

Effect of occupational noise on the course and outcome of pregnancy

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OBJECTIVES — The goal of this investigation was to examine the effects of occupational noise during pregnancy prospectively.

METHODS — The exposed group [continuous A-weighted sound level ($L_{Aeq(8h)}$) ≥ 78 dB] consisted of 111 pregnant women, and the reference group comprised 181 pregnant women with approximately similar work conditions but without noise exposure. The noise-exposed women had more frequently other inconveniences in their work, however, like shift work, impulse noise exposure, vibration, and a high or low temperature.

RESULTS — With the limit of 78 dB ($L_{Aeq(8h)}$), the course and outcome of pregnancy did not differ between the groups. When the noise exposure was 90 dB ($L_{Aeq(8h)}$) or more, a decline in birthweight, either absolute [mean 3304 (SD 585) g for the exposed versus mean 3622 (SD 548) g for the unexposed, 95% CI of mean difference -471 – $+15$ g] or related to the gestational age (below the 10th percentile [5 of 25 (20%) versus 13 of 180 (7%)]), was seen. These findings were more pronounced if the woman was simultaneously exposed to a standing work position or shift work.

CONCLUSIONS — Working in high noise exposure can be considered a form of risk during pregnancy.

KEY TERMS — birthweight, blood pressure, malformation, noise exposure, prematurity, work environment.

Although hearing loss is the only indisputable permanent effect of noise, noise is one of the well-known exposures inducing a stress reaction in humans, involving disturbances in communication, task performance, and sleep (1–3). Noise is mainly considered an alpha-adrenergic stimulus which induces peripheral vasoconstriction, and it has been described in clinical experiments as inducing short-term physiological reactions in the vegetative, endocrinological, neurological, and respiratory systems (4–6). Changes in blood pressure have been frequently shown to be connected with noise exposure, but the results are ambiguous (5–6). If changes in circulation or endocrinological status take place, it can be expected that noise could have some adverse effects on human pregnancy. Some research into human pregnancy has connected environmental noise, main-

ly airport noise, with preterm birth, low birthweight, and malformations, but the association with malformations has not always been confirmed (7–11). The association of occupational noise exposure with low birthweight and preterm delivery is somewhat controversial on the basis of two recently published articles (12–13).

Our prospective cohort study was undertaken to evaluate the effect of occupational noise exposure on the course and outcome of pregnancy, especially on maternal blood pressure, preterm birth, birthweight, and malformations.

Subjects and methods

The subjects were enrolled from workplaces with noise exposure in the provinces of Oulu, Lapland, and Hame in Finland. Occupational health officers were informed about the research, and they in turn informed the women in the workplaces. Enrollment took place between April 1983 and December 1987. A measured 8-h equivalent continuous A-weighted sound level ($L_{Aeq(8h)}$) of ≥ 78 dB was selected as the criterion for noise exposure for a woman to be regarded as an exposed subject.

The women contacted the research group voluntarily at the beginning of pregnancy, and the group in turn contacted the respective maternity health center.

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The nurse in the maternity health center selected one to three unexposed mothers as referents for each exposed mother, matched by age (± 3 years) and parity (1 = nullipara, 2 = primipara-tripara, 3 = quadripara or more) according to the instructions of the research group. Their work conditions were also to be as similar as possible but without noise exposure.

The unexposed group was somewhat younger [mean 27.7 (SD 5.3) years] than the exposed group [mean 26.5 (SD 5.3) years]. Nulliparous subjects made up 45% of the unexposed group, parity being, on the average, higher among the exposed group. Social class, as judged according to the husband's occupational status, and according to the women's own status in the case of unmarried women, tended to be somewhat lower among the exposed women. The two groups did not differ with regard to their obstetric history (ie, spontaneous or induced abortions, earlier preterm deliveries, and malformed or stillborn infants). The prevalence of chronic diseases possibly influencing the course of the current pregnancy was also similar. The groups did not differ as to their reported drinking and smoking habits (table 1).

The final population consisted of 111 exposed and 181 unexposed pregnant women. Fifty-three of the exposed women had one referent, 46 had two referents, and 12 had three referents. There were problems in finding sufficiently concordant referents. All of the mothers were monitored in the same way during pregnancy. The data on the course of pregnancy were obtained from the maternity health centers and also from the maternity outpatient clinics of the hospitals. The data on the deliveries and the neonates were collected from the hospital records. The occupational health officer at each workplace filled out a questionnaire concerning the work conditions and measured exposures and work loads, and these data were checked at the Oulu Regional Institute of Occupational Health. After delivery, the women were also asked to answer a postal questionnaire with regard to daily habits and social conditions. Six exposed and four unexposed mothers did not respond to the questionnaire.

The occupations of the exposed and unexposed women are shown in table 2 according to the standard industrial classification of occupations (16). The largest occupational groups among the exposed women were processing of food (N = 19) and textiles (N = 55) and among the unexposed women the largest corresponding groups were the processing of textiles (N = 23), retail trade (N = 31), restaurants and hotels (N = 17), and public services (N = 27).

Almost all of the women in the exposed group (110 of 111) were manual workers in terms of occupational status, the remaining one being of lower-grade staff status. In the unexposed group 68% were manual workers and 31% were lower-grade staff. One person in the unexposed group was self-employed (17). Although there were more lower-

grade staff in the unexposed group, the actual types of work were similar in the two groups.

The average time elapsing before the first contact with the maternity health center was 10.9 (SD 2.5) gestational weeks in the exposed group and 10.4 (SD 2.2) weeks in the unexposed group. The mean number of contacts with the maternity health center was 14.2 (SD 3.9) versus 14.6 (SD 3.1), respectively.

The mean height of the women was similar for the exposed [163.7 (SD 5.3) cm] and unexposed [163.5 (SD 5.1) cm] groups, whereas the exposed women were somewhat heavier at the beginning of pregnancy, 62.3 (SD 7.9) kg versus 61.0 (SD 9.4) kg. There was a negligible difference in mean weight gain during pregnancy between the exposed and unexposed women [mean 12.3 (SD 4.3) kg versus 12.8 (SD 4.3) kg], but not in the mean hemoglobin concentration at the beginning of pregnancy or at the last exami-

Table 1. Background characteristics of the noise-exposed and unexposed women.

Background characteristics	Exposed women (N = 111)		Unexposed women (N = 181)	
	N	%	N	%
Age (years)				
<20	4	4	9	5
20-24	29	26	74	41
25-29	40	36	47	26
30-34	25	23	36	20
≥ 35	13	12	15	8
Parity				
0	51	46	81	45
1-2	53	48	92	51
≥ 3	7	6	8	4
Socioeconomic class ^a				
4	12	11	25	14
5	96	86	132	73
Other	3	3	24	13
Married	82	74	124	69
Smoker	39	35	57	31
Alcohol use	26	23	47	26

^a Social classes 4 and 5 are the two lowest (5-grade scale).

Table 2. Occupations of the women in the exposed and unexposed groups according to the standard industrial classification.

Industrial classification	Exposed group (N = 111)		Unexposed group (N = 181)	
	N	%	N	%
Agriculture	—	0	2	1
Manufacturing	93	84	49	27
Construction	1	1	—	0
Trade	6	5	53	29
Transport	1	1	4	2
Business services	—	0	9	5
Public, social and personal services	10	9	64	35

Table 3. Work load and exposures in the noise exposed and unexposed groups.

Work load or exposure	Exposed group (N = 111)		Unexposed group (N = 181)	
	N	%	N	%
Heavy physical load	7	6	8	4
Heavy psychological load	4	4	9	5
Standing position	69	62	128	71
Shift work	66	59	37	20
Considerable impulse noise	35	32	2	1
Vibration	31	28	20	11
High or low ambient temperature	26	23	18	10

nation [126 (SD 0.9) g · l⁻¹ versus 123 (SD 0.8) g · l⁻¹]. The occurrence of urine glucose, albumin, and urinary infections was similar in both groups.

The work loads and exposures were classified according to the principles used by the Oulu Regional Institute of Occupational Health (14). Impulse noise exposure was not measured, but it was classified into three levels (none, moderate, considerable) according to the reports of the occupational health officers.

The measured work loads and exposures are presented in table 3. The women's own opinions regarding their work loads differed from those of the occupational health officers. The physical work load, for example, was judged to be heavy by 32% of the exposed subjects and 24% of the unexposed ones, and, correspondingly, heavy mental load was reported by 14 and 9%, respectively, these figures being substantially higher than those given by the occupational health officers.

Blood pressure was measured at every visit to the maternity health center and in the hospital. The means of the systolic and diastolic blood pressures were calculated separately for each trimester of pregnancy.

The exposed and unexposed women were compared with respect to the outcome variables with the use of joint stratification by age and parity. These comparisons were also performed separately for certain possible confounding or modifying work conditions, such as vibration, a standing work position and shift work. The contrast with the unexposed women was further evaluated in subgroups of the exposed subjects defined by noise level (low dose = noise exposure <90 dB L_{Aeq}(8 h) and high dose = noise exposure ≥90 dB L_{Aeq}(8 h)) and by the presence or absence of impulse noise.

The means and standard deviations for continuous outcomes (diastolic blood pressure, birthweight, and height) were calculated in the appropriate groups. The adjusted mean difference between the exposed and unexposed subjects was calculated as a preci-

sion-maximizing weighted average of the stratum-specific differences, on the assumption of a constant error variance over the strata. Counts and percentages were obtained for the occurrence of preterm birth, low birthweight for gestational age [below the 10th percentile (15)], malformations, and care at a neonatal unit. No weight summary estimates for the differences in the proportions were calculated, as the data became too sparse after stratification.

Results

Thirty-two percent of the exposed women were subjected to considerable impulse noise in their work, as were two women in the unexposed group, although their 8-h equivalent continuous A-weighted sound level was still below 78 dB. The women exposed to considerable impulse noise (N = 35) more often worked in a standing position than the other noise-exposed women (74 versus 56%).

Forty-eight percent of the women in the impulse-noise group were exposed to noise of more than 89 dB L_{Aeq}(8 h) versus 14% of the other exposed women, and 60% of the impulse-noise group were also exposed to vibration, as compared with 14% of the others. Altogether 51% of the noise-exposed women reported using hearing protectors for over 80% of their worktime, and 39% of them for over 95%. All except one woman working with noise exposure exceeding 89 dB reported the time spent using protectors to be over 95%. Nine percent of the exposed women stated that they did not consider their work to involve exposure to noise. Seventy women in the exposed group had been working in noise for at least three years.

None of the women in the exposed or unexposed group had chronic arterial hypertension, and the mean systolic and diastolic blood pressures did not differ between the groups, either in the overall comparison or when stratified separately by the presence or absence of given work conditions (ie, vibration, standing position or shift work) (table 4). Similarly, no differences were found when the exposed women were further subdivided by the presence of impulse noise and the level of noise (table 5). Antihypertensive medication during pregnancy was prescribed for only two women in each group, and sick leave on account of elevated blood pressure was prescribed for four in the exposed group and 10 in the unexposed group (4 versus 6%).

The numbers of women admitted to a prenatal hospital ward and the main reasons for admittance are presented in table 6. The mean number of days spent in a prenatal ward did not differ greatly between the groups [7.2 (SD 11.0) d versus 5.6 (SD 5.1) d]. The mean duration of sick leave was 3.7 (SD 4.3) weeks in the exposed group and 3.3 (SD 3.9) weeks in the unexposed group, and the mean worktime during pregnancy was 29.6 (SD 5.8) and 29.9 (SD 5.5) weeks, respectively.

The various outcomes of pregnancy are summarized in table 7. The mean gestational week of delivery [39.1 (SD 2.1) versus 39.2 SD 1.7]) and the number of preterm deliveries were equal in the two groups. However, four of the five preterm deliveries among the exposed mothers occurred in the high-noise group; in other words, 16% (4 of 25) of this

particular exposure group had a preterm delivery. These four individuals were also exposed to vibration and a standing position in their work, and three of them also to impulse noise and shift work.

There were no differences between the groups in the prevalence of low birthweight for gestational age (below the 10th percentile), mortality (table 8), or

Table 4. Diastolic blood pressure in the third trimester of the women exposed to occupational noise and of the unexposed referents. Means, standard deviations (SD), the numbers of women (N) in the groups, and the adjusted difference (stratified by age and parity) in group means with a 95% confidence interval (95% CI). Overall comparison and subdivided separately by the presence of vibration, standing position, or shift work.

	Diastolic blood pressure (mm Hg) ^a						Adjusted difference (mean)	95% CI
	Exposed			Unexposed				
	N	Mean	SD	N	Mean	SD		
Overall	105	72.8	8.1	178	73.6	8.5	−1.3	−3.4— +0.8
Vibration								
No	74	73.8	7.7	156	73.2	8.4	+0.1	−2.3— +2.5
Yes	29	70.7	8.8	20	76.6	7.5	−6.2	−10.7— −1.8
Standing position								
No	41	73.0	8.4	52	74.7	8.2	−2.0	−5.7— +1.6
Yes	63	72.8	8.1	125	73.0	8.5	−0.8	−3.4— +1.9
Shift work								
No	43	72.3	8.2	113	74.6	7.8	−2.7	−5.6— +0.1
Yes	61	73.2	8.1	37	71.5	9.2	+2.1	−1.5— +5.7

^a 1 mm Hg ≈ 133.333 Pa.

Table 5. Diastolic blood pressure in the third trimester of the women exposed to occupational noise, subdivided separately by the presence of impulse noise and level of noise. Means, standard deviations (SD), the numbers of women (N) in the groups, and the adjusted difference (stratified by age and parity) of the group mean to that of the unexposed women with a 95% confidence interval (95% CI).

	Diastolic blood pressure (mm Hg) ^a						Adjusted difference (mean)	95% CI
	Exposed			Unexposed				
	N	Mean	SD	N	Mean	SD		
Impulse noise								
No	73	72.6	8.3	112	73.7	8.5	−1.7	−4.1— +0.7
Yes	31	73.3	7.8	62	73.2	8.5	−0.4	−3.6— +2.9
Noise level								
<90 dB	82	73.2	7.8	134	73.7	8.5	−1.2	−3.4— +1.1
≥90 dB	23	71.5	9.4	44	73.4	8.7	−2.5	−6.3— +1.3

^a 1 mm Hg ≈ 133.333 Pa.

Table 6. Admissions of the exposed and the unexposed women to a perinatal ward.

	Exposed women (N = 108)		Unexposed women (N = 180)	
	N	%	N	%
Women admitted	26	24	54	30
Main cause of admission				
Threatened preterm birth	7	6	12	7
Bleeding	4	4	7	4
Elevated blood pressure	4	4	13	7

Table 7. Outcomes of pregnancy of the noise-exposed and unexposed women.

	Exposed women (N = 111)		Unexposed women (N = 181)	
	N	%	N	%
Spontaneous abortion	2	2	—	0
Induced abortion	1	1	1	1
Delivery	108	97	180	99
≤37 weeks	5	5	7	4
≤34 weeks	2	2	3	2

mean birthweight of the neonates (table 9). Birthweight was not systematically related to the other work conditions (table 9) or to impulse noise (table 10), but the mean birthweight was, on the average, 0.2–0.3 kg lower in the group experiencing a high noise level than among the referents or those exposed

to a lower level of noise, and this contrast became more pronounced among the exposed women in this group who also had a standing work position or were engaged in shift work. The prevalence of low birthweight for gestational age was also higher in the high-noise group (5 of 25) than in the reference group (13 of 180; difference +13 percentage points, 95% CI –3—+29) or the low-noise group (4 of 82; difference +15 percentage points, 95% CI –1—+32). The prevalence of low birthweight was no higher in the impulse-noise group, nor was it systematically related to the other work conditions.

The infants of mothers belonging to the high-noise group more commonly needed care at a neonatal unit than those in the low-noise group (5 of 25 versus 11 of 83). There were nine malformed infants in the exposed group. Most of the malformations among the exposed cases (8 of 9) occurred in the low-noise group, one being an autosomally recessively inherited defect. When this case was excluded, the prevalence difference between the exposed groups was 5% (95% CI –1—+10). The only perinatal death, because of an intrauterine infection, occurred for an exposed mother (table 8).

Table 8. Data on the newborns of the noise exposed and unexposed mothers.

	Newborns of exposed mothers (N = 108)		Newborns of unexposed mothers (N = 180)	
	N	%	N	%
Birth weight below the 10th percentile	9	8	13	7
Apgar score below 7 (at 1 min)	2	2	4	2
Care at neonatal unit	16	15	21	12
Malformed	9	8	5	3
Perinatal deaths (stillborn and deaths < 7 d)	1	1	—	0

Table 9. Birthweight of the infants born to the women exposed to occupational noise and to the unexposed women. Means, standard deviations (SD), the numbers of women (N) in the groups, and the adjusted difference (stratified by age and parity) of the group means with a 95% confidence interval (95% CI), overall and subdivided separately by vibration, standing positions, and shift work.

	Birthweight (g)						Adjusted difference (mean)	95% CI
	Exposed women			Unexposed women				
	N	Mean	SD	N	Mean	SD		
Overall	108	3544	570	180	3527	565	+ 20	− 121— + 161
Vibration								
No	76	3528	550	158	3551	549	− 23	− 182— + 136
Yes	30	3586	638	20	3400	676	+ 216	− 176— + 608
Standing position								
No	41	3593	505	52	3475	554	+ 99	− 128— + 327
Yes	66	3515	613	127	3554	569	− 28	− 213— + 157
Shift work								
No	43	3597	571	114	3493	539	+ 73	− 125— + 272
Yes	64	3510	576	37	3681	630	− 142	− 395— + 112

Table 10. Birthweight of the infants born to women exposed to occupational noise subdivided separately by the presence of impulse noise and level of noise. Means, standard deviations (SD), the numbers of women in the groups, and the adjusted difference (stratified by age and parity) of the group mean to that of the unexposed women with a 95% confidence interval (95% CI).

	Birthweight (g)						Adjusted difference (mean)	95% CI
	Exposed women			Unexposed women				
	N	Mean	SD	N	Mean	SD		
Impulse noise								
No	74	3535	543	113	3488	527	− 3	− 163— + 158
Yes	33	3588	627	63	3619	628	+ 58	− 161— + 277
Noise level								
< 90 dB	83	3616	549	135	3495	569	+ 102	− 51— + 254
≥ 90 dB	25	3304	585	45	3622	548	− 228	− 471— + 15

Discussion

The occupational activity of Finnish women is high, and about 78% of women work outside the home during pregnancy (12). In an earlier report on occupational noise exposure during pregnancy (12), we ascertained that only 3.5% of the mothers were exposed to noise if the limit was set at 81 dB, and another report from Finland has set the corresponding percentage at 2.9% if the limit is 85 dB or more (11). Data on work conditions already exist since occupational health care is prescribed by law in Finland, but, for more accurate data on the work conditions of the subjects in our study, the work loads and exposures of the women were primarily obtained from the occupational health care system, which informed the women about the research. The enrollment of the subjects proceeded slowly, because of the obvious reluctance of some employers.

As suggested by our earlier study, it could be assumed that noise would hardly be a major hazard affecting the course and outcome of pregnancy (12). To control some well-known factors influencing the outcome of pregnancy, such as maternal age and parity, we aimed at matching the unexposed women in this respect. In addition to other effects, women with children are more likely to terminate their employment than childless ones (18). The matching by type of occupation also seemed to control the social class of the women well. The other base-line characteristics of the exposed and unexposed women were comparable. For example, there was an excess of women smoking in both groups (over 30%) relative to the figure of 15% reported in Finnish perinatal statistics (19). Maternity care is equally available to all women in Finland, and is free of charge to every woman, so that 99.8% of pregnant women use these services (19). The use of these services was comparable to the average figures for the whole country in both groups (19). Statutory maternity leave begins on the 36th gestational week, and paid sick leave can be obtained earlier for medical reasons. The mean worktime during pregnancy was the same in the exposed and unexposed groups, about 29 weeks.

The matching by occupational status was not perfect in that almost all of the exposed women were manual workers, whereas one-third of the women in the unexposed group were of lower-grade staff. Still, the percentages of women with heavy physical and mental loads and a standing work position were comparable. The noise-exposed women more frequently had other inconveniences in their work, like shift work, impulse noise, vibration, and a high or low ambient temperature, and these conditions were more prevalent at higher levels of noise exposure. On the other hand, there was a clear difference between the information given by the women themselves and the health officer. A heavy physical load, for example, was reported by 32% of the exposed subjects them-

selves in contrast to the figure of 6% by the health officers.

Elevated blood pressure has been connected with noise exposure, although the results are ambiguous (3–6). In our earlier study of experimental noise exposure during normotensive and hypertensive pregnancy, we could not find any effect of noise on blood pressure levels (20). Nurminen & Kurppa (13) reported that pregnancy-induced hypertension was not associated with noise exposure alone but that, upon additional strain caused by shift work, the pregnant women exposed to noise at a level of about 85 dB $L_{Aeq(8h)}$ or higher had a distinctly elevated risk of pregnancy hypertension. Similarly, shift work alone was not related to this complication of pregnancy. The present survey similarly did not detect any association between occupational noise exposure and hypertension in pregnancy.

There were no differences in the number of preterm deliveries between the groups. The mean gestational week at delivery over the whole country was 39.7, and the proportion of preterm deliveries (<37 weeks) was 5.2% (19), figures which are very close to the present ones. The mean birthweights of the infants of the groups did not differ significantly, and they were only a little lower than that for the whole country [3550 (SD 582) g (19)]. The prevalence of low birthweight for gestational age was also similar to that for the whole country. The only difference between the exposed and unexposed groups as a whole was seen in the occurrence of congenital malformations, but this contrast was statistically nonsignificant due to the small numbers.

When noise exposure rose to 90 dB ($L_{Aeq(8h)}$) or more, there was no difference in the systolic or diastolic blood pressure, although a lower than average birthweight, either in absolute terms or in relation to gestational age, was observed, albeit with rather wide confidence intervals. The neonates also needed observation at the neonatal unit more often. These findings were more pronounced for women simultaneously exposed to a standing work position or shift work. Four women out of twenty-five in this exposure group (16%) had a preterm delivery, but the effect of noise on this complication was impossible to distinguish from other coincident exposures associated with preterm birth. The noise exposure level was not associated with malformations.

In conclusion, it can be stated that high noise levels can have an independent effect on birthweight and they may be associated with preterm delivery, although the situation may be alleviated somewhat in our country by the opportunities for obtaining sick leave. With respect to noise-induced occupational hearing loss, 39% of the women reported an adequate use of hearing protectors, and it can also be assumed that these protectors had some effect on our results. Only a minority of women in our country are exposed to high noise levels in general or during pregnancy. On the other hand, high noise levels are of-

ten associated with other untoward conditions, and therefore they should perhaps be considered a form of occupational risk during pregnancy after all.

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