forces, 2007-2010



The Cost of Hearing Loss

- Noise-induced hearing loss and tinnitus are consistently the top two disabilities in Soldiers returning from OEF and OIF[1]
- 70,000 Soldiers who have served in Iraq and Afghanistan are collecting disability for tinnitus [1]
- 58,000 Soldiers on disability for hearing loss[1]
- Hearing loss and tinnitus compensation costs in FY06 totaled $1,210,228,404 [2]
- Compensation costs increased 18% from FY05 to FY06[2]

[1] Department of Veterans Affairs

[2] Dr. Stephen Fausti, Department of Veterans Affairs

Factors Influencing Hearing Loss

- Occupational Exposure
- Noise
  - Impulse
  - Continuous
  - Synergistic
- Hearing Protection Compliance Issues
  - Leadership
  - Situational Awareness
  - Cultural
  - Comfort

Addressing the Problem of Hearing Loss

- Noise
  - Military Medical Standards
    - MIL-STD 1474D, DoD Established in 1997 to estimate the hazard associated with exposure to “impulse” noise. Measurements of peak pressure and duration establish maximum “safe” conditions. Weakness-over-estimation of the hazard.
  - Health Hazard Assessments
    - Auditory Hazard Assessment Algorithm for Humans (AHAAH) – Army Research Laboratory Model predicts risk of hearing loss resulting from exposure to impulse noise by analyzing digitized impulse pressure-time signatures in Auditory Hazard Units (AHUs).
      - 500 AHUs – considered safe exposure for 95% of exposed population
    - Laeq8hr (injury model adopted by Europeans) integrates energy of measured short duration impulse and equates it to equivalent amount of energy for an 8-hour period in decibels (dB)
      - Predicts temporary threshold shifts
      - Predicts hearing injury from blast overpressure (BOP)
- Hearing Protection Compliance Issues
    - Training for Proper Use
    - Ensuring Junior Leaders check squad members are correctly wearing hearing protection
    - Protection that does not degrade situational awareness
    - Comfort

USAARL Hearing Injury Prevention Research

Evaluate hearing protection strategies to reduce the noise hazard from aircraft and weapons systems noise for special operations aircrew

Evaluate hearing enhancement and protection systems for noise-induced injury from exposure used by Warriors for sound source situational awareness during combat operations

Evaluate hearing protection to impulse and continuous noise using COTS custom ear molds and communication systems for effectiveness and comfort

USAARL Acoustical Sciences Branch

Tinnitus Secondary to NIHL

USAARL Acoustical Sciences Branch

Problem:
- Tinnitus and Noise-Induced Hearing Loss (NIHL) are the two highest disabilities in OIF/OEF Soldiers

Purpose:
- Evaluate Neuromonics Tinnitus program
- Multidisciplinary approach of audiology, neurology and psychology
- Neural stimulus pitch & loudness-matched to Soldier's tinnitus is embedded in music
- Program incorporates audiometrics, counseling & structured use of device to rewire brain via neuroplasticity

Product:
- Recommended solution for debilitating tinnitus to OTSG leading to an improvement in healthy and fit force

Payoff:
- Reduction in severity of tinnitus symptoms and associated complaints of anxiety, depression, insomnia, irritability, decreased concentration and stress
- Increased Soldier and Family Quality of Life

Defense Health Program Hearing Injury Research

Diagnostics and Metrics for Hearing Loss and Protection

- Extramural Performers: L-3 Communications, Southern Illinois University, Baylor College of Medicine, University of Washington, Applied Research Associates, Otologics
- Key Deliverables:
  - Modify existing active hearing protection to demonstrate ability to prevent hearing loss without compromising auditory situational awareness
  - Develop acoustic exposure dosimeter to indicate whether or not safe hearing exposure limits have been exceeded
  - Develop standardized testing methodology for collecting measurements of eardrum pressure under protector using an acoustical head form test device
  - Evaluate dose and time-response curves of D-methionine administration to prevent and/or treat noise-induced hearing loss
  - Develop dynamic model of the ear's response to pressure impulse on human temporal bones

Current Noise Dosimeter Technologies

Example Ruggedized Dosimeter "DoseBadge"

1951–2011
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

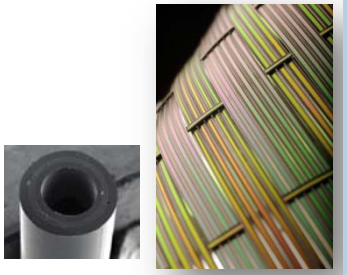
- Many noise dosimeters available, few are ruggedized for military use
- Typically not designed to measure rapid transients >140 dB that occur from weapons fire and other impulsive noise
- Tailored to measuring for OSHA / ISO regulations
- Other considerations: battery life, recording intervals, user acceptance
- Technology evaluation required to determine applicability of modification of COTS dosimeters

Future Noise Dosimeter Technologies

- Flexible electrochromic materials (polymers applied to fabric) are increasingly commonplace
- Color changes with applied voltage supplied by small, portable COTS microphone system

Microphones and Electrochromics

- *Potential Advantages*
  - Small Size, Weight and Power
  - Could be integrated into combat uniform
  - Rapid response to record individual impulses
- *Path to Implementation*
  - No reports on integrating microphones and electrochromic materials
  - Significant engineering required
  - Reliability, stability not yet established



Egusa et al. Nat. Mater. 2010
Fink Lab, MIT

- Piezoelectric fibers (pressure ➔charge)
- Flexible, distributed sensing platform
- External sensing(blasts, engines) & Internal sensing(blood pressure, myography)

Flexible Piezoelectric Fibers

- *Potential Advantages*
  - Small Size, Weight and Power
  - Woven into combat uniform fabric
  - Rapid response
  - Ability to sense several modalities (pressure, temperature, etc.)
- *Path to Implementation*
  - Materials exist but system integration and engineering required
  - Reliability not yet established

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