

An Audiometric Survey of Royal Artillery Gun Crews Following "Operation Corporate"

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SUMMARY: An Audiometric Survey was carried out on two batteries of 4 Fd Regt RA (n-84) who were exposed to massive levels of impulse noise during "OP CORPORATE". A control group (n-30) was obtained from the remaining battery which did not serve in the Falklands, and it was matched well in age, service and job.

They completed a questionnaire, were physically examined and had an audiogram using the MAICO M26 computer audiometer. Results were related to PULHEEMS standards and compared.

No subject in the control group was classed below H2 but in those exposed, 17 were H3 or worse. This is significant (p 0.01 for 1 df) but the significance is attenuated medically and statistically. No significant correlation was found between type of ear defender and degree of protection.

The survey showed that sufficient numbers had been affected to necessitate a full examination of all troops who fought in East Falkland.

Introduction

Noise Induced Hearing Loss (NIHL) has long been known as the result of repeated exposure to high levels of continuous noise, especially at work, being time related as regards exposure years and duration of each exposure.

The Armed Services are no exception to this problem, but have the additional complication of being exposed to high levels of impulse noise from assorted weaponry¹, particularly in the Royal Artillery. One of the difficulties in determining the severity of impulse noise, has been in equating it to continuous noise levels. Aterley and Martin² have devised a method of doing so using knowledge of peak levels (pressure), frequency rates and delay time constants of the noise waveform.

Separate papers by Livesey³ and Brasher⁴ have shown, within the Army, a significant number of soldiers were suffering from NIHL, without being aware of it, and these were particularly apparent in R.A. units. Studies into the effects of impulse noise on volunteers, limited ethically, showed that barotrauma to all structures in the ear and in particular the Organ of Corti could result in tinnitus and Temporary Threshold Shift (TTS) from impulsive noise⁴. In addition Brasher found that almost half of his exposed group were very 'sensitive' to impulse noise and were therefore in greater danger of suffering permanent damage. The tactical implications of having 'deaf' soldiers as sentries or wireless operators are obvious.

Among the Armed Services of other countries,

the artillery also appears to be most at risk. On studying a mixed group of soldiers in Singapore, Paul, Chai and Thomas⁵ found that of those with NIHL, 26% were artillerymen.

At a result of these studies and others, the Army Hearing Conservation Programme⁶ was formed to protect the Serviceman's hearing. The details are now well documented, but briefly, the main accent has been on personal protection of the man by ear defenders and routine audiometry. Group protection, where possible, has been attempted by sound monitoring measures laid down by the Health and Safety at Work Act 1974⁷ in conjunction with the 1972 Code of Practice⁸. These are now being updated and improvements are being achieved through a Consultative Document 1981⁹ which gives detailed advice on wearer protection.

From a Service viewpoint, such recommendations have been anticipated and are already in use, with regular audiometry being the main screening and monitoring test of an individual's hearing. New gradings in PULHEEMS standards have been introduced since 1979^{10,11}, and associated grades in decibels are shown in Table I. These grades refer to summated decibel loss in the 0.5, 1, 2 KHz (low), and 3, 4 and 6 KHz (high) ranges. The "H" level for each ear is now given as in Table I; the 'worse' ear grading will determine any restriction placed in the soldiers' work capacity. Where there is a great deal of exposure to high noise levels, yearly audiometry is advised and the Royal Artillery fall into this category.

Table I
New Joint Service Audiometrically Based Hearing Standards

	Degree	Sum of Hearing Loss at "Low" Frequencies 0.5, 1 & 2 KHz	Sum of Hearing Loss at "High" Frequencies 3, 4 & 6 KHz
Compatible with P1 and P2, H2 to remain minimum entry standard to most Army employments	H1	Not more than 45 dB	Not more than 45 dB
	H2	Not more than 84 dB	Not more than 123 dB
Limited flexibility to P2, P3, P7 at the discretion of the ENT specialist	H3	Not more than 150 dB	Not more than 210 dB
Compatible with P7 Unfit for service P8	H4 H8	Greater than 150 dB	Greater than 210 dB

The Problem

In 1982, the Falklands War broke out, and as a result, British troops were in active service on a scale not seen since the Fifties with Suez.

Modern weaponry has advanced to such a level that the impulse noise factor of many weapons is exceedingly high. Among one of the noisiest pieces is the 105 mm Fd gun (Fig 1) used by field artillery units.

Tests¹² on this gun have shown that at maximum impulse charge (charge super) the impulse noise level is 185dB(a) for a period of 20-25 msec. Since the gun has no shrapnel shield, the loader and the No 1 (Fig 1) as well as the limber men are all exposed to the maximum firing effect of the gun. Recommendations from the Army Personnel Research Establishment (APRE) are that all people exposed must wear ear defenders and, if necessary, both inserts and muffs together. The noise attenuations achieved by different types of ear defender are shown in Table II.

As part of routine gun drill, and in training for a North West Europe conflict, orders are given from command posts to the guns by wireless/

telephone links. These necessitate headsets which are incorporated in ear muffs, for full protection. Soldiers who do not serve close to the guns or have no need for earphones are issued with the insert type of defender, the Sonex V51 plug.

In the event of wireless/telephone facilities being impracticable (as in the Falklands) shouted orders through megaphones or loudspeakers are given. The cosmocord ear defender is designed for this, being a muff type defender with hearing aids placed inside it. Orders are then amplified but any impulse noise activates a baffle which disconnects the aid. The main drawbacks to these defenders are expense, the time taken to position them, the battery life of the hearing aid inserted and the soldier abusing them.

Tests done on the 105 mm gun firing have shown that because of the high impulse noise level, firing especially at charge super, must be limited even with the attenuation afforded by defenders.

The results have been tabulated and are reproduced here from the Interim Defence Standard 00-27/1 published by the Ministry of Defence.¹³

The two graphs (Figs 2a & b) show that the recommended limits to impulse noise and the maximal limits of exposure (100 impulses fired) are far below the levels existing with the 105 Fd gun. Protection can only be achieved therefore if the number of exposures is reduced and greater efficacy is achieved in ear defenders. The outcome is the recommendation that at charge super, 10 rounds/24 hrs is the maximum exposure during training.

4 Fd Regt RA were designated as artillery support to 5 Inf Brigade, to serve in the South Atlantic. By chance, the regiment took only two of its three batteries (No 29 and 97) the third (No 88) having recently returned from service in Belize. This battery remained in the United Kingdom, but while in

Table II
Noise Attenuation

Octave band centre frequency Hz	Attenuation Value dB		
	V51R Plug	Glass Down	Fluid Seal Muff
63	11		17
125	13		18
250	15	11	20
500	18	13	30
1000	22	16	38
2000	27	26	40
4000	32	33	43
8000	29		35

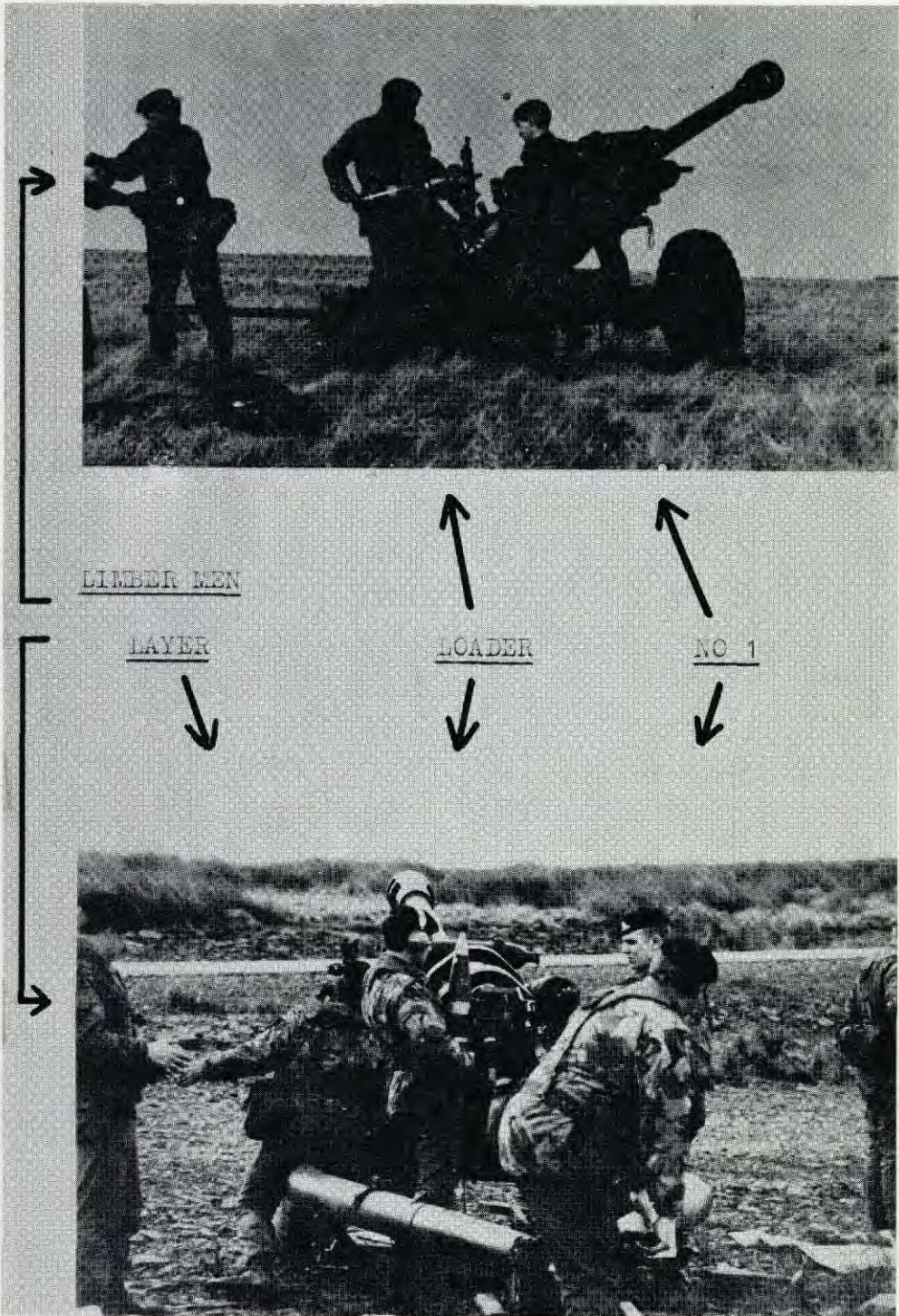


Fig. 1. 105mm Fd Gun Crews

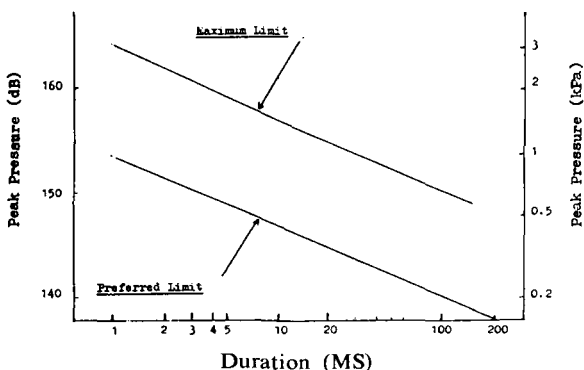


Fig. 2a. Limits for Impulse Noise Exposure Impulses/24 hours

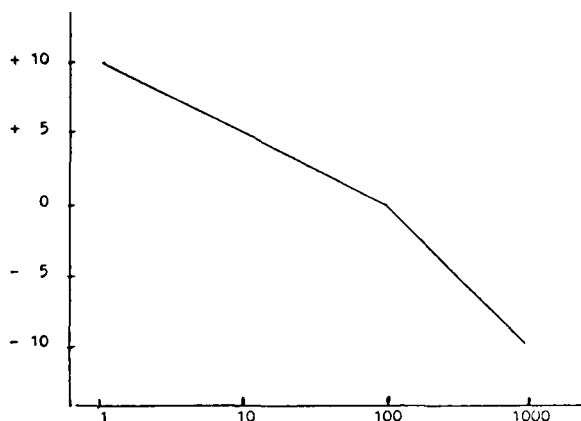


Fig. 2b. Allowances for number of Impulses/24 hours (Reprod.—Interim DEF STAN 00-27/1)

Belize it had fired a large number of rounds in practice under fully protective conditions¹⁴.

The two batteries who travelled south saw active service throughout the campaign and in the final stages of the assault on Port Stanley, fired up to 1,000 rounds per gun within 5 days. In addition, the personnel had fired their personal weapons in practice, and all were subject to enemy bombardment from air and artillery. Since this noise effect was of unknown timing little aural protection was achieved, but this was not classified as a severe insult to the ear. The high rate of firing also ensured that discipline with regard to ear protection was strained and tested to the limit¹⁴.

This survey attempts, therefore, to assess any permanent threshold shift caused by this massive assault on the auditory anatomy, exceeding all recommended limits of exposure to such weaponry.

Method

The survey was carried out after permission had been given to interview members of 4th Regiment Royal Artillery, from its Commanding Officer.

It consisted of three parts:

1. Detailed questioning about exposure events involving the two batteries who participated in the Falklands War, and the training schedule of the battery who served in Belize. This battery provided the control group in the survey.
2. A questionnaire.
3. Audiometric testing of subjects and controls.
 - a. *Exposure Events.* The author found out from various sources, including interviews with Battery Commanders, soldiers and his own experience, the length of time the batteries were in action in the Falklands and a reliable assessment of the number of rounds fired in that time, especially in the days preceding the final assault. This was used as a check against replies in the questionnaire.

Details of exposure time during practice and number of rounds fired were obtained about the control battery and this was used as a baseline for subsequent assessment of the difference in the exposure levels between controls and those exposed.

b. *Questionnaire.* An attempt was made to test all soldiers who fired the 105 mm Fd gun in the Falklands and those from the battery who did not go south. Eighty four soldiers who served in the Falklands and thirty who did not eventually took part in the survey.

They were asked to fill out the questionnaire which was orientated to those who served south. However, the control group were asked to answer any question, not applicable directly, with reference to events of the past year.

Controls and those exposed were matched by age, sex and length of service in the RA, as well as their positions on the gun. Because of Service needs in the Falklands, not all who supplied ammunition to the guns were RA, but were cooks and engineers. However, they matched as regards age and service and were therefore included.

c. *Audiometric Testing.* Subjects and controls were randomly allocated reporting times for examination and audiometry. The rate of 12/hr was achieved as three machines were available for testing.

The author examined all to be tested, clinically, to exclude obvious pathology, and he and

his assistant gave assistance at any query about the questionnaire.

Conditions for audiometry were not optimal, but a good effort to get acceptable quietness was obtained, by notification and location of the testing site in a quiet area. Background noise did not exceed 50 dBA at any time.

After the questionnaire had been completed, each subject was instructed in the test procedure and given a trial.

The audiometer used was the MAICO MA 26 Computer Audiometer allowing automatic testing. Once the author was certain that the subject understood the nature of the test, automatic audiometry was carried out.

In subjects who, because of a variety of reasons, had invalid tests, the procedure was repeated after a period of instruction and this time these subjects were tested on their own, with one of the directing staff supervising.

Where the machine advised masking (see discussion) a repeat audiogram was performed and if the results were compatible with the original, then the original results were accepted. Each machine was programmed to reject any attempt by subjects to anticipate the stimuli.

Results

General

Originally 130 soldiers of the regiment were detailed for the study. The numbers actually tested were 114—a response rate of 88% which was very gratifying. The reasons for the remainder not being tested include illness, leave or other Service commitments.

Questionnaire

This was not comprehensive nor specific to the regiment as it is being used as a basic screening test for a wider survey involving all arms of the Service who were exposed to loud noise levels while serving in the Falklands.

The results are summarised in Table III. The mean ages of both controls and those exposed are well matched as were their lengths of service. Positions on the gun were also well matched and numbers between controls (30) and each battery exposed (42) were acceptable.

All types of issue ear defenders were used as well as others obtained privately and these included one soldier who used the filter tips of a well known brand of cigarettes as defenders! There was a high percentage of defenders used in the control battery when firing and, as expected, considerably lower levels in those batteries who were exposed (Table

Table III

Centre	Number	Age		Service		Mean H Grade	
		Mean	SD	Mean	SD	Pre	Post
Control	30	23.5	3.5	5.4	3.0	1.4	1.5
Exposed 29 Bty	42	23.4	4.6	5.8	4.3	1.1	1.7
97 Bty	42			5.3	3.3	1.2	1.9

Table IVa
% Ear Defence by Batteries

Battery	Number	Degree of Hearing Protection (Expressed as % of Nos)		
		100%	Part	0%
88 (Control)	30	83	—	17
29	42	62	7	31
97	42	38	31	31
29 & 97	84	50	19	31

Table IVb
Post Exposure: Numbers affected related to degree of Ear Protection in 29 & 97 Btys n=84

	PULHEEMS			
	H1	H2	H3	H4
Always worn	20	17	5	—
Sometimes worn	2	7	5	1
Never worn	12	9	4	1

Table IVc
Hearing Grade of those exposed and who wore Defenders all or most of the time n=46

Defender	Hearing Grade (PULHEEMS)		
	H1	H2	H3 or above
Sonex V5 1	9	6	2
Muffs	10	7	
Others	4	5	3

IV). Analysis showed that one battery (97) in fact had a very low level of total use of defenders (38%) and this is mirrored in the audiometric results (Table III, last two columns).

Clinical

Each man was examined before undergoing audiometry and there were no cases found of tympanic membrane damage. Those with wax had it removed and were re-examined and tested 24 hrs later. Few of the subjects admitted to persisting tinnitus but

a higher proportion admitted to it during the firing events in the south, as was expected.

One subject was excluded because of an active case of otitis media for which he was being treated, and another case was already undergoing investigations for loss of hearing.

Audiogram

The results of the hearing loss in decibels, at each frequency, were summated into 'low' and 'high' categories eg:

- 0.5, 1 & 2 kHz = 'low'
- 3, 4 & 6 kHz = 'high'

Each person's ears were tested separately and the results are displayed as histograms in Figs 3 and 4.

As can be seen, the control group has a 'tight' configuration for each ear in the histogram, with no one being lower than H2 in PULHEEMS category. (Table 1).

Those exposed have a similar pattern, but there

is a tail to the right in each histogram with a total of 17 individuals having a hearing loss of H3 or worse. In fact one soldier had a summated hearing loss of more than 250 dBA — high range, in one ear!

There were so few pre-Falkland audiograms found in all personnel studied that the only data available about both groups was their PULHEEMS classification. Mean pre and post Falkland grades are given in Table III. Referring to Table I, it will be seen that this may not be a sensitive comparison. There was, however, a degree of shift from H1 to H2 in more than 50% of those who served in the Falklands compared with less than 7% of the controls. This would indicate some degree of NIHL in most individuals exposed, but they are still within the accepted Pulheems limits so that no restriction on further exposure to gunfire or to their jobs and promotion need be made.

However, if one charts those exposed by PUL-

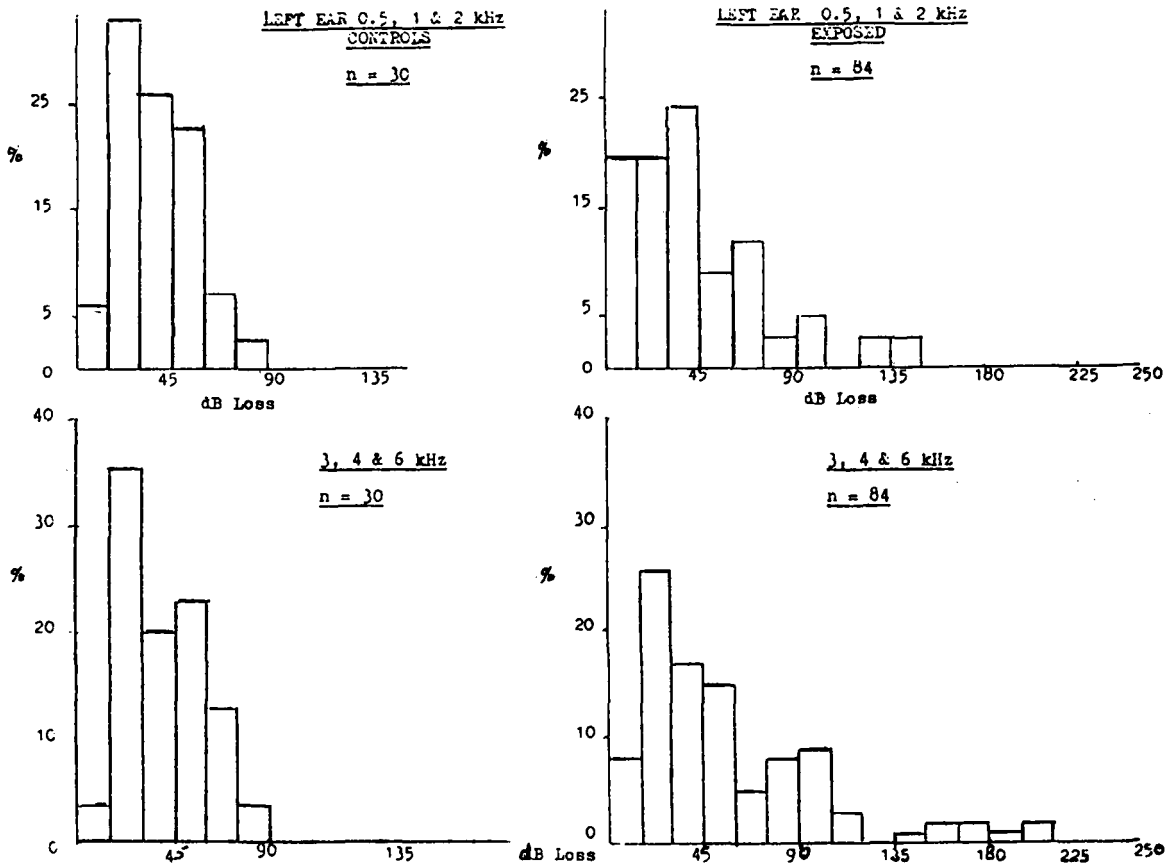


Fig. 3 Histogram showing results of audiometry on exposed and control groups, left ear.

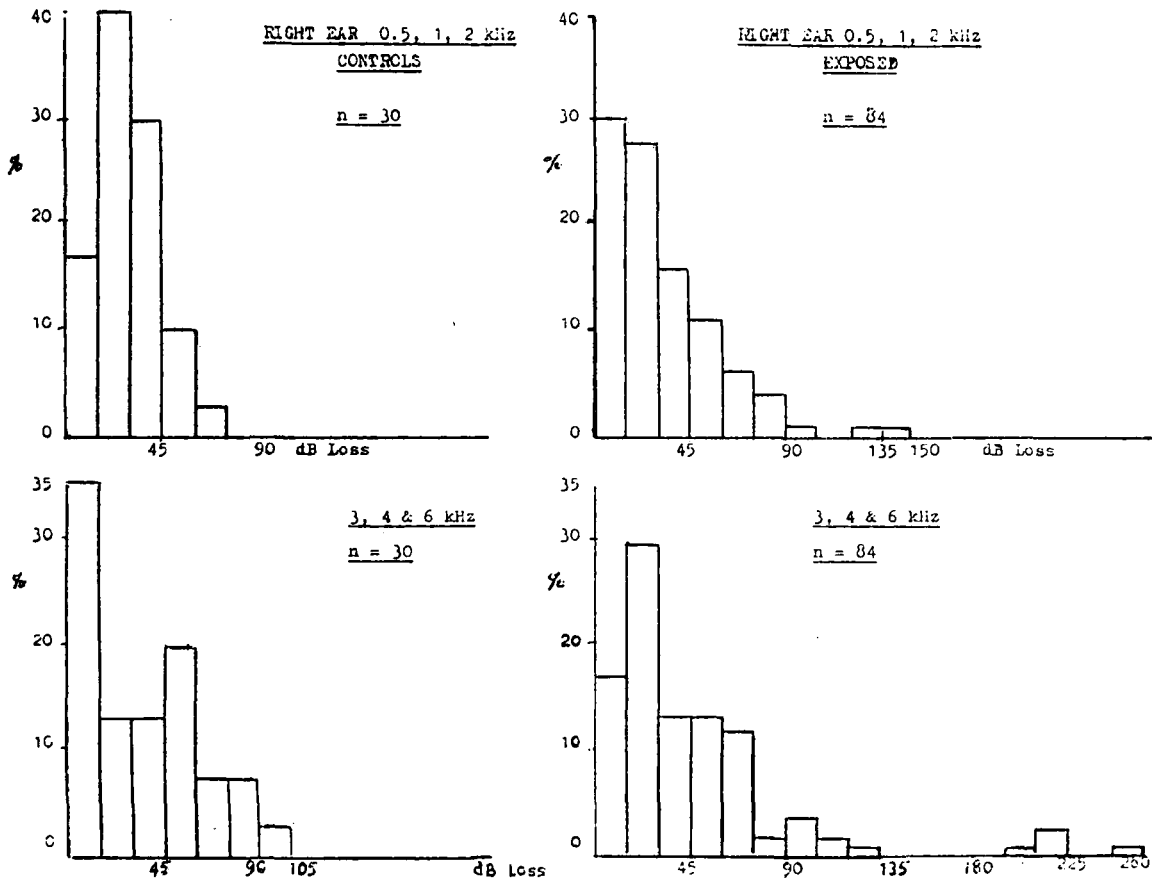


Fig. 4 Histogram showing results of audiometry on exposed and control groups, right ear.

HEEMS grading, accepting H1 and H2 as unaffected and H3 or H4 as affected, and does the same with the controls, then a chi squared (χ^2) test gives p less than .01 for 1df., which is significant. This result, however, is affected by statistical and medical reservations which will be explained in the discussion.

No significant relationship could be found between the degree of protection and the hearing loss sustained (Table IVb) nor is there any significantly greater efficiency of any one type of protector compared with any other (Table IVc).

Discussion

The aim of the survey was to assess the effect of exposure of artillerymen, with varying degrees of aural protection, to massive impulse noise levels from firing the 105 mm Field Guns used in "Op Corporate".

Previous studies have been limited ethically, by not exposing volunteers to excessive impulse noise

levels. There was no such limitation in this study due to active Service conditions being in operation.

The Army Medical Services have realised that any data from such an exposure will allow modifications to be made to its Hearing Conservation Programme⁶, if necessary, as well as giving an indication of the severity of NIHL suffered in the South Atlantic. This survey is only a small part of a wider one which is hoped will encompass all forces who took part in the land battles of "Op Corporate".

Many facts about NIHL are known and mention must be made of three with reference to the group studied.

Presbycusis. This factor was not considered due to the youthfulness of the subjects studied.

Imbalanced Hearing Loss is well associated with gunfire, and the group studied were no exception. Many showed imbalance of more than 40 dBA between ears, a difference picked up by the audio-

meter read out, with masking suggested. However, this was not done as the survey was performed to get an idea of the severity of the problem, with more accurate individual quantitative testing being left to a later date.

Barotrauma. Brasher⁴ has shown that the effects of barotrauma can range from a Temporary Threshold Shift of hearing with associated tinnitus to a severe and permanent loss possibly due to rupture of the round or oval window. Part of the questionnaire attempted to find out the subjective awareness of such trauma. However, one of the main problems of any questionnaire is the subjective response of opinion, judgement and fact, all of which must be treated as factual by the examiner. Accepting this, there appeared to be little permanent traumatic effect and transient tinnitus was the most common symptom admitted.

The subjective responses to the questionnaire have already been stated and where possible they were checked with actual facts. Accuracy was noted in the types of defenders worn and amount of shellfire the subjects were exposed to. It is obvious that during the campaign the unannounced exposure of impulse noise due to enemy air attack or shellfire did not allow time to carry out protective drills as would be the case in peacetime. This could explain the drop in numbers who admitted wearing defenders 100% of the time, between the controls and those exposed. The severity of this exposure, compared with that of the field gun being fired, cannot be classified as great.

It was feared that due to the immensity of the exposure, large numbers of soldiers could have had a significant hearing loss, especially as previous studies by Brasher⁴ and Coombe¹⁵ had shown that as many as 50% of all individuals can be sensitive to impulse noise. The results, therefore, are gratifying in that the large majority of those tested and exposed are still within the acceptable limits of H1 and H2 and no restrictions need be placed on their employment.

However, 17 of those exposed were found to be H3 or worse. Attempts at correlating degree of protection with severity of hearing loss and type of defender worn were of no significance. This is not surprising as the degree of reliability about this part of the questionnaire is low and consequently any significant results must be treated with a great deal of suspicion.

Table II shows the attenuation properties of the three main types of defender issued to the Army. It will be seen that the muffs offer the greatest degree of protection and so those who wore them could be expected to suffer the least. The results (Fig 5c) using those who admitted wearing defenders all or

most of the time, (n 46) in fact show there is little difference between the insert, Sonex V51 and the muff. One explanation could be the added protection given to the insert wearers by placing the fingers over the meati, and this could equate to the protection given by muffs.

Accepting the 17 who had an H3 or H4 grading as being affected, then the chi-squared test does show a significant change, but the factors listed below could have influenced this finding.

a. The audiometry was a single test, thus accuracy of hearing levels were not confirmed. Repeat audiometry was performed to confirm levels where masking was suggested.

b. Bias could have been introduced due to testing outside sound-proof booths although background noise level was not excessive.

c. No masking was carried out on subjects who had an inter-aural imbalance of more than 40 dBA and this of course could increase the severity of the summated hearing loss.

d. Examination of medical records showed that eight out of 114 had pre-Falkland audiometric records in the F Med 4; and this was insufficient to draw any conclusion over pre and post effects. Subsequently comparison was done using the PULHEEMS H grading but this was insensitive to minor differences and minimised any actual changes in category.

e. Statistically the numbers are very small and therefore the degree of reliability in the statistical test as being truly representative of the total exposed population must be questioned. However, the exposed sample was well matched as regards age, service and job so that any change must have some significance.

In conclusion, this survey has shown that despite the exposure to very high levels of assorted impulse noises, the problem is not as bad as was feared. There are numbers who have had a permanent threshold shift and who will have to be investigated further. However, the large majority have either been unaffected, or within the criteria used, have had minimal changes. This may have been through good ear protection, good anticipation or good discipline, but any change seen is not enough to warrant discharge from the Service or restriction of employment, especially in further exposure to gunfire.

As a test of the Army's audiometric programme, the study has indicated the increased attention to hearing conservation and the concern to improve the attenuating properties of ear defenders.

Such attention may be centred in using both types of defenders, inserts and muffs together, when exposed to weapons of known noisiness.

While the audiometric programme shows good progress with regard to protection, the same rate of progress is not maintained with regard to audiometry of serving soldiers and the availability of audiograms in their medical documents. The problem is large, and progress has been made, but until each soldier has been audiogrammed regularly, comparative assessments of the effects of continued exposure are impossible.

Despite the good results shown in the screening, there is a problem facing the Army Medical Services. There are sufficient numbers grossly affected and these will have to be referred to specialised clinics for accurate assessment and decisions about Service future. If these figures are reflected in the larger survey at present being undertaken, then the Army Medical Services may be faced with a severe administration and logistical problem with regard to screening, assessment and management. As a start, all who served in the Falklands have been designated 'specialised troops' and as such will be audiogrammed again in one year's time for confirmation of hearing grade.

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