Hearing loss
due to recreational exposure
to loud sounds

A review

World Health Organization
Hearing loss
due to recreational exposure
to loud sounds

A review

World Health Organization
Contributors:

Etienne Krug, Maria Alarcos Cieza, Shelly Chadha, Laura Sminkey, Thais Morata, DeWet Swanepoel, Adrian Fuente, Warwick Williams, Joseph Cerquone, Ricardo Martinez, Gretchen Stevens, Margie Peden, Sowmya Rao, Paras Agarwal, Eighmey Zeeck, Anna Bladey, Malachi Arunda, Aileen Ncube.

Graphics Credits: INIS Communications

WHO Library Cataloguing-in-Publication Data
Hearing loss due to recreational exposure to loud sounds: a review.

ISBN 978 92 4 150851 3 (NLM classification: WV 270)

© World Health Organization 2015

All rights reserved. Publications of the World Health Organization are available on the WHO website (http://www.who.int) or can be purchased from WHO Press, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland (tel.: +41 22 791 3264; fax: +41 22 791 4857; e-mail: bookorders@who.int).

Requests for permission to reproduce or translate WHO publications – whether for sale or for non-commercial distribution – should be addressed to WHO Press through the WHO website (http://www.who.int/about/licensing/copyright_form/en/index.html).

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.

The mention of specific companies or of certain manufacturers’ products does not imply that they are endorsed or recommended by the World Health Organization in preference to others of a similar nature that are not mentioned. Errors and omissions excepted, the names of proprietary products are distinguished by initial capital letters.

All reasonable precautions have been taken by the World Health Organization to verify the information contained in this publication. However, the published material is being distributed without warranty of any kind, either expressed or implied. The responsibility for the interpretation and use of the material lies with the reader. In no event shall the World Health Organization be liable for damages arising from its use.
**Introduction**

Excessive noise is increasingly encountered in many aspects of day-to-day life. Among the many people exposed to noise at their place of work, occupational hearing loss is common, and the cost of compensation is extremely high (1). Environmental noise from non-occupational sources such as traffic is also increasing and is responsible for an estimated 1–1.6 million DALYs (disability-adjusted life years) in western European countries, implying an annual loss of 1 million life years in that part of the world (2).

Additionally, concern is growing about the ever-greater exposure to noise in recreational settings: unsafe levels of sound are frequently experienced in a variety of non-occupational settings such as nightclubs, discotheques, pubs, bars, cinemas, concerts, live sporting events and even fitness classes (3–7). Moreover, recreational devices such as personal music players and video game consoles that emit sounds are commonly operated at unsafe volumes. Hearing can be damaged by regular participation in these loud activities (8–11).

**Cause for concern**

WHO estimates that 1.1 billion young people worldwide could be at risk of hearing loss due to unsafe listening practices. Nearly half of all teenagers and young adults (12–35 years old) in middle- and high-income countries are exposed to unsafe levels of sound from the use of personal audio devices and some 40% of them are exposed to potentially damaging sound levels at clubs, discotheques and bars.

Analysis of data from the National Health and Nutrition Examination Survey in the United States suggests that, between 1994 and 2006, the prevalence of hearing loss\(^1\) among teenagers (12–19 years old) rose from 3.5% to 5.3% (12). Another study from the USA indicates that the number of individuals listening to music through headphones and earphones increased by 75% between 1990 and 2005 (13). A 2008 European Commission report noted that personal audio devices are being used by an increasing proportion of the population; from 2004 to 2007, unit sales within the European Union are estimated to have been between 184 and 246 million (14). In recent years, music players have been increasingly replaced by smartphones. Worldwide sales of smartphones in 2011 amounted to 470 million units, and this figure is rising (15).

With the increased availability and use of personal audio devices for listening to music and the risky behaviour pattern of their use at high volume over long periods (16–18), the threat of hearing loss due to recreational exposure to noise is a real one.

**How we hear**

Ears are the organs that process sounds, enabling the brain to interpret what the individual is hearing. The ear is divided into three parts – outer ear, middle ear, inner ear – each of which has a unique function in the process of hearing. In simple terms, the outer and middle ears amplify the sound signal (vibration) and the inner ear converts this sound signal into an

---

\(^1\) A person who is not able to hear as well as someone with normal hearing (hearing thresholds of 25dB or better in both ears) is said to have hearing loss.
electric impulse that is transmitted to the brain. This process also produces a frequency (or pitch) and intensity (or loudness) analysis of the sound signal.

Sounds are complex mixtures of pressure variations and travel in invisible waves through air. When these sound waves reach the ear, the pinna (ear flap) funnels the sound waves into the ear canal. Sound waves travel down the canal to the eardrum, causing it to vibrate. The vibrations are transmitted by the ossicles (three small bones) within the ear to the cochlea, causing movement of the fluid and the sensory cells (hair cells) within the cochlea. The sensory cells convert the vibrations into electrical nerve signals that travel along the auditory nerve to the brain. The brain then interprets these signals as sounds that can be recognized and understood.

There are two types of sensory cells within the cochlea: inner and outer hair cells. The inner hair cells generate the electrical signals that are sent to the brain, while the outer hair cells act as amplifiers, increasing the stimulus delivered to the inner hair cells (19). It is important to note that a fixed number of these cochlea sensory cells is present at birth: in humans and other mammalian species, these sensory cells do not regenerate once they have been damaged (20).

**How noise affects our ears**

Excessive exposure to noise – both long-term, repeated exposure to noise and a single exposure to an extremely intense sound – causes damage to the auditory system and results in hearing loss, termed noise-induced hearing loss (21–24). The hearing loss is usually slow in onset but progresses relentlessly for as long as the exposure continues (25). Indeed, the harmful effects may continue long after noise exposure has ceased (26); they are irreversible (20, 23).

The damage caused to the cochlea by loud sounds occurs by two means:

- Mechanical destruction (20, 27, 28). Regular exposure to loud sounds causes the hair cells to lose their rigidity and thus their ability to work effectively. This change occurs
over time until the sensory cells are eventually destroyed and are no longer able to carry out their function (14, 20, 29).

- Intense metabolic activity at cellular level (20, 27, 28, 30, 31). A higher level of energy is required by hair cells during periods of intense exposure to loud sounds. The consequent increased consumption of oxygen generates raised levels of free radicals in the cochlea. The ear’s antioxidant defence mechanism is unable to cope with these levels and the free radicals cause cell death.

The physiological changes to the ear are reflected in a change in hearing sensitivity and/or the development of tinnitus (2, 14, 29, 32). Hearing loss can be temporary or permanent (29) and is usually bilateral (33).

**Temporary or permanent threshold shift**

Exposure to loud sounds for any length of time causes fatigue of the ear’s sensory cells, resulting in temporary hearing loss or tinnitus (a ringing sensation in the ear). This is termed a temporary threshold shift (temporary loss of hearing). For example, a person who attends a loud concert may come out feeling slightly deaf or experiencing tinnitus (20). Hearing usually recovers within a few hours or a day (34). Temporary threshold shifts have been reported and measured following attendance at discotheques, rock concerts and sporting events (35–40).

Regular or prolonged noise exposure can cause gradual, irreversible damage to the sensory cells and other structures, leading to a permanent threshold shift (permanent hearing loss) (7, 9, 20, 41, 42). Noise-induced hearing loss initially involves the sensory cells that respond to high-frequency (high-pitched) sounds, specifically 4 kHz (10, 19, 32, 34, 39, 40, 43). This initial hearing loss may remain unnoticed by the affected individual, since speech comprehension is largely unaffected (11). However, continued exposure leads to increasing damage in other frequencies and progression of hearing loss, which begins to interfere with the individual’s day-to-day activities (19, 20, 29, 32, 42, 44). Noise-induced hearing loss adversely affects conversation and communication, especially in the presence of background noise (14, 20, 32). It also creates difficulty in distinguishing between speech consonant sounds, such as “fish” and “fist” (32).

While temporary threshold shift gives no indication of the magnitude of permanent threshold shift, it is a good predictor of the early development of irreversible hearing loss (41). For individuals who consistently listen to personal audio devices at high intensities with earbuds, the risk of developing a temporary or permanent threshold shift is a significant concern, particularly when such listening habits persist for a number of years (45, 46). It has been demonstrated that persistent use of personal audio devices for more than five years can lead to changes in high-frequency hearing (4 kHz) (46). This hearing loss can be detected on audiological testing through pure tone audiometry (32). The audiogram displays a sharp reduction in hearing at frequencies between 3 and 6 kHz. With continued exposure the hearing loss extends to higher and lower frequencies; it is generally bilateral and symmetrical.
Tinnitus

The sensation of sound (e.g. roaring, hissing, or ringing) in the absence of an external sound source is known as tinnitus (2, 23, 47–49). Often the result of acute or chronic noise exposure, tinnitus can also be the result of other underlying pathologies or be associated with a variety of illnesses (47).

Researchers have demonstrated a strong correlation between recreational noise exposure and tinnitus (50, 51). In general, noise-induced tinnitus, like other forms of tinnitus, can be acute or chronic. Acute or temporary tinnitus lasts for relatively short periods (a few seconds to a few days) and usually occurs immediately following exposure to loud sounds. Chronic tinnitus can last for months to years and suggests cochlear injury (20). It can be unilateral or bilateral (47) and can occur concurrently with hearing loss or in the absence of measureable hearing loss (2).

Noise-induced tinnitus due to recreational exposure usually occurs immediately, is transient and can be an indication of early hearing damage (52, 53). Attendance at recreational activities, such as discotheques, clubs, sporting events or music concerts, has been known to result in temporary tinnitus (6, 35–38, 53). Temporary tinnitus has also been shown to occur in regular users of personal audio devices, although this is less prevalent (37, 50).

Chronic tinnitus following recreational noise exposure is comparatively less frequent than acute tinnitus (55). Like hearing loss, chronic tinnitus can lead to sleep disturbance, anxiety, depression, and impaired concentration and communication and thus has a significant impact on quality of life (2, 23, 52).

Effect of noise-induced hearing loss on presbyacusis (age-related hearing loss)

Inadequate hearing protection during activities like shooting firearms and listening to loud music in adolescence may significantly contribute to communication difficulties in later life. Presbyacusis refers to the progressive and irreversible hearing loss that is common among individuals aged 60–65 years or more (11, 56, 57). The process of age-related hearing loss in an ear that has not been exposed to noise differs from the pattern of loss that follows regular exposure to noise (26, 58, 59). Research suggests that exposure to noise, particularly loud noise, is more harmful to the cochlea than the natural process of ageing (60). The effect of noise is cumulative and can increase susceptibility and accelerate hearing deterioration in later life, even after the exposure has ceased (23, 59, 61–63). Hence, cochlear degeneration from early noise exposure can render the ears more vulnerable to the effects of ageing (58, 60, 62, 64). However, this association is a complex one as noise-induced hearing loss and presbyacusis frequently co-exist and it is difficult to distinguish between them (59, 65).

Predisposing factors

Certain people may be more susceptible to noise-induced hearing loss than others, meaning that individuals who experience identical noise exposure may develop different degrees of hearing damage (32). Genetic predisposition, age, chronic conditions such as diabetes and hypertension, and exposure to cigarette smoke can increase the risk of acquiring noise-induced hearing loss. Pre-existing sensorineural hearing loss, use of ototoxic medications
and exposure to solvents also predispose to the development of hearing loss (32, 59, 66). However, since it is impossible to identify the most susceptible individuals, and since noise-induced hearing loss is irreversible, prevention is the most effective strategy.

**How can noise-induced hearing loss be treated?**

There is no medical or surgical cure for noise-induced hearing loss: damaged hair cells cannot regenerate (20, 32, 67). Once hearing loss begins, however, its progression can be halted by avoiding further exposure to loud sounds (19).

Current treatment methods for noise-induced hearing loss focus on people in severely noisy environments such as the military. Approaches such as placement in a quiet room or hyperbaric oxygen therapy immediately following exposure to the loud sound aim to prevent further damage (67, 68). Post-exposure antioxidant and pharmacological therapy have also been shown to be partially effective and to prevent further sensory cell damage (27, 68–72).

Currently, no pharmacological agents are available for prevention or reversal of noise-induced hearing loss. Nevertheless, there have been recent advances in this area and it is claimed that preventive medications are likely to be available in the near future (73). Other areas of scientific research are focusing on gene and stem-cell therapies (74, 75). At present, there are only limited management options – such as hearing aids and counselling – for individuals with even a low degree of noise-induced hearing loss (19, 49, 76).

**Other negative impacts of loud sounds**

Noise-induced hearing loss can affect many aspects of life. In young children, it impairs language acquisition (20, 30, 77, 78). Learning disabilities, anxiety and attention-seeking behaviours are also common in children exposed to loud sounds (11). The impact of chronic noise exposure in children is reflected in lowered academic performance and outcomes as well as reduced motivation and concentration (23, 38, 79–89).

The use of personal audio devices is becoming commonplace in educational institutions in developed and developing countries alike. These portable devices often make distribution of educational material easier, particularly to students in remote locations (90–92). They offer flexibility, allowing students to access information (e.g. lecture material) at any time and while participating in other activities, such as commuting, exercising or doing housework (93–96). They have been particularly beneficial in learning languages and music (94, 97–100).

Using personal audio devices in the educational setting also appeals to students, who are familiar and comfortable with the technology. Students benefit from being able to record lectures, listen to podcasts and download books (98, 101, 102). However, some schools and universities prohibit the use of personal audio devices because of concerns about reduced communication and social isolation (103, 104). Studies suggest that misuse or overuse of these devices will lead to cognitive overload and result in impaired performance (86, 105).
**Road safety**

Exposure to loud sound is also of concern with respect to road safety for pedestrians, motorists and cyclists. The number of people using media players while driving, cycling or walking has risen, resulting in less safe road-use behaviour (106–108). These devices are a source of distraction and can affect the individual’s responses and compromise road safety (106, 107, 109). It is reported that listening to music, particularly when earbuds are used, worsens auditory perception (107, 110–112). College students also do often listen to personal audio devices with earbuds while engaged in activities that require auditory attention in order to avoid danger, such as walking, jogging, cycling and driving (45). Use of noise-cancelling headphones can also pose a risk to safety (113).

Cyclists who listen to music on a portable music device are more likely to exhibit unsafe behaviours than those who do not use such devices (114). A study focused on teenage cyclists revealed that they tend to listen to music while cycling and are more likely than younger or older individuals to be involved in crashes when using personal audio devices (115). Listening to music does not appear to have an influence on cyclists’ speed but it does impair their ability to respond to other auditory stimuli (107, 110, 116).

Pedestrians using personal audio devices receive less auditory information from their surroundings and are thus less aware of important alerting signals, e.g. car horns (106, 117–119). Young pedestrians who are distracted by music from personal audio devices while crossing the street have a higher risk of being hit by a vehicle (112). Some authors indicate mixed results, with some pedestrians exhibiting over-cautious behaviour and others unsafe behaviour (118–120). The risk is greater for elderly pedestrians who are more vulnerable than younger people to the hazards of crossing roads while listening to music (105, 121).

As portable audio technologies become ever more commonplace and widely used, it is likely that safety problems related to inattention and distraction will increase (122).

**What is safe listening?**

Ears are designed to process the moderate levels of sound that exist in our normal environment (e.g. quiet conversation). Common recreational activities (e.g. rock concerts, listening to personal music players), however, often involve exposure to much higher sound levels for extended periods (8), and scientific evidence is accumulating to demonstrate that these recreational noise activities are potentially harmful to hearing (4, 123). The factors that determine the level of risk are the intensity and duration of noise exposure.

The human ear is capable of detecting a large range of sound intensities (loudness levels) from extremely soft to extremely loud. The unit of measurement used to express the intensity of a sound is the decibel (dB). Measurement of sound intensity in decibels is based on a logarithmic scale, which allows the extreme range of sound intensities audible to humans to be quantified in manageable numbers. Thus, 10 dB is 10 times more intense than 1 dB and 20 dB is 100 times more intense than 1 dB.
The healthy hearing threshold is generally taken as 0 dB (11); a whisper is around 30 dB and normal conversation approximately 60 dB (124). Some common sounds and their intensities (dB) are indicated below.¹

<table>
<thead>
<tr>
<th>Device/situation</th>
<th>dB (approximate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ticking watch</td>
<td>20</td>
</tr>
<tr>
<td>Soft whisper</td>
<td>30</td>
</tr>
<tr>
<td>Refrigerator hum</td>
<td>40</td>
</tr>
<tr>
<td>Normal conversation</td>
<td>60</td>
</tr>
<tr>
<td>Air-conditioner hum</td>
<td>65</td>
</tr>
<tr>
<td>Washing machine</td>
<td>70</td>
</tr>
<tr>
<td>Vacuum cleaner</td>
<td>75</td>
</tr>
<tr>
<td>Alarm clock 60 cm away</td>
<td>80</td>
</tr>
<tr>
<td>Heavy city traffic (inside the car)</td>
<td>85</td>
</tr>
<tr>
<td>Lawn mower (gasoline)</td>
<td>90</td>
</tr>
<tr>
<td>Motorcycle (average)</td>
<td>95</td>
</tr>
<tr>
<td>Hairdryer, subway train, car horn at 5 m</td>
<td>100</td>
</tr>
<tr>
<td>MP3 player at maximum volume, chainsaw</td>
<td>105</td>
</tr>
<tr>
<td>Shouting into the ear</td>
<td>110</td>
</tr>
<tr>
<td>Loud rock concerts</td>
<td>115</td>
</tr>
<tr>
<td>Spectator trumpet (vuvuzela) 1 m from trumpet opening, sirens</td>
<td>120</td>
</tr>
<tr>
<td>Jackhammer, jet plane 30 m away</td>
<td>130</td>
</tr>
<tr>
<td>Firecrackers, firearms</td>
<td>150</td>
</tr>
</tbody>
</table>

Safe listening levels depend on the intensity (loudness) and duration of exposure (19, 32). These two factors are interrelated (19, 32, 128) and contribute to the overall sound energy level to which the individual is exposed. Effectively, the total amount of sound energy to which an individual can safely be exposed remains constant: the sound energy of lower volumes listened to over long periods of time is the same as that louder sounds heard for over a short period. Permissible levels of daily exposure to noise have been defined on this basis, taking into account the daily permissible dose of sound; they have been calculated for occupational settings and are extrapolated for application in recreational settings.

¹ Sources: references 24, 125–127.
Daily permissible noise level exposure*  

<table>
<thead>
<tr>
<th>Time per day</th>
<th>Sound level ($L_{eq}$), dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 hours</td>
<td>80</td>
</tr>
<tr>
<td>8 hours</td>
<td>85</td>
</tr>
<tr>
<td>2 hours 30 minutes</td>
<td>90</td>
</tr>
<tr>
<td>47 minutes</td>
<td>95</td>
</tr>
<tr>
<td>15 minutes</td>
<td>100</td>
</tr>
<tr>
<td>4 minutes</td>
<td>105</td>
</tr>
<tr>
<td>1 minute 30 seconds</td>
<td>110</td>
</tr>
<tr>
<td>28 seconds</td>
<td>115</td>
</tr>
<tr>
<td>9 seconds</td>
<td>120</td>
</tr>
</tbody>
</table>


The highest safe exposure level is considered to be 85 dB for up to a maximum of 8 hours (33, 129–132). The permissible time for safe listening decreases as sound levels increase. Thus, the safe duration of exposure to a sound level of 100 dB — the level produced by a subway train — is only 15 minutes a day. The output of personal audio devices may range from 75 dB to as much as 136 dB (11); maximum output levels vary with the regulations and legislation in different parts of the world. Typically, users of personal audio devices set the volume between 75 and 105 dB (34).

At discotheques, bars and clubs, mean sound levels can range from 104 to 112 dB. Noise levels at pop concerts may be even higher (34), and 15 minutes of music at 100 dB may represent the same noise level exposure as that experienced by an industrial worker in an 8-hour day at 85 dB (11).

High sound levels are also encountered at popular sporting events, which are frequented by adolescents and young adults (54, 127, 133–136). Noise levels at sporting venues have been found to range from 80 to 117 dB (40, 54, 127, 136, 137). The average noise exposure for spectators during the FIFA World Cup in 2010 was as high as 100.5 dB (127).

Adults and adolescents are not the only age groups exposed to louder sounds. Some common children’s toys, such as rattles, toy phones and guns, are capable of generating unsafe intensities ranging from 110 to 150 dB (30, 138). Moreover, the danger is probably underestimated as children have a tendency to hold such toys closer to their ears, which increases the intensity (30).

The sound intensity levels involved in various common pastimes and activities have been reported as summarized below:
<table>
<thead>
<tr>
<th>Recreational activity</th>
<th>Intensity of sound (dB)</th>
<th>Average time of activity</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rattles and squeaky toys</td>
<td>110 (max.)</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Musical toys, drums and horns</td>
<td>120 (max.)</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Toy phones</td>
<td>Range 123–129</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Toy guns</td>
<td>150 (max.)</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>Ice hockey game</td>
<td>Range 103.1–110.7</td>
<td>&gt;3 hours</td>
<td>54</td>
</tr>
<tr>
<td>Ice hockey game</td>
<td>Range 81–97, peak 105–117</td>
<td></td>
<td>136</td>
</tr>
<tr>
<td>Soccer match</td>
<td>92.7</td>
<td>90 minutes</td>
<td>137</td>
</tr>
<tr>
<td>Soccer match</td>
<td>100.5</td>
<td></td>
<td>127</td>
</tr>
<tr>
<td>Basketball game</td>
<td>84.64</td>
<td>2 hours</td>
<td>40</td>
</tr>
<tr>
<td>Sporting event</td>
<td>Range 85–100</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Sporting event</td>
<td>Mean 93</td>
<td>2.5 hours</td>
<td>139</td>
</tr>
<tr>
<td>Aerobics class</td>
<td>89.6</td>
<td></td>
<td>140</td>
</tr>
<tr>
<td>Fitness class</td>
<td>Range 73–96</td>
<td></td>
<td>141</td>
</tr>
<tr>
<td>Fitness class</td>
<td>Mean 87.1, range 83.4–90.7</td>
<td></td>
<td>142</td>
</tr>
<tr>
<td>Fitness class</td>
<td>Range 78–106</td>
<td>60 minutes</td>
<td>143</td>
</tr>
<tr>
<td>Fitness class</td>
<td>Mean 98.8</td>
<td>52.8 minutes</td>
<td>144</td>
</tr>
<tr>
<td>Fitness class</td>
<td>Range 74–97</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Fitness class</td>
<td>Mean 86</td>
<td>Mean 1.4 hours</td>
<td>139</td>
</tr>
<tr>
<td>Nightclub</td>
<td>Average 110.2, range 107.8–112.2</td>
<td>4 hours a week</td>
<td>9</td>
</tr>
<tr>
<td>Entertainment venue</td>
<td>Mean exceeded 95</td>
<td>5 hours per session</td>
<td>145</td>
</tr>
<tr>
<td>Concert, live music venue</td>
<td>Range 82–105</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Concert, live music venue</td>
<td>Mean 92</td>
<td>Mean 3 hours</td>
<td>139</td>
</tr>
<tr>
<td>Nightclub</td>
<td>Mean estimated sound pressure level is 101, range 85–105</td>
<td>Mean 4.3 hours/week</td>
<td>37</td>
</tr>
<tr>
<td>Clubs</td>
<td>Average 97.9</td>
<td>5 hours per week</td>
<td>5</td>
</tr>
<tr>
<td>Discotheque</td>
<td>Ranged 104.3–112.4</td>
<td></td>
<td>34</td>
</tr>
<tr>
<td>Club</td>
<td>Range</td>
<td>Nightclub</td>
<td>Range 89–106</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-------------</td>
<td>-----------</td>
<td>--------------</td>
</tr>
<tr>
<td>Club</td>
<td>Range 94.9–106.7</td>
<td>7</td>
<td>Nightclub</td>
</tr>
<tr>
<td>Pub bar, registered club</td>
<td>Range 71–96</td>
<td>3</td>
<td>Pub or registered club</td>
</tr>
</tbody>
</table>

Even a brief exposure to high decibel levels can be harmful. For young people particularly, noise exposure is often not from a single recreational source (18). Environmental and occupational noise exposure also contributes to the overall risk of an individual.

While habitual exposure can certainly lead to hearing loss over time, noise-induced hearing loss can be prevented by following safe listening practices.

**Preventing noise-induced hearing loss**

The effect on the auditory system of exposure to loud sounds or noise is cumulative and irreversible, and effective treatment is limited (11, 32, 61). However, noise-induced hearing loss is completely avoidable: prevention is thus paramount, and efforts to preserve hearing and prevent tinnitus should be made wherever hazardous noise is present (7, 23, 32, 49, 67, 147–151). Special mention should be made of developing countries, where preventive programmes and access to health services are limited and legislation may be inadequately enforced, even in occupational settings (152).

A number of prevention strategies can be employed to preserve hearing. The chosen approach will depend on the source of loud sound (e.g. personal audio device or rock concert) and the motivation of the individual. Motivation, in turn, often depends on the individual’s perception of the health threat; understanding this is important for the development of effective prevention strategies (153).

In general, people are less tolerant of noise and more motivated to take protective action if they have experienced symptoms such as tinnitus or have a positive attitude towards hearing health (44, 154–158). If noise-induced hearing loss is perceived as of lesser priority than other health issues, the level of motivation is likely to be lower (36, 159, 160). The attitude that noise is enjoyable and that its enjoyment is a part of the individual’s “image” is likely to hinder the practice of safe listening (35, 154, 161).

**Prevention**

The impact of loud sounds on hearing depends on three main factors: sound intensity (volume), duration of exposure and distance from the sound source. By regulating all or one of these variables, it is possible to protect the ears (11, 29, 30, 35, 61, 162–171).

Knowing which loud sounds have the potential to cause harm to the auditory system is the first step towards prevention (172). Avoiding these loud sounds is one of the easiest ways to prevent damage. In recreational settings this is not always achievable or practical (11, 19, 30,
individuals usually seek out these sound sources for pleasure, and so practical strategies, other than avoidance, need to be implemented.

Strategies for prevention of harm from exposure to loud sounds are the responsibility of individuals, communities and governments. Preventive action at each of these levels is imperative. Individuals can take responsibility for their own hearing health by following a number of basic and practical steps as suggested by experts in the field. These are outlined below.

Strategies

- **Keeping the volume down.** The recommended safe volume level is below 85 dB. Sounds could be too loud if:
  - other people must raise their voice to make themselves understood;
  - it is difficult to understand someone an arm’s length away;
  - listeners develop pain or a ringing sensation in the ear.

  Even a small reduction in volume can offer significant protection.

- **Using carefully fitted earbuds,** which allow music to be heard clearly at lower volumes.

- **Using noise-cancelling earphones or headphones, which can reduce the need to raise the volume on listening devices.** Personal audio devices can be turned up to harmful levels (164, 173) although the majority of listeners do not always listen to these devices at such high volumes (174–177). Preferred volumes for listening often depend on the level of background noise: in places with high ambient noise levels (e.g. subways, trains, aircraft), there is a tendency to increase the volume. Use of noise-cancelling earphones or headphones can reduce the need to raise the volume in such surroundings. By cutting down background noise, these headphones/earphones allow personal audio devices to be used at lower volumes than would otherwise be needed (147, 167, 168, 170).

- **Monitoring noise exposure.** Smartphone technology can be used to measure noise exposure levels and inform users about their risk for noise-induced hearing loss. Independently-developed applications (“apps”) are currently available for many devices. Many of these apps display noise intensity in decibels and can inform the user of whether the level of exposure is a risk for hearing loss, often using a colour-coded scale or reference to activities that involve similar risk. Any individual who wishes to estimate his or her noise exposure levels could easily download one of these apps to a smartphone and use it to collect information about their environment and risk for hearing loss (30, 178–181).

  It should be noted, however, that the accuracy of these apps is not completely reliable and caution is needed when using them to evaluate and assess potential risk. An analysis of 50 different apps indicated that only one was accurate to within 5 dB. Nevertheless, this type of app can act as a complementary educational tool, raising awareness among young people of the risk of noise-induced hearing loss (181, 182).

- **Limiting the time spent engaged in noisy activities**
  - Small listening breaks can help to reduce exposure.
  - Limiting headphones/earphones use to less than one hour a day is ideal.
The time spent in noisy environments should be limited.

- **Moving away from loud sounds.** At a noisy venue, it is better to stay as far away as possible from sources such as loudspeakers (30). If the individual has to raise his or her voice to be heard above the noise by someone at arm’s length (1 m away), this is a good indicator that the sound is too loud (147, 183). Moving to quieter locations within venues can reduce the level of exposure.

- **Wearing earplugs.** When visiting discotheques, bars, sporting events and other noisy places or participating in rifle shooting, use of hearing protection helps to avoid damage to hearing (29, 35, 144, 165, 166). Many countries have legislated, to a varying degree, on the use of personal hearing protection in the occupational setting. However, there is little in the way of legislation, guidelines or recommendations for use of hearing protection for recreational noise exposure (184).

Hearing protection devices can be broadly classified as either earplugs, which are inserted at the entrance of the ear canal, or earmuffs, which cover the outside of ear (185). Although neither will completely block out all sound (147), measurements of efficacy suggest that such devices can reduce exposure to loud sound by 5–45 dB if they are correctly used (147, 165, 186, 187). There is no significant difference between earplugs and earmuffs: both block sounds similarly and have the same long-term effects on the auditory system (185, 186, 188).

The effectiveness of hearing protection depends on its correct and consistent use. Consistent use of properly inserted earplugs, throughout the entire period of exposure can significantly reduce the level of exposure and is important to preserving hearing and reducing the risk of tinnitus (11, 29, 30, 35, 41, 49, 53, 144, 147, 163, 165, 166, 186, 189–192). Using a lower attenuating earplug or earmuff correctly and consistently can be more effective than using a higher-rated product incorrectly and sporadically (147).

- **Respecting safe listening levels.** All users of personal audio devices should identify the safe listening level for their particular equipment and not exceed that level (6, 11, 30, 174, 193):
Set the volume to a comfortable level in a quiet environment and avoid raising it in noisy environments; the volume should be no more than 60% of maximum.

Smartphone apps can be used to monitor the output levels of personal audio devices and ensure that they are below 85 dB.

It is important to be alert to the following warning signs of hearing loss and seek help from a hearing health care professional if the signs appear (23, 49, 76):

- ringing in the ears (tinnitus);
- difficulty in hearing high-pitched sounds (birds singing, doorbell, telephone, alarm clock);
- difficulty understanding speech, especially over the telephone;
- difficulty in following conversations in noisy environments, such as in restaurants or at social gatherings.

- **Regular hearing check-ups.** Regular check-ups can help to identify the onset of hearing loss. High-risk populations (secondary school pupils or college students) should be encouraged to have regular hearing checks. Schools, offices and communities should be encouraged to organize hearing screening.

- **Being aware.** Correct information about safe listening levels and times is empowering and should be available to all. It is important for users of MP3 players, ear- and headphones, etc. to learn more about these products and their safety features. If earbuds are used with these devices they should fit well and be worn correctly. Use of noise-cancelling earphones or headphones should be considered if music devices are used frequently in noisy environments, such as on trains or aircraft.

Because noise-induced hearing loss is irreversible, prevention is the most effective strategy. If tinnitus or some loss of hearing loss is already apparent, caution should be exercised and exposure to loud sounds limited.

**What is being done?**

Awareness is growing of the risk associated with recreational noise exposure as a contributing factor to hearing loss. Several strategies have been implemented at community and government levels around the world, but their scope varies by country.

**Legislation**

A number of legislative measures relating to environmental noise and occupational exposure are in place in many countries although they vary in scope and sophistication (194). Fewer countries have legislative measures pertaining specifically to recreational noise exposure.

For instance countries of the European Union, China and New Zealand have legislation in place to protect employees who work in the entertainment/recreational sector (bars, concerts, discotheques, nightclubs) from exposure to unsafe noise (33, 195–199). Legislation addresses the criteria for acceptable noise levels, acceptable control procedures and monitoring procedures to ensure that legislative requirements are met (33).
From the available data and a review of English-language legislation, it is evident that most countries of the world still have no legislation to control recreational noise exposure, either for recreational venues or with respect to the maximum output levels of personal audio devices.

There are a few examples of legislation that targets recreational noise exposures. In 2009, the European Commission issued a directive that output levels of new audio devices should be set to a standard of 85 dBA, allowing users to increase the volume to a maximum of 100 dBA. According to the directive, raising the volume to maximum level must prompt a warning message stating that hearing loss can occur at this level (200).

In April 2014, the Minneapolis City Council passed an ordinance making it compulsory for bars and clubs to offer free earplugs to patrons. Such a directive can have far-reaching impact, reducing the risk of noise exposure for those who frequent these entertainment venues (201).

Legal interventions have proved effective for many sentinel public health achievements (202, 203). Hence, it is important for legislation to address public health issues such as exposure to noise, in order to bring about a sustained behavioural change.

Other interventions are also possible. For example, a leading manufacturer of personal audio devices has developed software that allows customers easily to set their own customized maximum volume limit. It also gives parents the ability to set a maximum volume limit on a child’s device, locking it with a combination code (204). Another device displays an on-screen message warning that the user has reached dangerous listening levels and may want to turn the volume down (205). Such measures help raise awareness of the harmful effects of loud sounds.

Messages about the potential harm from recreational noise exposure can also be transmitted through education conservation programmes or campaigns. This approach has been widely used in a number of countries to raise awareness about safe listening practices, even in the absence of legislation.

Key target populations for prevention campaigns at the community level are children, teenagers and their parents (6, 10, 13, 44, 53, 55, 206–210). Children and teenagers appear to be most at risk from exposure to loud sounds associated with recreational activities (158).

The effectiveness of such programmes and campaigns in improving knowledge, establishing attitudes to loud sounds and encouraging appropriate behaviours has been demonstrated, particularly among young people (11, 123, 151, 211–218).

The following are examples of preventive campaigns:

- **Listen To Your Buds** (219) – a public education campaign launched by the American Speech and Hearing Association (ASHA) to educate children and parents about practising safe listening habits when using personal audio devices. It does this through a variety of bilingual media and public outreach tactics, partnerships with companies and organizations, “safe listening concerts” in schools, and dissemination of information throughout the school system.

- **Dangerous Decibels** (220) – a public health campaign that aims to reduce the incidence and prevalence of noise-induced hearing loss by changing knowledge, attitudes and behaviours of school-aged children. Through education and the use of exhibits, the
programme has been successful in producing long-term improvements in students’ knowledge of noise and its effects.

- It’s a Noisy Planet: Protect their Hearing (221) – a programme of the National Institute on Deafness and Other Communication Disorders (NIDCD) that uses social media, school presentations, awareness materials, conferences and exhibits to promote healthy hearing habits among parents and pre-teens.

- Don’t Lose the Music (222) – a campaign by Action on Hearing Loss, a nongovernmental organization based in the United Kingdom, that aims to increase awareness and promote safe listening habits among music lovers through innovative messages.

- Cheers for Ears campaign – a school health programme designed by the Ear Science Institute of Australia to educate young people and encourage healthy behaviours to prevent noise-induced hearing loss.

- NOISE (Non-occupational Incidents, Situations and Events) database (Beach, 2013b): – the National Acoustic Laboratories in Australia maintains a detailed and standardized record of sound levels at non-occupational leisure events. It provides researchers and health professionals with realistic estimates of the noise exposure involved in various non-work activities.

**What can be done**

**What can parents do?**

Parents need to play an active role in educating their children about safe listening and monitoring their exposure to loud noise; they also need to be role models of safe listening for their children (6, 11, 123, 139, 151, 153, 193, 206, 223, 224).

**What can teachers do?**

Children and adolescents must be educated about the possible dangers of exposure to loud sounds from the misuse of personal audio devices and encouraged to develop safe listening habits. Such information should be part of the health education curriculum and also be taught as part of music and dance classes (6, 11, 23, 139, 151, 153, 193, 206, 224, 225, 226, 227).

**What can physicians do?**

Physicians have a significant opportunity to educate and counsel adolescents and young adults regarding hearing protection (36, 159). Physicians, nurses, audiologists and speech-language pathologists can convey appropriate messages about the risks and promote healthy listening habits among users (226).

**What can managers do?**
Managers of venues in which noise levels are high – nightclubs, discotheques, bars, pubs, cinemas, concerts, sporting events and even fitness classes – have an important role to play in ensuring the personal safety of people who frequent such venues. To make listening safe, they can: monitor and apply the safe noise limit set by the establishment itself; make use of sound limiters to control noise levels in such settings; provide free earplugs to all patrons along with information about their proper use as well as “chill out” rooms, where volume levels are monitored and safe; and prominently display messages about the risk of hearing loss during moments when the volume goes beyond safe levels (3, 139, 154, 215, 228, 229, 230).

**What can manufacturers do?**

Manufacturers of personal audio devices possess the technical knowhow to design these devices with appropriate safety features, and a number have already taken steps to put in place these features. For example, software developed by a leading manufacturer of personal audio devices allows customers to easily set their own customized maximum volume limit. It also gives parents the ability to set a maximum volume limit on their child’s device and lock it with a combination code. Another device displays an on-screen message displaying the average dB level at different volume settings, along with a warning to keep the output below 85 dB (3, 231). Such measures offer protection and help raise awareness about the harmful effects of loud music and other noise. Manufacturers can also provide prominent warning labels on the products themselves, as well as on the external packaging and accompanying information materials (231).

**What can governments do?**

For their part, governments are encouraged to develop stricter laws and rigorously enforce already existing legislation regarding non-occupational noise (38, 112, 159). Governments can raise awareness about the issue through targeted public information campaigns highlighting the potential consequences of hearing loss (45, 112, 115, 119, 232). Creative use of those means of communication which are most often used by teenagers and young adults, including various social media platforms, would help to disseminate messages on the importance of safe listening (36, 38, 44, 139).
References


30


