ORIGINAL ARTICLES AAEM

Ann Agric Environ Med 2003, 10, 211–215

PRELIMINARY EVALUATION OF OCCUPATIONAL HEARING LOSS RISK AMONG PRIVATE FARMERS

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Solecki L: Preliminary evaluation of occupational hearing loss risk among private farmers. *Ann Agric Environ Med* 2003, **10**, 211–215.

Abstract: The article presents a preliminary evaluation of occupational hearing loss risk in a group of farmers selected at random and exposed to a mean annual level of exposure to noise $L_{EX,8h}$ = 89.1 dB. The study covered 31 family farms carrying out mixed production (plant-animal), possessing arable land of the size 5–40 ha, and equipped with the basic mechanical equipment (tractors, agricultural machinery, machines for production of animal fodder, workshop machinery, saws). Polish Standard: PN-ISO 1999:2000 was used in order to evaluate the expected hearing threshold among private farmers, an expected hearing loss due to noise, as well as risk of hearing impairment. The risk of hearing impairment was determined for the population of males aged 50, regularly exposed to noise for 30 years of occupational activity, assuming as a basis for calculations the mean value for 3 audiometric frequencies (1, 2 and 4 kHz). The results of the study showed that the mean expected hearing loss (median; $N_{0.50}$), associated only with noise for 50-year-old males after 30 years of employment will be: 5.5 dB (together with age-related loss: 14.5 dB). The risk of hearing impairment due to exposure to noise (for the allowable value of hearing loss: 30 dB), which may cause an occupational acoustic trauma, reaches the value 9.4%. The results obtained confirm that noise present in the working environment of private farmers creates a significant risk for the organ of hearing.

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Key words: risk of hearing impairment, age, hearing loss, level of exposure to noise, private farmers, period of employment.

INTRODUCTION

Studies of noise in private farming conducted by the Institute of Agricultural Medicine in Lublin showed [15, 16] that the degree of health risk due to noise among farmers employed on family farms is specific and very complex. This is associated with the use of various types of technical equipment, such as: agricultural tractors working with agricultural units (attached or mounted on a tractor, driven by drive shaft), self-propelled agricultural machines (combine harvesters, cutters, swathe movers), machines for production of animal fodder, and workshop machinery.

An agricultural tractor is the basic drive unit most often used in agriculture (over 1.3 million tractors are registered), therefore this machine is the main source of noise present in the agricultural environment. Noise occurring at a workplace of agricultural tractor and self-propelled machine operator is characterized by great variability during work. Field and transport work activities performed by farmers with the use of these machines takes place at various and varied speeds of agricultural vehicles, on different surfaces of soil (road), with varied (changeable) engine load, and during various time of exposure [10, 11]. The studies conducted showed that medium and small-

Received: 8 August 2003
Accepted: 24 November 2003

power tractors, most frequently used on private farms, as well as combine harvesters, create the greatest risk for the organ of hearing (84–101 dB and 88–92 dB respectively). High-power tractors - Polish and Czech made, are characterized by significantly lower levels of noise (81–93 dB and 84–87 dB). In the case of other machinery commonly used on farms the following devices deserve special attention: crusher for the production of fodder (99 dB), shredder "Bąk" (91 dB), angular grinder (104 dB), circular saw (108 dB), and chain saw (99 dB).

In addition, studies of the state of hearing carried out among 128 private farmers confirmed a considerable hearing impairment in this occupational group, which increased with age and duration of the period of employment [20, 21]. The results of these studies clearly show that the excessive noise produced by agricultural tractors and machinery used by farmers is the primary cause of development of such a significant hearing loss [13].

The seasonal character of work activities performed in agriculture, according to the season of the year and varied time of annual exposure, contributes to the complexity of exposure to this risk factor [10].

Two values decide the degree of exposure to noise. Apart from the parameter defining the value of acoustic energy (e.g. so-called exposure to noise: $E_{A,T}$ in Pa^2h) [12], the duration of exposure is also of great importance. Due to the great variability of the duration of exposure [17] and different machinery used, proper and reliable evaluation of the level of exposure to noise among private farmers may be obtained based on precise time-schedule records and dosimetric measurements of noise emitted carried out throughout the whole year. Studies conducted by this method on 31 selected family farms [14] carrying out mixed production (plant-animal with domination of plant production) confirmed that during the whole year farmers were exposed to noise of a daily exposure level [$E_{EX,8h}$] of 89.1 dB. The group of farmers analysed used primarily Polish-made small-power tractors (C-325, C-328, C-330, T-25, U-2812, MF-235) and medium power tractors (C-360, MF-255, MF-3512), whereas a smaller number of Czech-made tractors were also used (Z-5211, Z-7211, Z-7711) as well as high-power tractors (MTZ-82, U-1201, U-912, C-385, U-1614, U-5314). Out of the total number of 68 tractors examined, 27 (40%) were small-power, 21 (31%) - medium-power, 11 (16%) Czech-made and 9 (13%) high-power tractors. The studies concerned farmers who possessed arable land of the general area 5-40 ha (7 farms: 5–10 ha; 16 farms: 11–15 ha and 8 farms: 15–40 ha).

A calculated level of exposure to noise, average for the whole year, was the basis for developing a preliminary evaluation of the risk of hearing loss due to noise in the selected group of private farmers analysed. This was the objective of the present study.

METHODS

In order to estimate the expected hearing threshold among private farmers exposed to noise and the expected hearing impairment (hearing loss due to noise), as well as the risk of hearing impairment, the Polish standard was used in the present study [7]: PN-ISO 1999:2000, consistent with the international standard ISO 1999:1990.

Determination the level of hearing threshold among private farmers (H'). The level of hearing threshold among the selected population of private farmers running animal-plant production farms of the size 5–40 ha was determined based on the following empirical formula (according to the Polish standard):

$$H' = H + N - \frac{HN}{120} \quad [1]$$

where:

H' - is the level of hearing threshold (in dB) associated with age of the farmer examined, and noise, designated by the symbol HTLAN (Hearing Threshold Level associated with Age and Noise);

H - level of hearing threshold (in dB) associated only with age and denoted by the symbol HTLA (Hearing Threshold Level associated with Age);

N - actual or potential permanent shift the level of hearing threshold caused only by noise (in dB), designated by the symbol NIPTS (Noise Induced Permanent Threshold Shift).

The expression HN/120 begins to exert a significant influence on the result only if H+N is greater than 40 dB, after which special corrections have to be introduced. The formula [1] may be applied with respect to proper centils (from 0.05–0.95) for three defined values: H', H and N.

Determination the level of hearing threshold among males, associated only with age (H). In order to evaluate the level of hearing threshold among males, associated with age, only (HTLA), data were used contained in base A of the standard cited [7]. This base concerns otologically healthy people, i.e. those with normal state of health, who do not show any signs or symptoms of ear diseases, residual ear wax in the ear canals, and those who previously had not been excessively exposed to noise (a highly selected group of people).

The value of hearing threshold in males (H) was calculated for various ranges of centils Q in age function Y (years), according to the following dependence:

for $0.05 \leq Q < 0.50$ $\quad H_Q = H_{0.50} + k\, S_u$ [2]

for $Q = 0.50$ $\quad H_{0.50} = \alpha\,(Y - 18)^2 + H_{0.50;\,18}$ [3]

for $0.50 < Q \leq 0.95$ $\quad H_Q = H_{0.50} - k\, S_l$ [4]

where: $H_{0.50;18}$ is the hearing threshold median value in otologically normal people of the same gender (males) aged 18, which for practical reasons was ascribed the value 0.

The values of a coefficient and multipliers k are contained in the tables in the Polish standard, while values of S_u and S_1 are calculated from proper relationships contained in this standard.

The expected values of hearing threshold associated only with age were calculated separately for three selected audiometric frequencies: 1, 2 and 4 kHz for five centils (Q = 0.95; 0.90; 0.50; 0.10; 0.05).

Calculation of permanent shift of hearing threshold caused by noise only (N). In order to determine the expected permanent hearing threshold shift due to noise

Table 1. Values of expected hearing threshold (in dB) – statistical distribution (HTLA) according to the audiometric frequency for males aged 50 years, not exposed to noise.

Audiometric frequency (kHz)	Statistical distribution (centiles)				
	0.95	0.90	0.50	0.10	0.05
1	-6	-4	4	14	17
2	-7	-4	7	20	24
4	-4	0	16	36	41
Mean value for three frequencies	-5,7	-2.7	9.0	23.3	27.3

Table 2. Values of expected hearing loss (in dB) – statistical distribution, induced exclusively by noise (NIPTS), according to the audiometric frequency, for private farmers (aged 50 years, exposed for 30 years).

Audiometric frequency (kHz)	Statistical distribution (centiles)				
	0.95	0.90	0.50	0.10	0.05
1	0	0	0	0	0
2	2.1	2.6	4.3	7.3	8.1
4	8.0	9.0	12.3	17.0 (11.9)*	18.3 (12.0)*
Mean value for three frequencies	3.4	3.9	5.5	6.4*	6.7*

* corrected due to H+N > 40 dB

Table 3. Expected hearing threshold levels (in dB) - statistical distribution among private farmers (H‘), among males not exposed to noise (H), and estimated risk of hearing impairment (in %).

Persons	Statistical distribution (centiles)					Risk of hearing impairment
	0.95	0.90	0.50	0.10	0.05	(%)
Private farmers	-1.3	1.2	14.5	29.7	34.0	12.5
Males not exposed to noise	-5.7	-2.7	9.0	23.3	27.3	3.1

only (in selected population of private farmers), designated by the symbol NIPTS, the median of this parameter was calculated ($N_{0.50}$) and statistical distribution of N_Q value approximated with two different halves of normal (Gausse) distributions, within the range: $0.05 \leq Q < 0.50$ and $0.50 < Q \leq 0.95$.

Median value of permanent hearing threshold shift due to noise ($N_{0.50}$) was calculated based on the following formula:

$$N_{0.50} = [\, u + v \log (\Theta/\Theta_0) \,] \, (L_{EX,8h} - L_0)^2 \quad [5]$$

where:

L_0 - boundary value of the level of acoustic pressure (in dB), defined as frequency function, in Table 2 of the standard;

Θ - time of exposure in years;

Θ_0 - period of one year;

u, v - constant described as frequency function in Table 2 of the standard.

The equation [5] may be applied for $L_{EX,8h}$ values greater than L_0 (if not, $L_{EX,8h} = L_0$ is adopted and then $N_{0.50} = 0$). The formula [5] concerns exposure longer than 10 years ($10 < q < 40$ years).

For the population for which Q value remains within the range $0.05 \leq Q < 0.50$ (the upper part of normal distribution, equivalent to centiles with hearing worse than median, is above median value $N_{0.50}$), N_Q is expressed by the following equation:

$$N_Q = N_{0.50} + k\, d_u \quad [6]$$

whereas for the population for which Q value remains within the range $0.50 < Q \leq 0.95$ (lower part of normal distribution equivalent to centiles, with better hearing than median and is below median value $N_{0.50}$), N_Q is expressed by the following formula:

$$N_Q = N_{0.50} - k\, d_l \quad [7]$$

Values of multiplier k equivalent to normal distribution are given in Table 3, while d_u and d_l coefficients are calculated according to formulas contained in section 5.3.2.2 of the standard quoted.

Values of expected permanent hearing threshold shift due to noise (N) for the selected population of private farmers, were calculated separately for three frequencies: 1, 2 and 4 kHz and for five centiles Q.

In order to estimate hearing impairment caused by noise (N) with defined exposure ($L_{EX,8h}$), mean values were calculated from the data obtained for three audiometric frequencies: 1, 2 and 4 kHz, separately for the established five centil values (0.95; 0.90; 0.50; 0.10; 0.05).

Estimation of hearing impairment risk. Hearing impairment risk was determined for the three following cases where:

- risk is associated with age and exposure to noise;
- risk is associated with age only;
- risk is associated only with exposure to noise.

When assuming a proper boundary of hearing threshold (allowable value) it may be presumed that above this value one should expect a defined hearing impairment in some part of the population examined. For the allowable boundary defined in this way the centil of population may be calculated, for which the mean hearing threshold level is equal to or exceeds the previously selected boundary.

In the present study, the level of hearing threshold associated with noise only of 30 dB (mean value for three frequencies: 1, 2 and 4 kHz) was adopted according to the guidelines by the Polish Minister of Health [6] of 1987.

RESULTS

Estimation of the expected hearing loss due to noise among private farmers [18] was conducted assuming the following conditions: farmers’ age - 50, and period of employment in conditions of exposure to noise - 30 years. Farmers were exposed to basic sources of noise occurring on farms (agricultural tractors, self-propelled agricultural machines, machines for production of fodder, workshop machines, circular and chain saws).

Using the research methodology presented in a general way (details specified in the Polish standard quoted: PN-ISO 1999:2000 and international standard: ISO 1999-1990), expected values of the hearing threshold associated

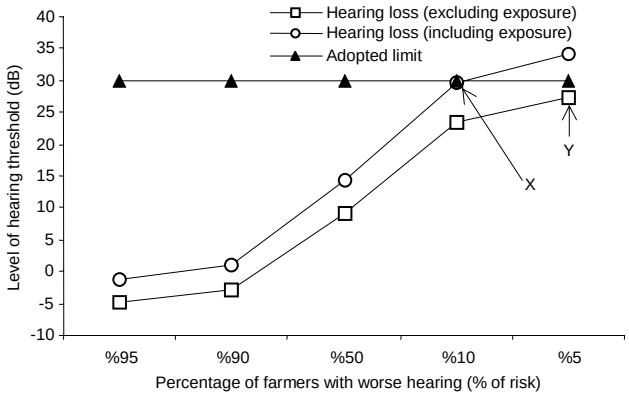

Figure 1. Expected hearing loss and risk of hearing impairment among private farmers (X - risk of hearing impairment associated with age and exposure = 12.5%; Y - risk of age-related hearing impairment = 3.1%; X-Y = 9.4%).

only with age were calculated (H), for males aged 50, in statistical distribution (for five centiles), each time for three audiometric frequencies. The data obtained are presented in Table 1. The Table shows that the greatest expected hearing loss associated solely with age are observed at a frequency of 4 kHz (median: 16 dB). The mean calculated value (for three frequencies) shows loss equal to 9 dB in the case of median (for 0.50 centiles), whereas the statistical distribution indicates that 10% of males aged 50 will have mean hearing loss equal or higher than 23.3 dB, while 5% ≥ 27.3 dB.

The Table 2 contains the expected permanent hearing loss cause only by noise (N) for the selected study group (selected population of private farmers) characterised by the level of daily exposure $L_{EX,8h}$ = 89.1 dB. According to the Table, it should be expected that half of the farmers (0.50 centiles - median) will have mean hearing loss (mean value from three frequencies) due to noise only of ≥ 5.5 dB, in 10% of farmers hearing loss will be equal or higher than 6.4 dB, while 5% ≥ 6.7 dB.

Summing up these values of hearing loss associated solely with noise and the above-calculated hearing loss associated only with age, we obtain the values of expected total hearing threshold levels in 50-year-old farmers exposed to noise (loss associated with age and exposure to noise). The values obtained (Tab. 3) indicate that in half of the farmers the total mean hearing loss will be equal or higher than 14.5 dB (median), in 10% - the mean hearing loss will be ≥ 29.7 dB, while in 5% - ≥ 34.0 dB.

By using the formulas [2], [5] and [1], the value of the multiplier k was determined, assumed that the hearing threshold level associated with age (H) and the level of hearing threshold associated with age and noise (H') reach the value equivalent to the adopted hearing threshold boundary, i.e. 30 dB.

Based on statistical tables referring to the normal distribution [22], values of multiplier k were adjusted equivalent to centil values. On this basis, the expected risk of hearing impairment was estimated (in %) for two specified research groups (Tab. 3). Thus, for males (aged 50) not exposed to noise, the risk of hearing loss above the adopted boundary (30 dB) is 3.1%, whereas for private farmers the joint risk of hearing impairment associated with age and exposure to noise (30 years) will be: 12.5%. Finally, in the case of private farmers the risk of hearing impairment associated solely with exposure to noise will reach the value: 9.4% (12.5–3.1%). The defined expected hearing loss and the estimated risk of hearing impairment are presented in graphic form in Figure 1.

DISCUSSION

The method of estimation of the expected hearing threshold level used in this study allowed us to define an expected hearing loss caused by noise, as well as the risk of hearing impairment, based on individual farmers performing work activities on selected family farms.

Studies of the state of hearing [20] conducted in a relatively numerous group of private farmers (128 people) showed that hearing loss associated solely with exposure to noise reaching values of ≥ 30dB (mean value from three frequencies) occurred in 9.4% of farmers for the left ear and in 8.6% for the right ear. This confirms a relatively high compliance of epidemiological data with the estimation data presented in this study (based on the results of studies of the working environment). Therefore, it should be presumed that the group of farmers defined in this way may meet criteria which would allow them to apply for making a decision about occupational disease (hearing impairment due to noise). It may be estimated that this would concern 30–40 thousand farmers in the whole country (per general number of 2 million 122 thousand occupationally-active male farmers in Poland; data from Statistical Register of the Main Statistical Agency, 2000 [1]).

Also, previous estimations of the risk of hearing loss among two occupational groups representing operators of agricultural tractors [19] employed on multi-production farms and operating medium and high power tractors ($L_{EX,8h}$ = 96.6 dB and $L_{EX,8h}$ = 89.6 dB respectively) showed a significant compliance (p = 0.18 - 0.25; according to ear) of expected mean hearing loss with actual loss (measured by audiometric methods).

Polish standard PN-ISO 1999–2000 (consistent with the international standard ISO-1999/1990) is a valuable research tool, which enables the estimation of hearing impairment in a statistical way for a specified population exposed to noise (this method cannot be applied to individual cases due to great personal variations). This estimation of impairment may be conducted provided that the following is relatively precisely defined:

- average level of exposure to noise, referred to 8-hour work day ($L_{EX,8h}$);
- frequency or combination of frequencies;
- database for control group not exposed to noise, and
- perception threshold level (so-called boundary of exposure).

The standard discussed was used in many publications of various researchers from abroad, such as: Macrae J.H.

[5], Rosler G. [9], Ising H. *et al.* [4], Henselman L.W. *et al.* [3], Prince M.M. [8], Henderson D., Saunders S.S. [2], and others. However, there is a lack of data concerning the application of this standard in Poland. This standard may and should be applied in medical practice in order to prevent excessive hearing loss which is the basis for compensation due to making decisions about an occupational disease.

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