Suffering in Silence?
Health Implications of Noise Exposure in the Workplace

IOSH UAE Annual Conference 2012
Dr Tom Loney - Institute of Public Health
Presentation Overview

1. Define the terms sound & noise

2. Understand the basic physics related to sound & the anatomy & physiology of the ear

3. Discuss the relationship between occupational noise and:
   - Hearing Loss (incl. smoking & solvent exposure)
   - Cardiovascular Disease
   - Pregnancy.
Sound = pressure changes caused by a series of air vibrations due to a pressure wave travelling through air or water.

Air vibrations detected by the ear & transmitted → brain.
Basic Physics of Sound

Sound is a pressure wave (disturbance)

Normal Atmospheric Pressure

Sound Pressure

NOTE: "C" stands for compression and "R" stands for rarefaction
Sound Waves

- Different sounds have different wave characteristics with respect to frequency, wavelength & speed of sound (depending on medium)
Anatomy of the Human Ear

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Anatomy of the Human Ear

- External Auditory Canal
- Helix
- Crus of Helix
- Concha
- Earlobe (ear drum)
- Malleus
- Incus
- Stapes
- Tympanic Membrane
- Cochlea
Audiometric Testing
Sound vs. Noise

World Health Organisation

• No physical difference between sound & noise

• Noise is any unwanted or undesirable sound

• Only humans can distinguish between a sound & a noise

NIOSH

• Noise usually bears no information

• Unwarranted disturbance within a useful frequency band (i.e. wanted or useful sound).
Types of Noise

Noise exposure durations can be:

Continuous Noise

• Occurrence of sound is greater than once per second → considered to be continuous sound

Impulse Noise

• Characterised by a steep rise in sound level to a high peak followed by a rapid drop (e.g. gunshot).
• Technically, sound is measured in units of pressure either Pascals (PA) or micropascals (μPa)

• Human ear is capable of detecting a wide range of absolute pressures (0.00002 to 200 Pa)

• People hear ↑ Hz noise much better than ↓ Hz noise
  – Two sounds of the same sound pressure but different frequencies, one sound may appear louder

• Decibels (dB) scale indicate relative loudness of a sound → A-weighting (dBA) weights the sound based on the injurious effects of the noise on the ear.
Noise Assessment

Sound Level Meter

• Measures sound pressure variations in air at a given moment or over time
  – Useful for assessing noise levels in specific areas

Personal Noise Dosimeter

• Measures & stores sound level assessments
  – Useful for determining an individual’s amount of exposure to noise.
## Examples of Sound/Noise

<table>
<thead>
<tr>
<th>Source</th>
<th>Intensity Level</th>
<th>Multiples &gt; TOH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold of Hearing (TOH)</td>
<td>0 dB</td>
<td>$10^0$</td>
</tr>
<tr>
<td>Rustling Leaves</td>
<td>10 dB</td>
<td>$10^1$</td>
</tr>
<tr>
<td>Whisper</td>
<td>20 dB</td>
<td>$10^2$</td>
</tr>
<tr>
<td>Normal Conversation</td>
<td>60 dB</td>
<td>$10^6$</td>
</tr>
<tr>
<td>Busy Street Traffic</td>
<td>70 dB</td>
<td>$10^7$</td>
</tr>
<tr>
<td>Vacuum Cleaner</td>
<td>80 dB</td>
<td>$10^8$</td>
</tr>
<tr>
<td>Large Orchestra</td>
<td>98 dB</td>
<td>$10^{9.8}$</td>
</tr>
<tr>
<td>iPod at Maximum Vol.</td>
<td>100 dB</td>
<td>$10^{10}$</td>
</tr>
<tr>
<td>Front Row of Rock Concert</td>
<td>110 dB</td>
<td>$10^{11}$</td>
</tr>
<tr>
<td>Threshold of Pain</td>
<td>130 dB</td>
<td>$10^{13}$</td>
</tr>
<tr>
<td>Military Jet Take Off</td>
<td>140 dB</td>
<td>$10^{14}$</td>
</tr>
<tr>
<td>Instant Ear Drum Perforation</td>
<td>160 dB</td>
<td>$10^{16}$</td>
</tr>
</tbody>
</table>
Occupational Noise

- Noise is one of the most common physical hazards encountered in the workplace
  - Estimated that ~600 million workers exposed worldwide
  - Approx. 30 million Americans are exposed to high-intensity noise in their workplace
  - One in four of these workers (≈7.5 million workers) will develop permanent hearing loss

- Occupational noise is usually a combination of continuous and impulsive-type noises.
OSHA Noise Standard, Code of Federal Regulations

- PEL 90 dBA as an 8 h TWA
- Action Level 85 dBA as an 8 h TWA

NIOSH

- REL 85 dBA as an 8 h TWA

HSE Control of Noise at Work Regulations 2005

- Personal hearing protection must be provided to all employees working where noise levels reach ≥ 85 dBA.
# Occupational Noise

<table>
<thead>
<tr>
<th>Task</th>
<th>Avg. Noise Level (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Forklift</td>
<td>87</td>
</tr>
<tr>
<td><strong>Cutting Wood</strong></td>
<td>93</td>
</tr>
<tr>
<td>Cutting Lawn</td>
<td>94</td>
</tr>
<tr>
<td>Installing Trench Conduit</td>
<td>96</td>
</tr>
<tr>
<td><strong>Welding</strong></td>
<td>99</td>
</tr>
<tr>
<td><strong>Grinding</strong></td>
<td>100</td>
</tr>
<tr>
<td>Chipping Concrete</td>
<td>103</td>
</tr>
<tr>
<td><strong>Working Near Generator</strong></td>
<td>116</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tools</th>
<th>Avg. Noise Level (dBA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lathe</td>
<td>81</td>
</tr>
<tr>
<td>Welding Equipment</td>
<td>95</td>
</tr>
<tr>
<td><strong>Hand Power Saw</strong></td>
<td>97</td>
</tr>
<tr>
<td>Screw Gun, Drill</td>
<td>97</td>
</tr>
<tr>
<td>Rotohammer</td>
<td>98</td>
</tr>
<tr>
<td>Chop/Mitre Saw</td>
<td>98</td>
</tr>
<tr>
<td>Stationary Power Tool</td>
<td>102</td>
</tr>
<tr>
<td><strong>Chipping Hammer</strong></td>
<td>103</td>
</tr>
</tbody>
</table>

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Noisy Hobbies
- Loud music & speakers
- Firearms
- Car/motorcycle race track
- Sporting events......

Noisy Environment
- Airport flight path
- Traffic
- Construction......

Noisy Household
- Crying babies
- Vacuum/Lawn mower
- Power tools
- Ipod/Boom box...
Evaluation of Potential Noise Exposures in Hospital Operating Rooms

NIOSH received a request from West Virginia University Hospital to evaluate noise exposures from surgical instruments in OR.

Noise dosimeters worn by 4 surgical asst., 4 registered nurses & 1 surgeon to measure full-shift personal noise exposures during 2 d.

Measurements did not exceed NIOSH noise exposure limits.

Area sound measurements = intermittent activities generated sound levels above 90 dBA

- Surgery preparation, drilling or other powered surgical instruments

Proper maintenance of powerful surgical instruments or replacement of old equipment with newer, quieter models & keep music levels low.
Noise Impacts from Professional Dog Grooming Forced-Air Dryers

Dog Grooming in the US

- Most noise exposures occur in the mining, manufacturing & construction industries
- Workers that are not typically known for having high workplace noise exposures → less likely to wear hearing protection
- US Pet Industry 2010 – 78.2 million dogs in 46.3 million homes → yearly profits of $48.4 billion - $2.8 billion on grooming
  - 80 000 professional groomers using high-velocity dryers
- **Aim:** Measure the sound output of four commonly used brands of forced-air dryers used by US dog groomers.
High-Velocity Dryers

• **Model 1:** K9 II
• **Model 2:** Metro Air Force Master Blaster
• **Model 3:** Double K Challenge Air DBL 9000 II Stand Dryer
• **Model 4:** MDC Romani Granddaddy

Noise level exposure assessed for dog & groomer under typical operating conditions for 5 minutes.
## Average Sound Pressure Levels for Forced-Air Dryers

<table>
<thead>
<tr>
<th>Make</th>
<th>Model</th>
<th>dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>K9</td>
<td>II</td>
<td>107.2</td>
</tr>
<tr>
<td>Metro</td>
<td>Air Force Master Blaster</td>
<td>108.0</td>
</tr>
<tr>
<td>Double K</td>
<td>Challenge Air DBL 9000 II Stand Dryer</td>
<td>94.8</td>
</tr>
<tr>
<td>MDC Romani</td>
<td>Grandaddy</td>
<td>105.1</td>
</tr>
</tbody>
</table>
• All four dryers produced significant noise levels that have the potential to impact dog & groomer hearing
  – Average noise level for three of the dryers = 105-105 dbA
• OSHA standard for occupational noise specifies a limit of 90 dBA for 8h TWA (federal regulation)
  – ∴ Limit exposure to this noise level to 45-60 min/d
• NIOSH advocates more stringent guideline 85 dBA
  – ∴ Limit exposure to this noise level to <5 min/d
• On average, professional groomers are exposed to these noise levels from forced-air dryers for 2 h/d.
Noise-Induced Hearing Loss
Bernardino Ramazzini 1633-1714

De Morbis Artificum Diatriba (Diseases of Workers) 1713

"...workers engaged all day in hammering copper to make it ductile so that with it they may manufacture vessels of various kinds......from this quarter there arises a terrible din.....the ears are injured by that perpetual din so that workers of this class become hard of hearing and, if they grow old at this work, completely deaf”
Types of Hearing Loss

**Conductive**

- Sound is not conducted from outer ear to inner ear
- Due to fluid in middle ear, foreign bodies, infection in ear canal, impacted ear wax, or malformation of ear

**Sensorineural**

- Damage to the inner ear hair cells or nerve pathways from ear to brain affecting ability to hear some frequencies i.e. sounds appear distorted
- Caused by birth injury, diseases, noise exposure, head trauma, & aging
Noise-Induced Hearing Loss

Temporary & Permanent Threshold Shift

- ↑ sound intensity required to elicit hearing → muffled sound
- Temporary shift usually results following exposure to a high noise level (>85 dBA) or impulse type noise (e.g. explosion)
  - Occurs within 1-2 hours of the exposure & hearing acuity usually returns after a period away from noisy environments
- Continued overexposure = shift can worsen → permanent (non-reversible)
- Due to chemical change in the composition of the fluid in the organ of Corti or a metabolic change in the hair cells.
Anatomy & Physiology of Damaged Ear

- Hairlike cells are flattened
- You do not adapt to noise; you gradually lose your hearing
- Once hearing is damaged - cannot be repaired or replaced.
Healthy Cochlea

The cilia (sensory hairs) appear normal.
Damaged Cochlea

Loss of cilia as a result of Noise
Tinnitus

- Subjective condition → perception of ringing sound in the ear in the absence of any corresponding external sound
- Chronic overexposure to noise can lead to permanent condition & constant annoyance

Presbycusis (age-related hearing loss)

- Progressive & symmetrical reduction in bilateral sensorineural hearing acuity at higher frequencies of the audio range
- Degeneration of cochlea hair cells as a result of ageing.
Cigarette Smoking and Occupational Noise-Induced Hearing Loss

• Emerging evidence → cigarette smoking ↑ risk of NIHL

• Cross-sectional study in large wagon manufacturing factory in Iran assessed the interaction of smoking & noise on NIHL

• Smokers 9 times more likely to develop NIHL compared to non-smokers following chronic exposure to >85 dB
  – >25 times more likely to suffer from NIHL if ≥20 pack-years smoking

• Possible mechanism = cigarette smoking causes impaired cochlear circulation through ↑ blood viscosity + ↓ oxygenation

• Potential additive effect of non-occupational noise exposure & exposure to industrial solvents (e.g. glues, paints).
OSH Implications

- Regardless of smoking status, 30-40% workers experienced hearing loss = insufficient noise controls/protection
  - Noise exposure should be minimised using efficient controls and/or PPE, independent of smoking status
- Age (>40 y), duration of noise exposure (>19 y) & smoking pack-years (≥20 y) increases odds of hearing loss
  - Education programmes should focus on adherence to PPE & smoking cessation
  - Periodic audiometric testing to track NIHL – perhaps biannually for smokers.
Effect of Combined Occupational Exposure to Noise and Organic Solvents on Hearing

Introduction

• Noise exposure → most common ototoxic hazard related to occupational hearing loss

• Occupational ototoxic substances include organic solvents such as xylene (inks, pesticides), toluene (paint thinners, glues), & styrene (containers, packaging)

• Workers exposed to solvents → poorer hearing thresholds vs. matched non-exposed workers → auditory damage

Aim

• Investigate the hearing defects among workers exposed to mixtures of solvents and noise at safe industry levels.
Methods

- Retrospective case-control study in Egypt

- **Group 1 (G1):** 70 workers exposed to noise in carpentry, air compressor or engineering department in NRC

- **Group 2 (G2):** 93 workers exposed to noise & organic solvents (i.e. xylene, toluene) in paint production plant

- **Group 3 (G3):** 59 control workers (administration clerks) in NRC *not* exposed to either noise or solvents

- No sig. diff between groups for age, smoking habits or duration of noise exposure (≈20 yrs 8h/d for 5 d/wk).
Results

- Higher prevalence of sensory neural hearing impairment (43%) in workers exposed to both noise & solvents (G2) compared to workers exposed only to noise (G1; 24%)
  - G1+G2: Exposure duration +ve correlated with hearing loss
  - G2: Hearing impairment occurred at ↓ exposure duration

- Environmental noise assessment levels were within the permissible limits according to Egyptian law (90 dB)

- Levels of different organic solvent were much lower than levels recommended by Egyptian Environmental law.
• Greater hearing impairment in workers exposed to solvents + noise vs. workers exposed to noise only
  – Findings supported by numerous other studies
• Physiological mechanism – toluene inhibits middle ear reflex action allowing higher acoustic energy to penetrate the cochlea
• Findings highlight the importance of reducing noise exposure in solvent-rich environments to prevent solvent-enhanced potentiation of NIHL.
Exposure to Occupational Noise & CVD in the United States: 1999-2004

Introduction

• Noise exposure can cause hearing impairment, sleep disturbance, annoyance & psychological stress

• Physiological stressor = ↑ HR, BR, BPa & Muscle Tension

• Long-term exposure → development & aggravation of stress-related conditions = HTN, gastric ulcers & CVD, especially in occupational settings

Aim

• Examine the association between occupational noise exposure & prevalence of CVD, particularly CHD & HTN.
National Health & Nutrition Examination Survey

- Assesses the health & nutritional status of adults & children in the US (interviews & physical examinations)
- Stratified multi-stage procedure → representative sample
- Household interview – health- & occupational-related questionnaires + history
- Medical examination – laboratory tests on blood & urine
Self-Reported Noise Exposure Assessment

“Thinking of all the jobs you have ever had, have you ever been exposed to loud noise at work for at least three months? By loud noise I mean noise was so loud that you had to speak in a raised voice to be heard”

• **No** – Never Exposed Group

• **Yes** – Currently Exposed Group
  
  – Accumulated exposure time estimated average hours/day x no. of months working in the current job
  
  – Short- (0-0.3 yrs), medium- (0.4-1.5 yrs), & long-term (1.6-18.8 yrs) exposure to occupational noise.
Methods

Cardiovascular Diseases & Biomarkers

- Self-reported smoking status (i.e. pack-years) & SHS
- Self-reported diagnosis by a doctor
- Systolic & diastolic blood pressure measurements
- Blood sample
  - Lipid profile (total cholesterol, LDL-C, HDL-C & TG)
  - Circulating inflammatory mediators (e.g. CRP, platelets).
Results

- 6307 participants included in analysis (21% currently exposed to noise – 83% males aged 40 yrs, 8.8 mnths noise exposure)

- Participants chronically exposed to occupational noise = 2-3 fold ↑ prevalence of angina pectoris, MI, CHD & HTN
  - 2.9 times more likely to experience angina pectoris
  - 2.0 times more likely to develop CHD
  - 2.2 times more likely to develop HTN

- Clear exposure-response relationship for observed associations.
• Long-term exposure to self-reported loud noise in the workplace is associated with a 2-3 fold ↑ CV risk

• A 24-yr retrospective cohort study of Canadian sawmill workers reported 2-4 fold ↑ risk of acute MI mortality (Davies HW. Epidemiol 2005;16:25-32)

• A 13-yr prospective cohort study of Finnish male workers found a 1.5 fold ↑ in CHD hosp. or mortality for those exposed to occupational noise (Virkkunen H. Occup Environ Med 2006;63:378-86)

• Case-control study in Berlin – self-reported exposure to loud occupational noise = 1.4-3.8 fold ↑ acute MI hosp. (Ising H. Soz Praventivmed 1997;42:216-22).
Effects of Noise on Pregnancy
• Foetal HR & activity ↑ in response to sound
• Low Hz sound is transmitted into the uterine environment
  – Frequencies below 500 Hz - maternal tissues attenuate sound 10-15 dB
• Female mice exposed to 100 dB during early pregnancy = ↓ pregnancy rates, ↓ no. of live foetuses/litter & ↓ foetal weights
• Human cochlea & peripheral sensory end organs complete their normal development by 24 weeks of gestation
• Slightly ↑ frequency of birth defects (e.g. spina bifida) & LBW among families residing near airports vs. Controls.
Pregnancy

• Case-control study → pregnant women exposed to workplace noise averaging 80 dB 8h TWA = ↑ risk for threatened abortion, HT & premature birth
  

  – No increased risk of congenital malformations
  

• Children (aged 4-10 yrs) with high-frequency hearing loss → more likely to be born to women consistently exposed to noise 85-95 dB during pregnancy


1. Excessive noise exposure during pregnancy may result in high-frequency hearing loss in newborns & may be associated with prematurity & intrauterine growth retardation

2. Noise exposure in Neonatal Intensive Care Units may result in cochlear damage & may disrupt the normal growth & development of premature infants

**Conclusion:** On the basis of these results, noise-induced health effects on foetuses & newborns merits further study.
Summary

• Noise is a common workplace hazard & occupational noise exposure is an important OSH issue

• Constant exposure to noise over 85 dB can cause hearing damage & other health problems
  – NIHL cannot be cured or repaired → 100% PREVENTABLE!

• Occupational noise exposure limits designed to protect against NIHL
  – Future research is required to establish safe noise exposures for other health conditions.
Thank You for Listening

Questions?

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