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Intermittent Noise Exposure and Associated Damage Risk to Hearing of Chain Saw Operators

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A survey of the noise exposures of U.S. Forest Service employees engaged as chain saw operators for thinning forested areas is reported. The results are concerned with the types of intermittent exposures, the resultant temporary threshold shifts and subsequent recovery rates. The hazard risks are related to proposed standards for intermittent noise. The manner of operation was found to be more significant than the model or size of saw used. Threshold shift was not as great as the level of noise exposure would seem to indicate.

Introduction

INTERMITTENT-TYPE NOISE CONDITIONS in industry present difficulties both in their measurement and rating as a hazard to hearing. Depending on workplace operations, generated noises might be subject to interruption intervals ranging from a fraction of a second to an hour or more, while the number of these interruptions might run from one to thousands over the length of the workshift.

Since hearing can recover to some degree during periods of interruption, risk of hearing loss from intermittent noise exposures is presumed less than from continuous noise insults. As such, proposed limits for intermittent noise are more liberal than those for continuous noise, given comparable exposure durations.

This report describes a study of intermittent noise effects on hearing as observed in a group of U.S. Forest Service workers employed as chainsaw operators. The purposes of this study were to (a) describe the nature of intermittent high level noise conditions produced through routine use of this equipment, and (b) assess the potential

hazard to hearing in light of proposed limits for intermittent noise exposure and by evaluation of the temporary post-exposure threshold shifts in the hearing of the chainsaw operators when measured over a number of consecutive workdays.

The site for this investigation was the Lolo National Forest near Missoula, Montana. The chainsaw operations under study, termed "thinning," involved felling approximately six of every seven trees in a densely wooded area with trees ranging in height from 25-100 feet and trunk diameters 5 to 15 inches. Such operations were observed for a group of 10 chainsaw operators using five different types of saws. Different characteristics of the saws are listed in Table I.

Noise Measurement Equipment

Direct readings of overall noise levels were taken on the A-weighting network of Bruel and Kjaer precision sound level meter (Type 2203). These measurements were made with the instrument near the operator's left or right ear and a B & K condenser microphone (Type 4131) directed toward the chainsaw.

Samples of the noise were also recorded on

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tape for later laboratory analyses. The tape recording system utilized a microphone (B & K Type 4131) attached to a 3 meter B & K microphone extension cable (Type AO 0033) which connected to a B & K sound level meter (Type 2203) whose output was fed directly to a battery powered Nagra III tape recorder operating at a tape speed of 3¾ inches per second. The microphone was taped to the end of a three foot steel rod which was held by a technician who kept the microphone positioned 6 to 12 inches from the worker's ear.

Each tape contained a previously recorded 250 Hz calibration tone (124 dB SPL re: 0.0002 microbar). In the laboratory spectral analysis of the taped chain saw noise data, and quantification and distribution of overall levels was accomplished by referencing the recorded noise levels to the pre-recorded pure tone. A statistical B & K distribution analyzer (Model 4420) and B & K graphic level recorder (Model 2305) were used to determine the length of time certain noise

levels fell within specified dBA intervals.

Stop-watches were utilized in the field in monitoring the amounts of time, in a given work period, that the worker was engaged in actual cutting or just revving his saw. The number of cutting or revving noise bursts were tabulated.

Results of Noise Survey

The noise exposure experienced by these sawyers was variable and intermittent. A profile of the sound levels encountered in the different activities comprising their eight-hour workday is described in Figure 1. It can be seen that these sawyers were actually involved in cutting operations for little more than four hours each day.

The octave band spectra of the five types of saws demonstrated that more energy lay in the mid-frequency range in the area of 500-1500 Hz. As can be seen in Table I, the noise produced by the chain saws varied from 91 to 116 dBA. At idling speed, the range was 91 to 98 dBA. It could be noted

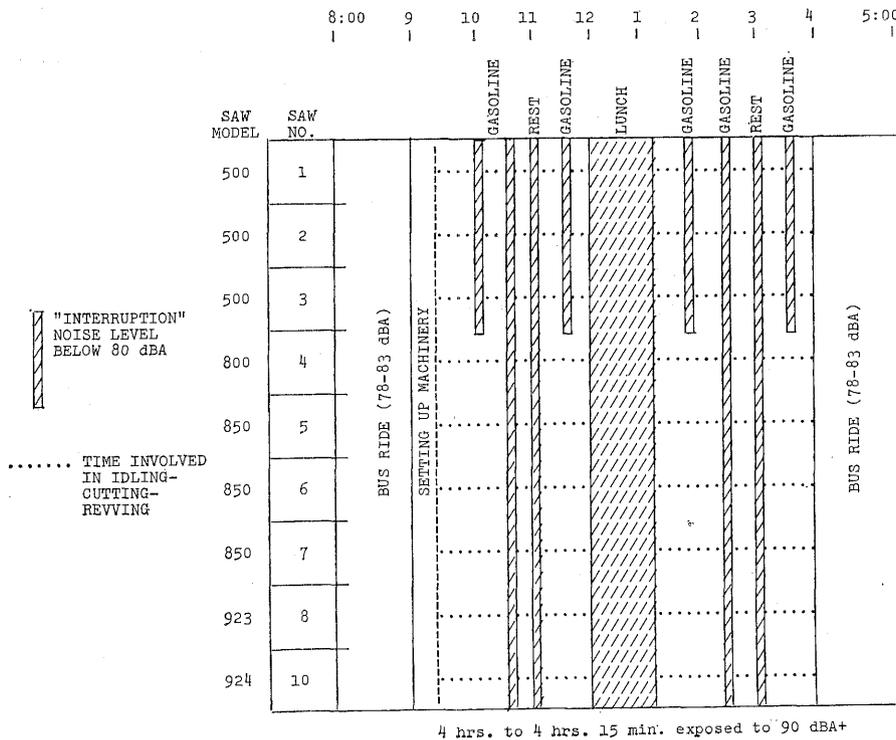


Figure 1. Profile of the 8-hour workday noise exposures of 9 sawyers in the study.

TABLE I
Noise Exposure Levels (dBA) of Idling, Cutting and Revving Noise Bursts
For Groups A and B

Group A							
Sawyer	Model	Engine (inches)	Weight (lbs)	Idle (dBA)	Cut (dBA)	Rev (dBA)	C+R 2 (dBA)
# 1	A-1	3.5	13.5	92	109	113	111
# 3	A-3	3.5	13.5	92	110	111	110.5
# 5	C-1	5.0	14.5	93	108	110	109
# 8	D	5.0	16.5	95	110	112	111
Mean		4.25	14.5	93.0	109.2	111.5	110.3
Group B							
# 2	A-2	3.5	13.5	91	107	109	108
# 4	B	4.7	14.0	98	113	115	114
# 6	C-2	5.0	14.5	98	111	115	113
# 7	C-3	5.0	14.5	95	109	115	112
#10	E	5.0	16.5	92	116	116	116
Mean		4.64	14.6	94.8	111.2	114	112.6

that, while idling, saw C-2 was 5 dB louder than saw C-1, even though they were the same model. Similar differences can be noted in saws D and E. It can also be seen from this table that Model B, one of the smaller saws, was also one of the loudest. The settings of these machines are determined by each individual sawyer as he adapts the tool to his own work rate and style. The levels reached during the cutting

and revving measurements also reflected this individual style variable. It should be concluded therefore that the smaller saws listed in Table I do not necessarily produce noise levels which are lower than those produced by larger machines. For this reason the noise data will concentrate on cutting styles of the sawyers as this more realistically relates to the actual noise exposures experienced in the use of such equipment.

TABLE II
Sawyer Cutting Styles in Eight-Hour Workday
Group A

Sawyer	Model	Number of Noise Bursts	% of Time C-R ^a	C-R (sec)	I ^b (sec)	C-R:I
# 1	A-1	1500	55.0	5	4	1. 2:1
# 3	A-3	2150	57.1	4	3	1. 3:1
# 5	C-1	1200	37.5	3	5	0. 6:1
# 8	D	1750	55.0	5	4	1. 2:1
Mean		1650	51.2	4.2	4	1.08:1
Group B						
# 2	A-2	900	62.5	10	6	1. 7:1
# 4	B	1300	72.0	8	3	2. 6:1
# 6	C-2	1100	69.2	9	4	2. 2:1
# 7	C-3	1500	77.7	7	2	3. 5:1
#10	E	2000	71.5	5	2	2. 5:1
Mean		1360	70.6	7.8	3.4	2. 5:1

^aC-R = Cutting and Revving

^bI = Idling

Based on cutting style, the sawyers fell into two categories. The first, Group A, was comprised of workers who spent just about equal amounts of time at cutting and

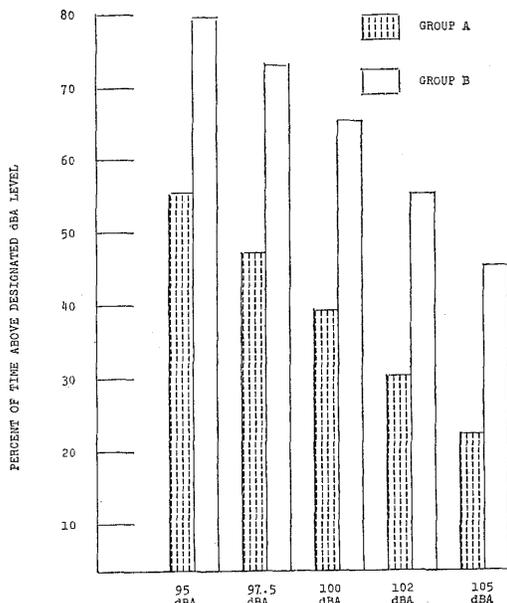


Figure 2. Percentage of the time which Groups A and B exceeded certain designated dBA exposure levels during the workday.

revving as at idle. In Table II, it can be seen that this includes workers #1, #3, #5, and #8. It should be noted here that these four workers used three different saw models. For this group the ratio of time at cutting-revving to time at idle ranged from 0.6:1 to 1.3:1. Group B contained five sawyers (#2, #4, #6, #7 and #10—due to his frequent absences, data for sawyer #9 was incomplete) who used four different machine models and showed work style (cutting/revving: idle) ratios from 1.7:1 to 3.5:1. These differences are also expressed in percentage of time at cutting-revving. Group A was involved in cutting-revving 51.2% of the work time and Group B, 70.6%. Using the Mann-Whitney U-test, a statistically significant difference was found in percentage of time cutting-revving between Groups A and B ($\alpha < 0.01$).

These differences in style reflect another

point as regards the noise exposures experienced by the sawyers. It can be seen in Figure 2, that Group A was exposed to high levels of noise a smaller percentage of the time. For example, Group B was exposed to noise levels above 100 dBA for 65% of the time, while Group A was exposed to 100 dBA 39% of the time.

Table I also compares the noise levels of the saws used by Groups A and B. It can be seen from this table that there is no significant difference in mean noise levels produced by saws in Groups A and B. The differences between the means levels for respective idle, cut, rev and combined cutting-revving levels range from 1.5 to 2.5 dBA. The differences between Groups A and B for the number of cutting-revving bursts were also found to be insignificant (Mann-Whitney U-test). This seems to indicate that since Group A worked with saws capable of producing noise levels closely equivalent to those used by Group B and since the number of cut-rev bursts appears to be singularly insignificant, the ratio of cutting-revving to idle time in relation to the number of cut-rev noise bursts seems to be an acceptable way to relate the sawyers work style to the noise exposure.

Limits for protecting workers from hazardous intermittent noise exposures have been proposed by a working group of CHABA (National Academy of Sciences, National Research Council, Committee on Hearing Bioacoustics and Biomechanics). These limits were used in a proposed standard which appeared in the Federal Register.³

According to supplementary definitions which accompanied this proposed standard, a noise interruption exists when the noise level falls below 80 dBA. Referring back to Figure 1, it can be seen that there were 6 to 11 "noise bursts" (5-10 "noise interruptions") during the eight-hour workday. According to this proposed standard, safe noise exposures for workers who experience 6 to 11 "noise bursts" in an eight-hour workday with 4 hours total exposure should

be between 94.5 and 95.5 dBA. As can be seen in Figure 2, 48% to 72% of the noise exposure was above 97.5 dBA for both Groups A and B. This would indicate that all the sawyers were being exposed to hazardous levels of noise and should show evidence of excessive hearing threshold shifts.

Hearing Measurement

Subjects: The ten sawyers that served as subjects ranged in age from 18-21. Since sawyer #9 was not available for testing and noise monitoring for five of the eight workdays, his data was excluded from the survey. The sawyers were all students who were working for the U.S. Forest Service during the summer months. All sawyers but #7 had hearing that fell within normal limits. It should be pointed out that this subject, who exhibited a 32 dB threshold at 4 kHz and a 70 dB threshold at 6 kHz, also reported that he had been knocked unconscious five years before by a blow to the right parietal region. This event in conjunction with previous exposures from shooting (11 years, more than 1000 rounds yearly), machine shop hobby (10 years, daily), mechanized farming (11 years, seasonally) and previous chainsaw work (only subject to have previously worked for the Forest Service) could have all contributed to produce the subject's hearing impairment.

Methodology

The pre-exposure and post-exposure hearing levels were measured on each sawyer for eight days. Each pre-exposure test was performed near the living quarters of the sawyers between 7:15 and 7:45 a.m. The post-exposure test was taken at the close of the workday, approximately 16-36 minutes after the work shift (and last exposure to saw noise) had terminated. The latter hearing tests were given at locations convenient to the work site where the men were tested inside a closed station wagon so as to reduce ambient noise levels as

much as possible (measured ambient levels: 30-35 dBA). During the testing, the subjects sat in the front or rear seat, while the technicians sat between them in the middle seat.

Individual pure-tone air conduction hearing tests were performed utilizing two battery-operated audiometers (Zenith ZA-110T) with TDH-39 earphones and standard (MX/41 AR) ear cushions. Calibration checks (re: ISO 1964) of both instruments before and after the field operations demonstrated insignificant amounts of divergence from standard reference values in audiometry.

Testing was started at 1 kHz and continued successively to 2 kHz, 3 kHz, 4 kHz, 6 kHz, 8 kHz and 0.5 kHz. Initial testing determined the subject's better ear. Subsequent pre-exposure and post-exposure tests were performed on only the better ear.

On two occasions the audiometers were brought down to the actual cutting work sites and 4 kHz was checked for each worker. In this testing situation the elapsed time from the last saw noise exposure ranged from 2 to 12 minutes.

Evaluation of Hearing Data

Pre-exposure and post-exposure hearing thresholds were measured and resultant threshold shifts were corrected back to post-exposure measurements at two minutes (TTS₂). The hearing data in Table III presents TTS₂ for the frequencies 3, 4, and 6 kHz of one ear of each sawyer when averaged for 8 days of testing. These three frequencies were chosen because previous research shows them to be most sensitive to loud noise exposures, and threshold shifts at other frequencies were so insignificant that no statement could be made about them.

TTS₂ from noise exposure has been used to index potential damage risk to hearing by Kryter^{1,2} and various working groups of CHABA. Specifically noise exposures which produce TTS₂ no greater than 10 dB at 1 kHz and below, 15 dB at 2 kHz and 20 dB at 3 kHz and above should result

TABLE III
Amounts of TTS₂ For 9 Sawyers
After Daily Work Exposure
Group A

Sawyer	Ear	3 kHz	4 kHz	6 kHz
# 1	R	12.0	14.0	12.0
# 3	R	11.0	18.5	12.0
# 5	L	16.0	15.0	16.0
# 8	L	11.5	11.5	11.5
Mean		12.8	14.8	13.1
Group B				
# 2	L	15.0	20.5	15.0
# 4	L	17.0	19.0	26.0
# 6	R	15.0	20.0	19.0
# 7	R	17.0	24.0	14.0
# 10	L	14.5	21.0	22.0
Mean		15.7	20.8	19.2

in minimal hearing changes which could pose a handicap to speech reception.

In Table III, it can be seen that the TTS₂ exhibited by Group A were below the 20 dB ceiling for the test frequencies 3, 4 and 6 kHz while four of the five sawyers in Group B demonstrated shifts which ranged from 0.5 to 6 dB above the 20 dB ceiling. Even though the results of the noise measurements indicated that both groups were being exposed to hazardous levels of noise which should produce excessive threshold shifts, the resultant audiometric data did not bear out this point. It can be seen in Table III that 21 of the 27 mean TTS₂ were below the 20 dB ceiling while only 3 mean

TTS₂ shifts were more than one dB above the 20 dB ceiling. It is hypothesized here that the level of noise during the four hours of interruption time could have significantly affected the resultant TTS₂. The sound levels during "quiet" measured on this mountain top in Montana ranged from 40-45 dBA.

It could therefore be suggested that these sawyers were afforded an opportunity to rest in a low level noise environment that could have heightened the effectiveness of the interruptions, in that it allowed the hearing mechanism to recover more substantially from the previous noise insult. Laboratory data reported by Schmidek, Margolis, and Henderson⁴ tend to support this hypothesis.

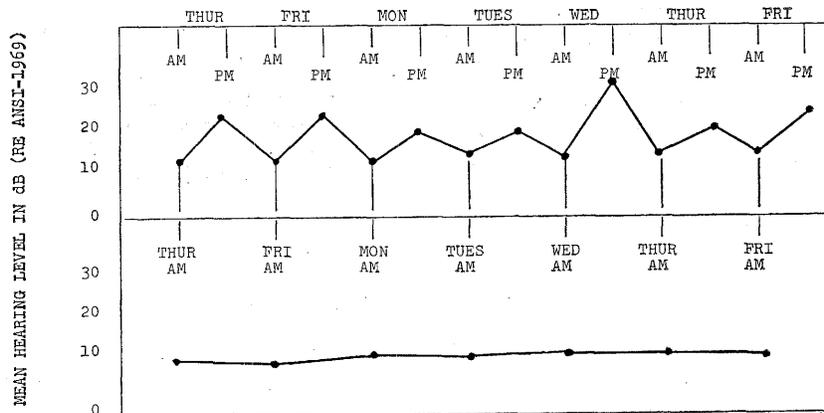


Figure 3. Threshold shift changes at 4 kHz after the end of the workday and subsequent return to normal by the following morning.

Another evaluation of damage risk can be made by monitoring the morning hearing thresholds of the workers to determine if the hearing levels upon conclusion of the workday have recovered by the time the next workday begins. Figure 3 demonstrates that just such a recovery did take place in the sawyers, further emphasizing the minimal hazard risk inherent in this particular sawing operation.

While it has been noted that the noise exposures experienced by these sawyers were not as hazardous as had been expected, significant differences in amounts of TTS₂ produced were observed in comparing Group A and Group B. At 3 kHz TTS₂ differences between the two groups were significant at the 0.05 level of confidence, while at 4 and 6 kHz significance was achieved at the 0.005 level of confidence. This indicated that while both noise exposures caused apparently tolerable amounts of temporary threshold shifts, Group B did exhibit significantly more TTS₂ than Group A. This difference could be attributed to the cutting style variable which indicated that the ratio of cutting-revving to idling was 2.5:1 for Group B as compared to 1.1:1 for Group A.

Conclusions

Initially it should be stressed that these conclusions should only apply to sawyers involved in "thinning" operations. The significant variations between Groups A and B in cutting styles and resultant threshold shifts should caution the application of these results to other chain saw operations.

One objective of this survey was to monitor the extent of variation associated with

intermittency as it relates to chain saw noise. It was found that while some machines were larger than others, it did not necessarily follow that they produced higher noise levels. It was also discovered that sawing styles vary significantly such that one group of sawyers could have louder noise exposure than another group of sawyers involved in the identical operation and with similar equipment.

When the results of the noise survey were applied to proposed standards for intermittent noise exposure, there were indications that both groups of sawyers were being exposed to hazardous noise levels.

Pre- and post-exposure audiometric testing were also utilized to assess the potential hazard to hearing. The resultant temporary threshold shifts, corrected to two minutes, indicated that this type of sawing operation did appear to produce some small risk to hearing for Group B but not for Group A. However, the temporary threshold exhibited at the close of the workday that had disappeared by the following morning underscored the minimal risk to hearing involved in the work operations.

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