

BMJ Open

The effect of occupational noise exposure on tinnitus and sound fatigue among obstetrics personnel: a cross-sectional study

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2014-005793
Article Type:	Research
Date Submitted by the Author:	26-May-2014
Complete List of Authors:	Fredriksson, Sofie; University of Gothenburg, Public Health and Community Medicine Hammar, Oscar; University of Gothenburg, Public Health and Community Medicine Torén, Kjell; University of Gothenburg, Public Health and Community Medicine Tenenbaum, Artur; Occupational health care unit, Skaraborg Hospital Persson Waye, Kerstin; University of Gothenburg, Public Health and Community Medicine
Primary Subject Heading:	Occupational and environmental medicine
Secondary Subject Heading:	Ear, nose and throat/otolaryngology, Obstetrics and gynaecology
Keywords:	OCCUPATIONAL & INDUSTRIAL MEDICINE, Audiology < OTOLARYNGOLOGY, OBSTETRICS

SCHOLARONE™
Manuscripts

only

1
2
3 **The effect of occupational noise exposure on tinnitus and sound fatigue**
4
5 **among obstetrics personnel: a cross-sectional study**
6
7
8
9

10 **Authors' names**

11 Sofie Fredriksson (SF), Oscar Hammar (OH), Kjell Torén (KT), Artur Tenenbaum (AT),
12
13 Kerstin Persson Waye (KPW)
14

15
16
17
18
19 **Corresponding author:**

20 Sofie Fredriksson

21 University of Gothenburg

22 Dept. of Public health & Community Medicine

23 Occupational and Environmental Medicine

24 PO Box 414, SE 405 30 Gothenburg, Sweden

25 sofie.fredriksson@gu.se

26 +46317863610 (telephone), +4631409728 (fax)
27
28
29
30
31
32
33
34
35
36
37
38
39

40 **Address for co-authors:**

41 Oscar Hammar (1), Kjell Torén (1), Artur Tenenbaum (2), Kerstin Persson Waye (1)

- 42
43 1) Department of Public Health and Community Medicine, Occupational and
44 Environmental Medicine, University of Gothenburg, S-405 30 Gothenburg
45
46 2) Occupational health care unit (Hälsan & Arbetslivet), Skaraborg Hospital, S-541 85
47 Skövde, Sweden
48
49
50
51
52
53
54

55 **Keywords:** Noise, occupational; stress; hearing disorders; cross-sectional studies; obstetrics

56 **Word count** (excluding title page, abstract, references, figures and tables): 4253
57
58
59
60

ABSTRACT

Objective: There is a lack of research on effects of occupational noise exposure in traditionally female-dominated workplaces. Therefore, the aim was to assess risk of noise-induced hearing-related symptoms among obstetrics personnel.

Design: A Cross-sectional study at an obstetric ward in Sweden including a questionnaire among all employees and sound level measurements in 61 work-shifts at the same ward.

Participants: 115 female employees responded to a questionnaire (72% of all 160 employees invited).

Main outcome measures: Self-reported hearing-related symptoms, noise annoyance, work-related stress, calculated cumulative occupational noise exposure and measured sound levels.

Results: Sound levels exceeded the 80 dB LAeq limit for protection of hearing in 46% of the measured work-shifts. One or more hearing-related symptom was reported by 55% of the personnel. In logistic regression models a significant association was found between cumulative occupational noise exposure and tinnitus (OR 1.04, 95% confidence interval 1.00 to 1.09) and sound fatigue (OR 1.04, 95% confidence interval 1.00 to 1.07). Work-related stress and noise annoyance were reported by almost half of the personnel group. Sound fatigue was associated to work-related stress and noise annoyance, although stress just missed significance in a multivariable model. No significant interactions were found.

Conclusion: This study presents new results showing that obstetrics personnel are at risk of noise-induced hearing-related symptoms. Current exposure levels at the work-place are high and cumulative exposure has significant effects on tinnitus and sound fatigue among the personnel. These results indicate that preventative action regarding noise exposure is required in obstetrics care and that risk-assessments may be needed in previously unstudied non-industrial communication-intense sound environments.

Strengths and limitations of this study:

- The vast majority of previous research into noise-induced hearing disorders has been performed in industrial-like settings, whereas practically nothing is known of risks in non-industrial, traditionally female-dominated and communication-intense workplaces, such as hospitals. This is to our knowledge the first published study that assesses occupational noise exposure and hearing among obstetrics personnel.
- Both objective sound level measurements and analysis of subjective data indicate an increased risk of hearing-related disorder.
- Due to the cross-sectional design the influence of subjects' age cannot be disentangled.
- The study sample size and the cross-sectional design without an unexposed control group limits the generalisation of the results and prevents us from drawing definite conclusions on causality.
- Further studies are needed to confirm the results and assess the magnitude of the problem. However, we suggest that occupational health care services implement available preventative actions such as making hearing protective devices available for personnel as an action of precaution.

INTRODUCTION

Occupational noise exposure and effects on hearing is well described in industrial-like, traditionally male-dominated settings.[1] In contrast, few studies have reported on traditionally female-dominated work environments. This has been acknowledged by the European Agency for Safety and Health at Work, who conclude that areas such as health and social services are largely overlooked concerning noise research,[2] and that the noise in these types of workplaces may interfere with performance and wellbeing. High sound levels regardless of its source can cause hearing loss, tinnitus and sound sensitivity and may also result in sound fatigue, described as avoidance of everyday sounds.[1 3-7] Apart from hearing-related symptoms, noise exposure can also evoke non-auditory effects such as annoyance and stress.[8] According to a recent meta-analysis, noise levels in hospitals have steadily increased since the mid-1960.[9] One heavily female-dominated workplace in the hospital is the obstetrics care. According to data from Statistics Sweden in 2011, more than 99% of midwives are women. To the best of our knowledge, only one peer-reviewed study have reported on sound level measurements from obstetrics care in a hospital in India, where the highest night time level (71.9 dB LAeq) was measured in the obstetrics and gynaecology ward, with slightly lower levels in the labour ward.[10]

In addition to potentially harmful noise levels in the obstetrics care, midwives report a high degree of work-related stress and burnout,[11] and according to a recent report burnout syndrome have doubled among midwives employed in the western region of Sweden during the last years.[12] The fact that obstetrics personnel are exposed to high levels of stress may be important when considering noise exposure at the workplace, since the combination of these exposures may interact in causing adverse health effects.[13-15]

There is a substantial lack of knowledge regarding occupational noise exposure, noise annoyance and hearing-related symptoms among obstetrics care personnel, as well as possible

1
2
3 interaction effects between noise exposure, noise annoyance and work-related stress.
4
5 Therefore, the aim of this study was to assess the risk of noise-induced hearing-related
6
7 symptoms among obstetrics personnel by measuring sound levels in the labour ward of a
8
9 general obstetrics ward and by analysing the effect of and interaction between occupational
10
11 noise exposure, noise annoyance and work-related stress on hearing-related symptoms among
12
13 obstetrics personnel.
14

15 16 17 18 **METHODS** 19

20 21 **Sound level measurements** 22

23 Sound level measurements were carried out during 61 work shifts in the labour ward of a
24
25 general obstetrics ward at the Sahlgrenska University Hospital in Gothenburg. Day shifts
26
27 (n=19) were measured between 7 a.m. and 3:30 p.m. (8.5 h), evening shifts (n=12) between
28
29 1:45 p.m. and 9 p.m. (7.25 h) and nightshifts (n=30) between 9 p.m. and 7 a.m. (10 h). The
30
31 day and evening shifts were measured during separate weeks so as not to overlap. A
32
33 convenient sample of ten employees per shift each wore a personal dosimeter (Larson Davis
34
35 705+) with the microphone attached to the right shoulder and kept a written log documenting
36
37 work activities during the measured shift. A total of 610 separate measurements were
38
39 collected. However, due to technical errors a few faulty measurements were excluded leaving
40
41 529 (87%) to be included in the analysis. The dosimeters were set to measure A-weighted
42
43 equivalent and maximum (fast) levels with a sampling interval of 30 seconds. The equivalent
44
45 levels reported refer to the full-shift length and will hence vary between 7.25 – 10 hours,
46
47 hereinafter denoted as LAeq_(7-10h). Sound levels were analysed at group level as arithmetic
48
49 mean and compared to Swedish Work Authorities' exposure regulations. Sound levels
50
51 exceeding the lower action level of 80 dB LAeq(8h) indicate a risk for hearing damage and
52
53 the employer is responsible to take preventative action, such as providing employees with
54
55
56
57
58
59
60

1
2
3 hearing protection devices (HPDs). The exposure limits 85 dB LAeq (8h) and 115 dB
4
5 LAFmax are set as a maximum allowed level above which the employer is required to take
6
7 measures in order to reduce the noise exposure, and where use of HPDs are mandatory.
8
9
10 Employees must not be exposed to noise levels at or above the exposure limits (taking
11
12 attenuation of HPDs into account).

13 14 15 16 **Questionnaire survey**

17
18 All personnel (n=160, all women), employed at the general obstetrics ward were included in a
19
20 questionnaire survey. A total of 115 (72%) participated by responding either electronically
21
22 (n=63) or in paper format (n=52) and these data were pooled together. The questionnaire was
23
24 constructed using items specifically constructed for this study as well as items adapted from
25
26 previous studies and international standards (ISO/TS 15666).[7 16] Similar self-reported
27
28 items assessing noise exposure as well as hearing loss and tinnitus have previously been
29
30 subject for validation.[17-20]
31
32

33
34 The main explanatory variable cumulative occupational noise exposure dose, was calculated
35
36 as an exposure index derived from six questionnaire items including; number of years worked
37
38 in delivery care, number of years worked in alternative birth care, work allocation (delivery
39
40 care, postpartum care or both), two separate items on frequency of current work-related noise
41
42 exposure (one assessing how often the sound levels are so high that the person has to speak
43
44 with raised voice and one assessing how often the person have trouble hearing what is said)
45
46 and finally one item on frequency of hearing protection use. A higher noise index indicates a
47
48 higher noise exposure dose. The scoring for each items contribution to the index is presented
49
50 in detail in supplementary table 1. Work-related stress and noise annoyance were analysed as
51
52 additional explanatory variables. Work-related stress was assessed using two separate
53
54 questionnaire items asking responders to report how often they experience high degree of
55
56
57
58
59
60

1
2
3 stress and how often they feel unwell due to stress at work. Participants were defined as
4
5 having work-related stress if answering often or always/almost always on one or both of the
6
7 items. These stress-related items have previously been used in noise-related research.[21]
8
9
10 Noise annoyance was assessed by the item ‘Are you annoyed by sounds/noise at your
11
12 workplace?’, which is based on the International standard ISO/TS 15666, adapted for a
13
14 workplace survey as opposed to community surveys. The hearing-related outcome variables
15
16 included are hearing loss (yes), tinnitus, sound sensitivity and sound fatigue (a few times each
17
18 week or more often), general hearing status (poor or very poor) and difficulty perceiving
19
20 speech (yes both at work and in leisure time). Variables considered as possible moderators for
21
22 the association between exposure and outcome were smoking (previous or current) and
23
24 leisure-time noise exposure (once a month or more often). Age (in years) was considered a
25
26 possible confounder. The questionnaire items are presented in full in the supplementary
27
28 table 2.
29
30
31
32
33

34 **Statistical analyses**

35
36 Hypothesis testing was performed using IBM SPSS Statistics 20. Differences in arithmetic
37
38 mean were analysed using one-way analysis of variance (ANOVA) or independent samples t-
39
40 test where applicable. Test for trend was analysed using Linear regression with dummy
41
42 coding for categorical predictors or Mantel-Haentzel linear-by-linear association where
43
44 applicable. Binary logistic regression with Wald tests was used for analysis of associations
45
46 and interaction. The significance level was set at 5% ($p= 0.05$) for all tests. Based on a
47
48 hypothesised order of importance of explanatory variables, manual sequential regression
49
50 models were analysed. For each binary hearing-related outcome variable we used the
51
52 following model testing procedure. In a first model, noise exposure index was analysed as a
53
54 single continuous explanatory variable with the hearing-related symptom as a binary outcome
55
56
57
58
59
60

1
2
3 variable. If noise exposure index was significant for the hearing-related symptom, then a
4
5 second model was analysed, adjusting for moderators (leisure noise exposure and smoking),
6
7 each one at a time. Age as a possible confounder was analysed separately due to initial
8
9 hypothesised strong correlation to the noise index (due to its cumulative nature). If point
10
11 estimates for noise index was comparable with and without adjustment and the adjustment
12
13 variable itself was non-significant, then it was not included in subsequent multivariable
14
15 models. In the third model, work-related stress was analysed as an additional explanatory
16
17 variable and in a fourth model noise annoyance instead of stress was included together with
18
19 significant explanatory variables from model 2. The fifth model included explanatory
20
21 variables found to be significant in any of the previous steps. Hypothesised interactions
22
23 between explanatory variables were assessed in separate models by including an interaction
24
25 term. Multi-collinearity between explanatory variables was assessed using Pearson's
26
27 correlation or Spearman's rank correlation, where applicable, and correlation below $r=0.6$ was
28
29 deemed acceptable. Odds ratios (OR) with 95% confidence intervals were derived from the
30
31 logistic regressions and relative risk (RR) was calculated from predictive values derived from
32
33 model 1. Goodness of fit for the regression models were assessed using the Hosmer-
34
35 Lemeshow test and a non-significant p-value (>0.05) was used to indicate adequate fit.
36
37
38
39
40
41
42

43 RESULTS

44 Sound levels in the labour ward

45
46 Overall, the dosimeter measurements from the labour ward showed moderately high sound
47
48 levels, as presented in table 1. The levels reached or exceeded both the action and limit levels.
49
50 The lower action level 80 dB LAeq was exceeded in 30 different dosimeter measurements
51
52 during 28 different work shifts, which corresponds to 46% of all measured shifts or 6% of all
53
54 dosimeter measurements. The upper exposure action level and exposure limit 85 dB LAeq
55
56
57
58
59
60

1
2
3 was reached or exceeded in three measurements from three different shifts, corresponding to
4
5 5% of all measured shifts or 0.6% of all measurements. The limit 115 dB LAFmax was
6
7 reached or exceeded at 50 different occasions. However, of these 9 separate events could not
8
9 be verified by the written logs and were therefore excluded. The remaining 41 events occurred
10
11 in 17 different shifts corresponding to 28% of all measured shifts or 8% of all dosimeter
12
13 measurements. There were no statistical differences in arithmetic mean equivalent nor in
14
15 maximum levels when comparing measurements from different work-shifts nor measurements
16
17 from dosimeters worn by midwives compared to assistant nurses. Due to incomplete written
18
19 logs however, we were unable to categorise a third of the measurements into professional
20
21 group. A segment sample from a dosimeter measurement is shown in figure 1, where high
22
23 maximum levels (119 dB LAFmax) was recorded during a delivery, which according to the
24
25 written log occurred between 10:30 and 11:05 pm. The equivalent level in this particular
26
27 measurement was 84 dB LAeq(10h) for the measured shift length. As exposure limits should be
28
29 regarded with HPDs taken into account, it is noteworthy that the majority of the respondents
30
31 (92%) reported to never or almost never use hearing protective devices at work.
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

FIGURE 1

Table 1. Sound level measurements at the labour ward showing arithmetic mean, standard deviation (SD), 95% confidence interval confidence interval (CI) of mean and range of the measured equivalent, LAeq_(7-10h) and maximum, LAFmax sound levels in dB. Also showing mean and standard deviation of measurements categorised by work shift and by professional group as reported in written logs by the personnel carrying the dosimeter. Frequencies (n) in the table represent unique dosimeter measurements.

	Sound level measurements		
	dB LAeq _(7-10h)	dB LAFmax	n
All measurements			
Arithmetic mean (SD)	70.3 (6.0)	106.3 (6.0)	529
95% CI of mean	69.7 - 70.8	105.8 - 106.8	
Min – Max	56.0 – 87.0	83.0 – 122.0	
Measurements categorised by work shift (arithmetic mean, SD)^a			
Day shift	70.8 (6.2)	106.2 (5.9)	139
Evening shift	70.8 (5.2)	106.3 (5.6)	127
Night shift	69.8 (6.3)	106.4 (6.2)	263
Measurements categorised by professional group (arithmetic mean, SD)			
Midwives	71.3 (5.1)	106.2 (5.9)	289
Assistant nurses	72.2 (5.0)	107.8 (5.2)	114
Uncategorised	76.2 (7.0)	103.9 (6.5)	126

^a Number of shifts categories as day (n=19), evening (n=12) and night (n=30).

Association between noise exposure and hearing disorder

Demographics, occurrence of explanatory variables; work-related stress, noise annoyance and adjustment variables; smoking and leisure noise exposure as well as prevalence of hearing-related outcomes are presented in table 2, both for the total study sample as well as categorised into four noise exposure index groups calculated from quartiles of the noise index. The first noise index group (1) represents the respondents with the lowest calculated noise exposure dose. Valid responses for the individual questionnaire items included in the analysis

ranged from n=108 to 115. A test for trend in the four exposure groups shows that age, number of years worked in obstetrics and prevalence of sound fatigue is significantly increasing with higher noise exposure group; $p < 0.001$, $p < 0.001$ and $p = 0.049$ respectively.

Table 2. Demographics, explanatory and adjustment variables and hearing-related outcomes from questionnaire survey among personnel at the general obstetrics ward. Prevalence is presented categorised in four noise index groups based on quartiles of the index (1 – 4) and as total prevalence in the study sample. Percentages are given as column %.

	Grouping by noise index quartiles				Total	95% CI of total
	1	2	3	4		
Number of participants	28	29	29	29	115	-
Noise exposure index (range)	4.5 – 9.5	10 – 15	16 – 26	27 – 64	4.5 - 64	16.8 - 21.2
Demographics						
Mean age in years (SD)	39 (10)	39 (7)	45 (8)	57 (5)	45 (11)	42.8 - 46.8
Mean years worked (SD)	3 (2)	6 (2)	14 (3)	28 (6)	12 (11)	10.3 - 14.3
Professional groups, % ^a	54/36/11	69/24/7	69/21/10	76/21/3	68/25/7	-
Explanatory and adjustment variables (%)						
Work-related stress	43	52	31	41	42	32.9-51.1
Noise annoyance at work	50	45	55	45	49	39.8-58.2
Ever smoker	36	48	28	25	34	25.3-42.7
Leisure noise exposure	14	24	7	7	13	6.8-19.2
Outcome variables (%)						
Sound fatigue	21	24	41	41	32	23.4-40.6
Tinnitus	7	11	10	24	13	6.8-19.2
Sound sensitivity	7	17	17	10	13	6.8-19.2
Poor hearing	11	21	17	14	16	9.3-22.7
Hearing loss	4	7	21	4	9	3.7-14.3
Difficulty perceiving speech	39	31	24	36	32	23.4-40.6
Any symptom ^b	54	48	55	63	55	45.9-64.1

^a Shown in table as proportion of Midwife/Assistant nurse/Other. Other also includes missing.

^b Any symptom was constructed as a binary variable including all those who reported either sound fatigue, tinnitus, sound sensitivity, difficulty perceiving speech, poor hearing and/or hearing loss.

1
2
3 Associations between occupational noise exposure dose (continuous noise index), work-
4 related stress, noise annoyance and hearing-related symptoms were evaluated in manual
5 sequential binary logistic regression models, results of which are presented in table 3. The
6
7 calculated noise index ranged from 4.5 to 64 in the study sample. The proportional
8
9 contribution of years worked in obstetrics care to the index, as a proxy for cumulative
10
11 exposure, is shown in figure 2 A. The percentage of participants over the range of noise index
12
13 also conveys the skewness in the distribution of the index, e.g. less than 25% of the
14
15 participants have noise index values in the upper half of the range.
16
17
18
19
20
21
22
23

FIGURE 2

24
25
26
27 Occupational noise exposure as a single explanatory variable was significantly associated to
28
29 tinnitus and sound fatigue, but not to the other hearing-related symptoms. Work-related stress
30
31 and noise annoyance were both significantly associated to sound fatigue in separate models,
32
33 but not to tinnitus. For sound fatigue, including all three significant explanatory variables
34
35 (noise, stress and annoyance) in model 5 resulted in marginal changes in point estimates for
36
37 noise exposure and noise annoyance. It did however affect the estimates for work-related
38
39 stress, which just missed statistical significance ($p=0.053$). No significant statistical
40
41 interactions were found between explanatory variables. Neither work-related stress nor noise
42
43 annoyance were significantly correlated to noise exposure index, there was however a weak
44
45 yet significant correlation between stress and noise annoyance ($r=0.249$, $p=0.008$). The point
46
47 estimates for noise exposure was comparable with or without adjustment for smoking and
48
49 leisure-time noise exposure in model 2, and neither one of the adjustment variables were
50
51 themselves significant. Hence, they were not included in the subsequent multivariable models.
52
53
54
55
56 All reported models had an acceptable goodness of fit.
57
58
59
60

1
2
3 As prevalence of sound fatigue was much higher than 10%, assessing odds ratios (OR) only
4 may overestimating the risk. The calculated risk ratios (RR) for sound fatigue from model 1,
5
6 in comparable 1 unit steps of the noise index, however showed that the difference between
7
8 OR and RR was minor (at the most 0.02 difference).
9

10
11 Due to the cumulative property of the noise index, the index was assumed to be correlated to
12 age, which was also confirmed in the analysis ($r=0.706$, $p<0.001$) with $R^2=0.498$, as shown in
13 figure 2 B. Multi-collinearity issues therefore precluded the assessment of both variables in
14 one regression model. Notably and importantly though, age was not significantly associated to
15
16 any of the hearing-related symptoms when assessed as a single explanatory variable in
17
18 separate regression models.
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 3. Point estimates of effect (B) and standard error (SE), odds ratios (OR), 95% confidence intervals of OR (95% CI) from binary logistic regression models for hearing-related symptom outcomes (binary dependent variables) among personnel in an obstetrics ward. All dependent variables were analysed in separate models. Manual sequential analysis was adopted, adding work-related stress and noise annoyance and adding an interaction term if the initial model was statistically significant ($p < 0.05$).

Dependent variables	Explanatory variables	B (SE)	OR (95% CI)	p-value
Sound fatigue				
<i>Model 1</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.07)	0.031
<i>Model 3</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.08)	0.027
	Work-related stress	0.96 (0.42)	2.62 (1.15 – 5.98)	0.022
<i>Model 4</i>	Noise exposure index	0.04 (0.02)	1.04 (1.01 – 1.08)	0.026
	Noise annoyance	1.73 (0.47)	5.67 (2.25 – 14.27)	<0.001
<i>Model 5</i>	Noise exposure index	0.04 (0.02)	1.04 (1.01 – 1.08)	0.025
	Work-related stress	0.87 (0.45)	2.39 (0.99 – 5.79)	0.053
	Noise annoyance	1.66 (0.48)	5.25 (2.05 – 13.42)	0.001
Tinnitus				
<i>Model 1</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.09)	0.049
<i>Model 3</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.09)	0.046
	Work-related stress	-0.43 (0.60)	0.65 (0.20 – 2.10)	0.470
<i>Model 4</i>	Noise exposure index	0.04 (0.02)	1.05 (1.00 – 1.09)	0.038
	Noise annoyance	0.56 (0.58)	1.85 (0.56 – 5.46)	0.335
Sound sensitivity	Noise exposure index	0.01 (0.02)	1.03 (0.97 – 1.06)	0.570
Poor hearing	Noise exposure index	0.00 (0.02)	1.00 (0.96 – 1.04)	0.985
Hearing loss	Noise exposure index	0.00 (0.03)	1.00 (0.95 – 1.06)	0.995
Difficulty perceiving speech	Noise exposure index	0.01 (0.02)	1.01 (0.98 – 1.05)	0.461
Any symptom^a	Noise exposure index	0.02 (0.02)	1.02 (0.99 – 1.05)	0.273

^a Any symptom was constructed as a binary variable including all those who reported either sound fatigue, tinnitus, sound sensitivity, difficulty perceiving speech, poor hearing and/or hearing loss.

DISCUSSION

The effect of noise exposure on hearing

In order to assess the effect of occupational noise exposure on hearing-related symptoms among obstetrics personnel, sound level measurements were carried out at the labour ward at a general obstetrics ward and associations between calculated occupational noise exposure dose and hearing-related symptoms were analysed in binary logistic regression models based on self-reported data from personnel at the same ward.

Prevalence of hearing-related symptoms among the personnel showed that tinnitus and sound fatigue was most common among personnel with the highest exposure dose. Accordingly, we were also able to detect statistically significant associations between occupational noise exposure and both tinnitus and sound fatigue in logistic regression models. Sound fatigue is a new concept that has previously been reported among preschool personnel and is hypothesised as a consequence of a constant noise load during the work day.[7 16] As for preschool personnel, the obstetric personnel are mainly exposed to intermittent sounds from voices and screams, but also from alarms and medical equipment. It is possible that the demands and needs of attending to meaningful sounds with a high element of irregularity contribute to a mental fatigue that some individuals with sound fatigue describe. As for sound fatigue, we could also show a significant association between tinnitus and noise exposure. Although it is well established that noise may contribute to tinnitus,[4 22 23] it has to our knowledge not been reported previously among obstetrics personnel; hence this result is highly interesting as it supports the concerns that noise levels in non-industrial and previously less studied work environments, mainly female-dominated, may be harmful.[2] As the prevalence especially for sound fatigue was high, it is important to note that odds ratios may not directly be translated into a measure of relative risk.[24] We did however not detect major divergences between the two measures.

1
2
3 In addition to increased risk of hearing-related symptoms of cumulative occupational noise
4 exposure, we also found high current sound level exposure in the labour ward, above
5 regulated limits. The sound level measurements further heighten the concern that obstetrics
6 personnel may risk acquiring hearing-related disorder as personnel carrying the dosimeters
7 were exposed to levels exceeding the lower action level of 80 dB LAeq during as much as
8 approximately half of the measured work shifts. While the average noise levels were in
9 accordance with an earlier study reporting noise levels from an obstetrics and labour ward at a
10 general hospital,[10] our study further showed that the exposure limit 115 dB LAFmax may
11 be exceeded in as much as one third of the work-shifts in a labour ward. The data is also in
12 accordance with results from a workplace inspection performed in 2010 by the occupational
13 health care unit at a small obstetrics ward in Sweden which showed that personnel were at
14 times exposed to sound levels above the regulated action and limit levels adopted by the
15 Swedish work environment authority.[25] This result is especially alarming as very few
16 personnel report use of hearing protection, which certainly may be impractical in this type of
17 work setting. Although caution is required in establishing the source of high maximum levels
18 recorded in unsupervised measurements the results are indeed important, since such high
19 sound levels have been described as mechanism in acquired hearing loss, tinnitus and sound
20 sensitivity.[3] These results highlight the need to initiate preventive action regarding noise
21 exposure in the obstetrics care, which include but is not limited to; information to all
22 employees, access to suitable hearing protection devices and cooperation between the
23 employer and an occupational health care unit for assessment of noise exposure and hearing-
24 related symptoms. Hearing tests and anamnesis regarding hearing-related symptoms may also
25 be considered for new employees.

26
27 No significant associations between noise exposure and the other hearing related symptoms
28 were detected in this study. This may be explained partly by the fact that hearing loss is

1
2
3 developed over a long period of time, usually becoming apparent after the age of retirement,
4
5 and that mild deterioration in hearing may not be easily detected via self-assessment. As the
6
7 study was cross-sectional, the fact that hearing loss was most prevalent in the third noise
8
9 exposure group lower prevalence in the highest exposure group may have influenced the
10
11 analysis. This in turn is possibly due to a healthy worker effect as individuals with hearing
12
13 loss may not be able to continue working in obstetrics care. Similarly but in the opposite
14
15 direction, as difficulty perceiving speech was reported by many young individuals it may have
16
17 influenced the analysis of the effect of occupational noise exposure. It is in any case alarming
18
19 with such a high prevalence of difficulty perceiving speech. Compared to prevalence data
20
21 from the Swedish National Board of Health and Welfare from 2000-2005, using a similar
22
23 survey item as in this study,[26] our data indicate higher age and gender matched prevalence.
24
25 Between the ages 25-64 years the prevalence in our sample ranged from 26-35%, while the
26
27 prevalence in the same age range among women in the reference material was 5-15%. Sound
28
29 sensitivity is less researched, but one previous study from Sweden reports prevalence in the
30
31 general population of 8-9%.[27] No gender-specific prevalence was reported, making direct
32
33 comparisons to our data somewhat problematic; yet our data indicate slightly higher
34
35 prevalence. In addition to the significant association between occupational noise exposure and
36
37 both tinnitus and sound fatigue, our data also shows that having one or more hearing-related
38
39 symptom is most common among those with highest cumulative noise exposure dose as seen
40
41 in table 2. However, this variable was not significantly associated to noise exposure in the
42
43 regression model, probably due to the variable difficulty perceiving speech having a large
44
45 influence with the high prevalence in the lower noise exposure group. Again, it is staggering
46
47 to find that more than half of the participating personnel group report one or more hearing-
48
49 related symptom. The risks of acquiring hearing-related symptoms in this work environment
50
51 should also be seen in the light of recent animal studies, showing that noise contribute to
52
53
54
55
56
57
58
59
60

1
2
3 neurodegenerative effects and acute loss of afferent nerve terminals - the effects of which is
4
5 believed to be of importance for auditory processing and subsequently resulting in hearing
6
7 injuries emerging only later in life.[28-30] If applicable to humans, an implication would
8
9 hence be that hearing functions of importance for auditory processing in adverse listening
10
11 conditions may be impaired even though subjects have apparent normal hearing,[31] and
12
13 importantly that risk of auditory injury from noise exposure is greater than previously
14
15 assumed. Studies such as ours, investigating risks for hearing injury within occupational
16
17 groups exposed to levels at or just below the stipulated risk levels, are therefore of high
18
19 relevance.
20
21

22 23 24 25 **Work-related stress and noise annoyance**

26
27 Work-related stress was common among the obstetrics personnel surveyed, which is in line
28
29 with previous research.[11 12] A new finding though, was that noise annoyance is also highly
30
31 prevalent in this occupational group and that both stress and noise annoyance were positively
32
33 associated to sound fatigue; although the estimated effect for stress was reduced when both
34
35 stress and noise annoyance were included in the same model. This may be due to lack of
36
37 power in the analysis and possibly also multi-collinearity, as there was a weak yet significant
38
39 correlation between stress and annoyance. The associations were hypothesised based on
40
41 models of pathways previously suggested by Babish,[13] and in a more recent model by
42
43 Heinonen-Guzejev et al.[32] In contrast to previous results of an association between stress
44
45 and tinnitus,[33 34] our results do not support this association despite the fact that work-
46
47 related stress was very common in our sample. It is possible that our measure of work-related
48
49 stress did not capture the association, that the relationship is far more complex or that tinnitus
50
51 is instead more strongly associated to psychological distress as is also suggested by studies on
52
53 tinnitus and depression and anxiety,[35 36] rather than physiological or psychosocial stress.
54
55
56
57
58
59
60

Methodological consideration

We are aware of methodological issues in assessing exposure dose retrospectively.[37 38] In this study an estimate of cumulative occupational noise exposure was calculated by using years worked as a proxy for the exposure dose. In order to increase the sensitivity of this estimate, we also including years worked with the alternative birth care method (ABC-method, predominantly used during the 1980's hypothesised to have given rise to higher sound levels in the labour ward due to the non-use of anaesthetics), including an assessment of current noise exposure as well as considering the protective effect of personal hearing protective devices. A common problem in studies where cumulative exposure is estimated is that age will naturally be incorporated in the exposure assessment, possibly confounding the results. In our data there was a strong correlation between calculated cumulative noise exposure and age, which is illustrated in figure 2B. It is therefore difficult to distinguish between effects of age and noise exposure dose, which would be the case independently of how the index was constructed as an accumulated exposure dose would naturally always correlate to increased age. As such, the possible confounding effect of age could not be properly adjusted for in the statistical model for the association between noise exposure and hearing-related outcomes. When both were included in the logistic regression model neither noise nor age showed a statistically significant effect on any of the hearing-related outcomes. Interestingly though, we could show that the noise exposure index was significantly associated to the hearing-related outcomes tinnitus and sound fatigue, while this was not the case for age alone as a predictor in a separate bi-variable model. Pathological changes in the inner ear resulting in hearing loss as an effect of age alone is debated in the research community.[39] Results are even less solid when considering age as a sole cause of tinnitus.[40] Instead, the effect of noise exposure is hypothesised to largely contribute to the increased prevalence of hearing-related disorder seen in increased age.[30 39 40]

1
2
3 Finally, being an initial study in this area we were not able to include a large study sample,
4
5 which affects the reliability of the analyses and the generalisation of the results. Also, though
6
7 the cross-sectional design prevents drawing definite conclusions on causal relationships, we
8
9 argue based on previous research and our study results that it is reasonable to assume a causal
10
11 pathway from noise exposure to hearing-related symptoms; the hypothesised casual pathway
12
13 involving stress and noise annoyance however, being less certain.
14
15

16 17 18 **CONCLUSION** 19

20
21 This study presents new results regarding risk of noise-induced hearing-related symptoms
22
23 among obstetrics personnel, which to the best of our knowledge has not been described
24
25 before. The results show that obstetrics personnel are at times exposed to sound levels above
26
27 regulated limits and that more than half of the participants report one or more hearing-related
28
29 symptom. Furthermore, a statistically significant association was found between cumulative
30
31 occupational noise exposure and the hearing-related symptom tinnitus and sound fatigue.
32
33 Noise annoyance was a common complaint and in addition to noise exposure also an
34
35 important factor for sound fatigue. These results indicate that preventative action regarding
36
37 noise exposure is required in obstetrics care and that risk-assessments may be needed in
38
39 previously unstudied non-industrial communication-intense sound environments.
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Acknowledgments

The authors would like to thank Lars Larsson for performing the dosimeter measurements, Christofer Andersson for assistance with the web-survey and Agneta Agge for survey data entry, as well as all the participating personnel at the obstetrics care unit at the Sahlgrenska University hospital.

Footnotes

Contributors All authors contributed to this work. KPW and KT obtained funding. KPW, SF and AT contributed to the study concept and design. SF collected the data with help from KPW. OH, SF, KPW and KT designed the plan of analysis. SF performed the final analyses. SF, KPW, OH and KT drafted the manuscript and interpreted the results. SF, KPW, OH, KT, AT made substantive editorial contributions at all stages of manuscript preparation.

Funding This study was funded by grants from the Swedish research council for Health, Working Life and Welfare (Forte) as well as the Swedish funder AFA insurance. The researchers are independent from funders.

Competing interests All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval The study was approved by the ethics committee in Gothenburg Sweden, Nr 788-11.

Provenance and peer review Not commissioned; externally peer reviewed

Data sharing statements No additional data are available

This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 3.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial.

See: <http://creativecommons.org/licenses/by-nc/3.0/>

References

1. Nelson DI, Nelson RY, Concha-Barrientos M, Fingerhut M. The global burden of occupational noise-induced hearing loss. *American Journal of Industrial Medicine* 2005;**48**(6):446-58 doi: 10.1002/ajim.20223.
2. European Agency for Safety and Health at Work. *Risks and Trends in the Safety and Health of Women at Work*, 2012.
3. Axelsson A, Hamernik RP. Acute acoustic trauma. *Acta Oto-laryngologica* 1987;**104**(3-4):225-33 doi: doi:10.3109/00016488709107322.
4. Henry JA, Dennis KC, Schechter MA. General Review of Tinnitus: Prevalence, Mechanisms, Effects, and Management. *Journal of Speech Language and Hearing Research* 2005;**48**(5):1204-35 doi: 10.1044/1092-4388(2005/084).
5. Kähäri K, Zachau G, Eklöf M, Sandsjö L, Möller C. Assessment of hearing and hearing disorders in rock/jazz musicians: Evaluación de la audición y de los problemas auditivos en músicos de rock y jazz. *International Journal of Audiology* 2003;**42**(5):279-88 doi: doi:10.3109/14992020309078347.
6. Palmer K, Griffin M, Syddall H, Davis A, Pannett B, Coggon D. Occupational exposure to noise and the attributable burden of hearing difficulties in Great Britain. *Occupational and Environmental Medicine* 2002;**59**(9):634-39
7. Persson Wayne K, Kähäri K. Consequences on hearing when working in a communication intense environment with high noise levels. *International Journal of Audiology* (For submission)

- 1
2
3 8. Kjellberg A. Subjective, behavioral and psychophysiological effects of noise. *Scandinavian*
4 *journal of work, environment & health* 1990;29-38
5
6
- 7 9. Busch-Vishniac IJ, West JE, Barnhill C, Hunter T, Orellana D, Chivukula R. Noise levels
8 in Johns Hopkins hospital. *The Journal of the Acoustical Society of America*
9 2005;**118**:3629
10
11
- 12 10. Vinodhkumaradithyaa A, Kumar D, Ananthalakshmi I, et al. Noise levels in a tertiary care
13 hospital. *Noise and Health* 2008;**10**(38):11-13 doi: 10.4103/1463-1741.39003.
14
15
- 16 11. Hildingsson I, Westlund K, Wiklund I. Burnout in Swedish midwives. *Sexual &*
17 *Reproductive Healthcare* 2013;**4**:87-91
18
19
- 20 12. Hultberg A, Hadžibajramović E, Pettersson S, Skagert K, Ahlberg G. KART-studien.
21 *Arbetsmiljö, stress och hälsa bland anställda vid Västra Götalandsregionen. Delrapport 5:*
22 *Uppföljning utifrån organisations-, yrkesgrupps- och individperspektiv 2008 - 2010. In:*
23 *Ahlberg G, ed.: Institute of Stress Medicine, 2011. [In Swedish]*
24
25
- 26 13. Babisch W. The noise/stress concept, risk assessment and research needs. *Noise and*
27 *Health* 2002;**4**(16):1-11
28
29
- 30 14. Leather P, Beale D, Sullivan L. Noise, psychosocial stress and their interaction in the
31 workplace. *Journal of Environmental Psychology* 2003;**23**(2):213-22
32
33
- 34 15. Lercher P, Hörtnagl J, Kofler WW. Work noise annoyance and blood pressure: combined
35 effects with stressful working conditions. *International archives of occupational and*
36 *environmental health* 1993;**65**(1):23-28
37
38
- 39 16. Being in a pre-school sound environment – annoyance and subjective symptoms among
40 personnel and children. *Internoise*; 2010 13-16 June; Lisbon, Portugal.
41
42
- 43 17. Neitzel R, Daniell W, Sheppard L, Davies H, Seixas N. Comparison of Perceived and
44 Quantitative Measures of Occupational Noise Exposure. *Annals of Occupational Hygiene*
45 2009;**53**(1):41-54 doi: 10.1093/annhyg/men071.
46
47
- 48 18. Nondahl DM, Cruickshanks KJ, Wiley TL, Tweed TS, Klein R, Klein BEK. Accuracy of
49 Self-reported Hearing Loss. *International Journal of Audiology* 1998;**37**(5):295-301 doi:
50 doi:10.3109/00206099809072983.
51
52
53
54
55
56
57
58
59
60

- 1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
19. Schlaefer K, Schlehofer B, Schüz J. Validity of self-reported occupational noise exposure. *Occupational and Environmental Medicine* 2011;**68**(Suppl 1):A42 doi: 10.1136/oemed-2011-100382.137.
 20. Sindhusake D, Mitchell P, Smith W, et al. Validation of self-reported hearing loss. The Blue Mountains hearing study. *International Journal of Epidemiology* 2001;**30**(6):1371-78
 21. Ryberg JB, Agge A, Wayne KP. Low frequency noise in a paper mill control room. *Journal of low frequency noise, vibration and active control* 2007;**26**(3):165-76
 22. Axelsson A, Prasher D. Tinnitus induced by occupational and leisure noise. *Noise and Health* 2000;**2**(8):47
 23. Nouvian R, Eybalin M, Puel J-L. The coclea and the Auditory Nerve as a Primary Source of Tinnitus. In: Eggermont JJ, Zeng F-G, Popper AN, eds. *Tinnitus*. New York: Springer Science and Business Media, 2012.
 24. Schmidt CO, Kohlmann T. When to use the odds ratio or the relative risk? *International journal of public health* 2008;**53**(3):165-67
 25. Tenenbaum A, Hendriksson A, Larsson L. Bullernivåer och hörselundersökning på förlossningsavdelning. *Läkarstämman*. Stockholm, Sweden, 2010. [In Swedish]
 26. Danermark B, Hanning M. Hearing and vision: Health in Sweden: The National Public Health Report 2012. Chapter 17. *Scandinavian Journal of Public Health* 2012;**40**(9 suppl):287-92 doi: 10.1177/1403494812459621.
 27. Andersson G, Lindvall N, Hursti T, Carlbring P. Hypersensitivity to sound (hyperacusis): a prevalence study conducted via the internet and post. *International Journal of Audiology* 2002;**41**(8):545-54 doi: 10.3109/14992020209056075.
 28. Kujawa SG, Liberman MC. Adding insult to injury: cochlear nerve degeneration after “temporary” noise-induced hearing loss. *The Journal of Neuroscience* 2009;**29**(45):14077-85

- 1
2
3 29. Lin HW, Furman AC, Kujawa SG, Liberman MC. Primary neural degeneration in the
4 Guinea pig cochlea after reversible noise-induced threshold shift. *Journal of the*
5 *Association for Research in Otolaryngology* 2011;**12**(5):605-16
6
7
8
9 30. Kujawa SG, Liberman MC. Acceleration of age-related hearing loss by early noise
10 exposure: evidence of a misspent youth. *The Journal of Neuroscience* 2006;**26**(7):2115-
11 23
12
13
14 31. Ruggles D, Bharadwaj H, Shinn-Cunningham BG. Normal hearing is not enough to
15 guarantee robust encoding of suprathreshold features important in everyday
16 communication. *Proceedings of the National Academy of Sciences* 2011;**108**(37):15516-
17 21
18
19
20
21
22 32. Heinonen-Guzejev M, Koskenvuo M, Silventoinen K, et al. Noise Sensitivity and
23 Disability Retirement: A Longitudinal Twin Study. *Journal of Occupational and*
24 *Environmental Medicine* 2013;**55**(4):365-70
25
26
27
28 33. Alpini D, Cesarani A. Tinnitus as an alarm bell: stress reaction tinnitus model. *ORL*
29 2006;**68**(1):31-37
30
31
32
33 34. Hébert S, Lupien SJ. The sound of stress: blunted cortisol reactivity to psychosocial stress
34 in tinnitus sufferers. *Neuroscience letters* 2007;**411**(2):138-42
35
36
37 35. Holgers K-M, Erlandsson SI, Barrenäs M-L. Predictive Factors for the Severity of
38 Tinnitus: Factores predictivos de la severidad del tinnitus. *International Journal of*
39 *Audiology* 2000;**39**(5):284-91
40
41
42
43 36. Robinson SK, Viirre ES, Stein MB. Antidepressant therapy in tinnitus. *Hearing research*
44 2007;**226**(1):221-31
45
46
47 37. Davies HW, Teschke K, Kennedy SM, Hodgson MR, Hertzman C, Demers PA.
48 Occupational exposure to noise and mortality from acute myocardial infarction.
49 *Epidemiology* 2005;**16**(1):25-32
50
51
52
53 38. Nilsson T, Burström L, Hagberg M. Risk assessment of vibration exposure and white
54 fingers among platers. *International archives of occupational and environmental health*
55 1989;**61**(7):473-81
56
57
58
59
60

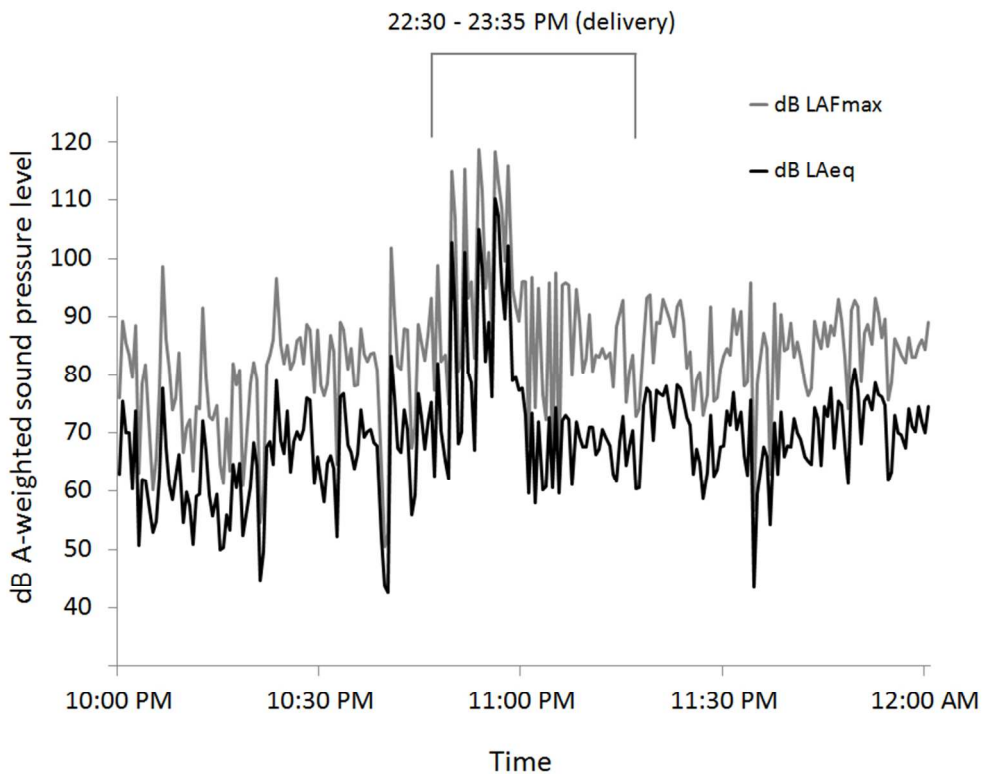
- 1
2
3 39. Van Eyken E, Van Camp G, Van Laer L. The complexity of age-related hearing
4 impairment: contributing environmental and genetic factors. *Audiology and Neurotology*
5 2007;**12**(6):345-58
6
7
8
9 40. Sanchez L. The epidemiology of tinnitus. *Audiological Medicine* 2004;**2**(1):8-17
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

FIGURE LEGENDS

Figure 1. Two hour section of a time history graph from sound level measurement with dosimeter carried by a midwife during a sample night shift in the obstetrics ward. Equivalent sound level during the entire shift was 85 dB LAeq_(approx. 9 hours) and 118.7 dB LAFmax was the highest recorded during the shift (shown in the selected section). According to the written log the midwife attended a delivery during 10:30 – 23:05 PM. Black curve shows the dB LAeq and grey curve shows dB LAFmax.

Figure 2. Calculated occupational noise index for obstetrics personnel. To the right in figure 2 A, contribution of number of years worked in obstetrics (in black) to the noise index for each participant, each bar representing one participant. The percentages of participants are shown on the x-axis and the calculated noise index value on the y-axis. To the left in figure 2 B, the correlation between noise index and age of participants.

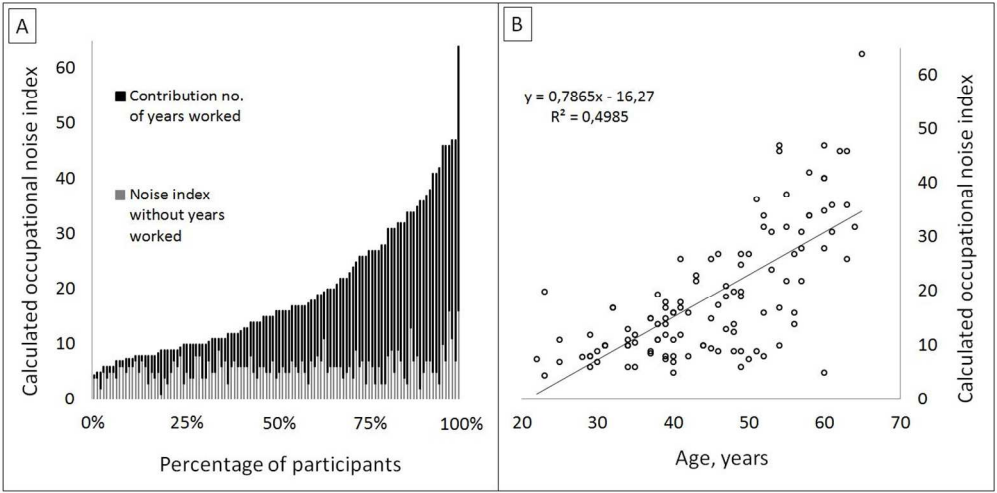


Two hour section of a time history graph from sound level measurement with dosimeter carried by a midwife during a sample night shift in the obstetrics ward. Equivalent sound level during the entire shift was 85 dB LAeq(approx. 9 hours) and 118.7 dB LAFmax was the highest recorded during the shift (shown in the selected section). According to the written log the midwife attended a delivery during 10:30 – 23:05 PM. Black curve shows the dB LAeq and grey curve shows dB LAFmax.
244x206mm (96 x 96 DPI)

only

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60



Calculated occupational noise index for obstetrics personnel. To the right in figure 2 A, contribution of number of years worked in obstetrics (in black) to the noise index for each participant, each bar representing one participant. The percentages of participants are shown on the x-axis and the calculated noise index value on the y-axis. To the left in figure 2 B, the correlation between noise index and age of participants.

372x186mm (96 x 96 DPI)

Review only

Supplementary table 1 Calculation of occupational noise index for obstetrics personnel based on questionnaire data, where scoring for each item and each response alternative is shown.

Questionnaire item in full text	Response alternatives	Scoring for index
How many years have you worked in an obstetrics ward?	Free field answer	1 point per year ^a
Have you worked with the so called ABC-method (Alternative Birth Care), if so for how many years?	Free field answer	1 point per year ^b
How many working hours do you normally spend in postpartum care and in delivery care, respectively?	Free field answer	0 points 1 point 2 points ^c
Is the sound level at your workplace sometimes so loud that you have difficulty hearing what other people are saying?	Never/almost never	0 points
	25% of time	1 point
	50% of time	2 points
	75% of time	3 points
How often are you at your workplace exposed to such high sound levels that you have to raise your voice to be able to talk to other people?	Always/almost always	4 points
	Never/almost never	0 points
	25% of time	1 point
	50% of time	2 points
Do you use hearing protective devices (such as ear-plugs) at your current workplace?	75% of time	3 points
	Always/almost always	4 points
	Never/almost never	3 points
	Seldom	2 points
	Often	1 point
	Always/almost always	0 points

^a Missing data was replaced by number of years since graduating, n=6. One additional participant did not fill in number of years worked, nor years since graduating and therefore got 14.6 points which was the group median at that specific age (46 years old).

^b Missing data was replaced by group median (3 years), n=3.

^c Participants reporting 0 hours in delivery care received 0 points, those reporting any number of hours in postpartum care and delivery care received 1 point and those reporting 1 hour or more in delivery care only received 3 points.

Supplementary table 2 Questionnaire items and response alternatives used in survey among obstetrics care personnel. Derived variables used in the analysis are also shown based on the questionnaire items (translation from Swedish for article, not validated).

Hearing-related outcome variables	Response alternatives	Derived variables
Hearing loss Do you have a hearing loss?	Yes No Don't know	Hearing loss was defined as reporting yes.
Tinnitus, Sound sensitivity and Sound fatigue^a Do you during or after work experience any of the following symptoms: - Tinnitus? - Sound sensitivity? - Sound fatigue?	Never/rarely A few times each month Once or twice a week Several times each week Every day	Having either symptom was defined as reporting once a week or more often.
Poor hearing How do you think your hearing is?	Very good Good Normal Bad Very bad	Poor hearing was defined as reporting bad or very bad hearing.
Difficulty perceiving speech Do you have trouble hearing what is said in an environment where several people are talking at the same time - At work? - In leisure time?	Yes No	Difficulty perceiving speech was defined as reporting yes to both work and leisure time.
Explanatory variables	Response alternatives	Derived variables
Work-related stress How is your work typically? - I experience high degree of stress. - I feel unwell due to stress at work.	Never/seldom Sometimes Often Always/almost always	Work-related stress was defined as reporting often or always/almost always for one or both of the stress items.
Noise annoyance Are you annoyed by sounds/noise at your work place?	Not at all Some Pretty much Very Extremely	Noise annoyance was defined as reporting if pretty much, very or extreme annoyance.
Smoking Do you smoke?	Yes Yes, but only occasionally No, but I have smoked previously for ___ years No	Ever smokers were defined as those reporting yes, yes occasionally or previously smoked.
Leisure time noise exposure Are you exposed to high sound levels during leisure time (e.g. shooting/hunting, playing in a band, concert/disco, driving motorcycle, working with noisy tools/machines)?	No Yes, every day Yes, a few times each week Yes, once or twice each week Yes, a few times each month Yes, once or twice a month Yes, a few times each year or less often/never	Leisure time exposure was defined as those reporting exposure once a month or more often.

^a The items regarding the symptoms tinnitus, sound sensitivity and sound fatigue were included in a matrix with other symptoms such as headache and tiredness.

BMJ Open

The effect of occupational noise exposure on tinnitus and sound induced auditory fatigue among obstetrics personnel: a cross-sectional study

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2014-005793.R1
Article Type:	Research
Date Submitted by the Author:	03-Oct-2014
Complete List of Authors:	Fredriksson, Sofie; University of Gothenburg, Public Health and Community Medicine Hammar, Oscar; University of Gothenburg, Public Health and Community Medicine Torén, Kjell; University of Gothenburg, Public Health and Community Medicine Tenenbaum, Artur; Occupational health care unit, Skaraborg Hospital Persson Waye, Kerstin; University of Gothenburg, Public Health and Community Medicine
Primary Subject Heading:	Occupational and environmental medicine
Secondary Subject Heading:	Ear, nose and throat/otolaryngology, Obstetrics and gynaecology
Keywords:	OCCUPATIONAL & INDUSTRIAL MEDICINE, Audiology < OTOLARYNGOLOGY, OBSTETRICS

SCHOLARONE™
Manuscripts

only

1
2
3 **The effect of occupational noise exposure on tinnitus and sound induced**
4 **auditory fatigue among obstetrics personnel: a cross-sectional study**
5
6
7
8
9

10 **Authors' names**

11 Sofie Fredriksson (SF), Oscar Hammar (OH), Kjell Torén (KT), Artur Tenenbaum (AT),
12
13 Kerstin Persson Waye (KPW)
14

15
16
17
18
19 **Corresponding author:**

20 Sofie Fredriksson

21 University of Gothenburg

22 Dept. of Public health & Community Medicine

23 Occupational and Environmental Medicine

24 PO Box 414, SE 405 30 Gothenburg, Sweden

25 sofie.fredriksson@gu.se

26 +46317863610 (telephone), +4631409728 (fax)
27
28
29
30
31
32
33
34
35
36
37
38

39 **Address for co-authors:**

40 Oscar Hammar (1), Kjell Torén (1), Artur Tenenbaum (2), Kerstin Persson Waye (1)

- 41
42
43 1) Department of Public Health and Community Medicine, Occupational and
44 Environmental Medicine, University of Gothenburg, S-405 30 Gothenburg
45
46 2) Occupational health care unit (Hälsan & Arbetslivet), Skaraborg Hospital, S-541 85
47 Skövde, Sweden
48
49
50
51
52
53
54

55 **Keywords:** Noise, occupational; stress; hearing disorders; cross-sectional studies; obstetrics

56 **Word count** (excluding title page, abstract, references, figures and tables): 4582
57
58
59
60

ABSTRACT

Objective: There is a lack of research on effects of occupational noise exposure in traditionally female-dominated workplaces. Therefore, the aim was to assess risk of noise-induced hearing-related symptoms among obstetrics personnel.

Design: A cross-sectional study at an obstetric ward in Sweden including a questionnaire among all employees and sound level measurements in 61 work-shifts at the same ward.

Participants: 115 female employees responded to a questionnaire (72% of all 160 employees invited).

Main outcome measures: Self-reported hearing-related symptoms, noise annoyance, work-related stress, calculated cumulative occupational noise exposure and measured sound levels.

Results: Sound levels exceeded the 80 dB LAeq limit for protection of hearing in 46% of the measured work-shifts. One or more hearing-related symptom was reported by 55% of the personnel. In logistic regression models a significant association was found between cumulative occupational noise exposure and tinnitus (Odds Ratio 1.04, 95% confidence interval 1.00 to 1.09) and sound induced auditory fatigue (Odds Ratio 1.04, 95% confidence interval 1.00 to 1.07). Work-related stress and noise annoyance were reported by almost half of the personnel group. Sound induced auditory fatigue was associated to work-related stress and noise annoyance, although stress just missed significance in a multivariable model. No significant interactions were found.

Conclusion: This study presents new results showing that obstetrics personnel are at risk of noise-induced hearing-related symptoms. Current exposure levels at the work-place are high and cumulative exposure has significant effects on tinnitus and sound induced auditory fatigue among the personnel. These results indicate that preventative action regarding noise exposure is required in obstetrics care and that risk-assessments may be needed in previously unstudied non-industrial communication-intensive sound environments.

Strengths and limitations of this study:

- The vast majority of previous research into noise-induced hearing disorders has been performed in industrial-like settings, whereas practically nothing is known of risks in non-industrial, traditionally female-dominated and communication-intense workplaces, such as hospitals. As such, this study presents novel results on occupational noise exposure and hearing among obstetrics personnel.
- Both objective sound level measurements and analysis of subjective data indicate an increased risk of hearing-related disorder.
- Due to the cross-sectional design the influence of subjects' age cannot be disentangled.
- The study sample size and the cross-sectional design without an unexposed control group limits the generalisation of the results and prevents us from drawing definite conclusions on causality.
- Further studies are needed to confirm the results and assess the magnitude of the problem. However, we suggest that occupational health care services implement available preventative actions such as making hearing protective devices available for personnel as an action of precaution.

INTRODUCTION

Occupational noise exposure and effects on hearing is well described in industrial-like, traditionally male-dominated settings.[1] In contrast, few studies have reported on traditionally female-dominated work environments. This has been acknowledged by the European Agency for Safety and Health at Work, who conclude that areas such as health and social services are largely overlooked concerning noise research,[2] and that the noise in these types of workplaces may interfere with performance and wellbeing. High sound levels regardless of its source can cause hearing loss, tinnitus and sound sensitivity and may also result in sound induced auditory fatigue, the latter described by subjects as avoidance of everyday sounds and a need for silence.[1 3-7] The symptom sound induced auditory fatigue was first identified in pilot studies, interviewing preschool personnel, and have later shown to prevalent in questionnaire surveys [7]. We hypothesise the symptom to be a result of constant or overloading stimulation of sounds during the day. The effect may possibly be due to the high information content mainly of speech, such that overload is not merely a consequence of the sound energy as seen in auditory threshold shift, but as a result of an information intense sound environment. Apart from hearing-related symptoms, noise exposure can also evoke non-auditory effects such as annoyance and stress.[8] According to a recent meta-analysis, noise levels in hospitals have steadily increased since the mid-1960.[9] One heavily female-dominated workplace in the hospital is the obstetrics care. According to data from Statistics Sweden in 2011, more than 99% of midwives are women. One peer-reviewed study have reported on sound level measurements from obstetrics care in a hospital in India, where the highest night time level (71.9 dB LAeq) was measured in the obstetrics and gynaecology ward, with slightly lower levels in the labour ward.[10]

In addition to potentially harmful noise levels in the obstetrics care, midwives report a high degree of work-related stress and burnout,[11] and according to a recent report burnout

1
2
3 syndrome have doubled among midwives employed in the western region of Sweden during
4 the last years.[12] The fact that obstetrics personnel are exposed to high levels of stress may
5 be important when considering noise exposure at the workplace, since the combination of
6 these exposures may interact in causing adverse health effects.[13-15]
7
8

9
10
11 There is a substantial lack of knowledge regarding occupational noise exposure, noise
12 annoyance and hearing-related symptoms among obstetrics care personnel, as well as possible
13 interaction effects between noise exposure, noise annoyance and work-related stress.
14
15

16
17 Therefore, the aim of this study was to assess the risk of noise-induced hearing-related
18 symptoms among obstetrics personnel by measuring sound levels in the labour ward of a
19 general obstetrics ward and by analysing the effect of and interaction between occupational
20 noise exposure, noise annoyance and work-related stress on hearing-related symptoms among
21 obstetrics personnel.
22
23
24
25
26
27
28
29
30
31

32 **METHODS**

33 **Sound level measurements**

34
35 Sound level measurements were carried out during 61 work shifts in the labour ward of a
36 general obstetrics ward at the Sahlgrenska University Hospital in Gothenburg. Out of the 61
37 shifts 19 day shifts were measured between 7 a.m. and 3:30 p.m. (8.5 h), 12 evening shifts
38 between 1:45 p.m. and 9 p.m. (7.25 h) and 30 nightshifts between 9 p.m. and 7 a.m. (10 h).
39
40 The day and evening shifts were measured during separate weeks so as not to overlap. A
41 convenient sample of ten employees per shift each wore a personal dosimeter (Larson Davis
42 705+) with the microphone attached to the right shoulder and kept a written log documenting
43 work activities during the measured shift. A total of 610 separate measurements were
44 collected, as 10 individuals each wore a dosimeter during the 61 shifts measured. However,
45 due to technical errors a few faulty measurements were excluded leaving 529 (87%) to be
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 included in the analysis. The dosimeters were set to measure A-weighted equivalent and
4
5 maximum (fast) levels with a sampling interval of 30 seconds. All dosimeters were calibrated
6
7 using the software Blaze version 5.06 before measurements begun. The equivalent levels
8
9 reported refer to the full-shift length and will hence vary between 7.25 – 10 hours, hereinafter
10
11 denoted as LAeq(7-10h). Sound levels were analysed at group level as arithmetic mean and
12
13 compared to Swedish Work Authorities' exposure regulations. Sound levels exceeding the
14
15 lower action level of 80 dB LAeq(8h) indicate a risk for hearing damage and the employer is
16
17 responsible to take preventative action, such as providing employees with hearing protection
18
19 devices (HPDs). The exposure limits 85 dB LAeq (8h) and 115 dB LAFmax are set as a
20
21 maximum allowed level above which the employer is required to take measures in order to
22
23 reduce the noise exposure, and where use of HPDs are mandatory. Employees must not be
24
25 exposed to noise levels at or above the exposure limits (taking attenuation of HPDs into
26
27 account).
28
29
30
31
32
33

34 **Questionnaire survey**

35
36 All personnel (n=160, all women), employed at the general obstetrics ward were included in a
37
38 questionnaire survey. A total of 115 (72%) participated by responding either electronically
39
40 (n=63) or in paper format (n=52) and these data were pooled together, as no statistical
41
42 differences were seen on explanatory or outcome variables (p>0.05). The questionnaire was
43
44 constructed using items specifically constructed for this study as well as items adapted from
45
46 previous studies and international standards (ISO/TS 15666).[7 16] Similar self-reported
47
48 items assessing noise exposure as well as hearing loss and tinnitus have previously been
49
50 subject for validation.[17-20]
51
52

53
54 The main explanatory variable cumulative occupational noise exposure dose, was calculated
55
56 as an exposure index derived from six questionnaire items including; number of years worked
57
58
59
60

1
2
3 in delivery care, number of years worked in alternative birth care, work allocation (delivery
4 care, postpartum care or both), two separate items on frequency of current work-related noise
5 exposure (one assessing how often the sound levels are so high that the person has to speak
6 with raised voice and one assessing how often the person have trouble hearing what is said)
7 and finally one item on frequency of hearing protection use. A higher noise index indicates a
8 higher noise exposure dose. The scoring for each items contribution to the index is presented
9 in detail in supplementary table 1. Each variable score was summed using mathematical
10 addition to a total index score for each participant. In addition, the study group was
11 categorized into four noise index groups based on calculation of quartiles, with each noise
12 index category representing 25% of the study population. Work-related stress and noise
13 annoyance were analysed as additional explanatory variables. Work-related stress was
14 assessed using two separate questionnaire items asking responders to report how often they
15 experience high degree of stress and how often they feel unwell due to stress at work.
16
17 Participants were defined as having work-related stress if answering often or always/almost
18 always on one or both of the items. These stress-related items have previously been used in
19 noise-related research.[21] Noise annoyance was assessed by the item ‘Are you annoyed by
20 sounds/noise at your workplace?’, which is based on the International standard ISO/TS
21 15666, adapted for a workplace survey as opposed to community surveys. The hearing-related
22 outcome variables included are hearing loss (yes), tinnitus, sound sensitivity (i.e. hyperacusis)
23 and sound induced auditory fatigue (i.e. a need for silence) (a few times each week or more
24 often), general hearing status (poor or very poor) and difficulty perceiving speech (yes both at
25 work and in leisure time). Variables considered as possible moderators for the association
26 between exposure and outcome were smoking (previous or current) and leisure-time noise
27 exposure (once a month or more often). Age (in years) was considered a possible confounder.
28
29 The questionnaire items are presented in full in the supplementary table 2.
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Statistical analyses

Hypothesis testing was performed using IBM SPSS Statistics 20. Differences in arithmetic mean were analysed using one-way analysis of variance (ANOVA) or independent samples t-test where applicable. Test for trend was analysed using Linear regression with dummy coding for categorical predictors or Mantel-Haentzel linear-by-linear association where applicable. Binary logistic regression with Wald tests was used for analysis of associations and interaction. The significance level was set at 5% ($p= 0.05$) for all tests. Based on a hypothesised order of importance of explanatory variables, manual sequential regression models were analysed. For each binary hearing-related outcome variable we used the following model testing procedure. In a first model, noise exposure index was analysed as a single continuous explanatory variable with the hearing-related symptom as a binary outcome variable. If noise exposure index was significant for the hearing-related symptom, then a second model was analysed, adjusting for moderators (leisure noise exposure and smoking), each one at a time. Age as a possible confounder was analysed separately due to initial hypothesised strong correlation to the noise index (due to its cumulative nature). If point estimates for noise index was comparable with and without adjustment and the adjustment variable itself was non-significant, then it was not included in subsequent multivariable models. In the third model, work-related stress was analysed as an additional explanatory variable and in a fourth model noise annoyance instead of stress was included together with significant explanatory variables from model 2. The fifth model included explanatory variables found to be significant in any of the previous steps. Hypothesised interactions between explanatory variables were assessed in separate models by including an interaction term. Multi-collinearity between explanatory variables was assessed using Pearson's correlation or Spearman's rank correlation, where applicable, and correlation below $r=0.6$ was deemed acceptable. Odds ratios (OR) with 95% confidence intervals were derived from the

1
2
3 logistic regressions as a measure of association between exposure and outcome, and relative
4 risk (RR) was calculated from predictive values derived from model 1. Goodness of fit for the
5 regression models were assessed using the Hosmer-Lemeshow test and a non-significant p-
6 value (>0.05) was used to indicate adequate fit.
7
8
9
10

11 12 13 **RESULTS**

14 **Sound levels in the labour ward**

15
16 Overall, the dosimeter measurements from the labour ward showed moderately high sound
17 levels, as presented in table 1. The levels reached or exceeded both the action and limit levels.
18
19 The lower action level 80 dB LAeq was exceeded in 30 different dosimeter measurements
20 during 28 different work shifts, which corresponds to 46% of all measured shifts or 6% of all
21 dosimeter measurements. The upper exposure action level and exposure limit 85 dB LAeq
22 was reached or exceeded in three measurements from three different shifts, corresponding to
23 5% of all measured shifts or 0.6% of all measurements. The limit 115 dB LAFmax was
24 reached or exceeded at 50 different occasions. However, of these 9 separate events could not
25 be verified by the written logs and were therefore excluded. The remaining 41 events occurred
26 in 17 different shifts corresponding to 28% of all measured shifts or 8% of all dosimeter
27 measurements. There were no statistical differences in arithmetic mean equivalent nor in
28 maximum levels when comparing measurements from different work-shifts nor measurements
29 from dosimeters worn by midwives compared to assistant nurses. Due to incomplete written
30 logs however, we were unable to categorise a third of the measurements into professional
31 group. A segment sample from a dosimeter measurement is shown in figure 1, where high
32 maximum levels (119 dB LAFmax) was recorded during a delivery, which according to the
33 written log occurred between 10:30 and 11:05 pm. The equivalent level in this particular
34 measurement was 84 dB LAeq(10h) for the measured shift length. As exposure limits should be
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

regarded with HPDs taken into account, it is noteworthy that the majority of the respondents (92%) reported to never or almost never use hearing protective devices at work.

FIGURE 1

Table 1. Sound level measurements at the labour ward showing arithmetic mean, standard deviation (SD), 95% confidence interval confidence interval (CI) of mean and range of the measured equivalent, LAeq(7-10h) and maximum, LAFmax sound levels in dB. Also showing mean and standard deviation of measurements categorised by work shift and by professional group as reported in written logs by the personnel carrying the dosimeter. Frequencies (n) in the table represent unique dosimeter measurements.

	Sound level measurements		
	dB LAeq(7-10h)	dB LAFmax	n
All measurements			
Arithmetic mean (SD)	70.3 (6.0)	106.3 (6.0)	529
95% CI of mean	69.7 - 70.8	105.8 - 106.8	
Min – Max	56.0 – 87.0	83.0 – 122.0	
Measurements categorised by work shift (arithmetic mean, SD) ^a			
Day shift	70.8 (6.2)	106.2 (5.9)	139
Evening shift	70.8 (5.2)	106.3 (5.6)	127
Night shift	69.8 (6.3)	106.4 (6.2)	263
Measurements categorised by professional group (arithmetic mean, SD)			
Midwives	71.3 (5.1)	106.2 (5.9)	289
Assistant nurses	72.2 (5.0)	107.8 (5.2)	114
Uncategorised	66.2 (7.0)	103.9 (6.5)	126

^a Number of shifts categories as day (n=19), evening (n=12) and night (n=30).

Association between noise exposure and hearing disorder

Demographics, occurrence of explanatory variables; work-related stress, noise annoyance and adjustment variables; smoking and leisure noise exposure as well as prevalence of hearing-related outcomes are presented in table 2, both for the total study sample as well as categorised into four noise exposure index groups calculated from quartiles of the noise index. The first noise index group (1) represents the respondents with the lowest calculated noise exposure dose. Valid responses for the individual questionnaire items included in the analysis ranged from n=108 to 115. A test for trend in the four exposure groups shows that age, number of years worked in obstetrics and prevalence of sound induced auditory fatigue is significantly increasing with higher noise exposure group; $p<0.001$, $p<0.001$ and $p=0.049$ respectively.

Table 2. Demographics, explanatory and adjustment variables and hearing-related outcomes from questionnaire survey among personnel at the general obstetrics ward. Prevalence is presented categorised in four noise index groups based on quartiles of the index (1 – 4) and as total prevalence in the study sample. Percentages are given as column % in noise index quartile groups and % of total.

	Grouping by noise index quartiles				Total	95% CI of total
	1	2	3	4		
Number of participants	28	29	29	29	115	-
Noise exposure index (range)	4.5 – 9.5	10 – 15	16 – 26	27 – 64	4.5 - 64	16.8 - 21.2
Demographics						
Mean age in years (SD)	39 (10)	39 (7)	45 (8)	57 (5)	45 (11)	42.8 - 46.8
Mean years worked (SD)	3 (2)	6 (2)	14 (3)	28 (6)	12 (11)	10.3 - 14.3
Professional groups, % ^a	54/36/11	69/24/7	69/21/10	76/21/3	68/25/7	-
Explanatory and adjustment variables (%)						
Work-related stress	43	52	31	41	42	32.9-51.1
Noise annoyance at work	50	45	55	45	49	39.8-58.2
Ever smoker	36	48	28	25	34	25.3-42.7
Leisure noise exposure	14	24	7	7	13	6.8-19.2
Outcome variables (%)						
Sound induced auditory fatigue	21	24	41	41	32	23.4-40.6
Tinnitus	7	11	10	24	13	6.8-19.2
Sound sensitivity	7	17	17	10	13	6.8-19.2
Poor hearing	11	21	17	14	16	9.3-22.7
Hearing loss	4	7	21	4	9	3.7-14.3
Difficulty perceiving speech	39	31	24	36	32	23.4-40.6
Any symptom ^b	54	48	55	63	55	45.9-64.1

^a Shown in table as proportion of Midwife/Assistant nurse/Other. Other also includes missing.

^b Any symptom was constructed as a binary variable including all those who reported either sound induced auditory fatigue, tinnitus, sound sensitivity, difficulty perceiving speech, poor hearing and/or hearing loss.

1
2
3 Associations between occupational noise exposure dose (continuous noise index), work-
4 related stress, noise annoyance and hearing-related symptoms were evaluated in manual
5 sequential binary logistic regression models, results of which are presented in table 3. The
6
7 calculated noise index ranged from 4.5 to 64 in the study sample. The proportional
8
9 contribution of years worked in obstetrics care to the index, as a proxy for cumulative
10
11 exposure, is shown in figure 2 A. The percentage of participants over the range of noise index
12
13 also conveys the skewness in the distribution of the index, e.g. less than 25% of the
14
15 participants have noise index values in the upper half of the range.
16
17
18
19
20
21
22
23

FIGURE 2

24
25
26
27 Occupational noise exposure as a single explanatory variable was significantly associated to
28
29 tinnitus and sound induced auditory fatigue, but not to the other hearing-related symptoms.
30
31 Work-related stress and noise annoyance were both significantly associated to sound induced
32
33 auditory fatigue in separate models, but not to tinnitus. For sound induced auditory fatigue,
34
35 including all three significant explanatory variables (noise, stress and annoyance) in model 5
36
37 resulted in marginal changes in point estimates for noise exposure and noise annoyance. It did
38
39 however affect the estimates for work-related stress, which just missed statistical significance
40
41 ($p=0.053$). No significant statistical interactions were found between explanatory variables.
42
43
44 Neither work-related stress nor noise annoyance were significantly correlated to noise
45
46 exposure index. There was however a weak yet significant correlation between stress and
47
48 noise annoyance ($r=0.249$, $p=0.008$). The point estimates for noise exposure was comparable
49
50 with or without adjustment for smoking and leisure-time noise exposure in model 2, and
51
52 neither one of the adjustment variables were themselves significant. Hence, they were not
53
54
55
56
57
58
59
60

1
2 included in the subsequent multivariable models. All reported models had an acceptable
3
4 goodness of fit.
5
6

7 As prevalence of sound induced auditory fatigue was much higher than 10%, assessing odds
8 ratios (OR) only may overestimate the risk. The calculated risk ratios (RR) for sound induced
9 auditory fatigue from model 1, in comparable 1 unit steps of the noise index, however showed
10 that the difference between OR and RR was minor (at the most 0.02 difference).
11
12

13 Due to the cumulative property of the noise index, the index was assumed to be correlated to
14 age, which was also confirmed in the analysis ($r=0.706$, $p<0.001$) with $R^2=0.498$, as shown in
15 figure 2 B. Multi-collinearity issues therefore precluded the assessment of both variables in
16 one regression model. Notably and importantly though, age was not significantly associated to
17 any of the hearing-related symptoms when assessed as a single explanatory variable in
18 separate regression models.
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 3. Point estimates of effect (B) and standard error (SE), odds ratios (OR), 95% confidence intervals of OR (95% CI) from binary logistic regression models for hearing-related symptom outcomes (binary dependent variables) among personnel in an obstetrics ward. All dependent variables were analysed in separate models. Manual sequential analysis was adopted, adding work-related stress and noise annoyance and adding an interaction term if the initial model was statistically significant ($p < 0.05$).

Dependent variables	Explanatory variables	B (SE)	OR (95% CI)	p-value
Sound induced auditory fatigue				
<i>Model 1</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.07)	0.031
<i>Model 3</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.08)	0.027
	Work-related stress	0.96 (0.42)	2.62 (1.15 – 5.98)	0.022
<i>Model 4</i>	Noise exposure index	0.04 (0.02)	1.04 (1.01 – 1.08)	0.026
	Noise annoyance	1.73 (0.47)	5.67 (2.25 – 14.27)	<0.001
<i>Model 5</i>	Noise exposure index	0.04 (0.02)	1.04 (1.01 – 1.08)	0.025
	Work-related stress	0.87 (0.45)	2.39 (0.99 – 5.79)	0.053
	Noise annoyance	1.66 (0.48)	5.25 (2.05 – 13.42)	0.001
Tinnitus				
<i>Model 1</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.09)	0.049
<i>Model 3</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.09)	0.046
	Work-related stress	-0.43 (0.60)	0.65 (0.20 – 2.10)	0.470
<i>Model 4</i>	Noise exposure index	0.04 (0.02)	1.05 (1.00 – 1.09)	0.038
	Noise annoyance	0.56 (0.58)	1.85 (0.56 – 5.46)	0.335
Sound sensitivity	Noise exposure index	0.01 (0.02)	1.03 (0.97 – 1.06)	0.570
Poor hearing	Noise exposure index	0.00 (0.02)	1.00 (0.96 – 1.04)	0.985
Hearing loss	Noise exposure index	0.00 (0.03)	1.00 (0.95 – 1.06)	0.995
Difficulty perceiving speech	Noise exposure index	0.01 (0.02)	1.01 (0.98 – 1.05)	0.461
Any symptom^a	Noise exposure index	0.02 (0.02)	1.02 (0.99 – 1.05)	0.273

^a Any symptom was constructed as a binary variable including all those who reported either sound induced auditory fatigue, tinnitus, sound sensitivity, difficulty perceiving speech, poor hearing and/or hearing loss.

DISCUSSION

The effect of noise exposure on hearing

In order to assess the effect of occupational noise exposure on hearing-related symptoms among obstetrics personnel, sound level measurements were carried out at the labour ward at a general obstetrics ward and associations between calculated occupational noise exposure dose and hearing-related symptoms were analysed in binary logistic regression models based on self-reported data from personnel at the same ward.

Prevalence of hearing-related symptoms among the personnel showed that tinnitus and sound induced auditory fatigue was most common among personnel with the highest exposure dose.

Accordingly, we were also able to detect statistically significant associations between occupational noise exposure and both tinnitus and sound induced auditory fatigue in logistic regression models. Sound induced auditory fatigue is a new concept that has previously been reported among preschool personnel and is hypothesised as a consequence of a constant noise load during the work day.[7 16] As for pre-school personnel, the obstetric personnel are mainly exposed to intermittent sounds from voices and screams, but also from alarms and medical equipment. It is possible that the demands and needs of attending to meaningful sounds with a high element of irregularity contribute to a mental fatigue that some individuals with sound induced auditory fatigue describe. As for sound induced auditory fatigue, we could also show a significant association between tinnitus and noise exposure. Although it is well established that noise may contribute to tinnitus,[4 22 23] it has to our knowledge not been reported previously among obstetrics personnel; hence this result is highly interesting as it supports the concerns that noise levels in non-industrial and previously less studied work environments, mainly female-dominated, may be harmful.[2] As the prevalence especially for sound induced auditory fatigue was high, it is important to note that odds ratios may not

1
2
3 directly be translated into a measure of relative risk.[24] We did however not detect major
4
5 divergences between the two measures.
6

7
8 In addition to increased risk of hearing-related symptoms of cumulative occupational noise
9
10 exposure, we also found high current sound level exposure in the labour ward, above
11
12 regulated limits. The sound level measurements further heighten the concern that obstetrics
13
14 personnel may risk acquiring hearing-related disorder as personnel carrying the dosimeters
15
16 were exposed to levels exceeding the lower action level of 80 dB LAeq during as much as
17
18 approximately half of the measured work shifts. While the average noise levels were in
19
20 accordance with an earlier study reporting noise levels from an obstetrics and labour ward at a
21
22 general hospital,[10] our study further showed that the exposure limit 115 dB LAFmax may
23
24 be exceeded in as much as one third of the work-shifts in a labour ward. The data is also in
25
26 accordance with results from a workplace inspection performed in 2010 by the occupational
27
28 health care unit at a small obstetrics ward in Sweden which showed that personnel were at
29
30 times exposed to sound levels above the regulated action and limit levels adopted by the
31
32 Swedish work environment authority.[25] This result is especially alarming as very few
33
34 personnel report use of hearing protection, which certainly may be impractical in this type of
35
36 work setting. Although caution is required in establishing the source of high maximum levels
37
38 recorded in unsupervised measurements the results are indeed important, since such high
39
40 sound levels have been described as mechanism in acquired hearing loss, tinnitus and sound
41
42 sensitivity.[3] These results highlight the need to initiate preventive action regarding noise
43
44 exposure in the obstetrics care, which include but is not limited to; information to all
45
46 employees, access to suitable hearing protection devices and cooperation between the
47
48 employer and an occupational health care unit for assessment of noise exposure and hearing-
49
50 related symptoms. Hearing tests and anamnesis regarding hearing-related symptoms may also
51
52 be considered for new employees.
53
54
55
56
57
58
59
60

1
2
3 No significant associations between noise exposure and the other hearing related symptoms
4 were detected in this study. This may be explained partly by the fact that hearing loss is
5 developed over a long period of time, usually becoming apparent after the age of retirement,
6 and that mild deterioration in hearing may not be easily detected via self-assessment. As the
7 study was cross-sectional, the fact that hearing loss was most prevalent in the third noise
8 exposure group lower prevalence in the highest exposure group may have influenced the
9 analysis. This in turn is possibly due to a healthy worker effect as individuals with hearing
10 loss may not be able to continue working in obstetrics care. Similarly but in the opposite
11 direction, as difficulty perceiving speech was reported by many young individuals, whom to a
12 larger extent was classified in the lowest noise index quartile, it may have influenced the
13 analysis of the effect of occupational noise exposure such that no significant effect was seen.
14 It is in any case alarming with such a high prevalence of difficulty perceiving speech.

15
16 Compared to prevalence data from the Swedish National Board of Health and Welfare from
17 2000-2005, using a similar survey item as in this study,[26] our data indicate higher age and
18 gender matched prevalence. Between the ages 25-64 years the prevalence in our sample
19 ranged from 26-35%, while the prevalence in the same age range among women in the
20 reference material was 5-15%. Sound sensitivity is less researched, but one previous study
21 from Sweden reports prevalence in the general population of 8-9%.[27] No gender-specific
22 prevalence was reported, making direct comparisons to our data somewhat problematic; yet
23 our data indicate slightly higher prevalence. In addition to the significant association between
24 occupational noise exposure and both tinnitus and sound induced auditory fatigue, our data
25 also shows that having one or more hearing-related symptom is most common among those
26 with highest cumulative noise exposure dose as seen in table 2. However, this variable was
27 not significantly associated to noise exposure in the regression model, probably due to the
28 variable difficulty perceiving speech having a large influence with the high prevalence in the

1
2
3 lower noise exposure group. Again, it is staggering to find that more than half of the
4
5 participating personnel group report one or more hearing-related symptom. The risks of
6
7 acquiring hearing-related symptoms in this work environment should also be seen in the light
8
9 of recent animal studies, showing that noise contribute to neurodegenerative effects and acute
10
11 loss of afferent nerve terminals - the effects of which is believed to be of importance for
12
13 auditory processing and subsequently resulting in hearing injuries emerging only later in
14
15 life.[28-30] If applicable to humans, an implication would hence be that hearing functions of
16
17 importance for auditory processing in adverse listening conditions may be impaired even
18
19 though subjects have apparent normal hearing,[31] and importantly that risk of auditory injury
20
21 from noise exposure is greater than previously assumed. Studies such as ours, investigating
22
23 risks for hearing injury within occupational groups exposed to levels at or just below the
24
25 stipulated risk levels, are therefore of high relevance.
26
27
28
29
30
31

32 **Work-related stress and noise annoyance**

33
34 Work-related stress was common among the obstetrics personnel surveyed, which is in line
35
36 with previous research.[11 12] A new finding though, was that noise annoyance is also highly
37
38 prevalent in this occupational group and that both stress and noise annoyance were positively
39
40 associated to sound induced auditory fatigue; although the estimated effect for stress was
41
42 reduced when both stress and noise annoyance were included in the same model. This may be
43
44 due to lack of power in the analysis and possibly also multi-collinearity, as there was a weak
45
46 yet significant correlation between stress and annoyance. The associations were hypothesised
47
48 based on models of pathways previously suggested by Babish,[13] and in a more recent model
49
50 by Heinonen-Guzejev et al.[32] In contrast to previous results of an association between stress
51
52 and tinnitus,[33 34] our results do not support this association despite the fact that work-
53
54 related stress was very common in our sample. It is possible that our measure of work-related
55
56
57
58
59
60

1
2
3 stress did not capture the association, that the relationship is far more complex or that tinnitus
4
5 is instead more strongly associated to psychological distress as is also suggested by studies on
6
7 tinnitus and depression and anxiety,[35 36] rather than physiological or psychosocial stress.
8
9

11 **Methodological consideration**

14 We are aware of methodological issues in assessing exposure dose retrospectively.[37 38] In
15
16 this study an estimate of cumulative occupational noise exposure was calculated by using
17
18 years worked as a proxy for the exposure dose. In order to increase the sensitivity of this
19
20 estimate, we also including years worked with the alternative birth care method (ABC-
21
22 method, predominantly used during the 1980's hypothesised to have given rise to higher
23
24 sound levels in the labour ward due to the non-use of anaesthetics), including an assessment
25
26 of current noise exposure as well as considering the protective effect of personal hearing
27
28 protective devices. A common problem in studies where cumulative exposure is estimated is
29
30 that age will naturally be incorporated in the exposure assessment, possibly confounding the
31
32 results. In our data there was a strong correlation between calculated cumulative noise
33
34 exposure and age, which is illustrated in figure 2B. It is therefore difficult to distinguish
35
36 between effects of age and noise exposure dose, which would be the case independently of
37
38 how the index was constructed as an accumulated exposure dose would naturally always
39
40 correlate to increased age. As such, the possible confounding effect of age could not be
41
42 properly adjusted for in the statistical model for the association between noise exposure and
43
44 hearing-related outcomes. When both were included in the logistic regression model neither
45
46 noise nor age showed a statistically significant effect on any of the hearing-related outcomes.
47
48 Interestingly though, we could show that the noise exposure index was significantly
49
50 associated to the hearing-related outcomes tinnitus and sound induced auditory fatigue, while
51
52 this was not the case for age alone as a predictor in a separate bi-variable model. Pathological
53
54
55
56
57
58
59
60

1
2
3 changes in the inner ear resulting in hearing loss as an effect of age alone is debated in the
4
5 research community.[39] Results are even less solid when considering age as a sole cause of
6
7 tinnitus.[40] Instead, the effect of noise exposure is hypothesised to largely contribute to the
8
9 increased prevalence of hearing-related disorder seen in increased age.[30 39 40]

10
11 Finally, being an initial study in this area we were not able to include a large study sample,
12
13 which affects the reliability of the analyses and the generalisation of the results. Also, though
14
15 the cross-sectional design prevents drawing definite conclusions on causal relationships, we
16
17 argue based on previous research and our study results that it is reasonable to assume a causal
18
19 pathway from noise exposure to hearing-related symptoms; the hypothesised casual pathway
20
21 involving stress and noise annoyance however, being less certain.
22
23
24
25
26

27 **CONCLUSION**

28
29 This study presents new results regarding risk of noise-induced hearing-related symptoms
30
31 among obstetrics personnel, which to the best of our knowledge has not been described
32
33 before. The results show that obstetrics personnel are at times exposed to sound levels above
34
35 regulated limits and that more than half of the participants report one or more hearing-related
36
37 symptom. Furthermore, a statistically significant association was found between cumulative
38
39 occupational noise exposure and the hearing-related symptom tinnitus and sound induced
40
41 auditory fatigue. Noise annoyance was a common complaint and in addition to noise exposure
42
43 also an important factor for sound induced auditory fatigue. These results indicate that
44
45 preventative action regarding noise exposure is required in obstetrics care and that risk-
46
47 assessments may be needed in previously unstudied non-industrial communication-intense
48
49 sound environments.
50
51
52
53
54
55
56
57
58
59
60

Acknowledgments

The authors would like to thank Lars Larsson for performing the dosimeter measurements, Christofer Andersson for assistance with the web-survey and Agneta Agge for survey data entry, as well as all the participating personnel at the obstetrics care unit at the Sahlgrenska University hospital.

Footnotes

Contributors All authors contributed to this work. KPW and KT obtained funding. KPW, SF and AT contributed to the study concept and design. SF collected the data with help from KPW. OH, SF, KPW and KT designed the plan of analysis. SF performed the final analyses. SF, KPW, OH and KT drafted the manuscript and interpreted the results. SF, KPW, OH, KT, AT made substantive editorial contributions at all stages of manuscript preparation.

Funding This study was funded by grants from the Swedish research council for Health, Working Life and Welfare (Forte) as well as the Swedish funder AFA insurance. The researchers are independent from funders.

Competing interests All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval The study was approved by the ethics committee in Gothenburg Sweden, Nr 788-11.

Provenance and peer review Not commissioned; externally peer reviewed

Data sharing statements No additional data are available

1
2
3 This is an Open Access article distributed in accordance with the Creative Commons
4 Attribution Non Commercial (CC BY-NC 3.0) license, which permits others to distribute,
5 remix, adapt, build upon this work non-commercially, and license their derivative works on
6 different terms, provided the original work is properly cited and the use is non-commercial.
7
8
9
10
11 See: <http://creativecommons.org/licenses/by-nc/3.0/>
12
13

14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60

References

1. Nelson DI, Nelson RY, Concha-Barrientos M, Fingerhut M. The global burden of occupational noise-induced hearing loss. *American Journal of Industrial Medicine* 2005;**48**(6):446-58 doi: 10.1002/ajim.20223.
2. European Agency for Safety and Health at Work. *Risks and Trends in the Safety and Health of Women at Work*, 2012.
3. Axelsson A, Hamernik RP. Acute acoustic trauma. *Acta Oto-laryngologica* 1987;**104**(3-4):225-33 doi: doi:10.3109/00016488709107322.
4. Henry JA, Dennis KC, Schechter MA. General Review of Tinnitus: Prevalence, Mechanisms, Effects, and Management. *Journal of Speech Language and Hearing Research* 2005;**48**(5):1204-35 doi: 10.1044/1092-4388(2005/084).
5. Kähäri K, Zachau G, Eklöf M, Sandsjö L, Möller C. Assessment of hearing and hearing disorders in rock/jazz musicians: Evaluación de la audición y de los problemas auditivos en músicos de rock y jazz. *International Journal of Audiology* 2003;**42**(5):279-88 doi: doi:10.3109/14992020309078347.
6. Palmer K, Griffin M, Syddall H, Davis A, Pannett B, Coggon D. Occupational exposure to noise and the attributable burden of hearing difficulties in Great Britain. *Occupational and Environmental Medicine* 2002;**59**(9):634-39
7. Persson Wayne K, Ryherd E, Hsu T, Lindahl B, Bergbom I. (2010). Personnel response in intensive care units. *Internoise*; 2010 13-16 June; Lisbon, Portugal.

- 1
2
3 8. Kjellberg A. Subjective, behavioral and psychophysiological effects of noise. *Scandinavian*
4 *journal of work, environment & health* 1990;29-38
5
6
- 7 9. Busch-Vishniac IJ, West JE, Barnhill C, Hunter T, Orellana D, Chivukula R. Noise levels
8 in Johns Hopkins hospital. *The Journal of the Acoustical Society of America*
9 2005;**118**:3629
10
11
- 12 10. Vinodhkumaradithyaa A, Kumar D, Ananthalakshmi I, et al. Noise levels in a tertiary care
13 hospital. *Noise and Health* 2008;**10**(38):11-13 doi: 10.4103/1463-1741.39003.
14
15
- 16 11. Hildingsson I, Westlund K, Wiklkund I. Burnout in Swedish midwives. *Sexual &*
17 *Reproductive Healthcare* 2013;**4**:87-91
18
19
- 20 12. Hultberg A, Hadžibajramović E, Pettersson S, Skagert K, Ahlberg G. KART-studien.
21 Arbetsmiljö, stress och hälsa bland anställda vid Västra Götalandsregionen. Delrapport 5:
22 Uppföljning utifrån organisations-, yrkesgrupps- och individperspektiv 2008 - 2010. In:
23 Ahlberg G, ed.: *Institute of Stress Medicine*, 2011. [In Swedish]
24
25
26
27
28
- 29 13. Babisch W. The noise/stress concept, risk assessment and research needs. *Noise and*
30 *Health* 2002;**4**(16):1-11
31
32
- 33 14. Leather P, Beale D, Sullivan L. Noise, psychosocial stress and their interaction in the
34 workplace. *Journal of Environmental Psychology* 2003;**23**(2):213-22
35
36
- 37 15. Lercher P, Hörtnagl J, Kofler WW. Work noise annoyance and blood pressure: combined
38 effects with stressful working conditions. *International archives of occupational and*
39 *environmental health* 1993;**65**(1):23-28
40
41
42
- 43 16. Persson Waye K, Agge A, Hillström J, Lindström F. Being in a pre-school sound
44 environment – annoyance and subjective symptoms among personnel and children.
45 *Internoise*; 2010 13-16 June; Lisbon, Portugal.
46
47
48
- 49 17. Neitzel R, Daniell W, Sheppard L, Davies H, Seixas N. Comparison of Perceived and
50 Quantitative Measures of Occupational Noise Exposure. *Annals of Occupational Hygiene*
51 2009;**53**(1):41-54 doi: 10.1093/annhyg/men071.
52
53
54
55
56
57
58
59
60

18. Nondahl DM, Cruickshanks KJ, Wiley TL, Tweed TS, Klein R, Klein BEK. Accuracy of Self-reported Hearing Loss. *International Journal of Audiology* 1998;**37**(5):295-301 doi: doi:10.3109/00206099809072983.
19. Schlaefler K, Schlehofer B, Schüz J. Validity of self-reported occupational noise exposure. *European journal of epidemiology* 2009;**24**(8):469-475.
20. Sindhusake D, Mitchell P, Smith W, et al. Validation of self-reported hearing loss. The Blue Mountains hearing study. *International Journal of Epidemiology* 2001;**30**(6):1371-78
21. Ryberg JB, Agge A, Wayne KP. Low frequency noise in a paper mill control room. *Journal of low frequency noise, vibration and active control* 2007;**26**(3):165-76
22. Axelsson A, Prasher D. Tinnitus induced by occupational and leisure noise. *Noise and Health* 2000;**2**(8):47
23. Nouvian R, Eybalin M, Puel J-L. The cochlea and the Auditory Nerve as a Primary Source of Tinnitus. In: Eggermont JJ, Zeng F-G, Popper AN, eds. *Tinnitus*. New York: Springer Science and Business Media, 2012.
24. Schmidt CO, Kohlmann T. When to use the odds ratio or the relative risk? *International journal of public health* 2008;**53**(3):165-67
25. Tenenbaum A, Hendriksson A, Larsson L. Bullernivåer och hörselundersökning på förlossningsavdelning. Läkarsämman. Stockholm, Sweden, 2010. [In Swedish]
26. Danermark B, Hanning M. Hearing and vision: Health in Sweden: The National Public Health Report 2012. Chapter 17. *Scandinavian Journal of Public Health* 2012;**40**(9 suppl):287-92 doi: 10.1177/1403494812459621.
27. Andersson G, Lindvall N, Hursti T, Carlbring P. Hypersensitivity to sound (hyperacusis): a prevalence study conducted via the internet and post. *International Journal of Audiology* 2002;**41**(8):545-54 doi: doi:10.3109/14992020209056075.
28. Kujawa SG, Liberman MC. Adding insult to injury: cochlear nerve degeneration after “temporary” noise-induced hearing loss. *The Journal of Neuroscience* 2009;**29**(45):14077-85

- 1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
29. Lin HW, Furman AC, Kujawa SG, Liberman MC. Primary neural degeneration in the Guinea pig cochlea after reversible noise-induced threshold shift. *Journal of the Association for Research in Otolaryngology* 2011;**12**(5):605-16
30. Kujawa SG, Liberman MC. Acceleration of age-related hearing loss by early noise exposure: evidence of a missed youth. *The Journal of Neuroscience* 2006;**26**(7):2115-23
31. Ruggles D, Bharadwaj H, Shinn-Cunningham BG. Normal hearing is not enough to guarantee robust encoding of suprathreshold features important in everyday communication. *Proceedings of the National Academy of Sciences* 2011;**108**(37):15516-21
32. Heinonen-Guzejev M, Koskenvuo M, Silventoinen K, et al. Noise Sensitivity and Disability Retirement: A Longitudinal Twin Study. *Journal of Occupational and Environmental Medicine* 2013;**55**(4):365-70
33. Alpini D, Cesarani A. Tinnitus as an alarm bell: stress reaction tinnitus model. *ORL* 2006;**68**(1):31-37
34. Hébert S, Lupien SJ. The sound of stress: blunted cortisol reactivity to psychosocial stress in tinnitus sufferers. *Neuroscience letters* 2007;**411**(2):138-42
35. Holgers K-M, Erlandsson SI, Barrenäs M-L. Predictive Factors for the Severity of Tinnitus: Factores predictivos de la severidad del tinnitus. *International Journal of Audiology* 2000;**39**(5):284-91
36. Robinson SK, Viirre ES, Stein MB. Antidepressant therapy in tinnitus. *Hearing research* 2007;**226**(1):221-31
37. Davies HW, Teschke K, Kennedy SM, Hodgson MR, Hertzman C, Demers PA. Occupational exposure to noise and mortality from acute myocardial infarction. *Epidemiology* 2005;**16**(1):25-32
38. Nilsson T, Burström L, Hagberg M. Risk assessment of vibration exposure and white fingers among platers. *International archives of occupational and environmental health* 1989;**61**(7):473-81

- 1
2
3 39. Van Eyken E, Van Camp G, Van Laer L. The complexity of age-related hearing
4 impairment: contributing environmental and genetic factors. *Audiology and Neurotology*
5 2007;**12**(6):345-58
6
7
8
9 40. Sanchez L. The epidemiology of tinnitus. *Audiological Medicine* 2004;**2**(1):8-17
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

1
2
3 **The effect of occupational noise exposure on tinnitus and sound induced**
4 **auditory fatigue among obstetrics personnel: a cross-sectional study**
5
6
7
8
9

10 **Authors' names**

11 Sofie Fredriksson (SF), Oscar Hammar (OH), Kjell Torén (KT), Artur Tenenbaum (AT),
12
13 Kerstin Persson Waye (KPW)
14

15
16
17
18
19 **Corresponding author:**

20 Sofie Fredriksson

21 University of Gothenburg

22 Dept. of Public health & Community Medicine

23 Occupational and Environmental Medicine

24 PO Box 414, SE 405 30 Gothenburg, Sweden

25 sofie.fredriksson@gu.se

26 +46317863610 (telephone), +4631409728 (fax)
27
28
29
30
31
32
33
34
35
36
37
38

39 **Address for co-authors:**

40 Oscar Hammar (1), Kjell Torén (1), Artur Tenenbaum (2), Kerstin Persson Waye (1)

- 41
42
43 1) Department of Public Health and Community Medicine, Occupational and
44 Environmental Medicine, University of Gothenburg, S-405 30 Gothenburg
45
46
47 2) Occupational health care unit (Hälsan & Arbetslivet), Skaraborg Hospital, S-541 85
48 Skövde, Sweden
49
50
51
52
53
54

55 **Keywords:** Noise, occupational; stress; hearing disorders; cross-sectional studies; obstetrics

56 **Word count** (excluding title page, abstract, references, figures and tables): 4582
57
58
59
60

ABSTRACT

Objective: There is a lack of research on effects of occupational noise exposure in traditionally female-dominated workplaces. Therefore, the aim was to assess risk of noise-induced hearing-related symptoms among obstetrics personnel.

Design: A cross-sectional study at an obstetric ward in Sweden including a questionnaire among all employees and sound level measurements in 61 work-shifts at the same ward.

Participants: 115 female employees responded to a questionnaire (72% of all 160 employees invited).

Main outcome measures: Self-reported hearing-related symptoms, noise annoyance, work-related stress, calculated cumulative occupational noise exposure and measured sound levels.

Results: Sound levels exceeded the 80 dB LAeq limit for protection of hearing in 46% of the measured work-shifts. One or more hearing-related symptom was reported by 55% of the personnel. In logistic regression models a significant association was found between cumulative occupational noise exposure and tinnitus (Odds Ratio 1.04, 95% confidence interval 1.00 to 1.09) and sound induced auditory fatigue (Odds Ratio 1.04, 95% confidence interval 1.00 to 1.07). Work-related stress and noise annoyance were reported by almost half of the personnel group. Sound induced auditory fatigue was associated to work-related stress and noise annoyance, although stress just missed significance in a multivariable model. No significant interactions were found.

Conclusion: This study presents new results showing that obstetrics personnel are at risk of noise-induced hearing-related symptoms. Current exposure levels at the work-place are high and cumulative exposure has significant effects on tinnitus and sound induced auditory fatigue among the personnel. These results indicate that preventative action regarding noise exposure is required in obstetrics care and that risk-assessments may be needed in previously unstudied non-industrial communication-intensive sound environments.

Strengths and limitations of this study:

- The vast majority of previous research into noise-induced hearing disorders has been performed in industrial-like settings, whereas practically nothing is known of risks in non-industrial, traditionally female-dominated and communication-intense workplaces, such as hospitals. As such, our study presents novel results ~~This is to our knowledge the first published study that assesses occupational noise exposure and hearing among obstetrics personnel.~~ **As such, this study presents novel results on occupational noise exposure and hearing among obstetrics personnel.**
- Both objective sound level measurements and analysis of subjective data indicate an increased risk of hearing-related disorder.
- Due to the cross-sectional design the influence of subjects' age cannot be disentangled.
- The study sample size and the cross-sectional design without an unexposed control group limits the generalisation of the results and prevents us from drawing definite conclusions on causality.
- Further studies are needed to confirm the results and assess the magnitude of the problem. However, we suggest that occupational health care services implement available preventative actions such as making hearing protective devices available for personnel as an action of precaution.

INTRODUCTION

Occupational noise exposure and effects on hearing is well described in industrial-like, traditionally male-dominated settings.[1] In contrast, few studies have reported on traditionally female-dominated work environments. This has been acknowledged by the European Agency for Safety and Health at Work, who conclude that areas such as health and social services are largely overlooked concerning noise research,[2] and that the noise in these types of workplaces may interfere with performance and wellbeing. High sound levels regardless of its source can cause hearing loss, tinnitus and sound sensitivity and may also result in sound induced auditory fatigue, the latter described by subjects as avoidance of everyday sounds and a need for silence.[1 3-7] The symptom sound induced auditory fatigue was first identified in pilot studies, interviewing preschool personnel, and have later shown to prevalent in questionnaire surveys [7]. We hypothesise the symptom to be a result of constant or overloading stimulation of sounds during the day. The effect may possibly be due to the high information content mainly of speech, such that overload is not merely a consequence of the sound energy as seen in auditory threshold shift, but as a result of a an information intense sound environment. Apart from hearing-related symptoms, noise exposure can also evoke non-auditory effects such as annoyance and stress.[8] According to a recent meta-analysis, noise levels in hospitals have steadily increased since the mid-1960.[9] One heavily female-dominated workplace in the hospital is the obstetrics care. According to data from Statistics Sweden in 2011, more than 99% of midwives are women. To the best of our knowledge, only one peer-reviewed study have reported on sound level measurements from obstetrics care in a hospital in India, where the highest night time level (71.9 dB LAeq) was measured in the obstetrics and gynaecology ward, with slightly lower levels in the labour ward.[10] In addition to potentially harmful noise levels in the obstetrics care, midwives report a high degree of work-related stress and burnout,[11] and according to a recent report burnout

1
2
3 syndrome have doubled among midwives employed in the western region of Sweden during
4 the last years.[12] The fact that obstetrics personnel are exposed to high levels of stress may
5 be important when considering noise exposure at the workplace, since the combination of
6 these exposures may interact in causing adverse health effects.[13-15]
7
8

9
10
11 There is a substantial lack of knowledge regarding occupational noise exposure, noise
12 annoyance and hearing-related symptoms among obstetrics care personnel, as well as possible
13 interaction effects between noise exposure, noise annoyance and work-related stress.
14

15
16 Therefore, the aim of this study was to assess the risk of noise-induced hearing-related
17 symptoms among obstetrics personnel by measuring sound levels in the labour ward of a
18 general obstetrics ward and by analysing the effect of and interaction between occupational
19 noise exposure, noise annoyance and work-related stress on hearing-related symptoms among
20 obstetrics personnel.
21
22
23
24
25
26
27
28
29
30
31

32 **METHODS**

33 **Sound level measurements**

34
35 Sound level measurements were carried out during 61 work shifts in the labour ward of a
36 general obstetrics ward at the Sahlgrenska University Hospital in Gothenburg. **Out of the 61**
37 **shifts 19** Day shifts ($n=19$) were measured between 7 a.m. and 3:30 p.m. (8.5 h), **12** evening
38 shifts ($n=12$) between 1:45 p.m. and 9 p.m. (7.25 h) and **30** nightshifts ($n=30$) between 9 p.m.
39 and 7 a.m. (10 h). The day and evening shifts were measured during separate weeks so as not
40 to overlap. A convenient sample of ten employees per shift each wore a personal dosimeter
41 (Larson Davis 705+) with the microphone attached to the right shoulder and kept a written log
42 documenting work activities during the measured shift. A total of 610 separate measurements
43 were collected, **as 10 individuals each wore a dosimeter during the 61 shifts measured.**
44
45
46
47
48
49
50
51
52
53
54
55

56 However, due to technical errors a few faulty measurements were excluded leaving 529
57
58
59
60

(87%) to be included in the analysis. The dosimeters were set to measure A-weighted equivalent and maximum (fast) levels with a sampling interval of 30 seconds. All dosimeters were calibrated using the software Blaze version 5.06 before measurements began. The equivalent levels reported refer to the full-shift length and will hence vary between 7.25 – 10 hours, hereinafter denoted as LAeq(7-10h). Sound levels were analysed at group level as arithmetic mean and compared to Swedish Work Authorities' exposure regulations. Sound levels exceeding the lower action level of 80 dB LAeq(8h) indicate a risk for hearing damage and the employer is responsible to take preventative action, such as providing employees with hearing protection devices (HPDs). The exposure limits 85 dB LAeq (8h) and 115 dB LAFmax are set as a maximum allowed level above which the employer is required to take measures in order to reduce the noise exposure, and where use of HPDs are mandatory. Employees must not be exposed to noise levels at or above the exposure limits (taking attenuation of HPDs into account).

Questionnaire survey

All personnel (n=160, all women), employed at the general obstetrics ward were included in a questionnaire survey. A total of 115 (72%) participated by responding either electronically (n=63) or in paper format (n=52) and these data were pooled together, as no statistical differences were seen on explanatory or outcome variables (p>0.05). The questionnaire was constructed using items specifically constructed for this study as well as items adapted from previous studies and international standards (ISO/TS 15666).[7 16] Similar self-reported items assessing noise exposure as well as hearing loss and tinnitus have previously been subject for validation.[17-20]

The main explanatory variable cumulative occupational noise exposure dose, was calculated as an exposure index derived from six questionnaire items including; number of years worked

1
2
3 in delivery care, number of years worked in alternative birth care, work allocation (delivery
4 care, postpartum care or both), two separate items on frequency of current work-related noise
5 exposure (one assessing how often the sound levels are so high that the person has to speak
6 with raised voice and one assessing how often the person have trouble hearing what is said)
7 and finally one item on frequency of hearing protection use. A higher noise index indicates a
8 higher noise exposure dose. The scoring for each items contribution to the index is presented
9 in detail in supplementary table 1. Each variable score was summed using mathematical
10 addition to a total index score for each participant. In addition, the study group was
11 categorized into four noise index groups based on calculation of quartiles, with each noise
12 index category representing 25% of the study population. Work-related stress and noise
13 annoyance were analysed as additional explanatory variables. Work-related stress was
14 assessed using two separate questionnaire items asking responders to report how often they
15 experience high degree of stress and how often they feel unwell due to stress at work.
16 Participants were defined as having work-related stress if answering often or always/almost
17 always on one or both of the items. These stress-related items have previously been used in
18 noise-related research.[21] Noise annoyance was assessed by the item ‘Are you annoyed by
19 sounds/noise at your workplace?’, which is based on the International standard ISO/TS
20 15666, adapted for a workplace survey as opposed to community surveys. The hearing-related
21 outcome variables included are hearing loss (yes), tinnitus, sound sensitivity (i.e. hyperacusis)
22 and sound induced auditory fatigue (i.e. a need for silence) (a few times each week or more
23 often), general hearing status (poor or very poor) and difficulty perceiving speech (yes both at
24 work and in leisure time). Variables considered as possible moderators for the association
25 between exposure and outcome were smoking (previous or current) and leisure-time noise
26 exposure (once a month or more often). Age (in years) was considered a possible confounder.
27 The questionnaire items are presented in full in the supplementary table 2.

Statistical analyses

Hypothesis testing was performed using IBM SPSS Statistics 20. Differences in arithmetic mean were analysed using one-way analysis of variance (ANOVA) or independent samples t-test where applicable. Test for trend was analysed using Linear regression with dummy coding for categorical predictors or Mantel-Haentzel linear-by-linear association where applicable. Binary logistic regression with Wald tests was used for analysis of associations and interaction. The significance level was set at 5% ($p= 0.05$) for all tests. Based on a hypothesised order of importance of explanatory variables, manual sequential regression models were analysed. For each binary hearing-related outcome variable we used the following model testing procedure. In a first model, noise exposure index was analysed as a single continuous explanatory variable with the hearing-related symptom as a binary outcome variable. If noise exposure index was significant for the hearing-related symptom, then a second model was analysed, adjusting for moderators (leisure noise exposure and smoking), each one at a time. Age as a possible confounder was analysed separately due to initial hypothesised strong correlation to the noise index (due to its cumulative nature). If point estimates for noise index was comparable with and without adjustment and the adjustment variable itself was non-significant, then it was not included in subsequent multivariable models. In the third model, work-related stress was analysed as an additional explanatory variable and in a fourth model noise annoyance instead of stress was included together with significant explanatory variables from model 2. The fifth model included explanatory variables found to be significant in any of the previous steps. Hypothesised interactions between explanatory variables were assessed in separate models by including an interaction term. Multi-collinearity between explanatory variables was assessed using Pearson's correlation or Spearman's rank correlation, where applicable, and correlation below $r=0.6$ was deemed acceptable. Odds ratios (OR) with 95% confidence intervals were derived from the

1
2
3 logistic regressions as a measure of association between exposure and outcome, and relative
4
5 risk (RR) was calculated from predictive values derived from model 1. Goodness of fit for the
6
7 regression models were assessed using the Hosmer-Lemeshow test and a non-significant p-
8
9 value (>0.05) was used to indicate adequate fit.
10

11 12 13 **RESULTS**

14 15 **Sound levels in the labour ward**

16
17 Overall, the dosimeter measurements from the labour ward showed moderately high sound
18
19 levels, as presented in table 1. The levels reached or exceeded both the action and limit levels.
20
21 The lower action level 80 dB LAeq was exceeded in 30 different dosimeter measurements
22
23 during 28 different work shifts, which corresponds to 46% of all measured shifts or 6% of all
24
25 dosimeter measurements. The upper exposure action level and exposure limit 85 dB LAeq
26
27 was reached or exceeded in three measurements from three different shifts, corresponding to
28
29 5% of all measured shifts or 0.6% of all measurements. The limit 115 dB LAFmax was
30
31 reached or exceeded at 50 different occasions. However, of these 9 separate events could not
32
33 be verified by the written logs and were therefore excluded. The remaining 41 events occurred
34
35 in 17 different shifts corresponding to 28% of all measured shifts or 8% of all dosimeter
36
37 measurements. There were no statistical differences in arithmetic mean equivalent nor in
38
39 maximum levels when comparing measurements from different work-shifts nor measurements
40
41 from dosimeters worn by midwives compared to assistant nurses. Due to incomplete written
42
43 logs however, we were unable to categorise a third of the measurements into professional
44
45 group. A segment sample from a dosimeter measurement is shown in figure 1, where high
46
47 maximum levels (119 dB LAFmax) was recorded during a delivery, which according to the
48
49 written log occurred between 10:30 and 11:05 pm. The equivalent level in this particular
50
51 measurement was 84 dB LAeq(10h) for the measured shift length. As exposure limits should be
52
53
54
55
56
57
58
59
60

regarded with HPDs taken into account, it is noteworthy that the majority of the respondents (92%) reported to never or almost never use hearing protective devices at work.

FIGURE 1

Table 1. Sound level measurements at the labour ward showing arithmetic mean, standard deviation (SD), 95% confidence interval confidence interval (CI) of mean and range of the measured equivalent, LAeq(7-10h) and maximum, LAFmax sound levels in dB. Also showing mean and standard deviation of measurements categorised by work shift and by professional group as reported in written logs by the personnel carrying the dosimeter. Frequencies (n) in the table represent unique dosimeter measurements.

	Sound level measurements		
	dB LAeq(7-10h)	dB LAFmax	n
All measurements			
Arithmetic mean (SD)	70.3 (6.0)	106.3 (6.0)	529
95% CI of mean	69.7 - 70.8	105.8 - 106.8	
Min – Max	56.0 – 87.0	83.0 – 122.0	
Measurements categorised by work shift (arithmetic mean, SD) ^a			
Day shift	70.8 (6.2)	106.2 (5.9)	139
Evening shift	70.8 (5.2)	106.3 (5.6)	127
Night shift	69.8 (6.3)	106.4 (6.2)	263
Measurements categorised by professional group (arithmetic mean, SD)			
Midwives	71.3 (5.1)	106.2 (5.9)	289
Assistant nurses	72.2 (5.0)	107.8 (5.2)	114
Uncategorised	76.2 66.2 (7.0)	103.9 (6.5)	126

^a Number of shifts categories as day (n=19), evening (n=12) and night (n=30).

Association between noise exposure and hearing disorder

Demographics, occurrence of explanatory variables; work-related stress, noise annoyance and adjustment variables; smoking and leisure noise exposure as well as prevalence of hearing-related outcomes are presented in table 2, both for the total study sample as well as categorised into four noise exposure index groups calculated from quartiles of the noise index. The first noise index group (1) represents the respondents with the lowest calculated noise exposure dose. Valid responses for the individual questionnaire items included in the analysis ranged from n=108 to 115. A test for trend in the four exposure groups shows that age, number of years worked in obstetrics and prevalence of sound induced auditory fatigue is significantly increasing with higher noise exposure group; $p<0.001$, $p<0.001$ and $p=0.049$ respectively.

Table 2. Demographics, explanatory and adjustment variables and hearing-related outcomes from questionnaire survey among personnel at the general obstetrics ward. Prevalence is presented categorised in four noise index groups based on quartiles of the index (1 – 4) and as total prevalence in the study sample. Percentages are given as column % in noise index quartile groups and % of total.

	Grouping by noise index quartiles				Total	95% CI of total
	1	2	3	4		
Number of participants	28	29	29	29	115	-
Noise exposure index (range)	4.5 – 9.5	10 – 15	16 – 26	27 – 64	4.5 - 64	16.8 - 21.2
Demographics						
Mean age in years (SD)	39 (10)	39 (7)	45 (8)	57 (5)	45 (11)	42.8 - 46.8
Mean years worked (SD)	3 (2)	6 (2)	14 (3)	28 (6)	12 (11)	10.3 - 14.3
Professional groups, % ^a	54/36/11	69/24/7	69/21/10	76/21/3	68/25/7	-
Explanatory and adjustment variables (%)						
Work-related stress	43	52	31	41	42	32.9-51.1
Noise annoyance at work	50	45	55	45	49	39.8-58.2
Ever smoker	36	48	28	25	34	25.3-42.7
Leisure noise exposure	14	24	7	7	13	6.8-19.2
Outcome variables (%)						
Sound induced auditory fatigue	21	24	41	41	32	23.4-40.6
Tinnitus	7	11	10	24	13	6.8-19.2
Sound sensitivity	7	17	17	10	13	6.8-19.2
Poor hearing	11	21	17	14	16	9.3-22.7
Hearing loss	4	7	21	4	9	3.7-14.3
Difficulty perceiving speech	39	31	24	36	32	23.4-40.6
Any symptom ^b	54	48	55	63	55	45.9-64.1

^a Shown in table as proportion of Midwife/Assistant nurse/Other. Other also includes missing.

^b Any symptom was constructed as a binary variable including all those who reported either sound induced auditory fatigue, tinnitus, sound sensitivity, difficulty perceiving speech, poor hearing and/or hearing loss.

1
2
3 Associations between occupational noise exposure dose (continuous noise index), work-
4 related stress, noise annoyance and hearing-related symptoms were evaluated in manual
5 sequential binary logistic regression models, results of which are presented in table 3. The
6 calculated noise index ranged from 4.5 to 64 in the study sample. The proportional
7 contribution of years worked in obstetrics care to the index, as a proxy for cumulative
8 exposure, is shown in figure 2 A. The percentage of participants over the range of noise index
9 also conveys the skewness in the distribution of the index, e.g. less than 25% of the
10 participants have noise index values in the upper half of the range.
11
12
13
14
15
16
17
18
19
20
21
22
23

FIGURE 2

24
25
26
27 Occupational noise exposure as a single explanatory variable was significantly associated to
28 tinnitus and sound induced auditory fatigue, but not to the other hearing-related symptoms.
29 Work-related stress and noise annoyance were both significantly associated to sound induced
30 auditory fatigue in separate models, but not to tinnitus. For sound induced auditory fatigue,
31 including all three significant explanatory variables (noise, stress and annoyance) in model 5
32 resulted in marginal changes in point estimates for noise exposure and noise annoyance. It did
33 however affect the estimates for work-related stress, which just missed statistical significance
34 ($p=0.053$). No significant statistical interactions were found between explanatory variables.
35
36 Neither work-related stress nor noise annoyance were significantly correlated to noise
37 exposure index. There was however a weak yet significant correlation between stress and
38 noise annoyance ($r=0.249$, $p=0.008$). The point estimates for noise exposure was comparable
39 with or without adjustment for smoking and leisure-time noise exposure in model 2, and
40 neither one of the adjustment variables were themselves significant. Hence, they were not
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 included in the subsequent multivariable models. All reported models had an acceptable
4
5 goodness of fit.

6
7 As prevalence of sound induced auditory fatigue was much higher than 10%, assessing odds
8
9 ratios (OR) only may overestimating overestimate the risk. The calculated risk ratios (RR) for
10
11 sound induced auditory fatigue from model 1, in comparable 1 unit steps of the noise index,
12
13 however showed that the difference between OR and RR was minor (at the most 0.02
14
15 difference).

16
17
18 Due to the cumulative property of the noise index, the index was assumed to be correlated to
19
20 age, which was also confirmed in the analysis ($r=0.706$, $p<0.001$) with $R^2=0.498$, as shown in
21
22 figure 2 B. Multi-collinearity issues therefore precluded the assessment of both variables in
23
24 one regression model. Notably and importantly though, age was not significantly associated to
25
26 any of the hearing-related symptoms when assessed as a single explanatory variable in
27
28 separate regression models.
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 3. Point estimates of effect (B) and standard error (SE), odds ratios (OR), 95% confidence intervals of OR (95% CI) from binary logistic regression models for hearing-related symptom outcomes (binary dependent variables) among personnel in an obstetrics ward. All dependent variables were analysed in separate models. Manual sequential analysis was adopted, adding work-related stress and noise annoyance and adding an interaction term if the initial model was statistically significant ($p < 0.05$).

Dependent variables	Explanatory variables	B (SE)	OR (95% CI)	p-value
Sound induced auditory fatigue				
<i>Model 1</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.07)	0.031
<i>Model 3</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.08)	0.027
	Work-related stress	0.96 (0.42)	2.62 (1.15 – 5.98)	0.022
<i>Model 4</i>	Noise exposure index	0.04 (0.02)	1.04 (1.01 – 1.08)	0.026
	Noise annoyance	1.73 (0.47)	5.67 (2.25 – 14.27)	<0.001
<i>Model 5</i>	Noise exposure index	0.04 (0.02)	1.04 (1.01 – 1.08)	0.025
	Work-related stress	0.87 (0.45)	2.39 (0.99 – 5.79)	0.053
	Noise annoyance	1.66 (0.48)	5.25 (2.05 – 13.42)	0.001
Tinnitus				
<i>Model 1</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.09)	0.049
<i>Model 3</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.09)	0.046
	Work-related stress	-0.43 (0.60)	0.65 (0.20 – 2.10)	0.470
<i>Model 4</i>	Noise exposure index	0.04 (0.02)	1.05 (1.00 – 1.09)	0.038
	Noise annoyance	0.56 (0.58)	1.85 (0.56 – 5.46)	0.335
Sound sensitivity	Noise exposure index	0.01 (0.02)	1.03 (0.97 – 1.06)	0.570
Poor hearing	Noise exposure index	0.00 (0.02)	1.00 (0.96 – 1.04)	0.985
Hearing loss	Noise exposure index	0.00 (0.03)	1.00 (0.95 – 1.06)	0.995
Difficulty perceiving speech	Noise exposure index	0.01 (0.02)	1.01 (0.98 – 1.05)	0.461
Any symptom^a	Noise exposure index	0.02 (0.02)	1.02 (0.99 – 1.05)	0.273

^a Any symptom was constructed as a binary variable including all those who reported either sound induced auditory fatigue, tinnitus, sound sensitivity, difficulty perceiving speech, poor hearing and/or hearing loss.

DISCUSSION

The effect of noise exposure on hearing

In order to assess the effect of occupational noise exposure on hearing-related symptoms among obstetrics personnel, sound level measurements were carried out at the labour ward at a general obstetrics ward and associations between calculated occupational noise exposure dose and hearing-related symptoms were analysed in binary logistic regression models based on self-reported data from personnel at the same ward.

Prevalence of hearing-related symptoms among the personnel showed that tinnitus and sound induced auditory fatigue was most common among personnel with the highest exposure dose. Accordingly, we were also able to detect statistically significant associations between occupational noise exposure and both tinnitus and sound induced auditory fatigue in logistic regression models. Sound induced auditory fatigue is a new concept that has previously been reported among preschool personnel and is hypothesised as a consequence of a constant noise load during the work day.[7 16] As for pre-school personnel, the obstetric personnel are mainly exposed to intermittent sounds from voices and screams, but also from alarms and medical equipment. It is possible that the demands and needs of attending to meaningful sounds with a high element of irregularity contribute to a mental fatigue that some individuals with sound induced auditory fatigue describe. As for sound induced auditory fatigue, we could also show a significant association between tinnitus and noise exposure. Although it is well established that noise may contribute to tinnitus,[4 22 23] it has to our knowledge not been reported previously among obstetrics personnel; hence this result is highly interesting as it supports the concerns that noise levels in non-industrial and previously less studied work environments, mainly female-dominated, may be harmful.[2] As the prevalence especially for sound induced auditory fatigue was high, it is important to note that odds ratios may not

1
2
3 directly be translated into a measure of relative risk.[24] We did however not detect major
4
5 divergences between the two measures.
6

7
8 In addition to increased risk of hearing-related symptoms of cumulative occupational noise
9
10 exposure, we also found high current sound level exposure in the labour ward, above
11
12 regulated limits. The sound level measurements further heighten the concern that obstetrics
13
14 personnel may risk acquiring hearing-related disorder as personnel carrying the dosimeters
15
16 were exposed to levels exceeding the lower action level of 80 dB LAeq during as much as
17
18 approximately half of the measured work shifts. While the average noise levels were in
19
20 accordance with an earlier study reporting noise levels from an obstetrics and labour ward at a
21
22 general hospital,[10] our study further showed that the exposure limit 115 dB LAFmax may
23
24 be exceeded in as much as one third of the work-shifts in a labour ward. The data is also in
25
26 accordance with results from a workplace inspection performed in 2010 by the occupational
27
28 health care unit at a small obstetrics ward in Sweden which showed that personnel were at
29
30 times exposed to sound levels above the regulated action and limit levels adopted by the
31
32 Swedish work environment authority.[25] This result is especially alarming as very few
33
34 personnel report use of hearing protection, which certainly may be impractical in this type of
35
36 work setting. Although caution is required in establishing the source of high maximum levels
37
38 recorded in unsupervised measurements the results are indeed important, since such high
39
40 sound levels have been described as mechanism in acquired hearing loss, tinnitus and sound
41
42 sensitivity.[3] These results highlight the need to initiate preventive action regarding noise
43
44 exposure in the obstetrics care, which include but is not limited to; information to all
45
46 employees, access to suitable hearing protection devices and cooperation between the
47
48 employer and an occupational health care unit for assessment of noise exposure and hearing-
49
50 related symptoms. Hearing tests and anamnesis regarding hearing-related symptoms may also
51
52 be considered for new employees.
53
54
55
56
57
58
59
60

1
2
3 No significant associations between noise exposure and the other hearing related symptoms
4 were detected in this study. This may be explained partly by the fact that hearing loss is
5 developed over a long period of time, usually becoming apparent after the age of retirement,
6 and that mild deterioration in hearing may not be easily detected via self-assessment. As the
7 study was cross-sectional, the fact that hearing loss was most prevalent in the third noise
8 exposure group lower prevalence in the highest exposure group may have influenced the
9 analysis. This in turn is possibly due to a healthy worker effect as individuals with hearing
10 loss may not be able to continue working in obstetrics care. Similarly but in the opposite
11 direction, as difficulty perceiving speech was reported by many young individuals, whom to a
12 larger extent was classified in the lowest noise index quartile, it may have influenced the
13 analysis of the effect of occupational noise exposure such that no significant effect was seen.
14 It is in any case alarming with such a high prevalence of difficulty perceiving speech.
15
16
17
18
19
20
21
22
23
24
25
26
27
28

29 Compared to prevalence data from the Swedish National Board of Health and Welfare from
30 2000-2005, using a similar survey item as in this study,[26] our data indicate higher age and
31 gender matched prevalence. Between the ages 25-64 years the prevalence in our sample
32 ranged from 26-35%, while the prevalence in the same age range among women in the
33 reference material was 5-15%. Sound sensitivity is less researched, but one previous study
34 from Sweden reports prevalence in the general population of 8-9%.[27] No gender-specific
35 prevalence was reported, making direct comparisons to our data somewhat problematic; yet
36 our data indicate slightly higher prevalence. In addition to the significant association between
37 occupational noise exposure and both tinnitus and sound induced auditory fatigue, our data
38 also shows that having one or more hearing-related symptom is most common among those
39 with highest cumulative noise exposure dose as seen in table 2. However, this variable was
40 not significantly associated to noise exposure in the regression model, probably due to the
41 variable difficulty perceiving speech having a large influence with the high prevalence in the
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 lower noise exposure group. Again, it is staggering to find that more than half of the
4
5 participating personnel group report one or more hearing-related symptom. The risks of
6
7 acquiring hearing-related symptoms in this work environment should also be seen in the light
8
9 of recent animal studies, showing that noise contribute to neurodegenerative effects and acute
10
11 loss of afferent nerve terminals - the effects of which is believed to be of importance for
12
13 auditory processing and subsequently resulting in hearing injuries emerging only later in
14
15 life.[28-30] If applicable to humans, an implication would hence be that hearing functions of
16
17 importance for auditory processing in adverse listening conditions may be impaired even
18
19 though subjects have apparent normal hearing,[31] and importantly that risk of auditory injury
20
21 from noise exposure is greater than previously assumed. Studies such as ours, investigating
22
23 risks for hearing injury within occupational groups exposed to levels at or just below the
24
25 stipulated risk levels, are therefore of high relevance.
26
27
28
29
30
31

32 **Work-related stress and noise annoyance**

33
34 Work-related stress was common among the obstetrics personnel surveyed, which is in line
35
36 with previous research.[11 12] A new finding though, was that noise annoyance is also highly
37
38 prevalent in this occupational group and that both stress and noise annoyance were positively
39
40 associated to sound induced auditory fatigue; although the estimated effect for stress was
41
42 reduced when both stress and noise annoyance were included in the same model. This may be
43
44 due to lack of power in the analysis and possibly also multi-collinearity, as there was a weak
45
46 yet significant correlation between stress and annoyance. The associations were hypothesised
47
48 based on models of pathways previously suggested by Babish,[13] and in a more recent model
49
50 by Heinonen-Guzejev et al.[32] In contrast to previous results of an association between stress
51
52 and tinnitus,[33 34] our results do not support this association despite the fact that work-
53
54 related stress was very common in our sample. It is possible that our measure of work-related
55
56
57
58
59
60

1
2
3 stress did not capture the association, that the relationship is far more complex or that tinnitus
4
5 is instead more strongly associated to psychological distress as is also suggested by studies on
6
7 tinnitus and depression and anxiety,[35 36] rather than physiological or psychosocial stress.
8
9

10 11 **Methodological consideration**

12
13 We are aware of methodological issues in assessing exposure dose retrospectively.[37 38] In
14
15 this study an estimate of cumulative occupational noise exposure was calculated by using
16
17 years worked as a proxy for the exposure dose. In order to increase the sensitivity of this
18
19 estimate, we also including years worked with the alternative birth care method (ABC-
20
21 method, predominantly used during the 1980's hypothesised to have given rise to higher
22
23 sound levels in the labour ward due to the non-use of anaesthetics), including an assessment
24
25 of current noise exposure as well as considering the protective effect of personal hearing
26
27 protective devices. A common problem in studies where cumulative exposure is estimated is
28
29 that age will naturally be incorporated in the exposure assessment, possibly confounding the
30
31 results. In our data there was a strong correlation between calculated cumulative noise
32
33 exposure and age, which is illustrated in figure 2B. It is therefore difficult to distinguish
34
35 between effects of age and noise exposure dose, which would be the case independently of
36
37 how the index was constructed as an accumulated exposure dose would naturally always
38
39 correlate to increased age. As such, the possible confounding effect of age could not be
40
41 properly adjusted for in the statistical model for the association between noise exposure and
42
43 hearing-related outcomes. When both were included in the logistic regression model neither
44
45 noise nor age showed a statistically significant effect on any of the hearing-related outcomes.
46
47 Interestingly though, we could show that the noise exposure index was significantly
48
49 associated to the hearing-related outcomes tinnitus and sound induced auditory fatigue, while
50
51 this was not the case for age alone as a predictor in a separate bi-variable model. Pathological
52
53
54
55
56
57
58
59
60

1
2
3 changes in the inner ear resulting in hearing loss as an effect of age alone is debated in the
4
5 research community.[39] Results are even less solid when considering age as a sole cause of
6
7 tinnitus.[40] Instead, the effect of noise exposure is hypothesised to largely contribute to the
8
9 increased prevalence of hearing-related disorder seen in increased age.[30 39 40]

10
11 Finally, being an initial study in this area we were not able to include a large study sample,
12
13 which affects the reliability of the analyses and the generalisation of the results. Also, though
14
15 the cross-sectional design prevents drawing definite conclusions on causal relationships, we
16
17 argue based on previous research and our study results that it is reasonable to assume a causal
18
19 pathway from noise exposure to hearing-related symptoms; the hypothesised casual pathway
20
21 involving stress and noise annoyance however, being less certain.
22
23
24
25
26

27 CONCLUSION

28
29 This study presents new results regarding risk of noise-induced hearing-related symptoms
30
31 among obstetrics personnel, which to the best of our knowledge has not been described
32
33 before. The results show that obstetrics personnel are at times exposed to sound levels above
34
35 regulated limits and that more than half of the participants report one or more hearing-related
36
37 symptom. Furthermore, a statistically significant association was found between cumulative
38
39 occupational noise exposure and the hearing-related symptom tinnitus and sound induced
40
41 auditory fatigue. Noise annoyance was a common complaint and in addition to noise exposure
42
43 also an important factor for sound induced auditory fatigue. These results indicate that
44
45 preventative action regarding noise exposure is required in obstetrics care and that risk-
46
47 assessments may be needed in previously unstudied non-industrial communication-intense
48
49 sound environments.
50
51
52
53
54
55
56
57
58
59
60

Acknowledgments

The authors would like to thank Lars Larsson for performing the dosimeter measurements, Christofer Andersson for assistance with the web-survey and Agneta Agge for survey data entry, as well as all the participating personnel at the obstetrics care unit at the Sahlgrenska University hospital.

Footnotes

Contributors All authors contributed to this work. KPW and KT obtained funding. KPW, SF and AT contributed to the study concept and design. SF collected the data with help from KPW. OH, SF, KPW and KT designed the plan of analysis. SF performed the final analyses. SF, KPW, OH and KT drafted the manuscript and interpreted the results. SF, KPW, OH, KT, AT made substantive editorial contributions at all stages of manuscript preparation.

Funding This study was funded by grants from the Swedish research council for Health, Working Life and Welfare (Forte) as well as the Swedish funder AFA insurance. The researchers are independent from funders.

Competing interests All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval The study was approved by the ethics committee in Gothenburg Sweden, Nr 788-11.

Provenance and peer review Not commissioned; externally peer reviewed

Data sharing statements No additional data are available

This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 3.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/3.0/>

References

1. Nelson DI, Nelson RY, Concha-Barrientos M, Fingerhut M. The global burden of occupational noise-induced hearing loss. *American Journal of Industrial Medicine* 2005;**48**(6):446-58 doi: 10.1002/ajim.20223.
2. European Agency for Safety and Health at Work. Risks and Trends in the Safety and Health of Women at Work, 2012.
3. Axelsson A, Hamernik RP. Acute acoustic trauma. *Acta Oto-laryngologica* 1987;**104**(3-4):225-33 doi: doi:10.3109/00016488709107322.
4. Henry JA, Dennis KC, Schechter MA. General Review of Tinnitus: Prevalence, Mechanisms, Effects, and Management. *Journal of Speech Language and Hearing Research* 2005;**48**(5):1204-35 doi: 10.1044/1092-4388(2005/084).
5. Kähäri K, Zachau G, Eklöf M, Sandsjö L, Möller C. Assessment of hearing and hearing disorders in rock/jazz musicians: Evaluación de la audición y de los problemas auditivos en músicos de rock y jazz. *International Journal of Audiology* 2003;**42**(5):279-88 doi: doi:10.3109/14992020309078347.
6. Palmer K, Griffin M, Syddall H, Davis A, Pannett B, Coggon D. Occupational exposure to noise and the attributable burden of hearing difficulties in Great Britain. *Occupational and Environmental Medicine* 2002;**59**(9):634-39
7. Persson Waye K, Kähäri K. Consequences on hearing when working in a communication intense environment with high noise levels. *International Journal of Audiology* (For submission)

- 1
2
3 7. Persson Waye K, Ryherd E, Hsu T, Lindahl B, Bergbom I. (2010). Personnel response in
4 intensive care units. *Internoise; 2010 13-16 June; Lisbon, Portugal.*
- 5
6
7 8. Kjellberg A. Subjective, behavioral and psychophysiological effects of noise. *Scandinavian*
8 *journal of work, environment & health* 1990;29-38
- 9
10
11 9. Busch-Vishniac IJ, West JE, Barnhill C, Hunter T, Orellana D, Chivukula R. Noise levels
12 in Johns Hopkins hospital. *The Journal of the Acoustical Society of America*
13 2005;118:3629
- 14
15
16
17 10. Vinodhkumaradithyaa A, Kumar D, Ananthalakshmi I, et al. Noise levels in a tertiary care
18 hospital. *Noise and Health* 2008;10(38):11-13 doi: 10.4103/1463-1741.39003.
- 19
20
21
22 11. Hildingsson I, Westlund K, Wiklund I. Burnout in Swedish midwives. *Sexual &*
23 *Reproductive Healthcare* 2013;4:87-91
- 24
25
26 12. Hultberg A, Hadžibajramović E, Pettersson S, Skagert K, Ahlberg G. KART-studien.
27 *Arbetsmiljö, stress och hälsa bland anställda vid Västra Götalandsregionen. Delrapport 5:*
28 *Uppföljning utifrån organisations-, yrkesgrupps- och individperspektiv 2008 - 2010. In:*
29 *Ahlberg G, ed.: Institute of Stress Medicine, 2011. [In Swedish]*
- 30
31
32
33 13. Babisch W. The noise/stress concept, risk assessment and research needs. *Noise and*
34 *Health* 2002;4(16):1-11
- 35
36
37
38 14. Leather P, Beale D, Sullivan L. Noise, psychosocial stress and their interaction in the
39 workplace. *Journal of Environmental Psychology* 2003;23(2):213-22
- 40
41
42
43 15. Lercher P, Hörtnagl J, Kofler WW. Work noise annoyance and blood pressure: combined
44 effects with stressful working conditions. *International archives of occupational and*
45 *environmental health* 1993;65(1):23-28
- 46
47
48 16. Persson Waye K, Agge A, Hillström J, Lindström F. Being in a pre-school sound
49 environment – annoyance and subjective symptoms among personnel and children.
50 *Internoise; 2010 13-16 June; Lisbon, Portugal.*
- 51
52
53
54
55
56
57
58
59
60

- 1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
17. Neitzel R, Daniell W, Sheppard L, Davies H, Seixas N. Comparison of Perceived and Quantitative Measures of Occupational Noise Exposure. *Annals of Occupational Hygiene* 2009;**53**(1):41-54 doi: 10.1093/annhyg/men071.
18. Nondahl DM, Cruickshanks KJ, Wiley TL, Tweed TS, Klein R, Klein BEK. Accuracy of Self-reported Hearing Loss. *International Journal of Audiology* 1998;**37**(5):295-301 doi: doi:10.3109/00206099809072983.
19. Schlaefler K, Schlehofer B, Schüz J. Validity of self-reported occupational noise exposure. *Occupational and Environmental Medicine* 2011;**68**(Suppl 1):A42 doi: 10.1136/oemed-2011-100382.137.
19. Schlaefler K, Schlehofer B, Schüz J. Validity of self-reported occupational noise exposure. *European journal of epidemiology* 2009;**24**(8):469-475.
20. Sindhusake D, Mitchell P, Smith W, et al. Validation of self-reported hearing loss. The Blue Mountains hearing study. *International Journal of Epidemiology* 2001;**30**(6):1371-78
21. Ryberg JB, Agge A, Wayne KP. Low frequency noise in a paper mill control room. *Journal of low frequency noise, vibration and active control* 2007;**26**(3):165-76
22. Axelsson A, Prasher D. Tinnitus induced by occupational and leisure noise. *Noise and Health* 2000;**2**(8):47
23. Nouvian R, Eybalin M, Puel J-L. The cochlea and the Auditory Nerve as a Primary Source of Tinnitus. In: Eggermont JJ, Zeng F-G, Popper AN, eds. *Tinnitus*. New York: Springer Science and Business Media, 2012.
24. Schmidt CO, Kohlmann T. When to use the odds ratio or the relative risk? *International journal of public health* 2008;**53**(3):165-67
25. Tenenbaum A, Hendriksson A, Larsson L. Bullernivåer och hörselundersökning på förlossningsavdelning. *Läkarstämman*. Stockholm, Sweden, 2010. [In Swedish]
26. Danermark B, Hanning M. Hearing and vision: Health in Sweden: The National Public Health Report 2012. Chapter 17. *Scandinavian Journal of Public Health* 2012;**40**(9 suppl):287-92 doi: 10.1177/1403494812459621.

- 1
2
3 27. Andersson G, Lindvall N, Hursti T, Carlbring P. Hypersensitivity to sound (hyperacusis):
4 a prevalence study conducted via the internet and post. *International Journal of*
5 *Audiology* 2002;**41**(8):545-54 doi: doi:10.3109/14992020209056075.
6
7
8
9 28. Kujawa SG, Liberman MC. Adding insult to injury: cochlear nerve degeneration after
10 “temporary” noise-induced hearing loss. *The Journal of Neuroscience*
11 2009;**29**(45):14077-85
12
13
14 29. Lin HW, Furman AC, Kujawa SG, Liberman MC. Primary neural degeneration in the
15 Guinea pig cochlea after reversible noise-induced threshold shift. *Journal of the*
16 *Association for Research in Otolaryngology* 2011;**12**(5):605-16
17
18
19
20 30. Kujawa SG, Liberman MC. Acceleration of age-related hearing loss by early noise
21 exposure: evidence of a misspent youth. *The Journal of Neuroscience* 2006;**26**(7):2115-
22 23
23
24
25
26 31. Ruggles D, Bharadwaj H, Shinn-Cunningham BG. Normal hearing is not enough to
27 guarantee robust encoding of suprathreshold features important in everyday
28 communication. *Proceedings of the National Academy of Sciences* 2011;**108**(37):15516-
29 21
30
31
32
33 32. Heinonen-Guzejev M, Koskenvuo M, Silventoinen K, et al. Noise Sensitivity and
34 Disability Retirement: A Longitudinal Twin Study. *Journal of Occupational and*
35 *Environmental Medicine* 2013;**55**(4):365-70
36
37
38
39 33. Alpini D, Cesarani A. Tinnitus as an alarm bell: stress reaction tinnitus model. *ORL*
40 2006;**68**(1):31-37
41
42
43
44 34. Hébert S, Lupien SJ. The sound of stress: blunted cortisol reactivity to psychosocial stress
45 in tinnitus sufferers. *Neuroscience letters* 2007;**411**(2):138-42
46
47
48
49 35. Holgers K-M, Erlandsson SI, Barrenäs M-L. Predictive Factors for the Severity of
50 Tinnitus: Factores predictivos de la severidad del tinnitus. *International Journal of*
51 *Audiology* 2000;**39**(5):284-91
52
53
54
55 36. Robinson SK, Viirre ES, Stein MB. Antidepressant therapy in tinnitus. *Hearing research*
56 2007;**226**(1):221-31
57
58
59
60

- 1
2
3 37. Davies HW, Teschke K, Kennedy SM, Hodgson MR, Hertzman C, Demers PA.
4 Occupational exposure to noise and mortality from acute myocardial infarction.
5 Epidemiology 2005;**16**(1):25-32
6
7
8
9 38. Nilsson T, Burström L, Hagberg M. Risk assessment of vibration exposure and white
10 fingers among platers. International archives of occupational and environmental health
11 1989;**61**(7):473-81
12
13
14 39. Van Eyken E, Van Camp G, Van Laer L. The complexity of age-related hearing
15 impairment: contributing environmental and genetic factors. Audiology and Neurotology
16 2007;**12**(6):345-58
17
18
19
20
21 40. Sanchez L. The epidemiology of tinnitus. Audiological Medicine 2004;**2**(1):8-17
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

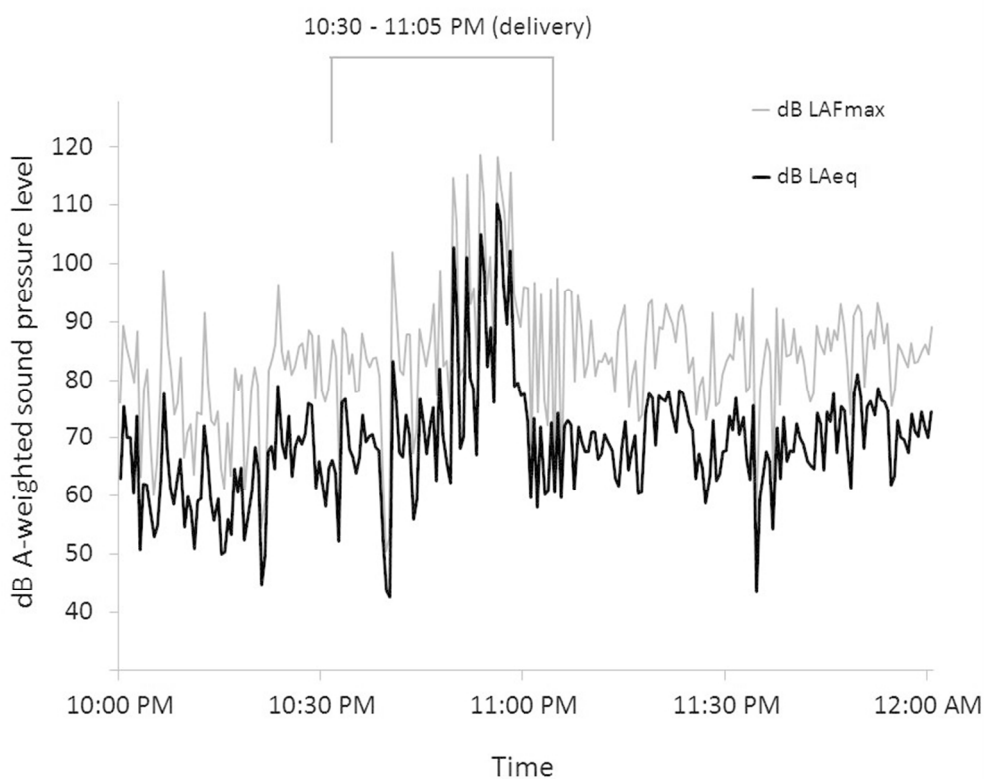
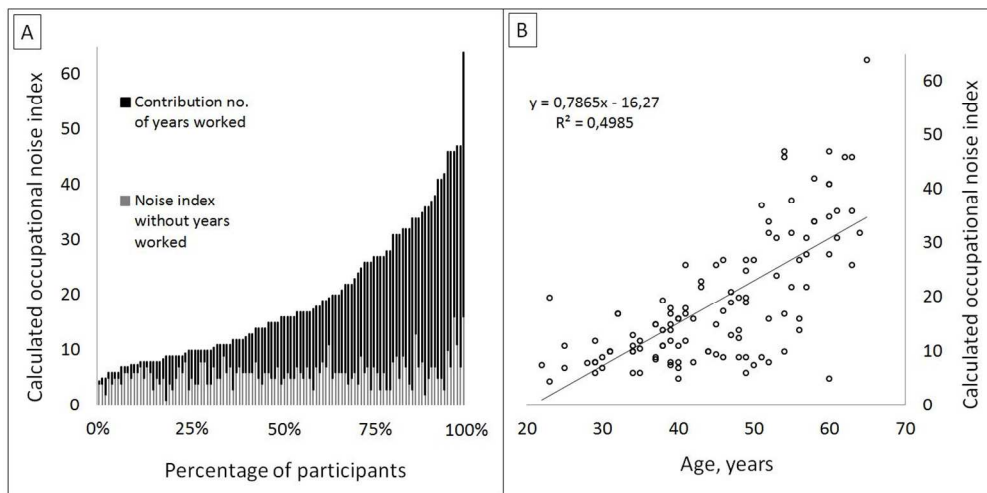


Figure 1. Two hour section of a time history graph from sound level measurement with dosimeter carried by a midwife during a sample night shift in the obstetrics ward. Equivalent sound level during the entire shift was 85 dB LAeq (approx. 9 hours) and 118.7 dB LAFmax was the highest recorded during the shift (shown in the selected section). According to the written log the midwife attended a delivery during 10:30 – 11:05 PM. Black curve shows the dB LAeq and grey curve shows dB LAFmax.

244x194mm (96 x 96 DPI)



Calculated occupational noise index for obstetrics personnel. To the right in figure 2 A, contribution of number of years worked in obstetrics (in black) to the noise index for each participant, each bar representing one participant. The percentages of participants are shown on the x-axis and the calculated noise index value on the y-axis. To the left in figure 2 B, the correlation between noise index and age of participants.

372x186mm (96 x 96 DPI)

Review only

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Supplementary table 1 Calculation of occupational noise index for obstetrics personnel based on questionnaire data, where scoring for each item and each response alternative is shown.

Questionnaire item in full text	Response alternatives	Scoring for index
How many years have you worked in an obstetrics ward?	Free field answer	1 point per year ^a
Have you worked with the so called ABC-method (Alternative Birth Care), if so for how many years?	Free field answer	1 point per year ^b
How many working hours do you normally spend in postpartum care and in delivery care, respectively?	Free field answer	0 points 1 point 2 points ^c
Is the sound level at your workplace sometimes so loud that you have difficulty hearing what other people are saying?	Never/almost never 25% of time 50% of time 75% of time Always/almost always	0 points 1 point 2 points 3 points 4 points
How often are you at your workplace exposed to such high sound levels that you have to raise your voice to be able to talk to other people?	Never/almost never 25% of time 50% of time 75% of time Always/almost always	0 points 1 point 2 points 3 points 4 points
Do you use hearing protective devices (such as ear-plugs) at your current workplace?	Never/almost never Seldom Often Always/almost always	3 points 2 points 1 point 0 points

^a Missing data was replaced by number of years since graduating, n=6. One additional participant did not fill in number of years worked, nor years since graduating and therefore got 14.6 points which was the group median at that specific age (46 years old).

^b Missing data was replaced by group median (3 years), n=3.

^c Participants reporting 0 hours in delivery care received 0 points, those reporting any number of hours in postpartum care and delivery care received 1 point and those reporting 1 hour or more in delivery care only received 3 points.

Supplementary table 2 Questionnaire items and response alternatives used in survey among obstetrics care personnel. Derived variables used in the analysis are also shown based on the questionnaire items (translation from Swedish for article, not validated). Original wording in Swedish provided for hearing-related items.

Hearing-related outcome variables	Response alternatives	Derived variables
Hearing loss Do you have a hearing loss? /hearing disorder? (Swe. "hörselnedsättning/hörselskada")	Yes No Don't know	Hearing loss was defined as reporting yes.
Tinnitus, Sound sensitivity and Sound fatigue^a Do you during or after work experience any of the following symptoms: - Tinnitus? - Sound sensitivity? (discomfort, pain from normal sounds)? (Swe. "ljudkänslighet, obehag eller smärta av normala ljud") - Sound fatigue? (Swe. "ljudtrötthet")	Never/rarely A few times each month Once or twice a week Several times each week Every day	Having either symptom was defined as reporting once a week or more often.
Poor hearing How do you think your hearing is? (Swe. "Hur tycker du att din hörsel är?")	Very good Good Normal Bad Very bad	Poor hearing was defined as reporting bad or very bad hearing.
Difficulty perceiving speech Do you have trouble hearing what is said in an environment where several people are talking at the same time (Swe. "Har du besvär att höra vad som sägs i en miljö där flera talar samtidigt?") - At work? - In leisure time?	Yes No	Difficulty perceiving speech was defined as reporting yes to both work and leisure time.
Explanatory variables	Response alternatives	Derived variables
Work-related stress How is your work typically? - I experience high degree of stress. - I feel unwell due to stress at work.	Never/seldom Sometimes Often Always/almost always	Work-related stress was defined as reporting often or always/almost always for one or both of the stress items.
Noise annoyance Are you annoyed by sounds/noise at your work place?	Not at all Some Pretty much Very Extremely	Noise annoyance was defined as reporting if pretty much, very or extreme annoyance.
Smoking Do you smoke?	Yes Yes, but only occasionally No, but I have smoked previously for ___ years No	Ever smokers were defined as those reporting yes, yes occasionally or previously smoked.
Leisure time noise exposure Are you exposed to high sound levels during leisure time (e.g. shooting/hunting, playing in a band, concert/disco, driving motorcycle, working with noisy tools/machines)?	No Yes, every day Yes, a few times each week Yes, once or twice each week Yes, a few times each month Yes, once or twice a month Yes, a few times each year or less often/never	Leisure time exposure was defined as those reporting exposure once a month or more often.

^a The items regarding the symptoms tinnitus, sound sensitivity and sound fatigue were included in a matrix with other symptoms such as headache and tiredness.

Supplementary table 1 Calculation of occupational noise index for obstetrics personnel based on questionnaire data, where scoring for each item and each response alternative is shown.

Questionnaire item in full text	Response alternatives	Scoring for index
How many years have you worked in an obstetrics ward?	Free field answer	1 point per year ^a
Have you worked with the so called ABC-method (Alternative Birth Care), if so for how many years?	Free field answer	1 point per year ^b
How many working hours do you normally spend in postpartum care and in delivery care, respectively?	Free field answer	0 points 1 point 2 points ^c
Is the sound level at your workplace sometimes so loud that you have difficulty hearing what other people are saying?	Never/almost never 25% of time 50% of time 75% of time Always/almost always	0 points 1 point 2 points 3 points 4 points
How often are you at your workplace exposed to such high sound levels that you have to raise your voice to be able to talk to other people?	Never/almost never 25% of time 50% of time 75% of time Always/almost always	0 points 1 point 2 points 3 points 4 points
Do you use hearing protective devices (such as ear-plugs) at your current workplace?	Never/almost never Seldom Often Always/almost always	3 points 2 points 1 point 0 points

^a Missing data was replaced by number of years since graduating, n=6. One additional participant did not fill in number of years worked, nor years since graduating and therefore got 14.6 points which was the group median at that specific age (46 years old).

^b Missing data was replaced by group median (3 years), n=3.

^c Participants reporting 0 hours in delivery care received 0 points, those reporting any number of hours in postpartum care and delivery care received 1 point and those reporting 1 hour or more in delivery care only received 3 points.

Supplementary table 2 Questionnaire items and response alternatives used in survey among obstetrics care personnel. Derived variables used in the analysis are also shown based on the questionnaire items (translation from Swedish for article, not validated). **Original wording in Swedish provided for hearing-related items.**

Hearing-related outcome variables	Response alternatives	Derived variables
Hearing loss Do you have a hearing loss? /hearing disorder? (Swe. "hörselnedsättning/hörselskada")	Yes No Don't know	Hearing loss was defined as reporting yes.
Tinnitus, Sound sensitivity and Sound fatigue^a Do you during or after work experience any of the following symptoms: - Tinnitus? - Sound sensitivity? (discomfort, pain from normal sounds)? (Swe. "ljudkänslighet, obehag eller smärta av normala ljud") - Sound fatigue? (Swe. "ljudtrötthet")	Never/rarely A few times each month Once or twice a week Several times each week Every day	Having either symptom was defined as reporting once a week or more often.
Poor hearing How do you think your hearing is? (Swe. "Hur tycker du att din hörsel är?")	Very good Good Normal Bad Very bad	Poor hearing was defined as reporting bad or very bad hearing.
Difficulty perceiving speech Do you have trouble hearing what is said in an environment where several people are talking at the same time (Swe. "Har du besvär att höra vad som sägs i en miljö där flera talar samtidigt?") - At work? - In leisure time?	Yes No	Difficulty perceiving speech was defined as reporting yes to both work and leisure time.
Explanatory variables	Response alternatives	Derived variables
Work-related stress How is your work typically? - I experience high degree of stress. - I feel unwell due to stress at work.	Never/seldom Sometimes Often Always/almost always	Work-related stress was defined as reporting often or always/almost always for one or both of the stress items.
Noise annoyance Are you annoyed by sounds/noise at your work place?	Not at all Some Pretty much Very Extremely	Noise annoyance was defined as reporting if pretty much, very or extreme annoyance.
Smoking Do you smoke?	Yes Yes, but only occasionally No, but I have smoked previously for ___ years No	Ever smokers were defined as those reporting yes, yes occasionally or previously smoked.
Leisure time noise exposure Are you exposed to high sound levels during leisure time (e.g. shooting/hunting, playing in a band, concert/disco, driving motorcycle, working with noisy tools/machines)?	No Yes, every day Yes, a few times each week Yes, once or twice each week Yes, a few times each month Yes, once or twice a month Yes, a few times each year or less often/never	Leisure time exposure was defined as those reporting exposure once a month or more often.

^a The items regarding the symptoms tinnitus, sound sensitivity and sound fatigue were included in a matrix with other symptoms such as headache and tiredness.

BMJ Open

The effect of occupational noise exposure on tinnitus and sound induced auditory fatigue among obstetrics personnel: a cross-sectional study

Journal:	<i>BMJ Open</i>
Manuscript ID:	bmjopen-2014-005793.R2
Article Type:	Research
Date Submitted by the Author:	28-Oct-2014
Complete List of Authors:	Fredriksson, Sofie; University of Gothenburg, Public Health and Community Medicine Hammar, Oscar; University of Gothenburg, Public Health and Community Medicine Torén, Kjell; University of Gothenburg, Public Health and Community Medicine Tenenbaum, Artur; Occupational health care unit, Skaraborg Hospital Persson Waye, Kerstin; University of Gothenburg, Public Health and Community Medicine
Primary Subject Heading:	Occupational and environmental medicine
Secondary Subject Heading:	Ear, nose and throat/otolaryngology, Obstetrics and gynaecology
Keywords:	OCCUPATIONAL & INDUSTRIAL MEDICINE, Audiology < OTOLARYNGOLOGY, OBSTETRICS

SCHOLARONE™
Manuscripts

only

1
2
3 **The effect of occupational noise exposure on tinnitus and sound induced**
4 **auditory fatigue among obstetrics personnel: a cross-sectional study**
5
6
7
8
9

10 **Authors' names**

11 Sofie Fredriksson (SF), Oscar Hammar (OH), Kjell Torén (KT), Artur Tenenbaum (AT),
12
13 Kerstin Persson Waye (KPW)
14

15
16
17
18
19 **Corresponding author:**

20 Sofie Fredriksson

21 University of Gothenburg

22 Dept. of Public health & Community Medicine

23 Occupational and Environmental Medicine

24 PO Box 414, SE 405 30 Gothenburg, Sweden

25 sofie.fredriksson@gu.se

26 +46317863610 (telephone), +4631409728 (fax)
27
28
29
30
31
32
33
34
35
36
37
38
39

40 **Address for co-authors:**

41 Oscar Hammar (1), Kjell Torén (1), Artur Tenenbaum (2), Kerstin Persson Waye (1)

- 42
43 1) Department of Public Health and Community Medicine, Occupational and
44 Environmental Medicine, University of Gothenburg, S-405 30 Gothenburg
45
46 2) Occupational health care unit (Hälsan & Arbetslivet), Skaraborg Hospital, S-541 85
47 Skövde, Sweden
48
49
50
51
52
53
54

55 **Keywords:** Noise, occupational; stress; hearing disorders; cross-sectional studies; obstetrics

56 **Word count** (excluding title page, abstract, references, figures and tables): 4582
57
58
59
60

ABSTRACT

Objective: There is a lack of research on effects of occupational noise exposure in traditionally female-dominated workplaces. Therefore, the aim was to assess risk of noise-induced hearing-related symptoms among obstetrics personnel.

Design: A cross-sectional study at an obstetric ward in Sweden including a questionnaire among all employees and sound level measurements in 61 work-shifts at the same ward.

Participants: 115 female employees responded to a questionnaire (72% of all 160 employees invited).

Main outcome measures: Self-reported hearing-related symptoms, noise annoyance, work-related stress, calculated cumulative occupational noise exposure and measured sound levels.

Results: Sound levels exceeded the 80 dB LAeq limit for protection of hearing in 46% of the measured work-shifts. One or more hearing-related symptom was reported by 55% of the personnel. In logistic regression models a significant association was found between cumulative occupational noise exposure and tinnitus (Odds Ratio 1.04, 95% confidence interval 1.00 to 1.09) and sound induced auditory fatigue (Odds Ratio 1.04, 95% confidence interval 1.00 to 1.07). Work-related stress and noise annoyance were reported by almost half of the personnel group. Sound induced auditory fatigue was associated to work-related stress and noise annoyance, although stress just missed significance in a multivariable model. No significant interactions were found.

Conclusion: This study presents new results showing that obstetrics personnel are at risk of noise-induced hearing-related symptoms. Current exposure levels at the work-place are high and cumulative exposure has significant effects on tinnitus and sound induced auditory fatigue among the personnel. These results indicate that preventative action regarding noise exposure is required in obstetrics care and that risk-assessments may be needed in previously unstudied non-industrial communication-intensive sound environments.

Strengths and limitations of this study:

- The vast majority of previous research into noise-induced hearing disorders has been performed in industrial-like settings, whereas practically nothing is known of risks in non-industrial, traditionally female-dominated and communication-intense workplaces, such as hospitals. As such, this study presents novel results on occupational noise exposure and hearing among obstetrics personnel.
- Both objective sound level measurements and analysis of subjective data indicate an increased risk of hearing-related disorder.
- Due to the cross-sectional design the influence of subjects' age cannot be disentangled.
- The study sample size and the cross-sectional design without an unexposed control group limits the generalisation of the results and prevents us from drawing definite conclusions on causality.
- Further studies are needed to confirm the results and assess the magnitude of the problem. However, we suggest that occupational health care services implement available preventative actions such as making hearing protective devices available for personnel as an action of precaution.

INTRODUCTION

Occupational noise exposure and effects on hearing is well described in industrial-like, traditionally male-dominated settings.[1] In contrast, few studies have reported on traditionally female-dominated work environments. This has been acknowledged by the European Agency for Safety and Health at Work, who conclude that areas such as health and social services are largely overlooked concerning noise research,[2] and that the noise in these types of workplaces may interfere with performance and wellbeing. High sound levels regardless of its source can cause hearing loss, tinnitus and sound sensitivity and may also result in sound induced auditory fatigue, the latter described by subjects as avoidance of everyday sounds and a need for silence.[1 3-7] The symptom sound induced auditory fatigue was first identified in pilot studies, interviewing preschool personnel, and have later shown to prevalent in questionnaire surveys [7]. We hypothesise the symptom to be a result of constant or overloading stimulation of sounds during the day. The effect may possibly be due to the high information content mainly of speech, such that overload is not merely a consequence of the sound energy as seen in auditory threshold shift, but as a result of an information intense sound environment. Apart from hearing-related symptoms, noise exposure can also evoke non-auditory effects such as annoyance and stress.[8] According to a recent meta-analysis, noise levels in hospitals have steadily increased since the mid-1960.[9] One heavily female-dominated workplace in the hospital is the obstetrics care. According to data from Statistics Sweden in 2011, more than 99% of midwives are women. One peer-reviewed study have reported on sound level measurements from obstetrics care in a hospital in India, where the highest night time level (71.9 dB LAeq) was measured in the obstetrics and gynaecology ward, with slightly lower levels in the labour ward.[10]

In addition to potentially harmful noise levels in the obstetrics care, midwives report a high degree of work-related stress and burnout,[11] and according to a recent report burnout

1
2
3 syndrome have doubled among midwives employed in the western region of Sweden during
4 the last years.[12] The fact that obstetrics personnel are exposed to high levels of stress may
5 be important when considering noise exposure at the workplace, since the combination of
6 these exposures may interact in causing adverse health effects.[13-15]
7
8

9
10
11 There is a substantial lack of knowledge regarding occupational noise exposure, noise
12 annoyance and hearing-related symptoms among obstetrics care personnel, as well as possible
13 interaction effects between noise exposure, noise annoyance and work-related stress.
14

15
16 Therefore, the aim of this study was to assess the risk of noise-induced hearing-related
17 symptoms among obstetrics personnel by measuring sound levels in the labour ward of a
18 general obstetrics ward and by analysing the effect of and interaction between occupational
19 noise exposure, noise annoyance and work-related stress on hearing-related symptoms among
20 obstetrics personnel.
21
22
23
24
25
26
27
28
29
30
31

32 **METHODS**

33 **Sound level measurements**

34
35 Sound level measurements were carried out during 61 work shifts in the labour ward of a
36 general obstetrics ward at the Sahlgrenska University Hospital in Gothenburg. Out of the 61
37 shifts 19 day shifts were measured between 7 a.m. and 3:30 p.m. (8.5 h), 12 evening shifts
38 between 1:45 p.m. and 9 p.m. (7.25 h) and 30 nightshifts between 9 p.m. and 7 a.m. (10 h).
39
40 The day and evening shifts were measured during separate weeks so as not to overlap. A
41 convenient sample of ten employees per shift each wore a personal dosimeter (Larson Davis
42 705+) with the microphone attached to the right shoulder and kept a written log documenting
43 work activities during the measured shift. A total of 610 separate measurements were
44 collected, as 10 individuals each wore a dosimeter during the 61 shifts measured. However,
45 due to technical errors a few faulty measurements were excluded leaving 529 (87%) to be
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 included in the analysis. The dosimeters were set to measure A-weighted equivalent and
4
5 maximum (fast) levels with a sampling interval of 30 seconds. All dosimeters were calibrated
6
7 using the software Blaze version 5.06 before measurements begun. The equivalent levels
8
9 reported refer to the full-shift length and will hence vary between 7.25 – 10 hours, hereinafter
10
11 denoted as LAeq(7-10h). Sound levels were analysed at group level as arithmetic mean and
12
13 compared to Swedish Work Authorities' exposure regulations. Sound levels exceeding the
14
15 lower action level of 80 dB LAeq(8h) indicate a risk for hearing damage and the employer is
16
17 responsible to take preventative action, such as providing employees with hearing protection
18
19 devices (HPDs). The exposure limits 85 dB LAeq (8h) and 115 dB LAFmax are set as a
20
21 maximum allowed level above which the employer is required to take measures in order to
22
23 reduce the noise exposure, and where use of HPDs are mandatory. Employees must not be
24
25 exposed to noise levels at or above the exposure limits (taking attenuation of HPDs into
26
27 account).
28
29
30
31
32
33

34 **Questionnaire survey**

35
36 All personnel (n=160, all women), employed at the general obstetrics ward were included in a
37
38 questionnaire survey. A total of 115 (72%) participated by responding either electronically
39
40 (n=63) or in paper format (n=52) and these data were pooled together, as no statistical
41
42 differences were seen on explanatory or outcome variables (p>0.05). The questionnaire was
43
44 constructed using items specifically constructed for this study as well as items adapted from
45
46 previous studies and international standards (ISO/TS 15666).[7 16] Similar self-reported
47
48 items assessing noise exposure as well as hearing loss and tinnitus have previously been
49
50 subject for validation.[17-20]
51
52

53
54 The main explanatory variable cumulative occupational noise exposure dose, was calculated
55
56 as an exposure index derived from six questionnaire items including; number of years worked
57
58
59
60

1
2
3 in delivery care, number of years worked in alternative birth care, work allocation (delivery
4 care, postpartum care or both), two separate items on frequency of current work-related noise
5 exposure (one assessing how often the sound levels are so high that the person has to speak
6 with raised voice and one assessing how often the person have trouble hearing what is said)
7 and finally one item on frequency of hearing protection use. A higher noise index indicates a
8 higher noise exposure dose. The scoring for each item's contribution to the index is presented
9 in detail in supplementary table 1. Each variable score was summed using mathematical
10 addition to a total index score for each participant. In addition, the study group was
11 categorized into four noise index groups based on calculation of quartiles, with each noise
12 index category representing 25% of the study population. Work-related stress and noise
13 annoyance were analysed as additional explanatory variables. Work-related stress was
14 assessed using two separate questionnaire items asking responders to report how often they
15 experience high degree of stress and how often they feel unwell due to stress at work.
16
17 Participants were defined as having work-related stress if answering often or always/almost
18 always on one or both of the items. These stress-related items have previously been used in
19 noise-related research.[21] Noise annoyance was assessed by the item 'Are you annoyed by
20 sounds/noise at your workplace?', which is based on the International standard ISO/TS
21 15666, adapted for a workplace survey as opposed to community surveys. The hearing-related
22 outcome variables included are hearing loss (yes), tinnitus, sound sensitivity (i.e. hyperacusis)
23 and sound induced auditory fatigue (once a week or more often), general hearing status (poor
24 or very poor) and difficulty perceiving speech (yes both at work and in leisure time).
25
26 Variables considered as possible moderators for the association between exposure and
27 outcome were smoking (previous or current) and leisure-time noise exposure (once a month
28 or more often). Age (in years) was considered a possible confounder. The questionnaire items
29 are presented in full in the supplementary table 2.
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Statistical analyses

Hypothesis testing was performed using IBM SPSS Statistics 20. Differences in arithmetic mean were analysed using one-way analysis of variance (ANOVA) or independent samples t-test where applicable. Test for trend was analysed using linear regression with dummy coding for categorical predictors or Mantel-Haentzel linear-by-linear association where applicable. Binary logistic regression with Wald tests was used for analysis of associations and interaction. The significance level was set at 5% ($p=0.05$) for all tests. Based on a hypothesised order of importance of explanatory variables, manual sequential regression models were analysed. For each binary hearing-related outcome variable we used the following model testing procedure: In a first model, noise exposure index was analysed as a single continuous explanatory variable with the hearing-related symptom as a binary outcome variable. If noise exposure index was significant for the hearing-related symptom, then a second model was analysed, adjusting for moderators (leisure noise exposure and smoking), each one at a time. Age as a possible confounder was analysed separately due to initial hypothesised strong correlation to the noise index (due to its cumulative nature). If point estimates for noise index was comparable with and without adjustment and the adjustment variable itself was non-significant, then it was not included in subsequent multivariable models. In the third model, work-related stress was analysed as an additional explanatory variable and in a fourth model noise annoyance instead of stress was included together with significant explanatory variables from model 2. The fifth model included explanatory variables found to be significant in any of the previous steps. Hypothesised interactions between explanatory variables were assessed in separate models by including an interaction term. Multi-collinearity between explanatory variables was assessed using Pearson's correlation or Spearman's rank correlation, where applicable, and correlation below $r=0.6$ was deemed acceptable. Odds ratios (OR) with 95% confidence intervals were derived from the

1
2
3 logistic regressions as a measure of association between exposure and outcome, and relative
4 risk (RR) was calculated from predictive values derived from model 1. Goodness of fit for the
5 regression models were assessed using the Hosmer-Lemeshow test and a non-significant p-
6 value (>0.05) was used to indicate adequate fit.
7
8
9
10

11 12 13 **RESULTS**

14 **Sound levels in the labour ward**

15
16 Overall, the dosimeter measurements from the labour ward showed moderately high sound
17 levels, as presented in table 1. The levels reached or exceeded both the action and limit levels.
18
19 The lower action level 80 dB LAeq was exceeded in 30 different dosimeter measurements
20 during 28 different work shifts, which corresponds to 46% of all measured shifts or 6% of all
21 dosimeter measurements. The upper exposure action level and exposure limit 85 dB LAeq
22 was reached or exceeded in three measurements from three different shifts, corresponding to
23 5% of all measured shifts or 0.6% of all measurements. The limit 115 dB LAFmax was
24 reached or exceeded at 50 different occasions. However, of these 9 separate events could not
25 be verified by the written logs and were therefore excluded. The remaining 41 events occurred
26 in 17 different shifts corresponding to 28% of all measured shifts or 8% of all dosimeter
27 measurements. There were no statistical differences in arithmetic mean equivalent nor in
28 maximum levels when comparing measurements from different work-shifts nor measurements
29 from dosimeters worn by midwives compared to assistant nurses. Due to incomplete written
30 logs however, we were unable to categorise a third of the measurements into professional
31 group. A segment sample from a dosimeter measurement is shown in figure 1, where high
32 maximum levels (119 dB LAFmax) was recorded during a delivery, which according to the
33 written log occurred between 10:30 and 11:05 pm. The equivalent level in this particular
34 measurement was 84 dB LAeq(10h) for the measured shift length. As exposure limits should be
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

regarded with HPDs taken into account, it is noteworthy that the majority of the respondents (92%) reported to never or almost never use hearing protective devices at work.

FIGURE 1

Table 1. Sound level measurements at the labour ward showing arithmetic mean, standard deviation (SD), 95% confidence interval (CI) of mean and range of the measured equivalent, LAeq_(7-10h) and maximum, LAFmax sound levels in dB. Also showing mean and standard deviation of measurements categorised by work shift and by professional group as reported in written logs by the personnel carrying the dosimeter. Frequencies (n) in the table represent unique dosimeter measurements.

	Sound level measurements		
	dB LAeq _(7-10h)	dB LAFmax	n
All measurements			
Arithmetic mean (SD)	70.3 (6.0)	106.3 (6.0)	529
95% CI of mean	69.7 - 70.8	105.8 - 106.8	
Min – Max	56.0 – 87.0	83.0 – 122.0	
Measurements categorised by work shift (arithmetic mean, SD)^a			
Day shift	70.8 (6.2)	106.2 (5.9)	139
Evening shift	70.8 (5.2)	106.3 (5.6)	127
Night shift	69.8 (6.3)	106.4 (6.2)	263
Measurements categorised by professional group (arithmetic mean, SD)			
Midwives	71.3 (5.1)	106.2 (5.9)	289
Assistant nurses	72.2 (5.0)	107.8 (5.2)	114
Uncategorised	66.2 (7.0)	103.9 (6.5)	126

^a Number of shifts categories as day (n=19), evening (n=12) and night (n=30).

Association between noise exposure and hearing disorder

Demographics, occurrence of explanatory variables; work-related stress, noise annoyance and adjustment variables; smoking and leisure noise exposure as well as prevalence of hearing-related outcomes are presented in table 2, both for the total study sample as well as categorised into four noise exposure index groups calculated from quartiles of the noise index. The first noise index group (1) represents the respondents with the lowest calculated noise exposure dose. Valid responses for the individual questionnaire items included in the analysis ranged from n=108 to 115. A test for trend in the four exposure groups shows that age, number of years worked in obstetrics and prevalence of sound induced auditory fatigue is significantly increasing with higher noise exposure group; $p<0.001$, $p<0.001$ and $p=0.049$ respectively.

Table 2. Demographics, explanatory and adjustment variables and hearing-related outcomes from questionnaire survey among personnel at the general obstetrics ward. Prevalence is presented categorised in four noise index groups based on quartiles of the index (1 – 4) and as total prevalence in the study sample. Percentages are given as column % in noise index quartile groups and % of total.

	Grouping by noise index quartiles				Total	95% CI of total
	1	2	3	4		
Number of participants	28	29	29	29	115	-
Noise exposure index (range)	4.5 – 9.5	10 – 15	16 – 26	27 – 64	4.5 - 64	16.8 - 21.2
Demographics						
Mean age in years (SD)	39 (10)	39 (7)	45 (8)	57 (5)	45 (11)	42.8 - 46.8
Mean years worked (SD)	3 (2)	6 (2)	14 (3)	28 (6)	12 (11)	10.3 - 14.3
Professional groups, % ^a	54/36/11	69/24/7	69/21/10	76/21/3	68/25/7	-
Explanatory and adjustment variables (%)						
Work-related stress	43	52	31	41	42	32.9-51.1
Noise annoyance at work	50	45	55	45	49	39.8-58.2
Ever smoker	36	48	28	25	34	25.3-42.7
Leisure noise exposure	14	24	7	7	13	6.8-19.2
Outcome variables (%)						
Sound induced auditory fatigue	21	24	41	41	32	23.4-40.6
Tinnitus	7	11	10	24	13	6.8-19.2
Sound sensitivity	7	17	17	10	13	6.8-19.2
Poor hearing	11	21	17	14	16	9.3-22.7
Hearing loss	4	7	21	4	9	3.7-14.3
Difficulty perceiving speech	39	31	24	36	32	23.4-40.6
Any symptom ^b	54	48	55	63	55	45.9-64.1

^a Shown in table as proportion of Midwife/Assistant nurse/Other. Other also includes missing.

^b Any symptom was constructed as a binary variable including all those who reported either sound induced auditory fatigue, tinnitus, sound sensitivity, difficulty perceiving speech, poor hearing and/or hearing loss.

1
2
3 Associations between occupational noise exposure dose (continuous noise index), work-
4 related stress, noise annoyance and hearing-related symptoms were evaluated in manual
5 sequential binary logistic regression models, results of which are presented in table 3. The
6
7 calculated noise index ranged from 4.5 to 64 in the study sample. The proportional
8
9 contribution of years worked in obstetrics care to the index, as a proxy for cumulative
10
11 exposure, is shown in figure 2 A. The percentage of participants over the range of noise index
12
13 also conveys the skewness in the distribution of the index, e.g. less than 25% of the
14
15 participants have noise index values in the upper half of the range.
16
17
18
19
20
21
22
23

FIGURE 2

24
25
26
27 Occupational noise exposure as a single explanatory variable was significantly associated to
28
29 tinnitus and sound induced auditory fatigue, but not to the other hearing-related symptoms.
30
31 Work-related stress and noise annoyance were both significantly associated to sound induced
32
33 auditory fatigue in separate models, but not to tinnitus. For sound induced auditory fatigue,
34
35 including all three significant explanatory variables (noise, stress and annoyance) in model 5
36
37 resulted in marginal changes in point estimates for noise exposure and noise annoyance. It did
38
39 however affect the estimates for work-related stress, which just missed statistical significance
40
41 ($p=0.053$). No significant statistical interactions were found between explanatory variables.
42
43
44 Neither work-related stress nor noise annoyance were significantly correlated to noise
45
46 exposure index. There was however a weak yet significant correlation between stress and
47
48 noise annoyance ($r=0.249$, $p=0.008$). The point estimates for noise exposure was comparable
49
50 with or without adjustment for smoking and leisure-time noise exposure in model 2, and
51
52 neither one of the adjustment variables were themselves significant. Hence, they were not
53
54
55
56
57
58
59
60

1
2
3 included in the subsequent multivariable models. All reported models had an acceptable
4
5 goodness of fit.
6

7 As prevalence of sound induced auditory fatigue was much higher than 10%, assessing odds
8
9 ratios (OR) only may overestimate the risk. The calculated risk ratios (RR) for sound induced
10
11 auditory fatigue from model 1, in comparable 1 unit steps of the noise index, however showed
12
13 that the difference between OR and RR was minor (at the most 0.02 difference).
14

15 Due to the cumulative property of the noise index, the index was assumed to be correlated to
16
17 age, which was also confirmed in the analysis ($r=0.706$, $p<0.001$) with $R^2=0.498$, as shown in
18
19 figure 2 B. Multi-collinearity issues therefore precluded the assessment of both variables in
20
21 one regression model. Notably and importantly though, age was not significantly associated to
22
23 any of the hearing-related symptoms when assessed as a single explanatory variable in
24
25 separate regression models.
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 3. Point estimates of effect (B) and standard error (SE), odds ratios (OR), 95% confidence intervals of OR (95% CI) from binary logistic regression models for hearing-related symptom outcomes (binary dependent variables) among personnel in an obstetrics ward. All dependent variables were analysed in separate models. Manual sequential analysis was adopted, adding work-related stress and noise annoyance and adding an interaction term if the initial model was statistically significant ($p < 0.05$).

Dependent variables	Explanatory variables	B (SE)	OR (95% CI)	p-value
Sound induced auditory fatigue				
<i>Model 1</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.07)	0.031
<i>Model 3</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.08)	0.027
	Work-related stress	0.96 (0.42)	2.62 (1.15 – 5.98)	0.022
<i>Model 4</i>	Noise exposure index	0.04 (0.02)	1.04 (1.01 – 1.08)	0.026
	Noise annoyance	1.73 (0.47)	5.67 (2.25 – 14.27)	<0.001
<i>Model 5</i>	Noise exposure index	0.04 (0.02)	1.04 (1.01 – 1.08)	0.025
	Work-related stress	0.87 (0.45)	2.39 (0.99 – 5.79)	0.053
	Noise annoyance	1.66 (0.48)	5.25 (2.05 – 13.42)	0.001
Tinnitus				
<i>Model 1</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.09)	0.049
<i>Model 3</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.09)	0.046
	Work-related stress	-0.43 (0.60)	0.65 (0.20 – 2.10)	0.470
<i>Model 4</i>	Noise exposure index	0.04 (0.02)	1.05 (1.00 – 1.09)	0.038
	Noise annoyance	0.56 (0.58)	1.85 (0.56 – 5.46)	0.335
Sound sensitivity	Noise exposure index	0.01 (0.02)	1.03 (0.97 – 1.06)	0.570
Poor hearing	Noise exposure index	0.00 (0.02)	1.00 (0.96 – 1.04)	0.985
Hearing loss	Noise exposure index	0.00 (0.03)	1.00 (0.95 – 1.06)	0.995
Difficulty perceiving speech	Noise exposure index	0.01 (0.02)	1.01 (0.98 – 1.05)	0.461
Any symptom^a	Noise exposure index	0.02 (0.02)	1.02 (0.99 – 1.05)	0.273

^a Any symptom was constructed as a binary variable including all those who reported either sound induced auditory fatigue, tinnitus, sound sensitivity, difficulty perceiving speech, poor hearing and/or hearing loss.

DISCUSSION

The effect of noise exposure on hearing

In order to assess the effect of occupational noise exposure on hearing-related symptoms among obstetrics personnel, sound level measurements were carried out at the labour ward at a general obstetrics ward and associations between calculated occupational noise exposure dose and hearing-related symptoms were analysed in binary logistic regression models based on self-reported data from personnel at the same ward.

Prevalence of hearing-related symptoms among the personnel showed that tinnitus and sound induced auditory fatigue was most common among personnel with the highest exposure dose.

Accordingly, we were also able to detect statistically significant associations between occupational noise exposure and both tinnitus and sound induced auditory fatigue in logistic regression models. Sound induced auditory fatigue is a new concept that has previously been reported among preschool personnel and is hypothesised as a consequence of a constant noise load during the work day.[7 16] As for pre-school personnel, the obstetric personnel are mainly exposed to intermittent sounds from voices and screams, but also from alarms and medical equipment. It is possible that the demands and needs of attending to meaningful sounds with a high element of irregularity contribute to a mental fatigue that some individuals with sound induced auditory fatigue describe. As for sound induced auditory fatigue, we could also show a significant association between tinnitus and noise exposure. Although it is well established that noise may contribute to tinnitus,[4 22 23] it has to our knowledge not been reported previously among obstetrics personnel; hence this result is highly interesting as it supports the concerns that noise levels in non-industrial and previously less studied work environments, mainly female-dominated, may be harmful.[2] As the prevalence especially for sound induced auditory fatigue was high, it is important to note that odds ratios may not

1
2
3 directly be translated into a measure of relative risk.[24] We did however not detect major
4
5 divergences between the two measures.
6

7
8 In addition to increased risk of hearing-related symptoms of cumulative occupational noise
9
10 exposure, we also found high current sound level exposure in the labour ward, above
11
12 regulated limits. The sound level measurements further heighten the concern that obstetrics
13
14 personnel may risk acquiring hearing-related disorder as personnel carrying the dosimeters
15
16 were exposed to levels exceeding the lower action level of 80 dB LAeq during as much as
17
18 approximately half of the measured work shifts. While the average noise levels were in
19
20 accordance with an earlier study reporting noise levels from an obstetrics and labour ward at a
21
22 general hospital,[10] our study further showed that the exposure limit 115 dB LAFmax may
23
24 be exceeded in as much as one third of the work-shifts in a labour ward. The data is also in
25
26 accordance with results from a workplace inspection performed in 2010 by the occupational
27
28 health care unit at a small obstetrics ward in Sweden which showed that personnel were at
29
30 times exposed to sound levels above the regulated action and limit levels adopted by the
31
32 Swedish work environment authority.[25] This result is especially alarming as very few
33
34 personnel report use of hearing protection, which certainly may be impractical in this type of
35
36 work setting. Although caution is required in establishing the source of high maximum levels
37
38 recorded in unsupervised measurements the results are indeed important, since such high
39
40 sound levels have been described as mechanism in acquired hearing loss, tinnitus and sound
41
42 sensitivity.[3] These results highlight the need to initiate preventive action regarding noise
43
44 exposure in the obstetrics care, which include but is not limited to; information to all
45
46 employees, access to suitable hearing protection devices and cooperation between the
47
48 employer and an occupational health care unit for assessment of noise exposure and hearing-
49
50 related symptoms. Hearing tests and anamnesis regarding hearing-related symptoms may also
51
52 be considered for new employees.
53
54
55
56
57
58
59
60

1
2
3 No significant associations between noise exposure and the other hearing related symptoms
4 were detected in this study. This may be explained partly by the fact that hearing loss is
5 developed over a long period of time, usually becoming apparent after the age of retirement,
6 and that mild deterioration in hearing may not be easily detected via self-assessment. As the
7 study was cross-sectional, the fact that hearing loss was most prevalent in the third noise
8 exposure group lower prevalence in the highest exposure group may have influenced the
9 analysis. This in turn is possibly due to a healthy worker effect as individuals with hearing
10 loss may not be able to continue working in obstetrics care. Similarly but in the opposite
11 direction, as difficulty perceiving speech was reported by many young individuals, whom to a
12 larger extent was classified in the lowest noise index quartile, it may have influenced the
13 analysis of the effect of occupational noise exposure such that no significant effect was seen.
14 It is in any case alarming with such a high prevalence of difficulty perceiving speech.

15
16 Compared to prevalence data from the Swedish National Board of Health and Welfare from
17 2000-2005, using a similar survey item as in this study,[26] our data indicate higher age and
18 gender matched prevalence. Between the ages 25-64 years the prevalence in our sample
19 ranged from 26-35%, while the prevalence in the same age range among women in the
20 reference material was 5-15%. Sound sensitivity is less researched, but one previous study
21 from Sweden reports prevalence in the general population of 8-9%.[27] No gender-specific
22 prevalence was reported, making direct comparisons to our data somewhat problematic; yet
23 our data indicate slightly higher prevalence. In addition to the significant association between
24 occupational noise exposure and both tinnitus and sound induced auditory fatigue, our data
25 also shows that having one or more hearing-related symptom is most common among those
26 with highest cumulative noise exposure dose as seen in table 2. However, this variable was
27 not significantly associated to noise exposure in the regression model, probably due to the
28 variable difficulty perceiving speech having a large influence with the high prevalence in the

1
2
3 lower noise exposure group. Again, it is staggering to find that more than half of the
4 participating personnel group report one or more hearing-related symptom. The risks of
5 acquiring hearing-related symptoms in this work environment should also be seen in the light
6 of recent animal studies, showing that noise contribute to neurodegenerative effects and acute
7 loss of afferent nerve terminals - the effects of which is believed to be of importance for
8 auditory processing and subsequently resulting in hearing injuries emerging only later in
9 life.[28-30] If applicable to humans, an implication would hence be that hearing functions of
10 importance for auditory processing in adverse listening conditions may be impaired even
11 though subjects have apparent normal hearing,[31] and importantly that risk of auditory injury
12 from noise exposure is greater than previously assumed. Studies such as ours, investigating
13 risks for hearing injury within occupational groups exposed to levels at or just below the
14 stipulated risk levels, are therefore of high relevance.
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31

32 **Work-related stress and noise annoyance**

33
34 Work-related stress was common among the obstetrics personnel surveyed, which is in line
35 with previous research.[11 12] A new finding though, was that noise annoyance is also highly
36 prevalent in this occupational group and that both stress and noise annoyance were positively
37 associated to sound induced auditory fatigue; although the estimated effect for stress was
38 reduced when both stress and noise annoyance were included in the same model. This may be
39 due to lack of power in the analysis and possibly also multi-collinearity, as there was a weak
40 yet significant correlation between stress and annoyance. The associations were hypothesised
41 based on models of pathways previously suggested by Babish,[13] and in a more recent model
42 by Heinonen-Guzejev et al.[32] In contrast to previous results of an association between stress
43 and tinnitus,[33 34] our results do not support this association despite the fact that work-
44 related stress was very common in our sample. It is possible that our measure of work-related
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 stress did not capture the association, that the relationship is far more complex or that tinnitus
4
5 is instead more strongly associated to psychological distress as is also suggested by studies on
6
7 tinnitus and depression and anxiety,[35 36] rather than physiological or psychosocial stress.
8
9

11 **Methodological consideration**

14 We are aware of methodological issues in assessing exposure dose retrospectively.[37 38] In
15
16 this study an estimate of cumulative occupational noise exposure was calculated by using
17
18 years worked as a proxy for the exposure dose. In order to increase the sensitivity of this
19
20 estimate, we also including years worked with the alternative birth care method (ABC-
21
22 method, predominantly used during the 1980's hypothesised to have given rise to higher
23
24 sound levels in the labour ward due to the non-use of anaesthetics), including an assessment
25
26 of current noise exposure as well as considering the protective effect of personal hearing
27
28 protective devices. A common problem in studies where cumulative exposure is estimated is
29
30 that age will naturally be incorporated in the exposure assessment, possibly confounding the
31
32 results. In our data there was a strong correlation between calculated cumulative noise
33
34 exposure and age, which is illustrated in figure 2B. It is therefore difficult to distinguish
35
36 between effects of age and noise exposure dose, which would be the case independently of
37
38 how the index was constructed as an accumulated exposure dose would naturally always
39
40 correlate to increased age. As such, the possible confounding effect of age could not be
41
42 properly adjusted for in the statistical model for the association between noise exposure and
43
44 hearing-related outcomes. When both were included in the logistic regression model neither
45
46 noise nor age showed a statistically significant effect on any of the hearing-related outcomes.
47
48 Interestingly though, we could show that the noise exposure index was significantly
49
50 associated to the hearing-related outcomes tinnitus and sound induced auditory fatigue, while
51
52 this was not the case for age alone as a predictor in a separate bi-variable model. Pathological
53
54
55
56
57
58
59
60

1
2
3 changes in the inner ear resulting in hearing loss as an effect of age alone is debated in the
4
5 research community.[39] Results are even less solid when considering age as a sole cause of
6
7 tinnitus.[40] Instead, the effect of noise exposure is hypothesised to largely contribute to the
8
9 increased prevalence of hearing-related disorder seen in increased age.[30 39 40]

10
11 Finally, being an initial study in this area we were not able to include a large study sample,
12
13 which affects the reliability of the analyses and the generalisation of the results. Also, though
14
15 the cross-sectional design prevents drawing definite conclusions on causal relationships, we
16
17 argue based on previous research and our study results that it is reasonable to assume a causal
18
19 pathway from noise exposure to hearing-related symptoms; the hypothesised casual pathway
20
21 involving stress and noise annoyance however, being less certain.
22
23
24
25
26

27 **CONCLUSION**

28
29 This study presents new results regarding risk of noise-induced hearing-related symptoms
30
31 among obstetrics personnel, which to the best of our knowledge has not been described
32
33 before. The results show that obstetrics personnel are at times exposed to sound levels above
34
35 regulated limits and that more than half of the participants report one or more hearing-related
36
37 symptom. Furthermore, a statistically significant association was found between cumulative
38
39 occupational noise exposure and the hearing-related symptom tinnitus and sound induced
40
41 auditory fatigue. Noise annoyance was a common complaint and in addition to noise exposure
42
43 also an important factor for sound induced auditory fatigue. These results indicate that
44
45 preventative action regarding noise exposure is required in obstetrics care and that risk-
46
47 assessments may be needed in previously unstudied non-industrial communication-intense
48
49 sound environments.
50
51
52
53
54
55
56
57
58
59
60

Acknowledgments

The authors would like to thank Lars Larsson for performing the dosimeter measurements, Christofer Andersson for assistance with the web-survey and Agneta Agge for survey data entry, as well as all the participating personnel at the obstetrics care unit at the Sahlgrenska University hospital.

Footnotes

Contributors All authors contributed to this work. KPW and KT obtained funding. KPW, SF and AT contributed to the study concept and design. SF collected the data with help from KPW. OH, SF, KPW and KT designed the plan of analysis. SF performed the final analyses. SF, KPW, OH and KT drafted the manuscript and interpreted the results. SF, KPW, OH, KT, AT made substantive editorial contributions at all stages of manuscript preparation.

Funding This study was funded by grants from the Swedish research council for Health, Working Life and Welfare (Forte) as well as the Swedish funder AFA insurance. The researchers are independent from funders.

Competing interests All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval The study was approved by the ethics committee in Gothenburg Sweden, Nr 788-11.

Provenance and peer review Not commissioned; externally peer reviewed

Data sharing statements No additional data are available

1
2
3 This is an Open Access article distributed in accordance with the Creative Commons
4 Attribution Non Commercial (CC BY-NC 3.0) license, which permits others to distribute,
5 remix, adapt, build upon this work non-commercially, and license their derivative works on
6 different terms, provided the original work is properly cited and the use is non-commercial.
7
8
9
10
11
12 See: <http://creativecommons.org/licenses/by-nc/3.0/>
13

14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60

References

1. Nelson DI, Nelson RY, Concha-Barrientos M, Fingerhut M. The global burden of occupational noise-induced hearing loss. *American Journal of Industrial Medicine* 2005;**48**(6):446-58 doi: 10.1002/ajim.20223.
2. European Agency for Safety and Health at Work. *Risks and Trends in the Safety and Health of Women at Work*, 2012.
3. Axelsson A, Hamernik RP. Acute acoustic trauma. *Acta Oto-laryngologica* 1987;**104**(3-4):225-33 doi: doi:10.3109/00016488709107322.
4. Henry JA, Dennis KC, Schechter MA. General Review of Tinnitus: Prevalence, Mechanisms, Effects, and Management. *Journal of Speech Language and Hearing Research* 2005;**48**(5):1204-35 doi: 10.1044/1092-4388(2005/084).
5. Kähäri K, Zachau G, Eklöf M, Sandsjö L, Möller C. Assessment of hearing and hearing disorders in rock/jazz musicians: Evaluación de la audición y de los problemas auditivos en músicos de rock y jazz. *International Journal of Audiology* 2003;**42**(5):279-88 doi: doi:10.3109/14992020309078347.
6. Palmer K, Griffin M, Syddall H, Davis A, Pannett B, Coggon D. Occupational exposure to noise and the attributable burden of hearing difficulties in Great Britain. *Occupational and Environmental Medicine* 2002;**59**(9):634-39
7. Persson Wayne K, Ryherd E, Hsu T, Lindahl B, Bergbom I. (2010). Personnel response in intensive care units. *Internoise*; 2010 13-16 June; Lisbon, Portugal.

- 1
2
3 8. Kjellberg A. Subjective, behavioral and psychophysiological effects of noise. *Scandinavian*
4 *journal of work, environment & health* 1990;29-38
5
6
- 7 9. Busch-Vishniac IJ, West JE, Barnhill C, Hunter T, Orellana D, Chivukula R. Noise levels
8 in Johns Hopkins hospital. *The Journal of the Acoustical Society of America*
9 2005;**118**:3629
10
11
- 12 10. Vinodhkumaradithyaa A, Kumar D, Ananthalakshmi I, et al. Noise levels in a tertiary care
13 hospital. *Noise and Health* 2008;**10**(38):11-13 doi: 10.4103/1463-1741.39003.
14
15
- 16 11. Hildingsson I, Westlund K, Wiklkund I. Burnout in Swedish midwives. *Sexual &*
17 *Reproductive Healthcare* 2013;**4**:87-91
18
19
- 20 12. Hultberg A, Hadžibajramović E, Pettersson S, Skagert K, Ahlberg G. KART-studien.
21 *Arbetsmiljö, stress och hälsa bland anställda vid Västra Götalandsregionen. Delrapport 5:*
22 *Uppföljning utifrån organisations-, yrkesgrupps- och individperspektiv 2008 - 2010. In:*
23 *Ahlberg G, ed.: Institute of Stress Medicine, 2011. [In Swedish]*
24
25
26
27
28
- 29 13. Babisch W. The noise/stress concept, risk assessment and research needs. *Noise and*
30 *Health* 2002;**4**(16):1-11
31
32
- 33 14. Leather P, Beale D, Sullivan L. Noise, psychosocial stress and their interaction in the
34 workplace. *Journal of Environmental Psychology* 2003;**23**(2):213-22
35
36
- 37 15. Lercher P, Hörtnagl J, Kofler WW. Work noise annoyance and blood pressure: combined
38 effects with stressful working conditions. *International archives of occupational and*
39 *environmental health* 1993;**65**(1):23-28
40
41
42
- 43 16. Persson Waye K, Agge A, Hillström J, Lindström F. Being in a pre-school sound
44 environment – annoyance and subjective symptoms among personnel and children.
45 *Internoise; 2010 13-16 June; Lisbon, Portugal.*
46
47
48
- 49 17. Neitzel R, Daniell W, Sheppard L, Davies H, Seixas N. Comparison of Perceived and
50 Quantitative Measures of Occupational Noise Exposure. *Annals of Occupational Hygiene*
51 2009;**53**(1):41-54 doi: 10.1093/annhyg/men071.
52
53
54
55
56
57
58
59
60

- 1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
18. Nondahl DM, Cruickshanks KJ, Wiley TL, Tweed TS, Klein R, Klein BEK. Accuracy of Self-reported Hearing Loss. *International Journal of Audiology* 1998;**37**(5):295-301 doi: doi:10.3109/00206099809072983.
 19. Schlaefter K, Schlehofer B, Schüz J. Validity of self-reported occupational noise exposure. *European journal of epidemiology* 2009;**24**(8):469-475.
 20. Sindhusake D, Mitchell P, Smith W, et al. Validation of self-reported hearing loss. The Blue Mountains hearing study. *International Journal of Epidemiology* 2001;**30**(6):1371-78
 21. Ryberg JB, Agge A, Wayne KP. Low frequency noise in a paper mill control room. *Journal of low frequency noise, vibration and active control* 2007;**26**(3):165-76
 22. Axelsson A, Prasher D. Tinnitus induced by occupational and leisure noise. *Noise and Health* 2000;**2**(8):47
 23. Nouvian R, Eybalin M, Puel J-L. The coclea and the Auditory Nerve as a Primary Source of Tinnitus. In: Eggermont JJ, Zeng F-G, Popper AN, eds. *Tinnitus*. New York: Springer Science and Business Media, 2012.
 24. Schmidt CO, Kohlmann T. When to use the odds ratio or the relative risk? *International journal of public health* 2008;**53**(3):165-67
 25. Tenenbaum A, Hendriksson A, Larsson L. Bullernivåer och hörselundersökning på förlossningsavdelning. Läkarsämman. Stockholm, Sweden, 2010. [In Swedish]
 26. Danermark B, Hanning M. Hearing and vision: Health in Sweden: The National Public Health Report 2012. Chapter 17. *Scandinavian Journal of Public Health* 2012;**40**(9 suppl):287-92 doi: 10.1177/1403494812459621.
 27. Andersson G, Lindvall N, Hursti T, Carlbring P. Hypersensitivity to sound (hyperacusis): a prevalence study conducted via the internet and post. *International Journal of Audiology* 2002;**41**(8):545-54 doi: doi:10.3109/14992020209056075.
 28. Kujawa SG, Liberman MC. Adding insult to injury: cochlear nerve degeneration after “temporary” noise-induced hearing loss. *The Journal of Neuroscience* 2009;**29**(45):14077-85

- 1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
29. Lin HW, Furman AC, Kujawa SG, Liberman MC. Primary neural degeneration in the Guinea pig cochlea after reversible noise-induced threshold shift. *Journal of the Association for Research in Otolaryngology* 2011;**12**(5):605-16
30. Kujawa SG, Liberman MC. Acceleration of age-related hearing loss by early noise exposure: evidence of a missed youth. *The Journal of Neuroscience* 2006;**26**(7):2115-23
31. Ruggles D, Bharadwaj H, Shinn-Cunningham BG. Normal hearing is not enough to guarantee robust encoding of suprathreshold features important in everyday communication. *Proceedings of the National Academy of Sciences* 2011;**108**(37):15516-21
32. Heinonen-Guzejev M, Koskenvuo M, Silventoinen K, et al. Noise Sensitivity and Disability Retirement: A Longitudinal Twin Study. *Journal of Occupational and Environmental Medicine* 2013;**55**(4):365-70
33. Alpini D, Cesarani A. Tinnitus as an alarm bell: stress reaction tinnitus model. *ORL* 2006;**68**(1):31-37
34. Hébert S, Lupien SJ. The sound of stress: blunted cortisol reactivity to psychosocial stress in tinnitus sufferers. *Neuroscience letters* 2007;**411**(2):138-42
35. Holgers K-M, Erlandsson SI, Barrenäs M-L. Predictive Factors for the Severity of Tinnitus: Factores predictivos de la severidad del tinnitus. *International Journal of Audiology* 2000;**39**(5):284-91
36. Robinson SK, Viirre ES, Stein MB. Antidepressant therapy in tinnitus. *Hearing research* 2007;**226**(1):221-31
37. Davies HW, Teschke K, Kennedy SM, Hodgson MR, Hertzman C, Demers PA. Occupational exposure to noise and mortality from acute myocardial infarction. *Epidemiology* 2005;**16**(1):25-32
38. Nilsson T, Burström L, Hagberg M. Risk assessment of vibration exposure and white fingers among platers. *International archives of occupational and environmental health* 1989;**61**(7):473-81

- 1
2
3 39. Van Eyken E, Van Camp G, Van Laer L. The complexity of age-related hearing
4 impairment: contributing environmental and genetic factors. *Audiology and Neurotology*
5 2007;**12**(6):345-58
6
7
8
9 40. Sanchez L. The epidemiology of tinnitus. *Audiological Medicine* 2004;**2**(1):8-17
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

1
2
3 **The effect of occupational noise exposure on tinnitus and sound induced**
4 **auditory fatigue among obstetrics personnel: a cross-sectional study**
5
6
7
8
9

10 **Authors' names**

11 Sofie Fredriksson (SF), Oscar Hammar (OH), Kjell Torén (KT), Artur Tenenbaum (AT),
12
13 Kerstin Persson Waye (KPW)
14

15
16
17
18
19 **Corresponding author:**

20 Sofie Fredriksson

21 University of Gothenburg

22 Dept. of Public health & Community Medicine

23 Occupational and Environmental Medicine

24 PO Box 414, SE 405 30 Gothenburg, Sweden

25 sofie.fredriksson@gu.se

26 +46317863610 (telephone), +4631409728 (fax)
27
28
29
30
31
32
33
34
35
36
37
38

39 **Address for co-authors:**

40 Oscar Hammar (1), Kjell Torén (1), Artur Tenenbaum (2), Kerstin Persson Waye (1)

- 41
42
43 1) Department of Public Health and Community Medicine, Occupational and
44 Environmental Medicine, University of Gothenburg, S-405 30 Gothenburg
45
46
47 2) Occupational health care unit (Hälsan & Arbetslivet), Skaraborg Hospital, S-541 85
48 Skövde, Sweden
49
50
51
52
53
54

55 **Keywords:** Noise, occupational; stress; hearing disorders; cross-sectional studies; obstetrics

56 **Word count** (excluding title page, abstract, references, figures and tables): 4582
57
58
59
60

ABSTRACT

Objective: There is a lack of research on effects of occupational noise exposure in traditionally female-dominated workplaces. Therefore, the aim was to assess risk of noise-induced hearing-related symptoms among obstetrics personnel.

Design: A cross-sectional study at an obstetric ward in Sweden including a questionnaire among all employees and sound level measurements in 61 work-shifts at the same ward.

Participants: 115 female employees responded to a questionnaire (72% of all 160 employees invited).

Main outcome measures: Self-reported hearing-related symptoms, noise annoyance, work-related stress, calculated cumulative occupational noise exposure and measured sound levels.

Results: Sound levels exceeded the 80 dB LAeq limit for protection of hearing in 46% of the measured work-shifts. One or more hearing-related symptom was reported by 55% of the personnel. In logistic regression models a significant association was found between cumulative occupational noise exposure and tinnitus (Odds Ratio 1.04, 95% confidence interval 1.00 to 1.09) and sound induced auditory fatigue (Odds Ratio 1.04, 95% confidence interval 1.00 to 1.07). Work-related stress and noise annoyance were reported by almost half of the personnel group. Sound induced auditory fatigue was associated to work-related stress and noise annoyance, although stress just missed significance in a multivariable model. No significant interactions were found.

Conclusion: This study presents new results showing that obstetrics personnel are at risk of noise-induced hearing-related symptoms. Current exposure levels at the work-place are high and cumulative exposure has significant effects on tinnitus and sound induced auditory fatigue among the personnel. These results indicate that preventative action regarding noise exposure is required in obstetrics care and that risk-assessments may be needed in previously unstudied non-industrial communication-intensive sound environments.

Strengths and limitations of this study:

- The vast majority of previous research into noise-induced hearing disorders has been performed in industrial-like settings, whereas practically nothing is known of risks in non-industrial, traditionally female-dominated and communication-intense workplaces, such as hospitals. As such, this study presents novel results on occupational noise exposure and hearing among obstetrics personnel.
- Both objective sound level measurements and analysis of subjective data indicate an increased risk of hearing-related disorder.
- Due to the cross-sectional design the influence of subjects' age cannot be disentangled.
- The study sample size and the cross-sectional design without an unexposed control group limits the generalisation of the results and prevents us from drawing definite conclusions on causality.
- Further studies are needed to confirm the results and assess the magnitude of the problem. However, we suggest that occupational health care services implement available preventative actions such as making hearing protective devices available for personnel as an action of precaution.

INTRODUCTION

Occupational noise exposure and effects on hearing is well described in industrial-like, traditionally male-dominated settings.[1] In contrast, few studies have reported on traditionally female-dominated work environments. This has been acknowledged by the European Agency for Safety and Health at Work, who conclude that areas such as health and social services are largely overlooked concerning noise research,[2] and that the noise in these types of workplaces may interfere with performance and wellbeing. High sound levels regardless of its source can cause hearing loss, tinnitus and sound sensitivity and may also result in sound induced auditory fatigue, the latter described by subjects as avoidance of everyday sounds and a need for silence.[1 3-7] The symptom sound induced auditory fatigue was first identified in pilot studies, interviewing preschool personnel, and have later shown to prevalent in questionnaire surveys [7]. We hypothesise the symptom to be a result of constant or overloading stimulation of sounds during the day. The effect may possibly be due to the high information content mainly of speech, such that overload is not merely a consequence of the sound energy as seen in auditory threshold shift, but as a result of an information intense sound environment. Apart from hearing-related symptoms, noise exposure can also evoke non-auditory effects such as annoyance and stress.[8] According to a recent meta-analysis, noise levels in hospitals have steadily increased since the mid-1960.[9] One heavily female-dominated workplace in the hospital is the obstetrics care. According to data from Statistics Sweden in 2011, more than 99% of midwives are women. One peer-reviewed study have reported on sound level measurements from obstetrics care in a hospital in India, where the highest night time level (71.9 dB LAeq) was measured in the obstetrics and gynaecology ward, with slightly lower levels in the labour ward.[10]

In addition to potentially harmful noise levels in the obstetrics care, midwives report a high degree of work-related stress and burnout,[11] and according to a recent report burnout

1
2
3 syndrome have doubled among midwives employed in the western region of Sweden during
4
5 the last years.[12] The fact that obstetrics personnel are exposed to high levels of stress may
6
7 be important when considering noise exposure at the workplace, since the combination of
8
9 these exposures may interact in causing adverse health effects.[13-15]
10

11 There is a substantial lack of knowledge regarding occupational noise exposure, noise
12
13 annoyance and hearing-related symptoms among obstetrics care personnel, as well as possible
14
15 interaction effects between noise exposure, noise annoyance and work-related stress.
16
17

18 Therefore, the aim of this study was to assess the risk of noise-induced hearing-related
19
20 symptoms among obstetrics personnel by measuring sound levels in the labour ward of a
21
22 general obstetrics ward and by analysing the effect of and interaction between occupational
23
24 noise exposure, noise annoyance and work-related stress on hearing-related symptoms among
25
26 obstetrics personnel.
27
28
29
30
31

32 **METHODS**

33 **Sound level measurements**

34
35 Sound level measurements were carried out during 61 work shifts in the labour ward of a
36
37 general obstetrics ward at the Sahlgrenska University Hospital in Gothenburg. Out of the 61
38
39 shifts 19 day shifts were measured between 7 a.m. and 3:30 p.m. (8.5 h), 12 evening shifts
40
41 between 1:45 p.m. and 9 p.m. (7.25 h) and 30 nightshifts between 9 p.m. and 7 a.m. (10 h).
42
43 The day and evening shifts were measured during separate weeks so as not to overlap. A
44
45 convenient sample of ten employees per shift each wore a personal dosimeter (Larson Davis
46
47 705+) with the microphone attached to the right shoulder and kept a written log documenting
48
49 work activities during the measured shift. A total of 610 separate measurements were
50
51 collected, as 10 individuals each wore a dosimeter during the 61 shifts measured. However,
52
53 due to technical errors a few faulty measurements were excluded leaving 529 (87%) to be
54
55
56
57
58
59
60

1
2
3 included in the analysis. The dosimeters were set to measure A-weighted equivalent and
4
5 maximum (fast) levels with a sampling interval of 30 seconds. All dosimeters were calibrated
6
7 using the software Blaze version 5.06 before measurements begun. The equivalent levels
8
9 reported refer to the full-shift length and will hence vary between 7.25 – 10 hours, hereinafter
10
11 denoted as LAeq_(7-10h). Sound levels were analysed at group level as arithmetic mean and
12
13 compared to Swedish Work Authorities' exposure regulations. Sound levels exceeding the
14
15 lower action level of 80 dB LAeq(8h) indicate a risk for hearing damage and the employer is
16
17 responsible to take preventative action, such as providing employees with hearing protection
18
19 devices (HPDs). The exposure limits 85 dB LAeq (8h) and 115 dB LAFmax are set as a
20
21 maximum allowed level above which the employer is required to take measures in order to
22
23 reduce the noise exposure, and where use of HPDs are mandatory. Employees must not be
24
25 exposed to noise levels at or above the exposure limits (taking attenuation of HPDs into
26
27 account).
28
29
30
31
32
33

34 **Questionnaire survey**

35
36 All personnel (n=160, all women), employed at the general obstetrics ward were included in a
37
38 questionnaire survey. A total of 115 (72%) participated by responding either electronically
39
40 (n=63) or in paper format (n=52) and these data were pooled together, as no statistical
41
42 differences were seen on explanatory or outcome variables (p>0.05). The questionnaire was
43
44 constructed using items specifically constructed for this study as well as items adapted from
45
46 previous studies and international standards (ISO/TS 15666).[7 16] Similar self-reported
47
48 items assessing noise exposure as well as hearing loss and tinnitus have previously been
49
50 subject for validation.[17-20]
51
52

53
54 The main explanatory variable cumulative occupational noise exposure dose, was calculated
55
56 as an exposure index derived from six questionnaire items including; number of years worked
57
58
59
60

1
2
3 in delivery care, number of years worked in alternative birth care, work allocation (delivery
4 care, postpartum care or both), two separate items on frequency of current work-related noise
5 exposure (one assessing how often the sound levels are so high that the person has to speak
6 with raised voice and one assessing how often the person have trouble hearing what is said)
7 and finally one item on frequency of hearing protection use. A higher noise index indicates a
8 higher noise exposure dose. The scoring for each item's contribution to the index is presented
9 in detail in supplementary table 1. Each variable score was summed using mathematical
10 addition to a total index score for each participant. In addition, the study group was
11 categorized into four noise index groups based on calculation of quartiles, with each noise
12 index category representing 25% of the study population. Work-related stress and noise
13 annoyance were analysed as additional explanatory variables. Work-related stress was
14 assessed using two separate questionnaire items asking responders to report how often they
15 experience high degree of stress and how often they feel unwell due to stress at work.
16
17 Participants were defined as having work-related stress if answering often or always/almost
18 always on one or both of the items. These stress-related items have previously been used in
19 noise-related research.[21] Noise annoyance was assessed by the item 'Are you annoyed by
20 sounds/noise at your workplace?', which is based on the International standard ISO/TS
21 15666, adapted for a workplace survey as opposed to community surveys. The hearing-related
22 outcome variables included are hearing loss (yes), tinnitus, sound sensitivity (i.e. hyperacusis)
23 and sound induced auditory fatigue (~~i.e. a need for silence~~) (~~a few times each~~ once a week or
24 more often), general hearing status (poor or very poor) and difficulty perceiving speech (yes
25 both at work and in leisure time). Variables considered as possible moderators for the
26 association between exposure and outcome were smoking (previous or current) and leisure-
27 time noise exposure (once a month or more often). Age (in years) was considered a possible
28 confounder. The questionnaire items are presented in full in the supplementary table 2.
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Statistical analyses

Hypothesis testing was performed using IBM SPSS Statistics 20. Differences in arithmetic mean were analysed using one-way analysis of variance (ANOVA) or independent samples t-test where applicable. Test for trend was analysed using [Linear regression with dummy coding](#) for categorical predictors or Mantel-Haentzel linear-by-linear association where applicable. Binary logistic regression with Wald tests was used for analysis of associations and interaction. The significance level was set at 5% ($p=0.05$) for all tests. Based on a hypothesised order of importance of explanatory variables, manual sequential regression models were analysed. For each binary hearing-related outcome variable we used the following model testing procedure: In a first model, noise exposure index was analysed as a single continuous explanatory variable with the hearing-related symptom as a binary outcome variable. If noise exposure index was significant for the hearing-related symptom, then a second model was analysed, adjusting for moderators (leisure noise exposure and smoking), each one at a time. Age as a possible confounder was analysed separately due to initial hypothesised strong correlation to the noise index (due to its cumulative nature). If point estimates for noise index was comparable with and without adjustment and the adjustment variable itself was non-significant, then it was not included in subsequent multivariable models. In the third model, work-related stress was analysed as an additional explanatory variable and in a fourth model noise annoyance instead of stress was included together with significant explanatory variables from model 2. The fifth model included explanatory variables found to be significant in any of the previous steps. Hypothesised interactions between explanatory variables were assessed in separate models by including an interaction term. Multi-collinearity between explanatory variables was assessed using Pearson's correlation or Spearman's rank correlation, where applicable, and correlation below $r=0.6$ was deemed acceptable. Odds ratios (OR) with 95% confidence intervals were derived from the

1
2
3 logistic regressions as a measure of association between exposure and outcome, and relative
4
5 risk (RR) was calculated from predictive values derived from model 1. Goodness of fit for the
6
7 regression models were assessed using the Hosmer-Lemeshow test and a non-significant p-
8
9 value (>0.05) was used to indicate adequate fit.
10

11 12 13 **RESULTS**

14 15 **Sound levels in the labour ward**

16
17 Overall, the dosimeter measurements from the labour ward showed moderately high sound
18
19 levels, as presented in table 1. The levels reached or exceeded both the action and limit levels.
20
21 The lower action level 80 dB LAeq was exceeded in 30 different dosimeter measurements
22
23 during 28 different work shifts, which corresponds to 46% of all measured shifts or 6% of all
24
25 dosimeter measurements. The upper exposure action level and exposure limit 85 dB LAeq
26
27 was reached or exceeded in three measurements from three different shifts, corresponding to
28
29 5% of all measured shifts or 0.6% of all measurements. The limit 115 dB LAFmax was
30
31 reached or exceeded at 50 different occasions. However, of these 9 separate events could not
32
33 be verified by the written logs and were therefore excluded. The remaining 41 events occurred
34
35 in 17 different shifts corresponding to 28% of all measured shifts or 8% of all dosimeter
36
37 measurements. There were no statistical differences in arithmetic mean equivalent nor in
38
39 maximum levels when comparing measurements from different work-shifts nor measurements
40
41 from dosimeters worn by midwives compared to assistant nurses. Due to incomplete written
42
43 logs however, we were unable to categorise a third of the measurements into professional
44
45 group. A segment sample from a dosimeter measurement is shown in figure 1, where high
46
47 maximum levels (119 dB LAFmax) was recorded during a delivery, which according to the
48
49 written log occurred between 10:30 and 11:05 pm. The equivalent level in this particular
50
51 measurement was 84 dB LAeq(10h) for the measured shift length. As exposure limits should be
52
53
54
55
56
57
58
59
60

regarded with HPDs taken into account, it is noteworthy that the majority of the respondents (92%) reported to never or almost never use hearing protective devices at work.

FIGURE 1

Table 1. Sound level measurements at the labour ward showing arithmetic mean, standard deviation (SD), 95% confidence interval (CI) of mean and range of the measured equivalent, LAeq(7-10h) and maximum, LAFmax sound levels in dB. Also showing mean and standard deviation of measurements categorised by work shift and by professional group as reported in written logs by the personnel carrying the dosimeter. Frequencies (n) in the table represent unique dosimeter measurements.

	Sound level measurements		
	dB LAeq(7-10h)	dB LAFmax	n
All measurements			
Arithmetic mean (SD)	70.3 (6.0)	106.3 (6.0)	529
95% CI of mean	69.7 - 70.8	105.8 - 106.8	
Min – Max	56.0 – 87.0	83.0 – 122.0	
Measurements categorised by work shift (arithmetic mean, SD) ^a			
Day shift	70.8 (6.2)	106.2 (5.9)	139
Evening shift	70.8 (5.2)	106.3 (5.6)	127
Night shift	69.8 (6.3)	106.4 (6.2)	263
Measurements categorised by professional group (arithmetic mean, SD)			
Midwives	71.3 (5.1)	106.2 (5.9)	289
Assistant nurses	72.2 (5.0)	107.8 (5.2)	114
Uncategorised	66.2 (7.0)	103.9 (6.5)	126

^a Number of shifts categories as day (n=19), evening (n=12) and night (n=30).

Association between noise exposure and hearing disorder

Demographics, occurrence of explanatory variables; work-related stress, noise annoyance and adjustment variables; smoking and leisure noise exposure as well as prevalence of hearing-related outcomes are presented in table 2, both for the total study sample as well as categorised into four noise exposure index groups calculated from quartiles of the noise index. The first noise index group (1) represents the respondents with the lowest calculated noise exposure dose. Valid responses for the individual questionnaire items included in the analysis ranged from n=108 to 115. A test for trend in the four exposure groups shows that age, number of years worked in obstetrics and prevalence of sound induced auditory fatigue is significantly increasing with higher noise exposure group; $p<0.001$, $p<0.001$ and $p=0.049$ respectively.

Table 2. Demographics, explanatory and adjustment variables and hearing-related outcomes from questionnaire survey among personnel at the general obstetrics ward. Prevalence is presented categorised in four noise index groups based on quartiles of the index (1 – 4) and as total prevalence in the study sample. Percentages are given as column % in noise index quartile groups and % of total.

	Grouping by noise index quartiles				Total	95% CI of total
	1	2	3	4		
Number of participants	28	29	29	29	115	-
Noise exposure index (range)	4.5 – 9.5	10 – 15	16 – 26	27 – 64	4.5 - 64	16.8 - 21.2
Demographics						
Mean age in years (SD)	39 (10)	39 (7)	45 (8)	57 (5)	45 (11)	42.8 - 46.8
Mean years worked (SD)	3 (2)	6 (2)	14 (3)	28 (6)	12 (11)	10.3 - 14.3
Professional groups, % ^a	54/36/11	69/24/7	69/21/10	76/21/3	68/25/7	-
Explanatory and adjustment variables (%)						
Work-related stress	43	52	31	41	42	32.9-51.1
Noise annoyance at work	50	45	55	45	49	39.8-58.2
Ever smoker	36	48	28	25	34	25.3-42.7
Leisure noise exposure	14	24	7	7	13	6.8-19.2
Outcome variables (%)						
Sound induced auditory fatigue	21	24	41	41	32	23.4-40.6
Tinnitus	7	11	10	24	13	6.8-19.2
Sound sensitivity	7	17	17	10	13	6.8-19.2
Poor hearing	11	21	17	14	16	9.3-22.7
Hearing loss	4	7	21	4	9	3.7-14.3
Difficulty perceiving speech	39	31	24	36	32	23.4-40.6
Any symptom ^b	54	48	55	63	55	45.9-64.1

^a Shown in table as proportion of Midwife/Assistant nurse/Other. Other also includes missing.

^b Any symptom was constructed as a binary variable including all those who reported either sound induced auditory fatigue, tinnitus, sound sensitivity, difficulty perceiving speech, poor hearing and/or hearing loss.

1
2
3 Associations between occupational noise exposure dose (continuous noise index), work-
4 related stress, noise annoyance and hearing-related symptoms were evaluated in manual
5 sequential binary logistic regression models, results of which are presented in table 3. The
6
7 calculated noise index ranged from 4.5 to 64 in the study sample. The proportional
8
9 contribution of years worked in obstetrics care to the index, as a proxy for cumulative
10
11 exposure, is shown in figure 2 A. The percentage of participants over the range of noise index
12
13 also conveys the skewness in the distribution of the index, e.g. less than 25% of the
14
15 participants have noise index values in the upper half of the range.
16
17
18
19
20
21
22
23

FIGURE 2

24
25
26
27 Occupational noise exposure as a single explanatory variable was significantly associated to
28
29 tinnitus and sound induced auditory fatigue, but not to the other hearing-related symptoms.
30
31 Work-related stress and noise annoyance were both significantly associated to sound induced
32
33 auditory fatigue in separate models, but not to tinnitus. For sound induced auditory fatigue,
34
35 including all three significant explanatory variables (noise, stress and annoyance) in model 5
36
37 resulted in marginal changes in point estimates for noise exposure and noise annoyance. It did
38
39 however affect the estimates for work-related stress, which just missed statistical significance
40
41 ($p=0.053$). No significant statistical interactions were found between explanatory variables.
42
43
44 Neither work-related stress nor noise annoyance were significantly correlated to noise
45
46 exposure index. There was however a weak yet significant correlation between stress and
47
48 noise annoyance ($r=0.249$, $p=0.008$). The point estimates for noise exposure was comparable
49
50 with or without adjustment for smoking and leisure-time noise exposure in model 2, and
51
52 neither one of the adjustment variables were themselves significant. Hence, they were not
53
54
55
56
57
58
59
60

1
2
3 included in the subsequent multivariable models. All reported models had an acceptable
4
5 goodness of fit.
6

7 As prevalence of sound induced auditory fatigue was much higher than 10%, assessing odds
8
9 ratios (OR) only may overestimate the risk. The calculated risk ratios (RR) for sound induced
10
11 auditory fatigue from model 1, in comparable 1 unit steps of the noise index, however showed
12
13 that the difference between OR and RR was minor (at the most 0.02 difference).
14

15 Due to the cumulative property of the noise index, the index was assumed to be correlated to
16
17 age, which was also confirmed in the analysis ($r=0.706$, $p<0.001$) with $R^2=0.498$, as shown in
18
19 figure 2 B. Multi-collinearity issues therefore precluded the assessment of both variables in
20
21 one regression model. Notably and importantly though, age was not significantly associated to
22
23 any of the hearing-related symptoms when assessed as a single explanatory variable in
24
25 separate regression models.
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 3. Point estimates of effect (B) and standard error (SE), odds ratios (OR), 95% confidence intervals of OR (95% CI) from binary logistic regression models for hearing-related symptom outcomes (binary dependent variables) among personnel in an obstetrics ward. All dependent variables were analysed in separate models. Manual sequential analysis was adopted, adding work-related stress and noise annoyance and adding an interaction term if the initial model was statistically significant ($p < 0.05$).

Dependent variables	Explanatory variables	B (SE)	OR (95% CI)	p-value
Sound induced auditory fatigue				
<i>Model 1</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.07)	0.031
<i>Model 3</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.08)	0.027
	Work-related stress	0.96 (0.42)	2.62 (1.15 – 5.98)	0.022
<i>Model 4</i>	Noise exposure index	0.04 (0.02)	1.04 (1.01 – 1.08)	0.026
	Noise annoyance	1.73 (0.47)	5.67 (2.25 – 14.27)	<0.001
<i>Model 5</i>	Noise exposure index	0.04 (0.02)	1.04 (1.01 – 1.08)	0.025
	Work-related stress	0.87 (0.45)	2.39 (0.99 – 5.79)	0.053
	Noise annoyance	1.66 (0.48)	5.25 (2.05 – 13.42)	0.001
Tinnitus				
<i>Model 1</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.09)	0.049
<i>Model 3</i>	Noise exposure index	0.04 (0.02)	1.04 (1.00 – 1.09)	0.046
	Work-related stress	-0.43 (0.60)	0.65 (0.20 – 2.10)	0.470
<i>Model 4</i>	Noise exposure index	0.04 (0.02)	1.05 (1.00 – 1.09)	0.038
	Noise annoyance	0.56 (0.58)	1.85 (0.56 – 5.46)	0.335
Sound sensitivity	Noise exposure index	0.01 (0.02)	1.03 (0.97 – 1.06)	0.570
Poor hearing	Noise exposure index	0.00 (0.02)	1.00 (0.96 – 1.04)	0.985
Hearing loss	Noise exposure index	0.00 (0.03)	1.00 (0.95 – 1.06)	0.995
Difficulty perceiving speech	Noise exposure index	0.01 (0.02)	1.01 (0.98 – 1.05)	0.461
Any symptom^a	Noise exposure index	0.02 (0.02)	1.02 (0.99 – 1.05)	0.273

^a Any symptom was constructed as a binary variable including all those who reported either sound induced auditory fatigue, tinnitus, sound sensitivity, difficulty perceiving speech, poor hearing and/or hearing loss.

DISCUSSION

The effect of noise exposure on hearing

In order to assess the effect of occupational noise exposure on hearing-related symptoms among obstetrics personnel, sound level measurements were carried out at the labour ward at a general obstetrics ward and associations between calculated occupational noise exposure dose and hearing-related symptoms were analysed in binary logistic regression models based on self-reported data from personnel at the same ward.

Prevalence of hearing-related symptoms among the personnel showed that tinnitus and sound induced auditory fatigue was most common among personnel with the highest exposure dose.

Accordingly, we were also able to detect statistically significant associations between occupational noise exposure and both tinnitus and sound induced auditory fatigue in logistic regression models. Sound induced auditory fatigue is a new concept that has previously been reported among preschool personnel and is hypothesised as a consequence of a constant noise load during the work day.[7 16] As for pre-school personnel, the obstetric personnel are mainly exposed to intermittent sounds from voices and screams, but also from alarms and medical equipment. It is possible that the demands and needs of attending to meaningful sounds with a high element of irregularity contribute to a mental fatigue that some individuals with sound induced auditory fatigue describe. As for sound induced auditory fatigue, we could also show a significant association between tinnitus and noise exposure. Although it is well established that noise may contribute to tinnitus,[4 22 23] it has to our knowledge not been reported previously among obstetrics personnel; hence this result is highly interesting as it supports the concerns that noise levels in non-industrial and previously less studied work environments, mainly female-dominated, may be harmful.[2] As the prevalence especially for sound induced auditory fatigue was high, it is important to note that odds ratios may not

1
2
3 directly be translated into a measure of relative risk.[24] We did however not detect major
4
5 divergences between the two measures.
6

7
8 In addition to increased risk of hearing-related symptoms of cumulative occupational noise
9
10 exposure, we also found high current sound level exposure in the labour ward, above
11
12 regulated limits. The sound level measurements further heighten the concern that obstetrics
13
14 personnel may risk acquiring hearing-related disorder as personnel carrying the dosimeters
15
16 were exposed to levels exceeding the lower action level of 80 dB LAeq during as much as
17
18 approximately half of the measured work shifts. While the average noise levels were in
19
20 accordance with an earlier study reporting noise levels from an obstetrics and labour ward at a
21
22 general hospital,[10] our study further showed that the exposure limit 115 dB LAFmax may
23
24 be exceeded in as much as one third of the work-shifts in a labour ward. The data is also in
25
26 accordance with results from a workplace inspection performed in 2010 by the occupational
27
28 health care unit at a small obstetrics ward in Sweden which showed that personnel were at
29
30 times exposed to sound levels above the regulated action and limit levels adopted by the
31
32 Swedish work environment authority.[25] This result is especially alarming as very few
33
34 personnel report use of hearing protection, which certainly may be impractical in this type of
35
36 work setting. Although caution is required in establishing the source of high maximum levels
37
38 recorded in unsupervised measurements the results are indeed important, since such high
39
40 sound levels have been described as mechanism in acquired hearing loss, tinnitus and sound
41
42 sensitivity.[3] These results highlight the need to initiate preventive action regarding noise
43
44 exposure in the obstetrics care, which include but is not limited to; information to all
45
46 employees, access to suitable hearing protection devices and cooperation between the
47
48 employer and an occupational health care unit for assessment of noise exposure and hearing-
49
50 related symptoms. Hearing tests and anamnesis regarding hearing-related symptoms may also
51
52 be considered for new employees.
53
54
55
56
57
58
59
60

1
2
3 No significant associations between noise exposure and the other hearing related symptoms
4
5 were detected in this study. This may be explained partly by the fact that hearing loss is
6
7 developed over a long period of time, usually becoming apparent after the age of retirement,
8
9 and that mild deterioration in hearing may not be easily detected via self-assessment. As the
10
11 study was cross-sectional, the fact that hearing loss was most prevalent in the third noise
12
13 exposure group lower prevalence in the highest exposure group may have influenced the
14
15 analysis. This in turn is possibly due to a healthy worker effect as individuals with hearing
16
17 loss may not be able to continue working in obstetrics care. Similarly but in the opposite
18
19 direction, as difficulty perceiving speech was reported by many young individuals, whom to a
20
21 larger extent was classified in the lowest noise index quartile, it may have influenced the
22
23 analysis of the effect of occupational noise exposure such that no significant effect was seen.
24
25 It is in any case alarming with such a high prevalence of difficulty perceiving speech.
26
27
28 Compared to prevalence data from the Swedish National Board of Health and Welfare from
29
30 2000-2005, using a similar survey item as in this study,[26] our data indicate higher age and
31
32 gender matched prevalence. Between the ages 25-64 years the prevalence in our sample
33
34 ranged from 26-35%, while the prevalence in the same age range among women in the
35
36 reference material was 5-15%. Sound sensitivity is less researched, but one previous study
37
38 from Sweden reports prevalence in the general population of 8-9%.[27] No gender-specific
39
40 prevalence was reported, making direct comparisons to our data somewhat problematic; yet
41
42 our data indicate slightly higher prevalence. In addition to the significant association between
43
44 occupational noise exposure and both tinnitus and sound induced auditory fatigue, our data
45
46 also shows that having one or more hearing-related symptom is most common among those
47
48 with highest cumulative noise exposure dose as seen in table 2. However, this variable was
49
50 not significantly associated to noise exposure in the regression model, probably due to the
51
52 variable difficulty perceiving speech having a large influence with the high prevalence in the
53
54
55
56
57
58
59
60

1
2
3 lower noise exposure group. Again, it is staggering to find that more than half of the
4
5 participating personnel group report one or more hearing-related symptom. The risks of
6
7 acquiring hearing-related symptoms in this work environment should also be seen in the light
8
9 of recent animal studies, showing that noise contribute to neurodegenerative effects and acute
10
11 loss of afferent nerve terminals - the effects of which is believed to be of importance for
12
13 auditory processing and subsequently resulting in hearing injuries emerging only later in
14
15 life.[28-30] If applicable to humans, an implication would hence be that hearing functions of
16
17 importance for auditory processing in adverse listening conditions may be impaired even
18
19 though subjects have apparent normal hearing,[31] and importantly that risk of auditory injury
20
21 from noise exposure is greater than previously assumed. Studies such as ours, investigating
22
23 risks for hearing injury within occupational groups exposed to levels at or just below the
24
25 stipulated risk levels, are therefore of high relevance.
26
27
28
29
30
31

32 **Work-related stress and noise annoyance**

33
34 Work-related stress was common among the obstetrics personnel surveyed, which is in line
35
36 with previous research.[11 12] A new finding though, was that noise annoyance is also highly
37
38 prevalent in this occupational group and that both stress and noise annoyance were positively
39
40 associated to sound induced auditory fatigue; although the estimated effect for stress was
41
42 reduced when both stress and noise annoyance were included in the same model. This may be
43
44 due to lack of power in the analysis and possibly also multi-collinearity, as there was a weak
45
46 yet significant correlation between stress and annoyance. The associations were hypothesised
47
48 based on models of pathways previously suggested by Babish,[13] and in a more recent model
49
50 by Heinonen-Guzejev et al.[32] In contrast to previous results of an association between stress
51
52 and tinnitus,[33 34] our results do not support this association despite the fact that work-
53
54 related stress was very common in our sample. It is possible that our measure of work-related
55
56
57
58
59
60

1
2
3 stress did not capture the association, that the relationship is far more complex or that tinnitus
4
5 is instead more strongly associated to psychological distress as is also suggested by studies on
6
7 tinnitus and depression and anxiety,[35 36] rather than physiological or psychosocial stress.
8
9

10 11 **Methodological consideration**

12
13 We are aware of methodological issues in assessing exposure dose retrospectively.[37 38] In
14
15 this study an estimate of cumulative occupational noise exposure was calculated by using
16
17 years worked as a proxy for the exposure dose. In order to increase the sensitivity of this
18
19 estimate, we also including years worked with the alternative birth care method (ABC-
20
21 method, predominantly used during the 1980's hypothesised to have given rise to higher
22
23 sound levels in the labour ward due to the non-use of anaesthetics), including an assessment
24
25 of current noise exposure as well as considering the protective effect of personal hearing
26
27 protective devices. A common problem in studies where cumulative exposure is estimated is
28
29 that age will naturally be incorporated in the exposure assessment, possibly confounding the
30
31 results. In our data there was a strong correlation between calculated cumulative noise
32
33 exposure and age, which is illustrated in figure 2B. It is therefore difficult to distinguish
34
35 between effects of age and noise exposure dose, which would be the case independently of
36
37 how the index was constructed as an accumulated exposure dose would naturally always
38
39 correlate to increased age. As such, the possible confounding effect of age could not be
40
41 properly adjusted for in the statistical model for the association between noise exposure and
42
43 hearing-related outcomes. When both were included in the logistic regression model neither
44
45 noise nor age showed a statistically significant effect on any of the hearing-related outcomes.
46
47 Interestingly though, we could show that the noise exposure index was significantly
48
49 associated to the hearing-related outcomes tinnitus and sound induced auditory fatigue, while
50
51 this was not the case for age alone as a predictor in a separate bi-variable model. Pathological
52
53
54
55
56
57
58
59
60

1
2
3 changes in the inner ear resulting in hearing loss as an effect of age alone is debated in the
4
5 research community.[39] Results are even less solid when considering age as a sole cause of
6
7 tinnitus.[40] Instead, the effect of noise exposure is hypothesised to largely contribute to the
8
9 increased prevalence of hearing-related disorder seen in increased age.[30 39 40]

10
11 Finally, being an initial study in this area we were not able to include a large study sample,
12
13 which affects the reliability of the analyses and the generalisation of the results. Also, though
14
15 the cross-sectional design prevents drawing definite conclusions on causal relationships, we
16
17 argue based on previous research and our study results that it is reasonable to assume a causal
18
19 pathway from noise exposure to hearing-related symptoms; the hypothesised casual pathway
20
21 involving stress and noise annoyance however, being less certain.
22
23
24
25
26

27 **CONCLUSION**

28
29 This study presents new results regarding risk of noise-induced hearing-related symptoms
30
31 among obstetrics personnel, which to the best of our knowledge has not been described
32
33 before. The results show that obstetrics personnel are at times exposed to sound levels above
34
35 regulated limits and that more than half of the participants report one or more hearing-related
36
37 symptom. Furthermore, a statistically significant association was found between cumulative
38
39 occupational noise exposure and the hearing-related symptom tinnitus and sound induced
40
41 auditory fatigue. Noise annoyance was a common complaint and in addition to noise exposure
42
43 also an important factor for sound induced auditory fatigue. These results indicate that
44
45 preventative action regarding noise exposure is required in obstetrics care and that risk-
46
47 assessments may be needed in previously unstudied non-industrial communication-intense
48
49 sound environments.
50
51
52
53
54
55
56
57
58
59
60

Acknowledgments

The authors would like to thank Lars Larsson for performing the dosimeter measurements, Christofer Andersson for assistance with the web-survey and Agneta Agge for survey data entry, as well as all the participating personnel at the obstetrics care unit at the Sahlgrenska University hospital.

Footnotes

Contributors All authors contributed to this work. KPW and KT obtained funding. KPW, SF and AT contributed to the study concept and design. SF collected the data with help from KPW. OH, SF, KPW and KT designed the plan of analysis. SF performed the final analyses. SF, KPW, OH and KT drafted the manuscript and interpreted the results. SF, KPW, OH, KT, AT made substantive editorial contributions at all stages of manuscript preparation.

Funding This study was funded by grants from the Swedish research council for Health, Working Life and Welfare (Forte) as well as the Swedish funder AFA insurance. The researchers are independent from funders.

Competing interests All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval The study was approved by the ethics committee in Gothenburg Sweden, Nr 788-11.

Provenance and peer review Not commissioned; externally peer reviewed

Data sharing statements No additional data are available

This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 3.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/3.0/>

References

1. Nelson DI, Nelson RY, Concha-Barrientos M, Fingerhut M. The global burden of occupational noise-induced hearing loss. *American Journal of Industrial Medicine* 2005;**48**(6):446-58 doi: 10.1002/ajim.20223.
2. European Agency for Safety and Health at Work. *Risks and Trends in the Safety and Health of Women at Work*, 2012.
3. Axelsson A, Hamernik RP. Acute acoustic trauma. *Acta Oto-laryngologica* 1987;**104**(3-4):225-33 doi: doi:10.3109/00016488709107322.
4. Henry JA, Dennis KC, Schechter MA. General Review of Tinnitus: Prevalence, Mechanisms, Effects, and Management. *Journal of Speech Language and Hearing Research* 2005;**48**(5):1204-35 doi: 10.1044/1092-4388(2005/084).
5. Kähäri K, Zachau G, Eklöf M, Sandsjö L, Möller C. Assessment of hearing and hearing disorders in rock/jazz musicians: Evaluación de la audición y de los problemas auditivos en músicos de rock y jazz. *International Journal of Audiology* 2003;**42**(5):279-88 doi: doi:10.3109/14992020309078347.
6. Palmer K, Griffin M, Syddall H, Davis A, Pannett B, Coggon D. Occupational exposure to noise and the attributable burden of hearing difficulties in Great Britain. *Occupational and Environmental Medicine* 2002;**59**(9):634-39
7. Persson Wayne K, Ryherd E, Hsu T, Lindahl B, Bergbom I. (2010). Personnel response in intensive care units. *Internoise*; 2010 13-16 June; Lisbon, Portugal.

- 1
2
3 8. Kjellberg A. Subjective, behavioral and psychophysiological effects of noise. *Scandinavian*
4 *journal of work, environment & health* 1990;29-38
5
6
- 7 9. Busch-Vishniac IJ, West JE, Barnhill C, Hunter T, Orellana D, Chivukula R. Noise levels
8 in Johns Hopkins hospital. *The Journal of the Acoustical Society of America*
9 2005;**118**:3629
10
11
- 12 10. Vinodhkumaradithyaa A, Kumar D, Ananthalakshmi I, et al. Noise levels in a tertiary care
13 hospital. *Noise and Health* 2008;**10**(38):11-13 doi: 10.4103/1463-1741.39003.
14
15
- 16 11. Hildingsson I, Westlund K, Wiklkund I. Burnout in Swedish midwives. *Sexual &*
17 *Reproductive Healthcare* 2013;**4**:87-91
18
19
- 20 12. Hultberg A, Hadžibajramović E, Pettersson S, Skagert K, Ahlberg G. KART-studien.
21 *Arbetsmiljö, stress och hälsa bland anställda vid Västra Götalandsregionen. Delrapport 5:*
22 *Uppföljning utifrån organisations-, yrkesgrupps- och individperspektiv 2008 - 2010. In:*
23 *Ahlberg G, ed.: Institute of Stress Medicine, 2011. [In Swedish]*
24
25
26
27
28
- 29 13. Babisch W. The noise/stress concept, risk assessment and research needs. *Noise and*
30 *Health* 2002;**4**(16):1-11
31
32
- 33 14. Leather P, Beale D, Sullivan L. Noise, psychosocial stress and their interaction in the
34 workplace. *Journal of Environmental Psychology* 2003;**23**(2):213-22
35
36
- 37 15. Lercher P, Hörtnagl J, Kofler WW. Work noise annoyance and blood pressure: combined
38 effects with stressful working conditions. *International archives of occupational and*
39 *environmental health* 1993;**65**(1):23-28
40
41
42
43
- 44 16. Persson Waye K, Agge A, Hillström J, Lindström F. Being in a pre-school sound
45 environment – annoyance and subjective symptoms among personnel and children.
46 *Internoise*; 2010 13-16 June; Lisbon, Portugal.
47
48
49
- 50 17. Neitzel R, Daniell W, Sheppard L, Davies H, Seixas N. Comparison of Perceived and
51 Quantitative Measures of Occupational Noise Exposure. *Annals of Occupational Hygiene*
52 2009;**53**(1):41-54 doi: 10.1093/annhyg/men071.
53
54
55
56
57
58
59
60

- 1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
18. Nondahl DM, Cruickshanks KJ, Wiley TL, Tweed TS, Klein R, Klein BEK. Accuracy of Self-reported Hearing Loss. *International Journal of Audiology* 1998;**37**(5):295-301 doi: doi:10.3109/00206099809072983.
19. Schlaefter K, Schlehofer B, Schüz J. Validity of self-reported occupational noise exposure. *European journal of epidemiology* 2009;**24**(8):469-475.
20. Sindhusake D, Mitchell P, Smith W, et al. Validation of self-reported hearing loss. The Blue Mountains hearing study. *International Journal of Epidemiology* 2001;**30**(6):1371-78
21. Ryberg JB, Agge A, Wayne KP. Low frequency noise in a paper mill control room. *Journal of low frequency noise, vibration and active control* 2007;**26**(3):165-76
22. Axelsson A, Prasher D. Tinnitus induced by occupational and leisure noise. *Noise and Health* 2000;**2**(8):47
23. Nouvian R, Eybalin M, Puel J-L. The cochlea and the Auditory Nerve as a Primary Source of Tinnitus. In: Eggermont JJ, Zeng F-G, Popper AN, eds. *Tinnitus*. New York: Springer Science and Business Media, 2012.
24. Schmidt CO, Kohlmann T. When to use the odds ratio or the relative risk? *International journal of public health* 2008;**53**(3):165-67
25. Tenenbaum A, Hendriksson A, Larsson L. Bullernivåer och hörselundersökning på förlossningsavdelning. Läkarsamman. Stockholm, Sweden, 2010. [In Swedish]
26. Danermark B, Hanning M. Hearing and vision: Health in Sweden: The National Public Health Report 2012. Chapter 17. *Scandinavian Journal of Public Health* 2012;**40**(9 suppl):287-92 doi: 10.1177/1403494812459621.
27. Andersson G, Lindvall N, Hursti T, Carlbring P. Hypersensitivity to sound (hyperacusis): a prevalence study conducted via the internet and post. *International Journal of Audiology* 2002;**41**(8):545-54 doi: doi:10.3109/14992020209056075.
28. Kujawa SG, Liberman MC. Adding insult to injury: cochlear nerve degeneration after “temporary” noise-induced hearing loss. *The Journal of Neuroscience* 2009;**29**(45):14077-85

- 1
2
3 29. Lin HW, Furman AC, Kujawa SG, Liberman MC. Primary neural degeneration in the
4 Guinea pig cochlea after reversible noise-induced threshold shift. *Journal of the*
5 *Association for Research in Otolaryngology* 2011;**12**(5):605-16
6
7
8
9 30. Kujawa SG, Liberman MC. Acceleration of age-related hearing loss by early noise
10 exposure: evidence of a missed youth. *The Journal of Neuroscience* 2006;**26**(7):2115-
11 23
12
13
14 31. Ruggles D, Bharadwaj H, Shinn-Cunningham BG. Normal hearing is not enough to
15 guarantee robust encoding of suprathreshold features important in everyday
16 communication. *Proceedings of the National Academy of Sciences* 2011;**108**(37):15516-
17 21
18
19
20
21
22 32. Heinonen-Guzejev M, Koskenvuo M, Silventoinen K, et al. Noise Sensitivity and
23 Disability Retirement: A Longitudinal Twin Study. *Journal of Occupational and*
24 *Environmental Medicine* 2013;**55**(4):365-70
25
26
27
28 33. Alpini D, Cesarani A. Tinnitus as an alarm bell: stress reaction tinnitus model. *ORL*
29 2006;**68**(1):31-37
30
31
32
33 34. Hébert S, Lupien SJ. The sound of stress: blunted cortisol reactivity to psychosocial stress
34 in tinnitus sufferers. *Neuroscience letters* 2007;**411**(2):138-42
35
36
37 35. Holgers K-M, Erlandsson SI, Barrenäs M-L. Predictive Factors for the Severity of
38 Tinnitus: Factores predictivos de la severidad del tinnitus. *International Journal of*
39 *Audiology* 2000;**39**(5):284-91
40
41
42
43 36. Robinson SK, Viirre ES, Stein MB. Antidepressant therapy in tinnitus. *Hearing research*
44 2007;**226**(1):221-31
45
46
47 37. Davies HW, Teschke K, Kennedy SM, Hodgson MR, Hertzman C, Demers PA.
48 Occupational exposure to noise and mortality from acute myocardial infarction.
49 *Epidemiology* 2005;**16**(1):25-32
50
51
52
53 38. Nilsson T, Burström L, Hagberg M. Risk assessment of vibration exposure and white
54 fingers among platers. *International archives of occupational and environmental health*
55 1989;**61**(7):473-81
56
57
58
59
60

- 1
2
3 39. Van Eyken E, Van Camp G, Van Laer L. The complexity of age-related hearing
4 impairment: contributing environmental and genetic factors. *Audiology and Neurotology*
5 2007;**12**(6):345-58
6
7
8
9 40. Sanchez L. The epidemiology of tinnitus. *Audiological Medicine* 2004;**2**(1):8-17
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

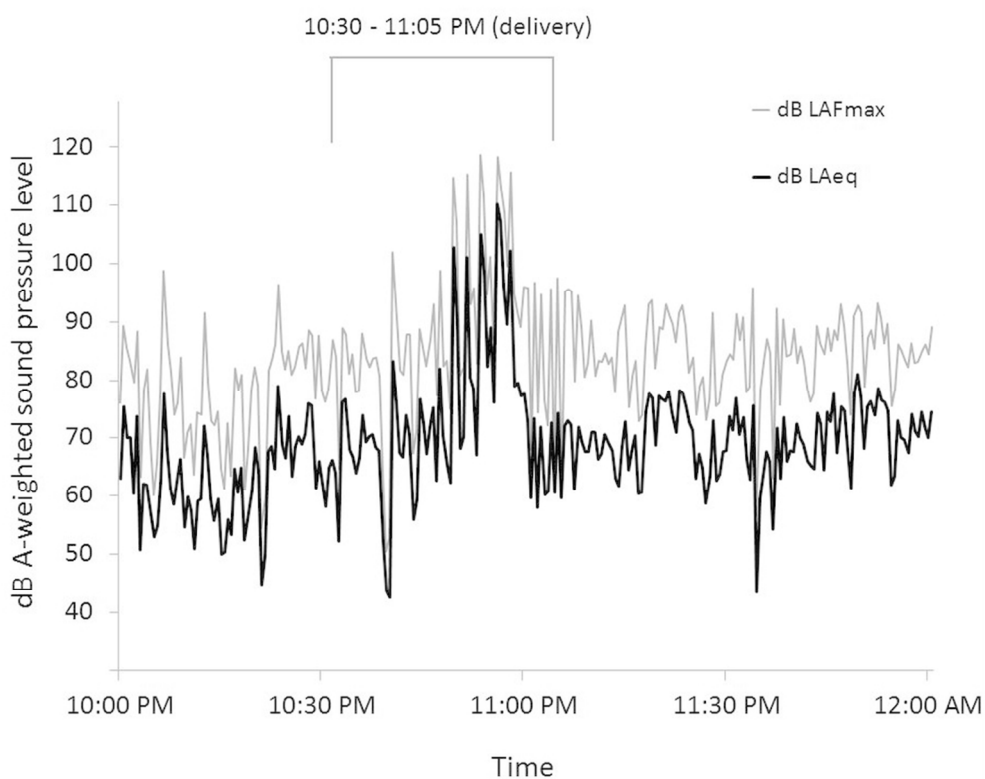


Figure 1. Two hour section of a time history graph from sound level measurement with dosimeter carried by a midwife during a sample night shift in the obstetrics ward. Equivalent sound level during the entire shift was 85 dB LAeq (approx. 9 hours) and 118.7 dB LAFmax was the highest recorded during the shift (shown in the selected section). According to the written log the midwife attended a delivery during 10:30 – 11:05 PM. Black curve shows the dB LAeq and grey curve shows dB LAFmax.
90x71mm (300 x 300 DPI)

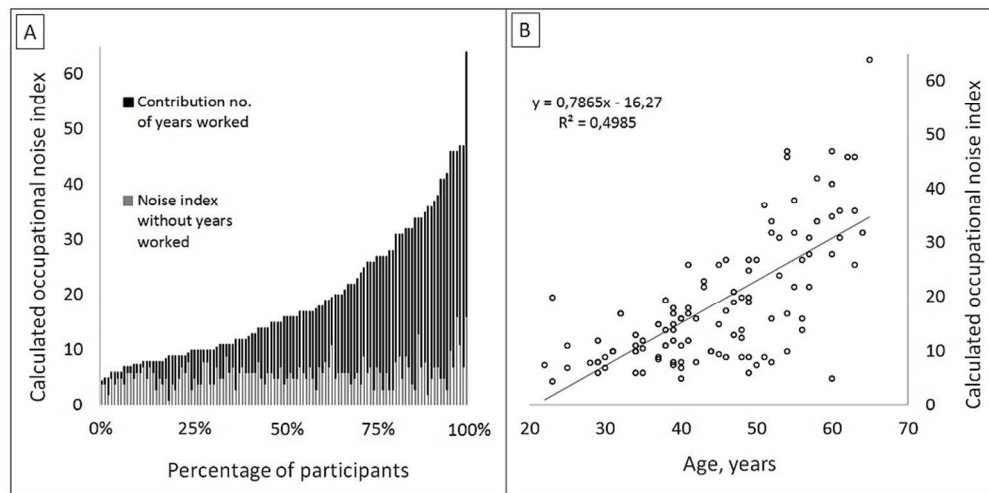


Figure 2. Calculated occupational noise index for obstetrics personnel. Figure 2 A to the left, shows the contribution of the variable number of years worked in obstetrics (in black) to the noise index for each participant, each bar representing one participant. The light grey bars represent the index with the variable years worked in obstetrics omitted. The percentages of participants are shown on the x-axis and the calculated noise index value on the y-axis. Figure 2 B, to the right shows the correlation between noise index and age of participants.
90x44mm (300 x 300 DPI)

review only

Supplementary table 1 Calculation of occupational noise index for obstetrics personnel based on questionnaire data, where scoring for each item and each response alternative is shown.

Questionnaire item in full text	Response alternatives	Scoring for index
How many years have you worked in an obstetrics ward?	Free field answer	1 point per year ^a
Have you worked with the so called ABC-method (Alternative Birth Care), if so for how many years?	Free field answer	1 point per year ^b
How many working hours do you normally spend in postpartum care and in delivery care, respectively?	Free field answer	0 points 1 point 2 points ^c
Is the sound level at your workplace sometimes so loud that you have difficulty hearing what other people are saying?	Never/almost never 25% of time 50% of time 75% of time Always/almost always	0 points 1 point 2 points 3 points 4 points
How often are you at your workplace exposed to such high sound levels that you have to raise your voice to be able to talk to other people?	Never/almost never 25% of time 50% of time 75% of time Always/almost always	0 points 1 point 2 points 3 points 4 points
Do you use hearing protective devices (such as ear-plugs) at your current workplace?	Never/almost never Seldom Often Always/almost always	3 points 2 points 1 point 0 points

^a Missing data was replaced by number of years since graduating, n=6. One additional participant did not fill in number of years worked, nor years since graduating and therefore got 14.6 points which was the group median at that specific age (46 years old).

^b Missing data was replaced by group median (3 years), n=3.

^c Participants reporting 0 hours in delivery care received 0 points, those reporting any number of hours in postpartum care and delivery care received 1 point and those reporting 1 hour or more in delivery care only received 3 points.

Supplementary table 2 Questionnaire items and response alternatives used in survey among obstetrics care personnel. Derived variables used in the analysis are also shown based on the questionnaire items (translation from Swedish for article, not validated). Original wording in Swedish provided for hearing-related items.

Hearing-related outcome variables	Response alternatives	Derived variables
Hearing loss Do you have a hearing loss? /hearing disorder? (Swe. "hörselnedsättning/hörselskada")	Yes No Don't know	Hearing loss was defined as reporting yes.
Tinnitus, Sound sensitivity and Sound fatigue^a Do you during or after work experience any of the following symptoms: - Tinnitus? - Sound sensitivity? (discomfort, pain from normal sounds)? (Swe. "ljudkänslighet, obehag eller smärta av normala ljud") - Sound fatigue? (Swe. "ljudtrötthet")	Never/rarely A few times each month Once or twice a week Several times each week Every day	Having either symptom was defined as reporting once a week or more often.
Poor hearing How do you think your hearing is? (Swe. "Hur tycker du att din hörsel är?")	Very good Good Normal Bad Very bad	Poor hearing was defined as reporting bad or very bad hearing.
Difficulty perceiving speech Do you have trouble hearing what is said in an environment where several people are talking at the same time (Swe. "Har du besvär att höra vad som sägs i en miljö där flera talar samtidigt?") - At work? - In leisure time?	Yes No	Difficulty perceiving speech was defined as reporting yes to both work and leisure time.
Explanatory variables	Response alternatives	Derived variables
Work-related stress How is your work typically? - I experience high degree of stress. - I feel unwell due to stress at work.	Never/seldom Sometimes Often Always/almost always	Work-related stress was defined as reporting often or always/almost always for one or both of the stress items.
Noise annoyance Are you annoyed by sounds/noise at your work place?	Not at all Some Pretty much Very Extremely	Noise annoyance was defined as reporting if pretty much, very or extreme annoyance.
Smoking Do you smoke?	Yes Yes, but only occasionally No, but I have smoked previously for ___ years No	Ever smokers were defined as those reporting yes, yes occasionally or previously smoked.
Leisure time noise exposure Are you exposed to high sound levels during leisure time (e.g. shooting/hunting, playing in a band, concert/disco, driving motorcycle, working with noisy tools/machines)?	No Yes, every day Yes, a few times each week Yes, once or twice each week Yes, a few times each month Yes, once or twice a month Yes, a few times each year or less often/never	Leisure time exposure was defined as those reporting exposure once a month or more often.

^a The items regarding the symptoms tinnitus, sound sensitivity and sound fatigue were included in a matrix with other symptoms such as headache and tiredness.