IMEG

The Independent Medical Expert Group

Report and recommendations on medical and scientific aspects of the Armed Forces Compensation Scheme

17 May 2013

Topic 2 – Hearing Loss

1. Hearing loss, more correctly permanent hearing threshold shift, caused by exposure to noise is a well recognised hazard in military and civilian life. Noise induced hearing loss due to many sources of occupational noise exposure, such as work in the mining industry, a textile mill or a foundry, is a prescribed disease in the Industrial Injuries Scheme.

2. In general, hearing loss in these circumstances is due to continuous hazardous noise exposure at work experienced over many years. This causes hearing loss, which increases slowly over time, with disabling hearing loss developing in middle or late middle life. Hazardous noise can be considered to produce a hearing loss earlier than would be expected as a consequence of the normal ageing of the auditory system. In later life (late 70s, 80s) the average difference between those who have, and those who have not, experienced noise exposure during working life is small.

3. The most commonly used test of hearing relies on threshold assessments of air conducted pure tones by means of manual or automated audiometry. Subjects listen in a sound proof/attenuated booth to pure tones at different frequencies from 0.5 kHz to 8 kHz and register when these are heard. The effect of hearing impairment is to increase the threshold at which these tones are heard. While the sense of hearing is multifaceted, in general, the most disabling effect of hearing loss is loss of speech sensitivity or discrimination, initially perceived in a noisy background. It is commonly considered that this disability correlates best with increased audiometric hearing thresholds at low and mid frequencies, i.e. up to 3 kHz and less so with threshold levels at the higher frequencies of 4 - 6 kHz, which are often impacted by impulse noise. There is no international agreement as to the best method to quantify auditory disability, nor the frequencies used in disability assessment, but in the UK courts and no fault compensation schemes, this is expressed as an average of audiometric thresholds measured at 1, 2 and 3 kHz. The audiometric frequencies affected by noise depend on the spectrum of the noise exposure. Broad band noise exposure typically first causes an isolated dip or notch centred at or around 4 kHz, above the primary speech discrimination frequencies. The functional impact of increased threshold at the higher frequencies of 4 kHz and above is incompletely understood. If hearing recovers to pre- exposure level, the shift in hearing threshold is described as temporary, i.e. temporary threshold shift. If hearing loss persists 20 to 30 days after removal from the noise, it is considered to be permanent - permanent threshold shift. The presence of temporary threshold shift does not accurately predict permanent threshold shift. In susceptible individuals, continued exposure to hazardous noise for up to thirty years results in an increasing permanent, high frequency loss, which gradually spreads to involve the lower frequencies of 3, 2 and 1 kHz, the primary speech discrimination frequencies, in that order and in the highest measured frequencies of 6 and 8 kHz (1).

4. The AFCS applies to injury and illness caused by service on or after 6 April 2005. With emphasis on noise reduction, hearing loss prevention and noise protection measures, sensorineural hearing loss due to chronic workplace noise injury, which was previously common in relation to military workshops, transport depots and aircraft noise, should now be uncommon and claims for hearing loss due to chronic noise unusual in this scheme. Recent operations have however, led to claims for hearing loss due to weapons related impulse noise or blast damage.

Hearing loss due to impulse noise

5. Impulse noise and blast damage produce pathological changes distinct from those of chronic noise injury. Any associated permanent hearing threshold shift occurs acutely over a short period, not over many years, usually impacts higher frequencies and affects a younger population. The audiometric pattern due to acute acoustic trauma can be variable; while gunfire produces a 3 or 4 kHz higher frequency audiometric notch, blast injury does not typically lead to this audiometric configuration. High frequency audiometric notches at 6 kHz have previously been reported to be an artefact and related to the type of ear-phone used (2). Most studies of gunshot and blast acoustic injury emphasise the preponderance of high frequency loss, while low frequency and flat hearing losses across the frequency range have been considerably less frequently reported. In a recent Finnish recruit study (3), acute acoustic trauma was associated most commonly with changes in the frequencies above 2 kHz. The seminal report of Kerr and Byrne (1975) on blast injuries in a confined area reported that 6% of affected ears (n=80+) had hearing loss of at least 40dB averaged over the speech frequencies (4).

6. Initially, acute acoustic trauma and blast, like chronic noise exposure, may cause a temporary threshold shift. At lower frequencies this may recover well with time, especially if due to gunfire, while loss at the higher frequencies, may persist, although more frequently recovers. In one series of military recruits who had suffered acute acoustic trauma, the average number of affected audiometric frequencies was five, with permanent threshold shift at any frequency, typically 20dB worse than the initial pre-exposure screening level (5). Often only one ear is affected in acoustic trauma and tinnitus is common immediately after the trauma. When people suffer acute acoustic trauma and are then removed from noise, any associated hearing loss, at one year after initial exposure, can be regarded as permanent (6).

7. Blast trauma may occur in an open or enclosed space, when pressure may be amplified. It results from a single stimulus and, for the first five or ten minutes, there may be severe deafness with all audiometric frequencies affected, although permanent sensorineural hearing loss is more common in the higher frequencies. Tinnitus is almost always present, but usually resolves in parallel with hearing improvement. Tympanic membrane rupture and middle ear damage may occur. If there is rupture of the oval or round window, labyrinthine failure with profound balance problems will result. In this situation vestibular failure and hearing loss will be permanent but, as a consequence of cerebral compensation, symptoms of vertigo will improve over time. If the blast injury is associated with head trauma, labyrinthine concussion or temporal bone fracture may compound any noise trauma and the patient presents with both auditory and vestibular symptoms, ranging from auditory and vestibular failure to benign paroxysmal positional vertigo. In the Kerr and Byrne study (4) of blast in the enclosed space of a restaurant, the perforated tympanic membranes healed spontaneously, in more than 80% of cases. Almost all those present experienced some sensorineural hearing loss, at least initially, with many recovering rapidly to normal hearing within a few hours. One year after the explosion about 30% had high frequency loss of, on average, greater than 30dB at 4 and 8 kHz in one or both ears. While some had some tinnitus most were not aware of any hearing problem. About 10% had loss which affected both high and speech frequencies but in some, only one ear was affected and they were asymptomatic. 6% had a loss of 40dB averaged over the speech frequencies in both ears and reported a hearing problem.

8. In addition to scrutiny of the international scientific literature, for the review of hearing loss, IMEG took oral and written evidence from the Royal British Legion and Action on Hearing Loss and from acknowledged UK experts in academic, civilian and military practice. The Chairman also met with the Medical Advisory Committee of the British Members' Council of the World Veterans' Federation (MAC) and the MAC Hearing Loss Sub-Group subsequently submitted its Policy Statement.

AFCS current approach

Total deafness in both ears.	Level 2
Blast injury to ears or acute acoustic trauma due to impulse noise with permanent bilateral sensorineural hearing loss of over 75dB averaged over 1, 2 and 3 kHz.	Level 5
Bilateral permanent hearing loss of more than 75dB averaged over 1, 2 and 3 kHz.	Level 6
Blast injury to ears or acute acoustic trauma due to impulse noise with bilateral permanent sensorineural hearing loss of 50-75dB averaged over 1, 2 and 3 kHz in on e ear and more than 75dB averaged over 1, 2 and 3 kHz in the other.	Level 6
Blast injury to ears or acute acoustic trauma due to impulse noise with permanent bilateral sensorineural hearing loss of 50-75dB averaged over 1, 2 and 3 kHz.	Level 7
Total deafness in one ear.	Level 8
Bilateral permanent hearing loss of 50-75dB averaged over 1, 2 and 3 kHz.	Level 8
Blast injury to ears or acute acoustic trauma due to impulse noise with permanent sensorineural hearing loss in one ear of more than 75dB averaged	Level 10
Blast injury to ears or acute acoustic trauma due to impulse noise with permanent sensorineural hearing loss in one ear of 50-75dB averaged over 1, 2 and 3 kHz.	Level 11
Blast injury to ears or acute acoustic trauma due to impulse noise.	Level 13

9. Awards between levels 2 and 11 are also paid a GIP from service termination for life.

Bilateral chronic noise induced hearing loss is compensated under the AFCS using descriptors beginning, "bilateral permanent hearing loss etc" where there is:

1) evidence of exposure to hazardous noise due to service on or after 6 April 2005

2) bilateral permanent sensorineural hearing loss with an audiometric configuration consistent with noise damage and audiometric threshold of 50dB or more averaged over 1, 2, 3 kHz.

A compensation threshold of 50dB averaged across 1, 2, 3 kHz equates to 20% disability (and the threshold for compensation) in the Industrial Injuries Disablement Benefit Scheme and the War Pensions Scheme.

10. From before the Second World War there, has been international discussion of the methods for quantitative hearing disability assessment. Some schemes have relied on the relation between measured audiometric impairment and loss of speech perception, as measured by a variety of performance tests e.g. speech in noise or quiet. Accepting that hearing ability is multifaceted and not limited to speech perception, other systems have focussed on self reported disability, most recently, expressed in quantitative terms.

11. A variety of audiometric descriptors have been proposed at different times, over the last sixty years, as best representing performance at speech tests, but there remains no agreement as

to the best descriptors. When the correlation co-efficients between different self-rated measures of disability and a range of audiometric descriptors are compared, the results strongly suggest that the choice of frequencies is largely arbitrary. There seems no advantage in a whole audiogram average as opposed to average over 1, 2 and 3 kHz. Technical audiometric factors influencing choice of frequencies include audiometric reliability. Frequencies at the extremes of the audiogram i.e. 500 Hz and 6 kHz and above are generally deemed less reliable in terms of repeatability, while bone conduction thresholds above 3 kHz are difficult to measure. Another issue is the possible effect of audiometric notches, particularly, if, as is common with noise damage, they are narrow but deep. These could inflate the hearing threshold average in the region of the notch. These issues do not provide a consistent evidence base to inform any change to the present audiometric frequencies used in MOD no–fault military compensation schemes (7).

12. While 1, and especially 2, and 3 kHz are important in speech perception, the functional significance of hearing deficit at the higher frequencies is incompletely understood. This is not the same as considering that hearing loss at other than these frequencies has no associated impact on function. At present, however, for civil and other compensation purposes, the disabling consequences of other types of hearing loss, including blast damage and acoustic trauma, are assessed on the same basis as hearing deficit due to chronic noise injury.

13. Both the Boyce Review and the first IMEG report (2011) led to changes in AFCS hearing loss descriptors and awards. The Boyce Review revalorised Table 7 awards for hearing loss, maintaining the awards for total deafness of one and two ears and increasing awards for all other descriptors by one tariff level. These changes were incorporated into legislation from August 2010. The first IMEG report (2011) increased the awards for total deafness in one and two ears bringing them into line with awards for the loss of sight. Total deafness is defined in AFCS as resulting from 90dB or more hearing deficit averaged over 1, 2 and 3 kHz. Circumstances or injury leading to total deafness as a result of service are rare compared with service attributable blindness.

14. Having considered how the scheme should approach tinnitus, for which there are no objectively verifiable tests, IMEG recommended that tinnitus should be taken into account in all AFCS awards for hearing descriptors. IMEG also considered weapons related acute acoustic trauma and recommended expansion of the existing “blast damage to ears” descriptors to include hearing loss due to “acute weapons related acoustic damage” and the addition of new descriptors for associated asymmetrical hearing loss. Reflecting the sudden onset of symptoms in acoustic trauma cases, and accepting that for the same level of permanent hearing loss, the longer term functional effect will be similar irrespective of causation, it was recommended that descriptors relating to blast or acute acoustic trauma should receive a lump sum award one tariff level higher than the equivalent award for chronic noise injury, any GIP being the same band for both types of injury.

15. Awards statistics confirm that from the start of the Scheme there have been less than 5 awards[1] for the more profound bilateral hearing losses of any cause i.e. more than 75dB bilateral loss averaged over 1, 2 and 3 kHz. Reflecting Defence industrial workshop conditions, Health and Safety practice since 2005 and the short time interval since the introduction of the scheme, there have been no AFCS awards for bilateral permanent hearing loss due to chronic industrial type noise injury.

[1] To maintain confidentiality where there are very small absolute numbers of cases or awards, MOD statistical convention is to use the expression “less than five awards”. This applies to AFCS awards to date both for bilateral total deafness and for total deafness in one ear.

16. Where there has been an AFCS award for acute acoustic trauma with unspecified level of hearing loss, pure tone audiograms at about a year from the trauma incident have been reviewed to gain some insight into the audiometric configuration and the average level of hearing deficit over 1, 2 and 3 kHz, and at low and higher audiometric frequencies. The sample was not random, people were of a range of ages and we cannot be certain of the quality of audiological testing, beyond the absence of any obvious signs suggesting low reliability and validity. In about 200 cases examined, the case history and audiometric pattern were not always typical but were compatible with a diagnosis of noise – or blast related damage. Results showed that of the total of 200 cases reviewed:

- The most common (over 90%) average threshold over 1, 2 and 3 kHz was 25 - 35dB.
- For the higher frequencies, (3, 4 and 6 kHz) average threshold was 40 - 60dB
- At the lower frequencies (0.5, 1 and 2 kHz) the most common deficit was 15 - 30dB.
- Less than five of the sample audiograms showed a straight line pattern across the frequencies.

Other causes of sensorineural hearing loss in the AFCS population

17. In the main, the military population is young with an average total service length of less than ten years. The effect of age on hearing is, therefore, generally less important in military personnel than in civilian industry, where, as a person is exposed to noise, he is also ageing. There is some evidence that the proportion of noise induced hearing loss, unrelated to occupation, is increasing in Western societies from traffic noise, construction sites and, especially in young people, from social noise, playing in bands, visiting pubs and clubs (8). In the military context, a recent Swedish study found that even with strict entry hearing criteria, 20% of those enlisted, reported experiencing hearing problems. More than a third had difficulty hearing in crowds, a quarter reported tinnitus and about 15% were said to be overly sensitive to noise. In most cases these effects were occasional, but 7% reported constant problems (9).

18. In the last ten years, there has been a new focus on genetic aspects of hearing loss with new insights into genetic susceptibility to noise damage (10) and, additionally, work, in the main on animal models, raises the future potential of gene therapy for sensorineural deafness (11).

19. That noisy work is associated with hearing loss has been recognised since the 18th century, since when a significant body of published work in humans has accumulated. However, there remain many unresolved issues, including the exposure-response relationship, the wide spectrum of individual susceptibility, the effects of different types of noise exposure and the effect of noise injury at different ages.

20. It has been appreciated for many years that the effect of occupational noise on hearing can seem quite different depending on the population chosen as the basis for comparison. There is risk of overestimating noise damage where the comparison group is highly screened, and of underestimating where the comparison is with a typical unscreened population, which will include some people who have or have had ear disease and have been exposed to noise. A recent multivariate regression analysis on a large (8000) US population aged 20 - 69 years (1999-2002

National Health and Nutrition Examination Survey) concluded that the occupational noise exposure effect was significantly associated with cigarette smoking, leisure noise exposure and educational attainment. Failure to adjust for these factors led to overestimation by a third of the effect of occupational noise (12). These issues are pertinent in occupational personal injury compensation schemes which would not be expected to award for non occupation related injury.

Hearing loss and vertigo from head injury

21. To date AFCS claims where sensorineural hearing loss and, or vertigo, is an issue secondary to head injury have been few, but in a military context the topic is important.

AFCS current approach

22. Hearing loss and vertigo are common in patients with head injury, due most often to injury within the membranous labyrinth. Because of the mechanism and prognosis, the approach in the scheme is to include hearing loss and vertigo related to head injury in Table 6 of the tariff, Neurological Disorders Including Spinal, Head and Brain Injury, with awards taking account of hearing deficit rather than on Table 7.

Table 6

Item	Level	Descriptor
5	1	Brain injury resulting in major loss or limitation of responsiveness to the environment, including absence or severe impairment of language function, and a requirement for regular professional nursing care.
11	2	Brain injury where the claimant has some limitation of response to the environment; substantial physical and sensory problems; and one or more of cognitive, personality or behavioural problems, requiring some professional nursing care and likely to require considerable regular support from other health professionals.
17	4	Brain injury where the claimant has moderate physical or sensory problems; one or more of cognitive, personality or behavioural problems and requires regular help from others with activities of everyday living, but not professional nursing care or regular help from other health professionals.
22	8	Brain injury from which the claimant has made a substantial recovery and is able to undertake some form of employment and social life, has no major physical or sensory deficits, but one or more of residual cognitive deficit, behavioural change or change in personality.(a)
27	11	Brain or traumatic head injury with persistent balance symptoms and other functionally limiting neurological damage including permanent sensorineural hearing loss of less than 50dB averaged over 1, 2 and 3

(a) **The claimant is unable to undertake work appropriate to experience, qualifications and skills at the time of onset of the illness, but able to work regularly in a less demanding job.**

***** **An award for brain injury in levels 1, 2 or 4 includes compensation for associated sexual dysfunction, incontinence of the bowel and bladder, and epilepsy.**

23. The audio vestibular effects depend on the site and type of damage sustained. Temporal bone fractures and labyrinthine concussion are involved.

i) 80% of temporal bone fractures are longitudinal, typically following blows to the parietal and temporal regions of the skull. The fracture often causes a laceration of the tympanic membrane and bleeding from the ear. Facial nerve

weakness may occur but is usually temporary. Damage can also occur to the ossicles along with tympanic membrane injury and blood in the ear canal, which results in conductive deafness. There may be additional sensorineural deafness of variable degree from labyrinthine concussion. With time, both the conductive and sensorineural hearing losses improve but in many cases there is a residual high frequency loss. Frequently after this injury, patients complain of transient vertiginous attacks, which usually subside over a few months post injury spontaneously or with appropriate medical management.

ii) Blows to the back of the skull (occiput) may cause a transverse fracture of the temporal bone. Frank bleeding from the ear is uncommon in this situation, although blood may be present in the middle ear. Facial palsy occurs in half the cases and may be permanent. The fracture crosses the vestibule of the inner ear, with labyrinthine failure and profound hearing loss and vertigo, nausea and vomiting. These latter symptoms may subside over a few weeks due to cerebral compensation, although there may be unsteadiness and a tendency to fall to the side of the affected ear for many months requiring medical management. Hearing loss does not recover.

iii) Labyrinthine concussion occurs when a blow, usually severe enough to cause loss of consciousness, but without fracture of the labyrinthine capsule causes sensorineural deafness and vertigo. The deafness may be permanent but the persistent vertigo is usually temporary lasting only a few months. Benign paroxysmal positional vertigo (BPPV) is the most common vestibular presentation after head injury and post-traumatic BPPV has a poorer prognosis than other aetiologies of this condition. Characteristically, clusters (lasting weeks or months) of brief (10 - 20 sec) positional episodes of vertigo occur over months or years with long intervals of freedom between episodes (13).

The relationship of hearing disability to audiometric threshold

24. Based on WHO 1980 definitions, impairment is abnormal hearing function usually measured by pure tone audiometry (PTA), disability is self reported reduced ability on common hearing tasks or as assessed by performance tests and handicap is psychosocial disadvantage in the person's circumstances. As evidenced in the Swedish recruit study (9) referenced at para 17, the three concepts are usually but not always related i.e. impairment gives rise to disability in the individual which in turn leads to handicap but not necessarily proportionately. Despite the limitations they underpin approaches to compensation for personal injury both in the civil courts and in the UK no fault compensation schemes including the AFCS. Civil damages, where negligence must be proved, reflect claimant individual circumstances and response to the injury, while AFCS awards aim to address the expected average disabling effects of the injury/disorder. The AFCS provides compensation for pain and suffering in the lump sum awarded, and for potential loss of earnings in future civilian employment in the GIP.

25. In the case of attributable hearing loss, recommendations in relation to appropriate descriptors and tariff require (a) knowledge of the level of loss of auditory function which is

most commonly measured by audiometric testing (b) the consequent disability which is primarily perceived as loss of speech discrimination and (c) the social and economic handicap caused by the attributable hearing loss, which in AFCS is focussed on the impact on civilian employability. Because of the variability discussed above in the relationship between measurable functional impairment, perceived disability and consequent handicap in relation to civilian employability, reliable judgements about the level of disability and extent of handicap in the workplace from the measured level of audiometric permanent threshold shift are difficult. Impulse and continuous noise injury may lead to abnormal function of the ear i.e. impairment, measured by pure tone audiometry, while the subsequent disabling effects are generally measured by self-report, using a questionnaire, or by performance testing e.g. speech identification in noise. There are also limits to these approaches to disability measurement. Self report is easy to administer and has face validity but it is subjective and is not easily replicated, even within subjects. Performance tests provide supplementary information but can only directly measure one dimension of hearing function and are limited by the frequency spectrum of the particular speech test. This topic has attracted much interest over many years. A classic critique of the innate limitations and challenges e.g. scaling of individual disability, individual variation and the essentially arbitrary nature of the various approaches to measuring the consequences of hearing loss, especially noise related loss, for compensation was published in 1988 (14).

26. There is marked inherent variability in measured hearing threshold levels amongst individual people of the same age and sex (15) and normal people also differ in their concept of hearing normality, their susceptibility to noise injury and the effects of ageing. A number of studies have investigated the relationship between permanent audiometric threshold shifts and hearing disability but as yet there is no agreement on the matter. The Inter Society Working Group on Hearing Disability (ISWGHD) devised a system to predict disability from measured audiometric threshold for a typical person in a population (7). However the methodology, the underlying assumption that disability is the reciprocal of ability, and the final recommendations of ISWGHD were not universally accepted, either within the working group or subsequently externally. The method was based on data from the National Study of Hearing (16) and a self rated scale of hearing, arranged in eleven categories covering the centiles from nil to 100, where nil is totally deaf and 100 excellent hearing ability. This approach has limitations which include the fact that there are only two fixed points on the scale and hearing abilities of the members of the population studied are not normally distributed, with most people being at the good hearing ability end and few with profound levels of hearing disability.

27. A study, also based on data used for the UK National Study of Hearing looked at four components of disability based on a self–administered questionnaire. These were (i) disability for everyday speech, (ii) for speech in quiet, (iii) localisation, and (iv) handicap i.e. psycho-social disadvantage in the person's circumstances. Disability for everyday speech and handicap accounted for 68% of the variance in reported disability. Pure tone audiometry was carried out with focus on i) low –mid frequency loss and ii) high frequency slope. All four disability components correlated with low-mid–frequency hearing loss and were independent of high frequency loss. There was, in this study, a general relationship between self reported disability and age i.e. a given hearing loss was more disabling in younger than older age groups, but at all ages there was wide individual variability between measured threshold and reported disability. For losses above about 40dB, conductive or mixed loss was more disabling than sensorineural loss. Other reported studies of the relationship between hearing threshold and speech discrimination have, like this one, been cross-sectional in design and have not distinguished between acutely acquired hearing loss and hearing loss developing over several years. Socio-economic group had no discernible effect; but in subjects with a classic noise induced high frequency pattern, men were more disabled than women for the same hearing deficit. The strongest correlation with changes in pure tone audiometry at lower frequencies was with everyday speech

discrimination (sensitivity) (r=0.6); there was also reasonable correlation, r=0.55, with handicap. Correlation between audiometric threshold and speech in quiet and localisation was generally less good, regardless of audiometric descriptors used. Localisation ability was best reflected in worse ear threshold shift. Speech discrimination reduction was generally associated with raised permanent hearing thresholds at lower frequencies i.e. 1, 2, and 3 kHz, and little affected by higher frequency thresholds, 4 to 6 kHz, the frequency band most often impacted by impulse noise (17).

28. Studies have also tried to map impairment and disability to identify the measured audiometric threshold which equates to the onset level of disability (18). The data are also cross-sectional. Regardless of population studied, the results suggest that as well as wide variability in reported disability for the same audiometric threshold, there is no clear point at which disability begins, but rather a continuum.

29. Because of individual variability, for sensorineural hearing loss, with little difference between the two ears, if self reported hearing ability expressed in centiles (19) on a scale of 1 - 100 is plotted against audiometrically measured hearing threshold, for a wide range of reported hearing ability (e.g. in the centiles 100 - 60), there is very little difference in measured median hearing threshold. Finally these studies and scales as required in some compensation schemes focus only on one injury, hearing deficit. AFCS must consider the whole body impact of injury and disorders and make consistent and equitable awards across the range of disorders and injuries.

The subsequent pattern and rate of hearing loss over time in a young adult with a noise induced hearing loss as a consequence of either continuous or impulse noise, when noise exposure ceases.

30. Acute acoustic trauma and blast induced hearing injury in the military no-fault compensation schemes have been considered separately from chronic noise induced deafness to acknowledge the different mechanism and typical young age of the affected person. The nature and natural history of hearing loss due to chronic industrial noise exposure means that most of the relevant literature concerns older adults, who, over many years, simultaneously experience gradual change due to noise and ageing. Knowledge of the impact on hearing function over the remaining lifetime, when a young adult suffers acute, discrete, noise injury or more continuous noise which ceases, requires longitudinal study of a suitably large population of young adults with hearing loss due to noise injury. No such studies have been undertaken and published. Those that have addressed the question of subsequent hearing loss after removal from noise exposure, have focussed on older people, usually at the end of a working life of continuous noise exposure. Their findings have been inconsistent. In general, studies in older people have found that those who had worked in noisy occupations at study entry had higher hearing thresholds across the frequencies. In one study, of persons in their early 70s, age related hearing loss was greater in those with a history of noise exposure; in the mid 70s the rate of decline was similar in those with and without a history of noise exposure and by age 80 years, the difference in hearing loss between those with and without a history of noise exposure was minimal (20). In another study with subjects aged 60 - 81 years at entry and followed for between 3 and 11 years (average 6.4 years), noise history had an effect on the initial threshold levels measured at the start of the study, but the rates of threshold change after that were not different whether or not there was a history of noise exposure (21). This contrasts with the findings of the 2000 Gates study (22) in older people which suggested that noise injury to the ear continued to have a damaging effect on hearing, long after the noise exposure ceased. There are however limitations in this study. First it makes the underlying assumption that all high

frequency notches are due to noise. It discusses only mean hearing loss and provides no information about variation amongst individual starting levels, nor of the variation over time. The change in threshold in dB over 15 years was calculated from only two measured hearing levels during the follow-up period. Despite the average age at the onset of 64 years, there is no discussion of the confounding nature of noise and age on measured overall hearing impairment. Lastly the authors assume that after retirement, people were no longer exposed to noise. No enquiry was made about possible sources of noise injury e.g. gardening equipment, DIY machinery and, importantly in the US, recreational shooting.

31. The hypothesis underlying the studies described in the last paragraph is that the effects of noise and age on hearing are generally additive except in the very old when they become less than additive. An explanation of this phenomenon is that the number of individual cochlear hair cells is finite and damage or loss can only occur once, whether due to noise or ageing (10) with no increase in rate of decline after cessation of exposure.

Evidence received

32. The Royal British Legion and Action on Hearing Loss in their evidence to IMEG raised a number of questions set out below (i) – (iv). The first three were also discussed in the MAC Hearing Loss Sub- Group Policy Statement.

i) Whether the present audiometric threshold of 50dB averaged over 1, 2 and 3 kHz for compensation of service related permanent hearing loss under AFCS is appropriate.

ii) The need to consider any discrepancy between the level of hearing loss leading to reduced military employability grading and eligibility for AFCS compensation.

iii) The most appropriate audiometric frequencies and weightings to assess hearing disability and how to weight better and worse ears.

iv) The relationship between compensation for total loss of hearing in one ear compared with bilateral permanent loss of just less than 50dB averaged over 1, 2 and 3 kHz.

i) Audiometric threshold for compensation in AFCS

33. The basis for the current threshold for compensation in the scheme was questioned, with the MAC submission recommending that the compensation threshold be set at 35dB retrospective to April 2005. It was suggested that the current process was a matter of administrative convenience in the early years following the introduction of compensation for noise induced hearing loss (Occupational Deafness) in the Industrial Injuries Scheme. The MAC submission proposed, although without specific supporting evidence, that a level of 35dB loss would lead to a "clearly debilitating effect" on communication and employability and considered that hearing aids are inadequate at improving discrimination in those with hearing disability caused by noise. Finally it made the general point that the AFCS approach is less generous than other international jurisdictions.

34. It is the scientific evidence, and in particular any published evidence relevant to the topic, particularly emerging since 2000, which is the focus of this IMEG review and which must form the basis of its conclusions and recommendations. It should however be noted that, despite several subsequent reviews of Occupational Deafness, in the absence of new identified scientific evidence since 2002, the Industrial Injuries Scheme has not changed the audiometric criteria for compensation, i.e. 50dB averaged across 1, 2 and 3 kHz.

35. It is recognised that the current AFCS compensation threshold represents a specific level of auditory deficit and not the onset of disabling hearing loss; and that many other schemes around the world have a lower threshold of compensation. Most experts would agree that above 30 - 40dB bilateral sensorineural hearing loss averaged over 1, 2 and 3 kHz, a young person is likely to report difficulty with speech discrimination. In some cases, there will also be some emotional effect and dependent on circumstances, impact on employment. Those with a bilateral deficit of over 40dB would similarly almost always benefit from hearing aids, particularly modern digital aids (23).

36. In most countries, pure tone audiometry remains the most commonly used method for diagnosis and assessment of hearing loss for compensation purposes but there is no international agreement on audiometric descriptors or disability scales or underlying ethos or assumptions and fair comparison across the different schemes is very difficult. For hearing loss, different schemes use different measures of hearing disability or impairment, make awards which start at different levels of loss, and differentially award rates of accrual of hearing loss. Some schemes make awards only where employment is compromised. The schemes may be for hearing loss only or, as in AFCS, cover a wide range of disorders, with the added requirement to preserve consistency and equity in assessment and awards both within and across injuries and diseases.

37. Consistency and equity in awards depends crucially on high quality audiometry for both diagnosis and assessment. Accurate diagnosis and assessment of hearing problems is also important for clinical management and employment screening and surveillance at recruitment, and in-service for allocation of duties and retention in post. Audiometers should be regularly calibrated to defined standards, and ear phones and booths meet appropriate technical standards. Staff carrying out tests should be qualified and trained in audiometry technique to defined standards and understand the physiology of hearing.

38. Accurate diagnosis of noise related hearing deficit remains challenging. Not every notch or dip at 4 kHz is a sign of noise damage (24). Valid pre-exposure comparator audiometry is highly desirable in diagnosis and potentially available in the UK military context. Tests should be planned and timed in relation to noise exposure, taking account of temporary threshold shift.

39. Pure tone audiometry is subjective and, therefore, confirmation of hearing threshold levels requires ready access to more objective assessment techniques, such as otoacoustic emissions (OAE) and CERA (25). A study of an Irish military population claiming noise induced hearing loss found that about a quarter of all claimants had exaggerated hearing thresholds, defined as average hearing thresholds by CERA, 10dB or more better than by pure tone audiometry at 500 Hz 1, 2 and 4 kHz. The researchers concluded that the presence of a flat

audiogram and a hearing threshold of 25dB or more at 500 Hz are useful predictors of non-organic hearing loss and, when present, CERA was recommended to determine objective auditory thresholds (26). It is important that these tests also are administered and interpreted by experts. CERA testing can take time and may be difficult for some patients. OAE testing on the other hand may be used as an initial rapid test of cochlear function detecting potential problems ahead of observable change in pure tone threshold or as a screening tool to identify a discrepancy between subjective audiometric thresholds and objective auditory responses. It does not require a behavioural response from patients, and provides an initial assessment of hearing sensitivity within a limited range, although not a full quantitative assessment (27).

40. Test-retest variability in an individual in audiometric threshold measurement in good hands can be between 6 – 11dB (28). Robust decisions on both employability and compensation therefore require technical standards which are valid and reproducible. Decisions about compensation and future military employment require access to supporting objective measurements, i.e. CERA. Since it became clear that the UK deployment to Afghanistan was associated with risk to hearing, action has been taken by the chain of command and Headquarters Surgeon General to improve awareness of good hearing hygiene, best practice hearing protection, the need for regular hearing surveillance and allocation of employability status and to address and unify technical standards of audiometry, diagnosis etc. in the geographically scattered and diverse military medical platform. Achievement of consistent high quality audiometry standards and access to specialist techniques such as CERA and OAE are a challenge. Delivering best practice hearing surveillance needs cooperation from the chain of command, to ensure the person's availability for testing. It also needs engagement by the man or woman, who may be reluctant to admit to hearing symptoms, with the risk of medical downgrading and restricted military employability/career prospects. MOD and the services are working with Action On Hearing Loss to emphasise the potentially permanent and life changing consequences of failure to use hearing protection.

41. There is no international agreement on the compensation threshold for noise induced hearing loss and contemporary scientific understanding does not provide a compelling case for any particular process or level. There remain many variables and unknowns and for robust and defensible decisions, ready access to quality audiometry and objective assessment methods must be a priority.

Recommendation

42. IMEG recognises that the current threshold for compensation is high. However the evidence at the present time is **not sufficient to make a recommendation** for change, which would be robust and based on clear scientific evidence. In particular we have been aware of: the extent of variation in audiometric measurements, in good hands, in the same individual (6-11dB); the lack of a direct and consistent relationship between measured audiometric impairment, hearing disability and, of particular importance for AFCS, future civilian employability; the need for AFCS to ensure equity of awards within and across the range of injuries. Taken together these **do not justify a recommendation** for change in the audiometric threshold at the present time.

43. Because of the lack of relevant published evidence, essential to allow well informed recommendations about the compensation threshold in this population, we **strongly recommend** that a prospective study be undertaken of in-service cases with hearing threshold of 35-50dB averaged over 1, 2 and 3 kHz to report within 3 years of publication of IMEG's second report. The study should address the relationship between measured hearing threshold and self-

reported hearing disability, military employability grading and restrictions on civilian employability. The need for quality assured audiometry testing and enquiry in relation to the causes and consequence of hearing impairment make it essential the study is undertaken prospectively with the informed consent of the participants.

44. It is **also recommended** that if the findings of this study provide clear evidence which indicates the need to reduce the level of hearing threshold for compensation that exceptionally consideration be given to backdating awards to the date of IMEG's second report.

In addition, we **recommend** the compensation threshold should be kept under review with close scrutiny for any pertinent developments.

45. The importance of accurate diagnosis and assessment of hearing loss and the continuing work to deliver consistent high quality assured audiometry (at appropriate times relative to exposure and regular time intervals), best practice hearing protection and surveillance across Defence are essential elements. Account should also be taken of military medical employability hearing standards, downgrading and medical discharge policy. It is **recommended** that the same quality assured audiometry data, should inform both military employability standard and any AFCS claim. Because of the potential life–changing impact for the person and operational consequences for the service, we **also recommend** routine use of objective testing, i.e. CERA or OAE or both, wherever downgrading to H3 or lower, or medical discharge is under consideration, with tests undertaken and interpreted by suitably experienced experts.

46. While the evidence to date indicates that numbers in this category will be small, for those whose service related hearing loss falls below the compensation threshold and is confirmed as between 40 - 50dB averaged over 1, 2 and 3 kHz in each ear, we **recommend** NHS supplied digital aids, as clinically appropriate. Conscious also of the potentially stigmatising effects of use of hearing aids, especially in young adults, we **further recommend** that RIC or ITE digital aids should be supplied whenever possible, as advised by the clinician in charge. Where hearing loss is due to service, Priority NHS access applies, based on clinical need. Recognition that the consequences of acute hearing loss sustained as a young adult, including psychological sequelae, may differ from that due to chronic noise injury becoming apparent in middle age or older, implies the need for a longitudinal investigation of the impact of acute noise injury over time, including disabling effects, audiometric changes and employability.

ii) The need to consider any discrepancy between the level of hearing loss leading to reduced military employability grading and eligibility for AFCS compensation

47. Pure tone audiometry became widely available in the 1970s and the current military system of assessing hearing acuity was introduced in 1981 (29). Reflecting the different operational requirements, principles are shared but slightly different standards apply to the three services. The present military approach to hearing and medical employability, including retention in service, does not depend on any particular level of hearing threshold but on the individual case facts and specialist otolaryngological and occupational health opinions. The military approach involves routine surveillance of overall hearing acuity, detection of the presence and progress of noise damage and the provision of hearing protection suitable for the individual and his circumstances. Allocation to a PULHHEEMS hearing standard is based only on hearing acuity. Pure tone audiometry is carried out at defined time intervals and, as required, clinically. Hearing acuity tested by pure tone audiometry at 250 Hz to 8 kHz is used to determine the PULHHEEMS category in each ear using the sum of the thresholds (dB) at low frequencies i.e.

500 Hz, 1 and 2 kHz and high frequencies 3, 4 and 6 kHz.

The standards are as follows

PULHHEEMS SUM (dB)	0.5, 1 and 2 kHz	3, 4 and 6 kHz
H1	not more than 45	not more than 45
H2	not more than 84	not more than 123
H3	not more than 150	not more than 210
H4	more than 150	more than 210

In addition the noise exposure history and audiometric pattern is used to establish whether noise induced hearing loss is present.

48. General minimum service entry standard is H2 and for aircrew, H1. Once in service, deterioration in high frequencies is presently taken as indicative of noise damage and so a need for enhanced protection and increased surveillance. Where a serving member is H3 or H4, temporary downgrading and specialist otolaryngological and occupational health opinions are obtained. H3 in one or both ears may make a person not fully deployable. H4 in one or both ears normally leads to medical discharge. Each case is however considered on its facts with account taken of the person's service occupation, employability and skills limitations and possible military job options. Objective auditory data should be reviewed at this time. These issues are complex and, although not convinced that AFCS compensation should be based on the same criteria as present UK military medical employability standards, we agree with the MAC that simplicity and transparency as well as coherence would greatly benefit if AFCS and PULHHEEMS criteria were aligned.

49. The income stream element of AFCS awards aims to recognise the impact of all accepted injuries and diseases on civilian employment. In terms of civilian employability some degree of hearing loss is common in UK working age adults. Based on the National Study of Hearing, 17% of UK adults have a hearing impairment of 25dB or more averaged over 0.5, 1, 2 and 4 kHz in the better ear (BE) (16). Loss of hearing seldom leads to time off work and there are few civilian jobs where perfect hearing is essential. Dependent on the requirements of the job, issues are person comfort, stress and strain associated with struggling to hear and above all safety for self and others. Employer issues include responsibility to reduce noise at source, hearing conservation, prevention, protection, and pre-employment screening and surveillance. As people are ageing with time in occupations, special attention needs to be paid to those with pre-existing or developing hearing impairment.

50. As discussed above, normal hearing is difficult to define, particularly in the context of occupation. It is age related and despite the efforts to define population ranges and predicted effects of noise exposure, there is wide individual variation in terms of measured threshold and perceived disability. Many service leavers are presently attracted to work in security, which has no defined hearing standards in the UK, and to the uniformed services and transport. Specific employment standards exist for relatively few UK civilian employments other than for civilian flying. For occupations such as the police, fire and ambulance, railways and merchant navy, there are published national audiometric standards (30) but, as with the military, these are guidelines rather than mandatory. Local issues such as competition for the job, and its status, specific job requirements, whether addressing recruitment or in employment surveillance, all come into play. Defective hearing does not preclude driving, including public service vehicles, unless a person is totally unable to communicate in an emergency. As in the military, quality assured audiometry

with access to objective testing by experts is essential for valid decisions on civilian employability. For both military and civilian employability, decisions to discharge medically, do not depend solely on audiometric hearing acuity but on a range of case specific factors.

iii) Choice of audiometric frequencies

51. We note the comment by the MAC that the descriptors for assessment should be changed to better reflect frequencies involved in blast injury or acute acoustic trauma. While an interesting idea, as the MAC submission confirms, such a change would be for the future and could only follow extensive research, bearing in mind the challenges and restrictions of study of acute acoustic trauma or blast injury in the 21st century. Careful review of the contemporary literature and discussion with expert clinicians active in the fields confirms that prediction of self-reported disability is not strongly influenced by audiometric descriptors. Some experts recommend inclusion of 0.5 kHz but the evidence is not compelling and there is no scientific reason to change from the existing 1, 2 and 3 kHz. Similarly UK public schemes use a binaural average which weighs better and worse ears in the ratio 4:1. Use of the 7:1 favoured in the US does not lead to significant difference in the correlation between audiometry and everyday speech disability (7).

Recommendation

52. It is recognised that other descriptors could be chosen, but IMEG finds no compelling evidence to require a change from the existing position. We **recommend** consideration of use of the same audiometric descriptors for medical employability standard and compensation determination.

iv) Compensation for total loss of hearing in one ear compared with bilateral permanent loss of just less than 50dB averaged over 1, 2 and 3 kHz

53. Extract from Table 7 Senses

Blast injury to ears or acute acoustic trauma due to impulse noise with permanent bilateral sensorineural hearing loss of 50 - 75dB averaged over 1, 2 and 3 kHz	Level 7
Total deafness in one ear	Level 8
Bilateral permanent hearing loss of 50 – 75dB averaged over 1, 2 and 3 kHz	Level 8

The present position is as above. For bilateral permanent sensorineural hearing loss of just less than 50dB, no award is payable. The award for total deafness in one ear was increased following IMEG Review of Paired Injuries. Previously at Level 10, it was increased to bring it into line with loss of one eye. The Level 8 award recognises effects beyond that of the direct loss of the organ itself. As discussed in the first IMEG report (2011) where there are paired organs senses or injuries and one is lost due to service, in addition to its direct functional effect, loss of the first organ due to service enhances the impact of any subsequent loss of the other organ. In relation to the bilateral loss, just below the compensation threshold level bilaterally, it is recognised that a compensation threshold level is introduced arbitrarily and it is accepted that such a loss would be likely to be disabling to a young person. However to date no claim with

objectively verified bilateral hearing threshold between 45 and 50dB loss has been received in the scheme.

Recommendation

54. IMEG should receive regular reports of the distribution of hearing levels claimed and awarded and this issue will be included in the prospective study.

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