Vibroacoustic Disease: Reality vs. Conceit

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Background

In Portugal, the biological effects of LFN exposure have been systematically studied since 1980 in human populations exposed to low frequency noise (LFN) in the workplace.

In 1992, we began using animal models (rats) exposed to LFN in an occupational-simulated schedule.

In 2000, came the first studies involving LFN in homes, or environmental exposure.

In 2011, studies continue among occupationally-exposed professionals, environmentally-exposed individuals, and animal models.
**Historical Conceit**

**Wrong Assumption**: What you can’t hear won’t hurt you.

**Therefore**: To protect against noise, only measure what humans can hear!

**Which implies**: No measurements of non-audible acoustic phenomena...

1926, USA

1929, UK

1941, USA
Human Hearing

Acoustical Spectrum:

Infrasound: $< 20$ Hz
LFN: 20-500 Hz

Audible: 20-20 000 Hz
Ultrasound: $> 20 000$ Hz

Do you believe that...
... you must perceive the agent of disease for it to have an effect on your health?
Modern Conceit

Measuring Low Frequency Noise with dBA units because:

- Only need to measure what humans hear, **which means**
- Only need to measure audible frequencies, **therefore**
- No need to measure infrasound, **hence**
- Infrasound is ignored and levels are unknown.

Frequency response curve for A-weighted measurements (dBA)
Conceit

Equal dBA measurements = Equal acoustical environments

- Cockpit: 72.1 dBA
- Stopped Train: 71.4 dBA
- Car: 71.2 dBA

TRUE or FALSE?
These are not acoustically equivalent environments!

Cockpit vs. Stopped Train

The person *hears* 72.1 in the cockpit and 71.4 on the stopped train.

The person *is exposed to* 83.2 in the cockpit and 92.0 on the train.
These are not acoustically equivalent environments!

Cockpit vs. Car

The person **hears** 72.1 in the cockpit, and 71.2 in the car. The person **is exposed to** 83.2 in the cockpit, and to 100.8 the car.
Because Infrasound and Low Frequency Noise is not heard

It cannot cause hearing impairment, and
It cannot cause sleep disturbances;

And Since
It is not quantified nor evaluated, and not everyone feels the same in its presence,

Then:
People who complain about this type of noise must be “noise-sensitive” and should seek psychological or psychiatric care.
Conceit

Noise only affects the human via the auditory system.

Hearing impairment.
Sleep disturbances.
Annoyance at different levels.
Cardiovascular disease.
Stress.

Perceived Stress
Physiologic Responses
Allostasis → Adaptation
Allostatic Load
Airborne Acoustical Wave = Pressure wave:

Zero dB is the minimum amount of pressure for humans to perceive a tone of 1000 Hz: 20 microPascal. This corresponds to a movement of the tympanic membrane of $10^{-9}$ cm. (Diameter of molecules $\approx 10^{-8}$ cm.)

Analogy: with pressure of 20 microPascal:

- Piston diameter: $D = 0.006$ cm
- Distance travelled: $L = 0.1$ mm
Science

- Cells are **not like elastic balloons** with floating organelles.
- Cells communicate through biochemical and **mechanical signals**.
- Cells are organized by **tensegrity architecture**.
- Cells **respond and redistribute** mechanical stimuli.

**Tensegrity:** Continuous Tension and Discontinuous Compression.
Cellular response to force along the vertical axis.

Cellular response to laminar flow.

Human Arm

Tensegrity model of cellular membrane pore
Vibroacoustic Disease (VAD)

Consistent Biological response to ILFN exposure:
-- Abnormal production of collagen & elastin
-- Absence of inflammatory response


In ILFN-rich Occupational Environments
- Respiratory conditions
- Immune disorders
- Genotoxic effects
- Neurological disturbances
- **Cardiovascular disease**
**Normal Pericardium**

- **Normal pericardium**
  - <0.5 mm thickness
  - **Two layers** of tissue:
    - Fibrous
    - Serous
VAD Parietal Pericardium

Pericardial thickness due to **four layers** of tissue:

-- Fibrosa layer splits into 2
-- New layer is formed and made of loose tissue
-- Serosa with dynamic cellular organizations, large amounts of cellular death and of inter-cellular connections
-- Absence of cilia

- 1.03 mm – 2.23 mm thick *(by histological analysis)*
- **ABSENCE** of inflammatory process *(by histological analysis)*
- **With NO dyastolic dysfunction** *(by echocardiography)*

12 VAD patients (age range: 32-62); cardiac surgery for other reasons (cardiac bypass or valve replacement) by national healthcare services; informed consent; removal of their pericardial fragments; light and electron microscopy.
Pericardial Thickening in VAD

The scale of these two micrographs is the same.

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Pericardial Thickening in VAD

• Can be assessed through echocardiography by a specifically trained technician / physician.

• Is not to be confused with pericarditis because no inflammatory process and no dyastolic dysfunction are present.

• In itself, not an immediate threat to cardiac function, although associated cellular dynamics and amount of cellular death is likely associated with VAD-related immune disorders.

• Is a clinical sign of infrasound and LFN exposure.

• Pericardial thickening usually means concomittant thickening of cardiac valves and of coronary artery walls, hence the risk for ischemic heart disease.
Thickened Vessel Walls

Thickened artery wall in LFN-exposed rat.

Thickened artery wall in VAD-patient pericardial loose-tissue layer.

VAD researchers are **not convinced** that this abnormal collagen growth is triggered solely via auditory stimuli.
Pericardial Thickening & Infrasound

Echocardiography in 30 Airline Pilots and 30 Flight Attendants (FA)

By age group (total exposure time):
Pilots had statistically significantly larger pericardial thickening scores than FA.

At first glance, this denies the claim that larger levels of LFN cause pericardial thickening because, everyone knows, cockpits are “quieter” than passenger cabins.

Acoustical measurements onboard commercial aircraft showed:

• No statistical difference between cockpit & cabin in the 25-500 Hz range.

• Statistically significant difference between cockpit & cabin within the 6.3-20 Hz (infrasound) range.
The higher the speed, the higher the levels of infrasound.

The higher the altitude, the lower the levels of infrasound.

Given these (and other) results, VAD researchers seriously question the assumption: “what you can’t hear won’t hurt you”. Conceit?
ILFN Effects on Hearing

• ILFN-Exposed People:
  -- Cannot stand any noise  -- Say: “I hear too much”  --
  -- Lower TV volume to where others cannot hear it  -- Rage
  reactions  -- Audiograms show losses at 250 Hz and 500 Hz

• ILFN-Exposed Rats:
  Control rats respond to the sound of a blown kiss by becoming
  tense and frozen, while ILFN-exposed rats would develop a
  seizure-like episode, falling backwards while shaking.

VAD TEAM:
• Considers noise annoyance as a SUBJECTIVE PARAMETER;
• In the presence of a noise annoyed person, previous noise
  exposure is suspected, and OBJECTIVE MEDICAL TESTS are
  provided.
Control Rat Cochlear Cilia

The cochlea of ILFN-exposed rats were studied using light and electron microscopy, and compared to controls.

Control rat cochlear cilia.
Upper membrane was completely removed to show independent tufts of cilia.
Missing cilia is due to normal aging process.
Upper membrane is fused with cilia and not easily removed. Cilia are fused amongst themselves.

Upper membrane is removed revealing cilia tufts fused amongst themselves. No missing cilia tufts due to natural aging process.

Given the function of actin-based stereocilia in relaying acoustical signals into electrical inputs to the brain, VAD researchers suspect that this ciliary fusion, if it occurs in humans, may be an organic explanation for noise annoyance.
Environmental vs Occupational

VAD Researchers’ Experience:

• In-home ILFN levels have been much lower than within the occupational environments studied by VAD researchers.

• In-home time exposure patterns are different from occupational time exposure patterns: people sleep in ILFN-rich home environments.

• People most annoyed with in-home ILFN already have non-trivial noise exposure histories (fetal, childhood, leisure, previous or present occupations).

• The work-at-home person is more sensitive to in-home ILFN than other members of the family unless they have additional ILFN exposure histories.
Cases of Environmental ILFN

- 2000 – Island of Vieques, Puerto Rico
  71% greater risk of hypertension, 65% greater risk of heart disease than rest of PR. Location of US military installations for 4 decades generating ILFN. Echocardiograms of 50 persons from Vieques compared to echos of 50 persons from another Island (Ponce). Pericardial thickening assessed by 2 different groups. Vieques population had significantly statistically higher levels of pericardial thickening than the Ponce population.
Cases of Environmental ILFN

• 2004 – Restelo Family + Grain Terminals
  Greater Lisbon Area. Father: 39-yr-old Architect; Mother: 43-year old Forestry Engineer; 10-yr old son. Father worked at home. Father with larger pericardial thickening than mother, son with largest of all and with mitral valve leaflet thickening. Son had exposure since gestation.

Cockpit vs. Restelo Home With Noise

- Cockpit
- Home with noise'
Cases of Environmental ILFN

- 2007 – Wind Turbine Family

**COMPARISON BETWEEN GRAIN TERMINAL AND WIND TURBINE HOMES**

- **Grain Terminal Home**
- **Wind Turbine Home**
Cases of Environmental ILFN

- 2010 – Wind Turbine Family Horses

2000-2006: 13 healthy thoroughbred Lusitanian horses born on the farm. 2007-2010: all 4 born or raised on the farm developed asymmetric flexural limb deformities (*boxy foot or club foot*). 2010: biopsy from 4 + control. Tissue samples of exposed horses: abnormal proliferation of collagen in the absence of an inflammatory process.
IN CONCLUSION

• Most consistent finding in 31 years of research: biological response specific to ILFN exposure is abnormal collagen growth in the absence of an inflammatory process.

• In cardiovascular structures: pericardial thickening, seen through echocardiography and anatomically confirmed confirms history of ILFN exposure.

• Postulation: pericardial thickening is directly related to infrasound exposure.

• In-home ILFN-rich environments: accelerates onset and severity of other VAD-related symptoms.
RECOMMENDATIONS

• For healthcare professionals:
  Give “noise-sensitive” or “noise annoyed” people appropriate and objective diagnostic tests (echocardiogram among others) before suspecting psychological and/or psychiatric disturbances. Get noise exposure histories.

• For acoustical and biomedical researchers:

• For the “noise-sensitive” people:
  Remove yourself from that environment. If not, make sure you have periodic recovery times – time away from the ILFN.
Thank you for your attention!

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