

# Effect of noise exposure in the entertainment sector

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## Background

The new noise directive (2003/10/EC) was introduced in 2003 to reduce the health effects of noise especially the induced hearing loss (NIHL). In the directive an exposure limit value of  $L_{EX,8h}=87$  dB(A) and  $L_{Cpeak}=200$  Pa are given. When applying the exposure limit values, the determination of the worker's effective exposure shall take account of the attenuation provided by the individual hearing protectors worn by the worker. In addition an upper exposure action value ( $L_{EX,8h}=85$  dB(A) and  $L_{Cpeak}=140$  Pa) and lower exposure action value ( $L_{EX,8h}=80$  dB(A) and  $L_{Cpeak}=112$  Pa). The exposure action values shall not take account of the effect of any protectors. In case where the daily noise exposure is varying a lot, weekly noise exposure can be used.

In the introductory part of the directive it is stated that the particular characteristics of the music and entertainment sectors require practical guidance to allow for an effective application of the provisions laid down by the Directive. In the directive is listed several points which have to be taken into consideration. In my presentation I am concentrating only one topic, namely the nature of the risks (article 8, clause a).

## Effect of noise to hearing

Noise is making the damage at the cell level. This damage is causing several symptoms which will social impacts. This presentations starts at the cell level and goes up-to the social impacts.

### *Noise effect at cell level*

The ear is a complicated system which amplifies the incoming sound and transforms it to mechanical waves which are detected in cochlea (fig 1) and transferred by the auditory nerve to the cortex. In the cortex the nerve signal is interpreted. The cochlea has the form of a spiral to reduce the size requirements. In the cochlea there are hear cells (fig 2). Usually there are 3-4 rows of outer hair cell and one row of inner hear cells. Figure 2b shows the effect of noise exposure to the hear cells.

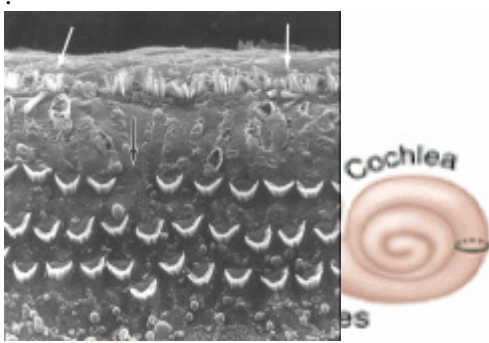


Figure 1. The cochlea

Figure 2  
A) non-damaged cochlea    B) cochlea after noise exposure

Until recently it was believed that the hear cells died because of the mechanical stress caused by the incoming sound waves. Recent research in molecular biology has shown that there are two mechanisms for

cell death (fig 3). Steady state noise is causing apoptosis. When working hear cell are producing reactive oxidative metabolites which are poisonous. Excessive exposure to these metabolites causes the cell to make a suicide (=apoptosis). After the death of the hear cell also neuron conducting the signal to the auditory nerve dies and finally the blood vessels transporting energy to the cell dies. Thus the destruction is total and the restoration of hear cell would not restore the hearing even if it would be possible.

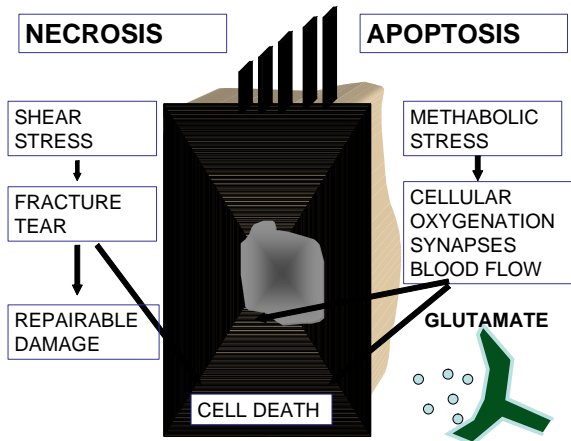


Figure 2. Cell death mechanisms

The second mechanism is necrosis, This is typically caused by impulse/impulsive noise. The noise intensity is so high that noise causes a shear stress which causes small fractures. If the cells have time they probably recover from the fracture but repeated fractures end up with necrotic death of the cells. Impulse noise can cause a necrotic pathway also in other cell types, like neurons and supporting cells. Damage of the neurons is experienced as tinnitus and damage of supporting cells as hyperacusis (pain in the ears). Also the shear stress can change the diffusion characteristics of the membrane

At the moment the connection between apoptosis and steady state noise is well established, but the connection between impulse noise and necrosis is not yet completely proven. Still this model explains well the different characteristic the hearing symptoms in steady state exposure and impulsive noise exposure

It seems to be that above 125 dB the cell death is mainly caused by necrosis. The limit where necrosis is not important is around 100 dB. In music you find often these kind of peak (fig 3).

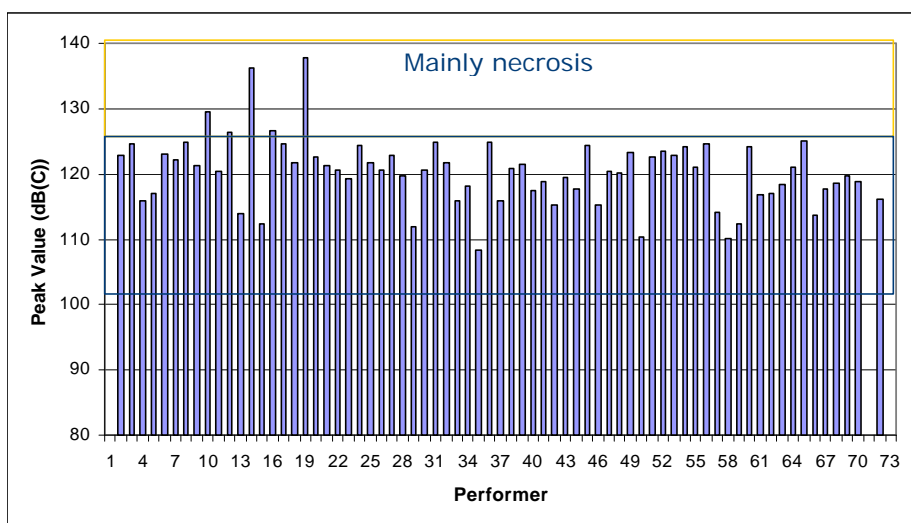


Figure 3. The peak levels in open air concert (measured at 25 m from the stage)

## Symptoms caused by noise exposure

When a single tone enters the ear a small fraction of the hair cells start to work in an intact cochlea (fig 2a red stripe). In a damaged cochlea a wide range of hair cells start to react. The advantage is that smaller sounds can be detected. However you have to pay the price of reduced frequency resolution. This is felt as reduced speech intelligibility. The reduction is first observed in background noise. With a large hair cell loss, the hearing threshold increases (fig 4). Usually over 50 % of hair cells are lost before anything is seen in the audiometry.

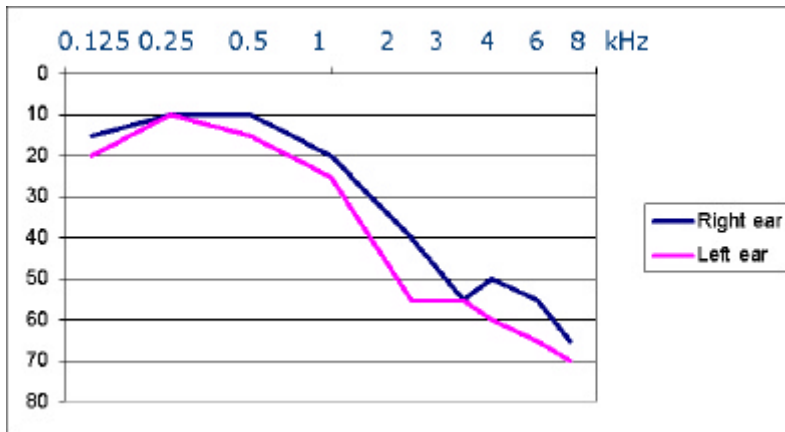


Figure 4. Example of a hearing threshold shift caused by noise

In addition to hearing symptoms described in the previous chapter hyperacusis and tinnitus are present. Also diplacusis may be experienced.

For classical musician we know the hearing threshold corresponds to the hearing threshold of non-exposed population. However for the other symptoms they are about four times more frequent among classical musicians than for non-exposed population.

It is unfortunate for musicians that the golden standard in the evaluation of hearing damage is audiometry, which is not showing particular risk of hearing loss in many fields of music. It is a well known fact that the audiometry is not a very good way of evaluating the hearing loss. When comparing average hearing loss at speech frequency and self-evaluated hearing loss the correlation is poor (fig 5).

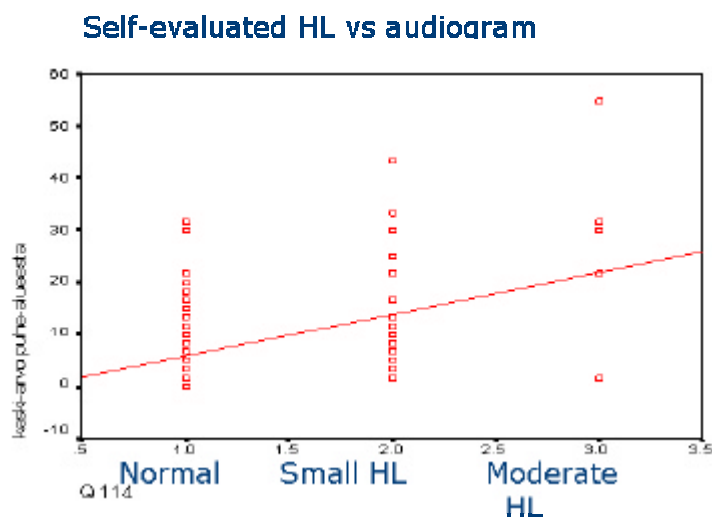


Figure 5. Correlation between self-evaluated hl and mean HL at 0.5 -2 kHz (speech frequencies)

There are many reasons to this. Tinnitus is experienced more disturbing than the threshold shift. The same seems to apply to hyperacusis. Also people who need to communicate in background noise seem to be more sensitive to hearing impairment than conventional industrial workers.

## Social effects of noise

A comprehensive list of all social effects is found at <http://www.hear-it.org/>.

High noise exposure is known to cause in addition to hearing damage also nausea, dizziness, anxiety, difficulties to initiating sleep.

In the entertainment sector it has been shown, that tinnitus, hyperacusis, palpitations of the heart, dizziness, Irritation or anxiety, nausea and difficulties initiating sleep have a strong effect to work motivation , work related stress and quality of life. The effect of self-evaluated hearing loss to the quality of life ([www.euroqol.org](http://www.euroqol.org)) is very strong in the entertainment sector (fig 6).

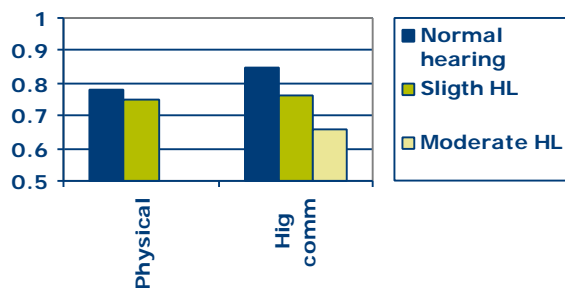


Figure 6. The effect of self-evaluated hearing loss to quality of life in conventional industrial work and in entertainment sector

## Conclusions

Music has high impact to the life of workers in the entertainment sector, but we do not have a good method for evaluating these effects.



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# Effect of noise exposure in the entertainment sector

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# Hearing loss in entertainment sector

- Musicians hearing corresponds to hearing of non-exposed population
- Common explanations
  - Training
  - Music is less damaging than industrial noise
  - exposure is interemittent

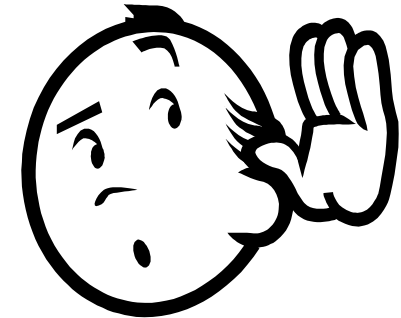
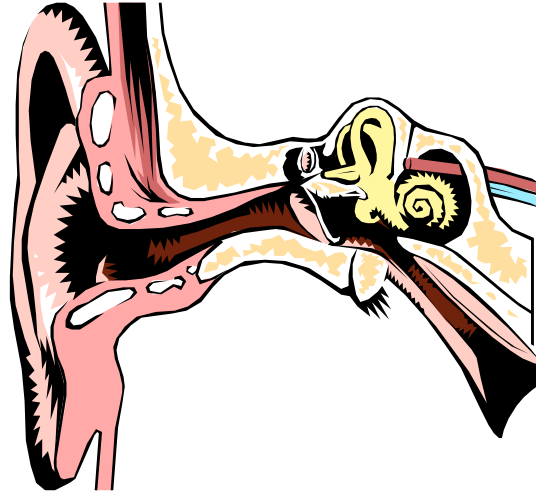
Is this true?



# Dose response model for hearing loss



- NOISE**
- level
  - duration
  - pauses
  - impulsiveness



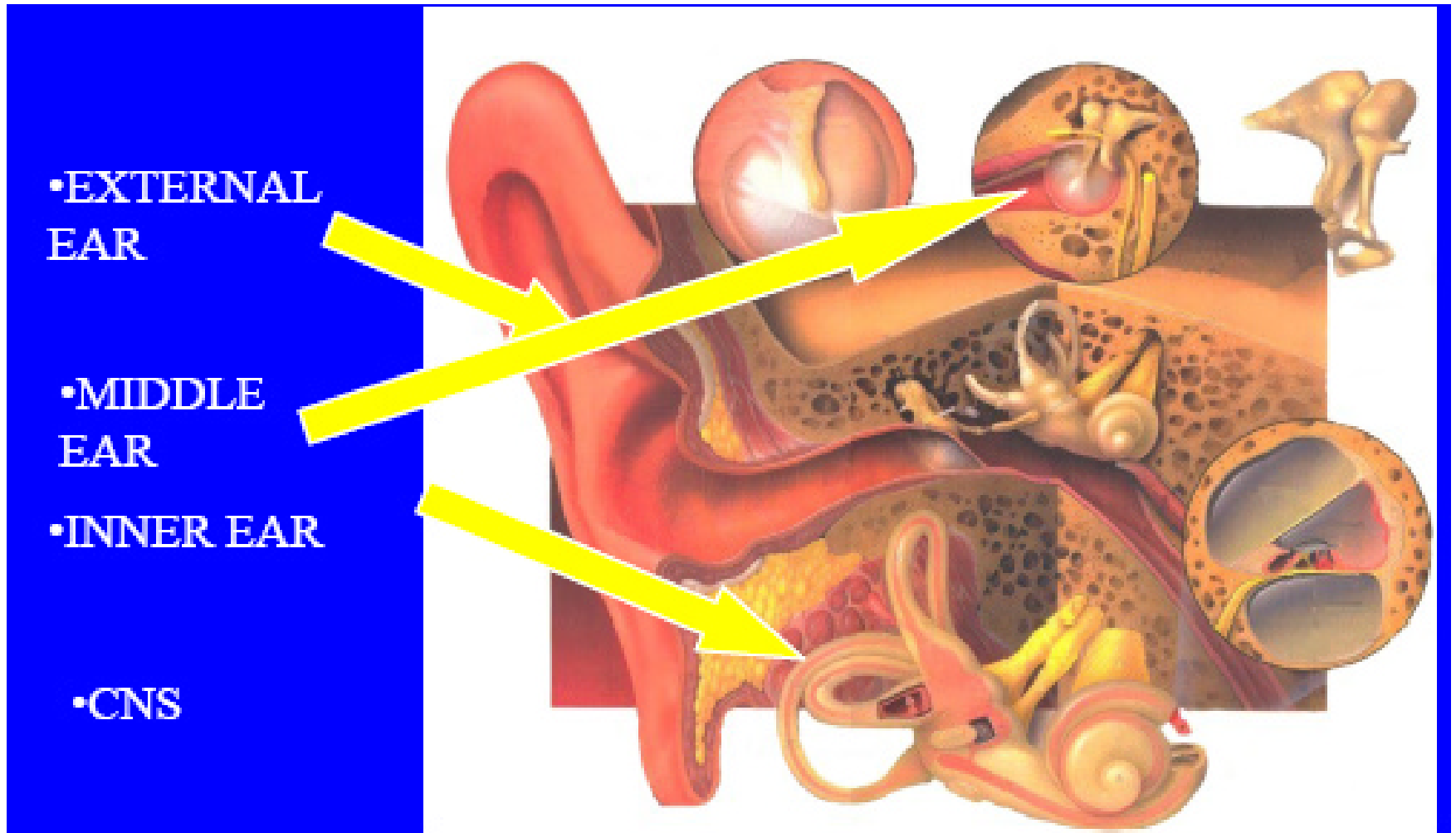
**Hearing loss**

**Dose**  
**Equivalent exposure**

**System**

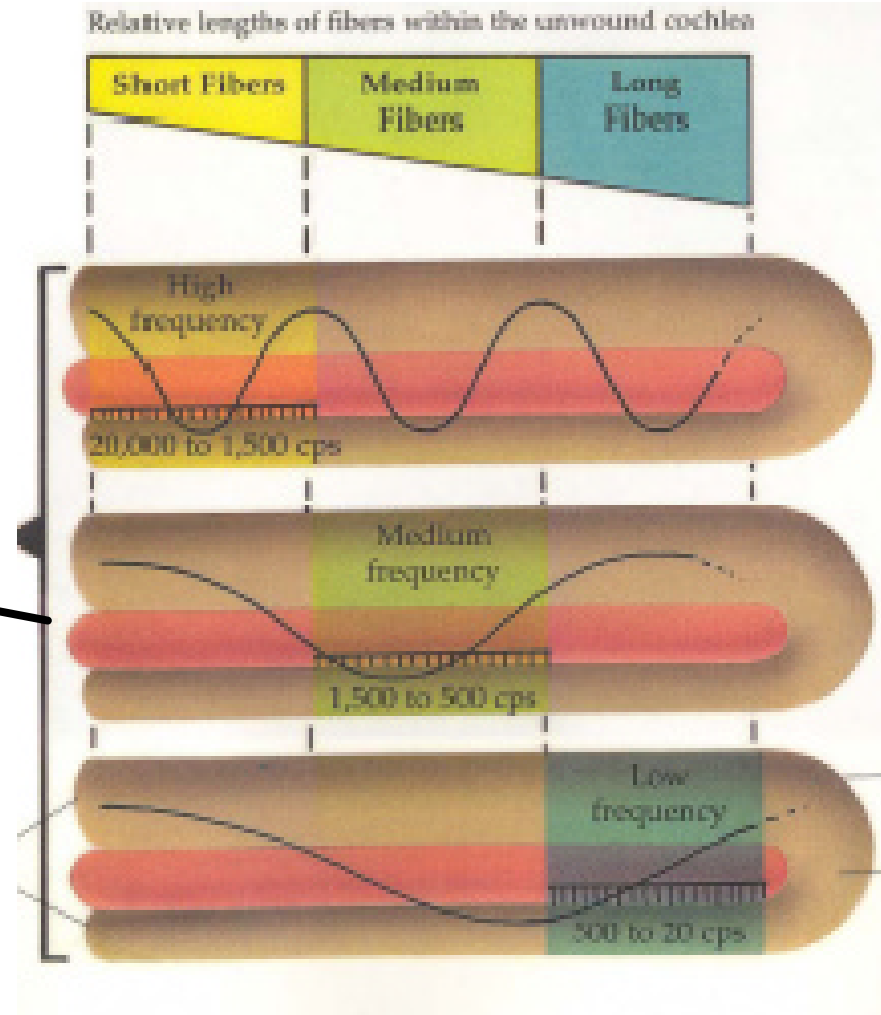
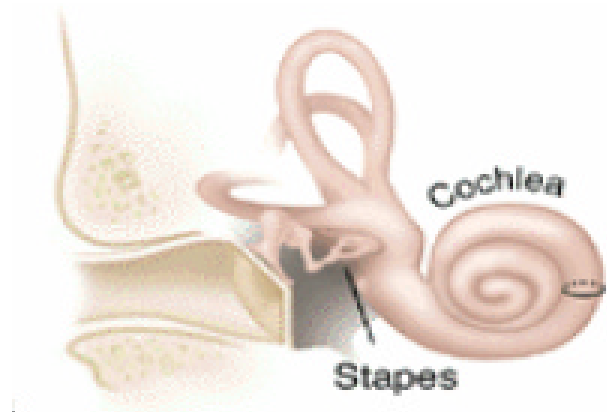
**Response**  
***Audiogram***

# The ear





# Organ of Corti and hair cells



# How the hear cells die in noise ?

Impulse noise

Steady state noise

**NECROSIS**

**APOPTOSIS**

SHEAR  
STRESS

METHABOLIC  
STRESS

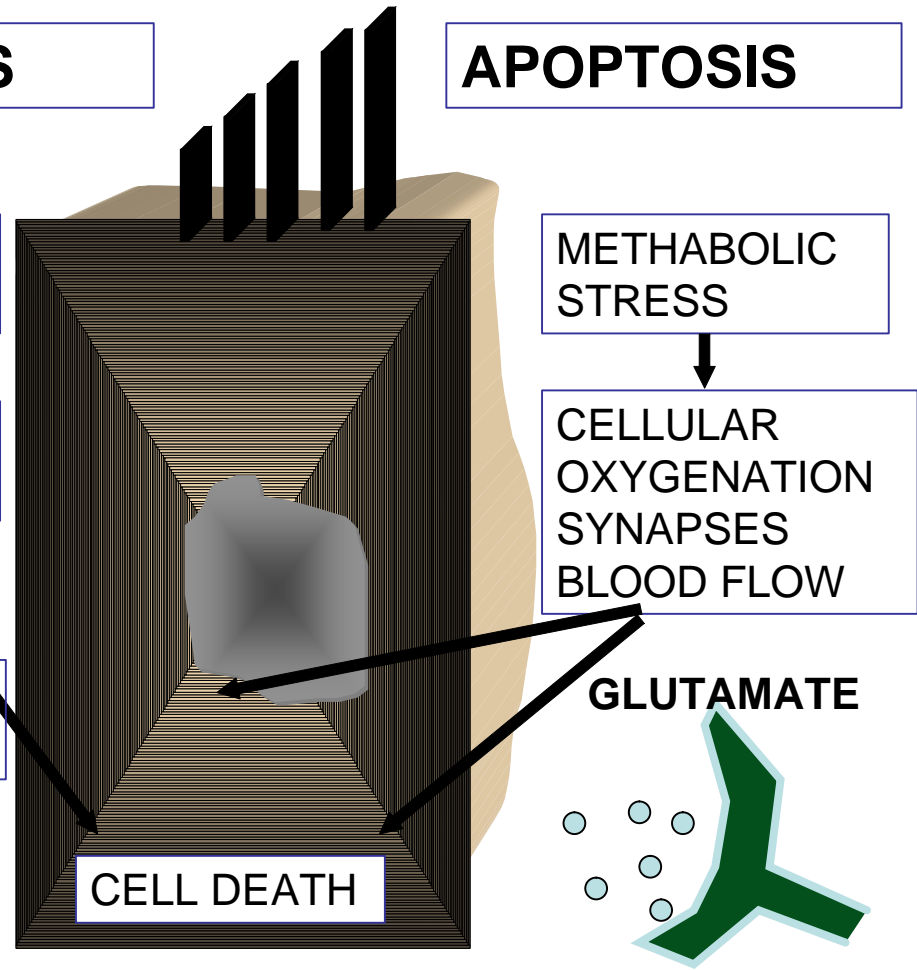
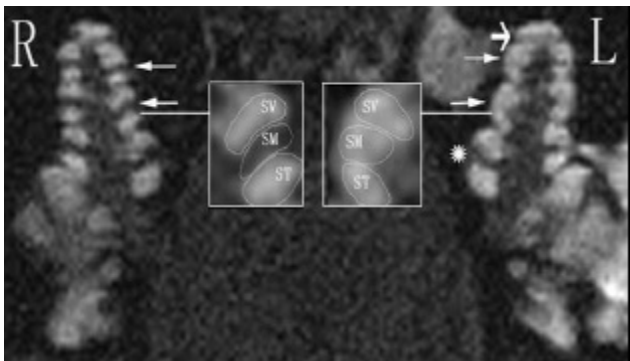
FRACTURE  
TEAR

CELLULAR  
OXYGENATION  
SYNAPSES  
BLOOD FLOW

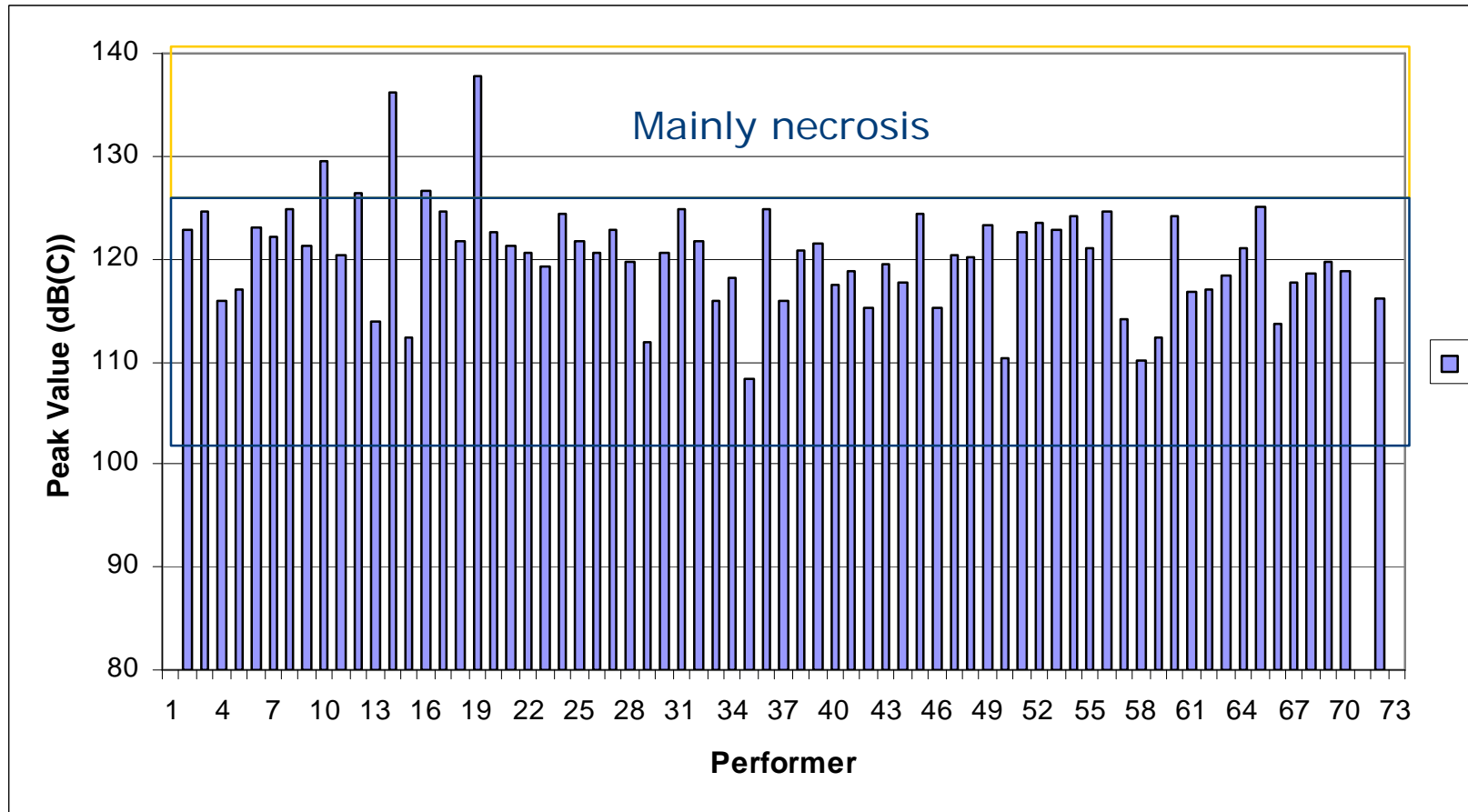
REPAIRABLE  
DAMAGE

GLUTAMATE

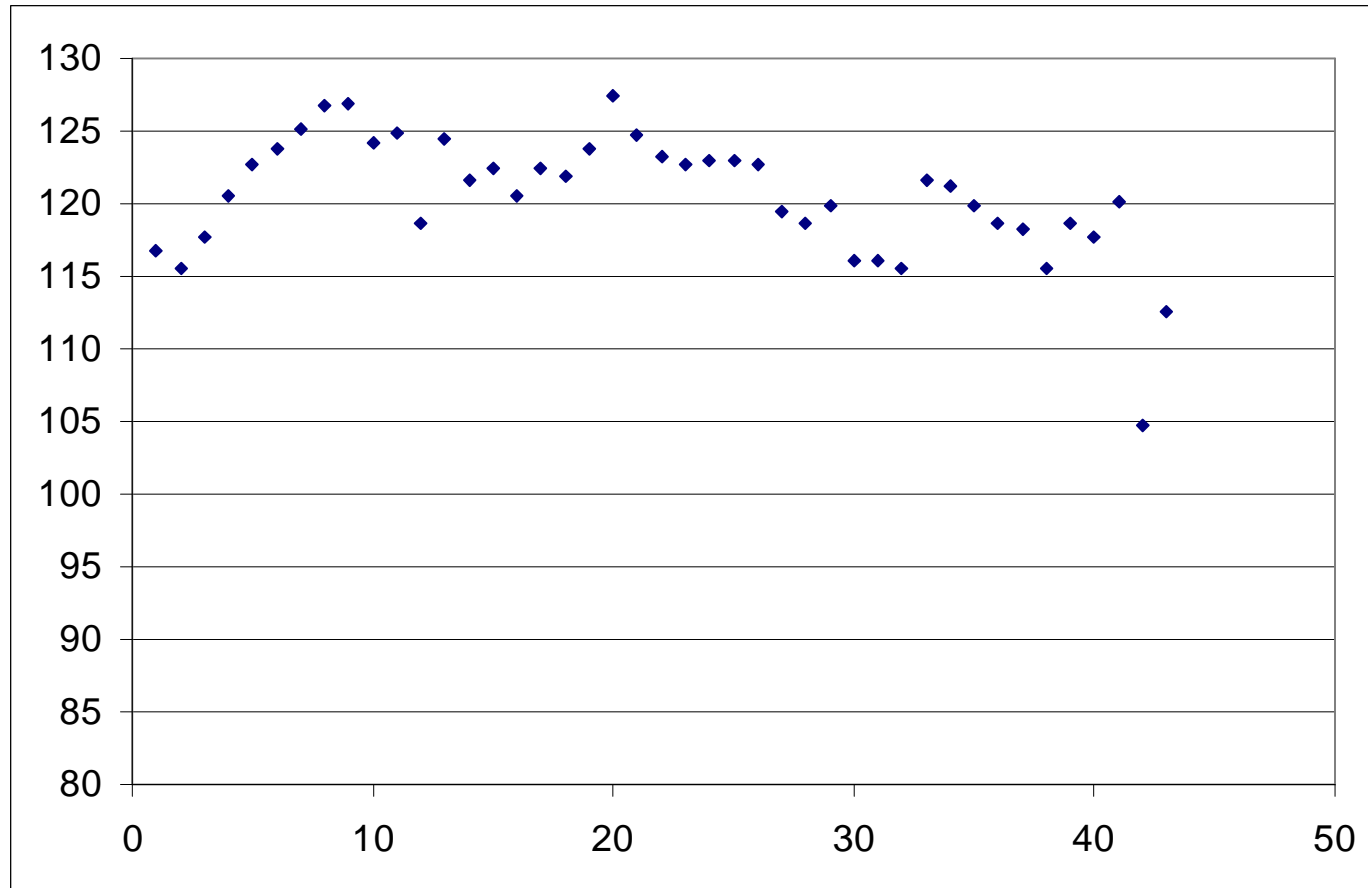
CELL DEATH



# Peak levels in a concert by performer at 25 m from the stage (Courtesy of K Saari)

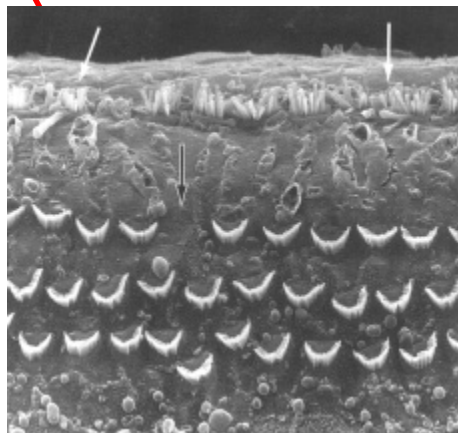
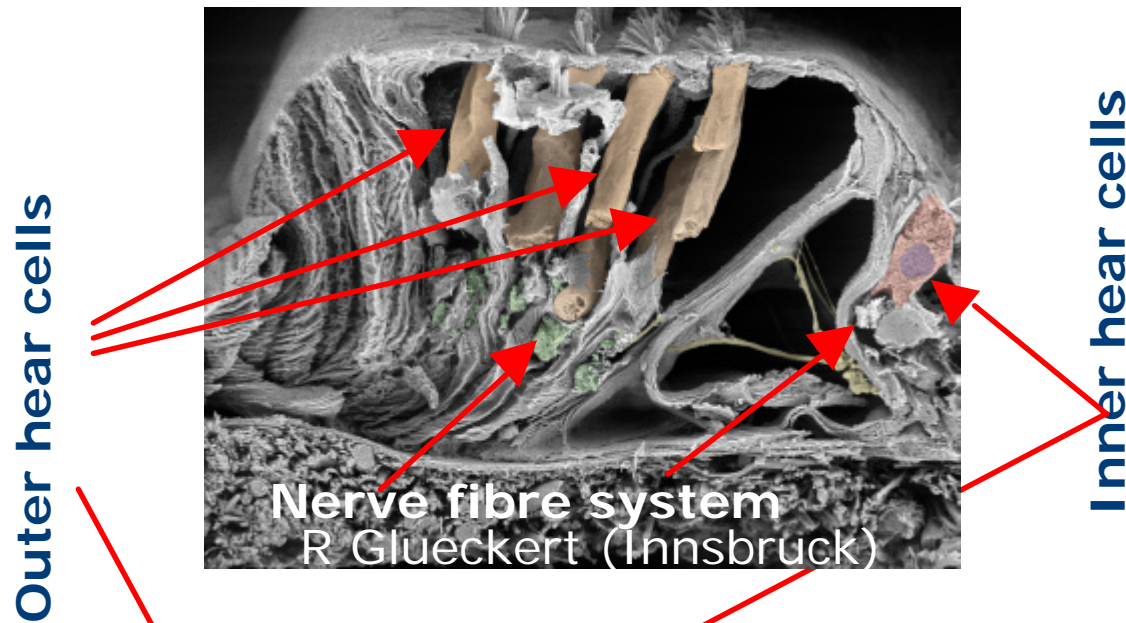


# Peak levels in a disco

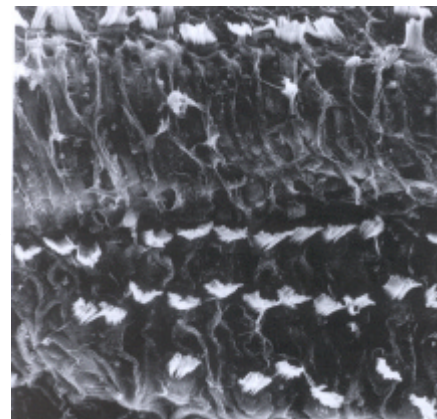


# Noise induced damage in the hearing organ

## Supporting cells



Noise



# Effects of noise to hearing organ

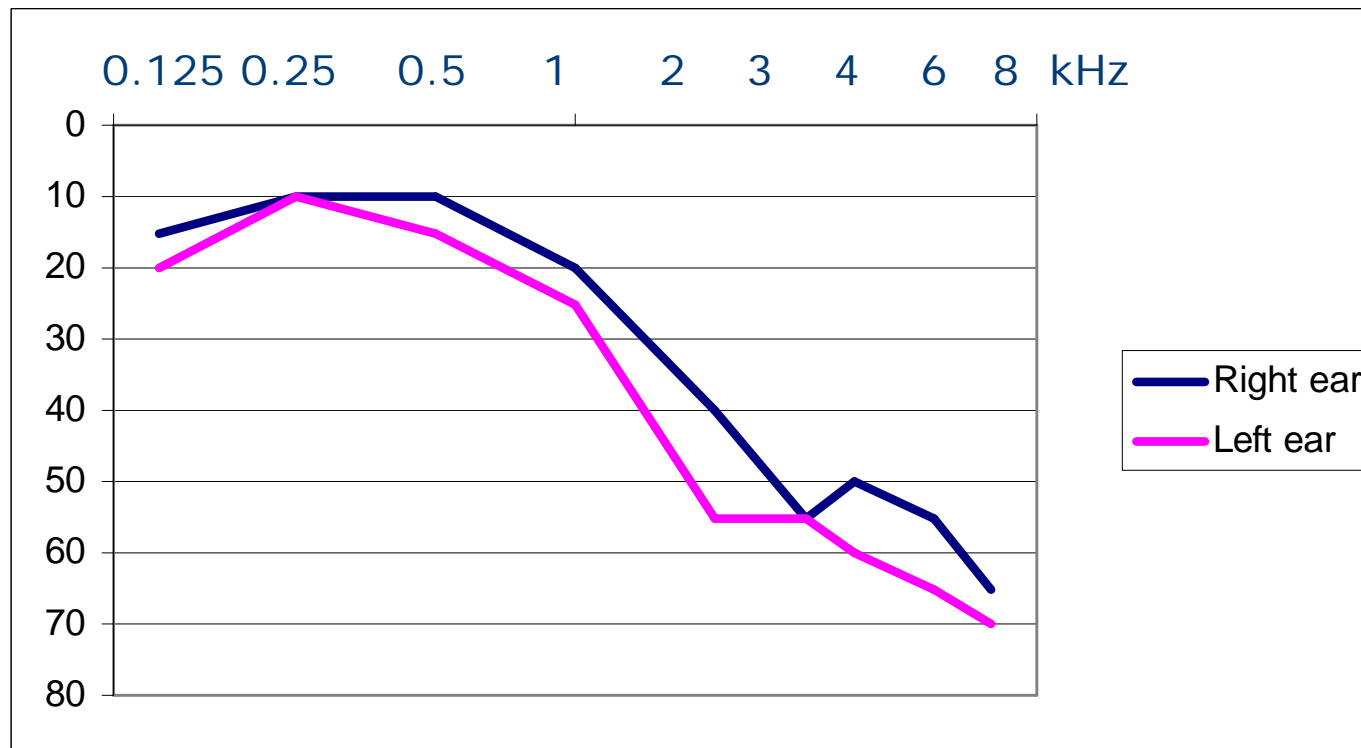
- Loss of hear cells
  - Change in hearing threshold (Audiometry)
  - Loss of speech intelligibility especially in background noise
  - Death of fibre nerves
- Damage of fibre nerves
  - Impulse noise causes ruptures the nerves as well
  - Tinnitus
- Damage of supporting cells
  - Impulse noise causes ruptures the supporting cells as well
  - Hyperacusis (pain in the ears)

# Prevalence of noise symptoms among musicians

- Change in hearing threshold 5-15%
  - About the same than non-exposed population
- Permanent tinnitus 15-20 %
  - ~2 % of cases
  - About four time more then non-exposed population
- Tinnitus after rehearsals or performances 60-70 %
  - About four time more then non-exposed population
- Hyperacusis 40-60 %
  - About four time more then non-exposed population
- Diplacusis <5%

# What is hearing loss ?

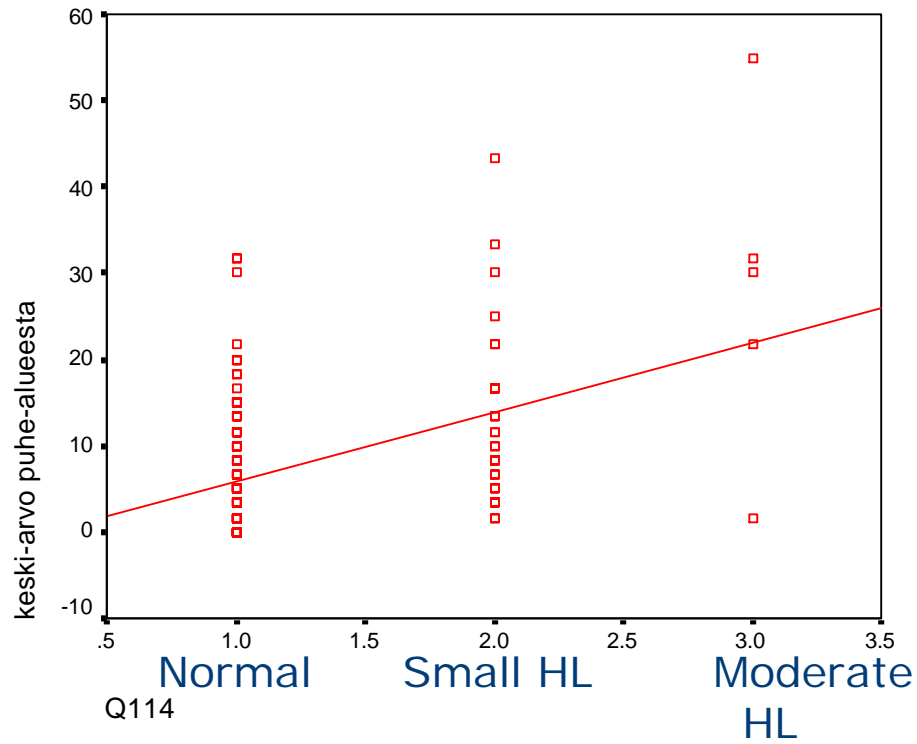
- Legal definition
  - Permanent threshold shift
  - Measured with audiometer





# Self evaluated hearing loss

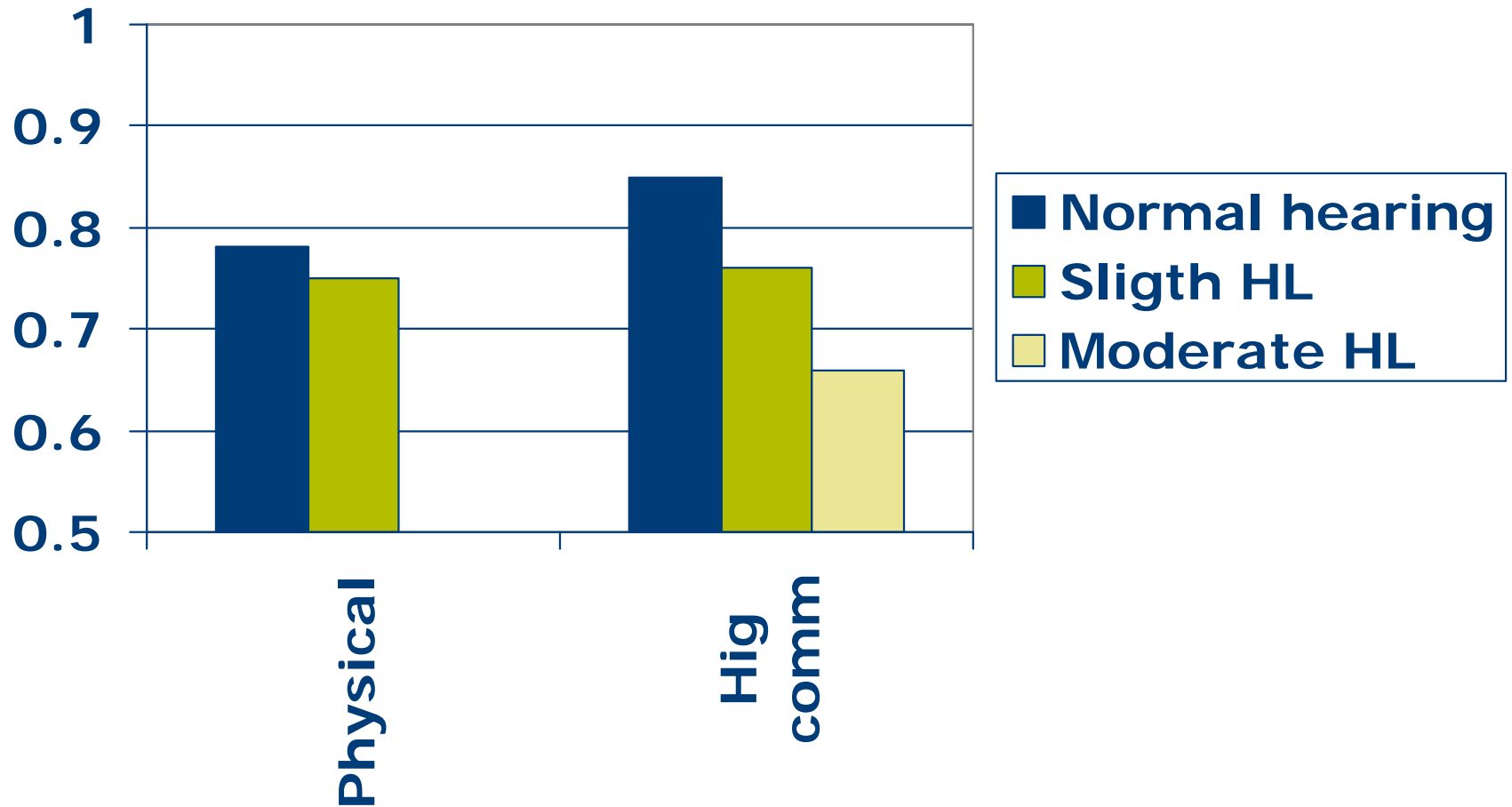
Self-evaluated HL vs audiogram



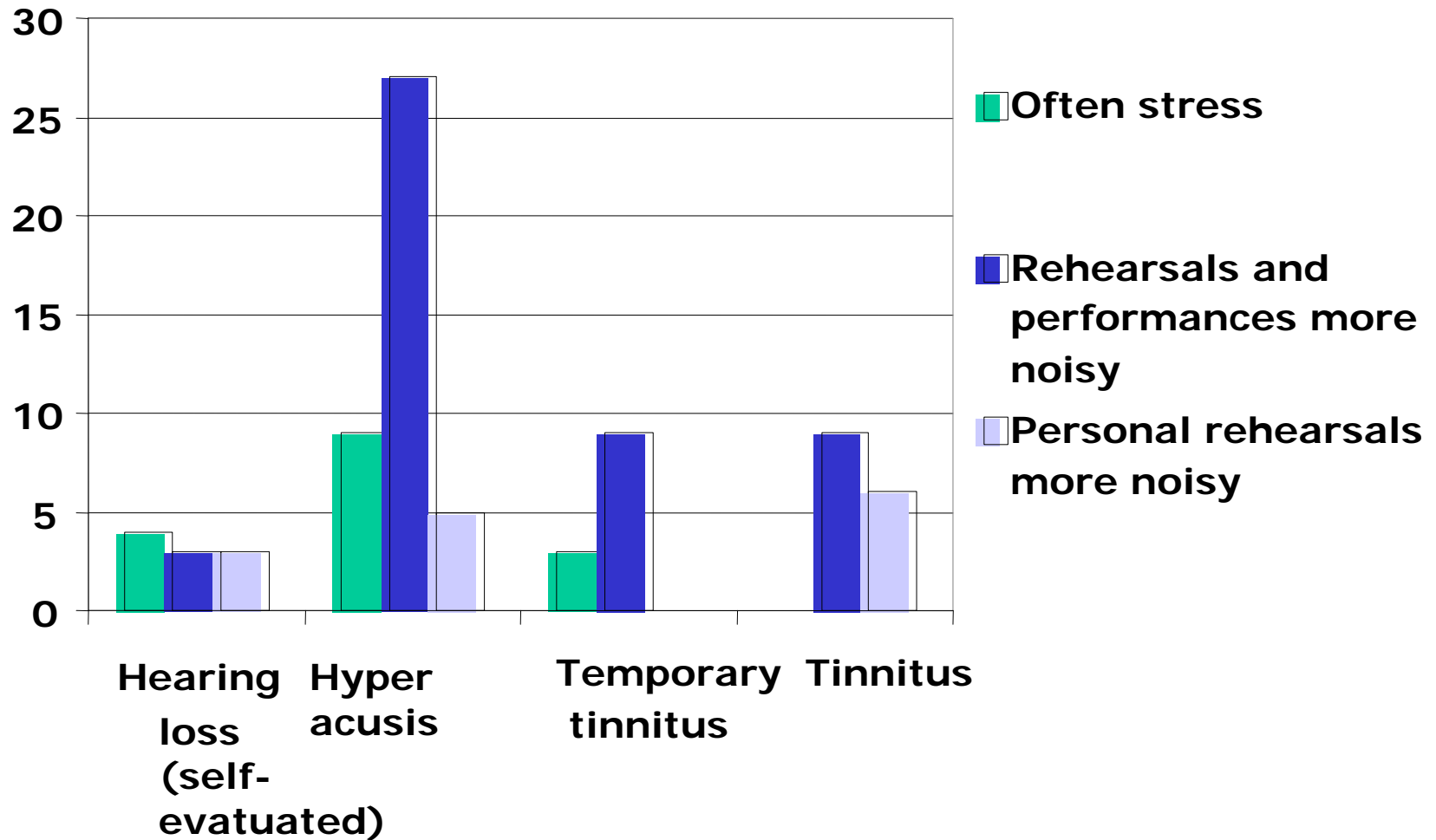
# WHO definition of hearing loss

- All social consequences of hearing impairment
  - Symptoms
    - sleep disturbances
    - nausea/dizziness
    - Palpitation of the heart
    - Hearing symptoms (Hearing loss, tinnitus, hyperacusis)
  - Social consequences
    - Increased unemployment
    - Social isolation
    - Stress
    - Reduced quality of life
    - Reduced work motivation

# Effect of hearing loss in populations



# The effect of hearing symptoms among musicians



# Relation between stress at work/quality of life and noise related symptoms

	Severe stress experience		Health related quality of life	
	no	yes	good	else
<b>n=354</b>				
<b>Tinnitus</b>	<b>13.2</b>	<b>23.2</b>	<b>8.0</b>	<b>22.9</b>
<b>Hyperacusis</b>	<b>2.6</b>	<b>8.5</b>	<b>1.7</b>	<b>6.1</b>
<b>Palpitations of the heart</b>	<b>3.3</b>	<b>9.8</b>	<b>1.7</b>	<b>7.8</b>
<b>Dizziness</b>	<b>1.8</b>	<b>7.3</b>	<b>0.6</b>	<b>5.6</b>
<b>Irritation or anxiety</b>	<b>5.5</b>	<b>57.3</b>	<b>3.4</b>	<b>31.3</b>
<b>Nausea</b>	<b>0.4</b>	<b>3.7</b>	<b>0.0</b>	<b>2.2</b>
<b>Difficulties initiating / sleep</b>	<b>9.6</b>	<b>41.5</b>	<b>6.3</b>	<b>27.4</b>

# Hearing loss in the entertainment sector

- Effect of hearing loss to musicians
  - Hearing is a major tools in music
    - Need to hear loud and silent music and nuances
  - Poor tool causes stress and reduced quality of life and work motivation
- Effect of hearing loss to other personnel
  - Need to hear and understand in high background noise
- OSH problems
  - No good diagnostic tools available for detection of the major problems
  - Audiogram refers only to threshold shift



# summary

Music has high impact to the life of workers in the entertainment sector



No good evaluation method exists