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

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## 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 midwifes 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, midwifes report a high degree of work-related stress and burnout,[11] and according to a recent report burnout syndrome have doubled among midwifes 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

interaction effects between noise exposure, noise annoyance and work-related stress. Therefore, the aim of this study was to assess the risk of noise-induced hearing-related symptoms among obstetrics personnel by measuring sound levels in the labour ward of a general obstetrics ward and by analysing the effect of and interaction between occupational noise exposure, noise annoyance and work-related stress on hearing-related symptoms among obstetrics personnel.

## METHODS

### Sound level measurements

Sound level measurements were carried out during 61 work shifts in the labour ward of a general obstetrics ward at the Sahlgrenska University Hospital in Gothenburg. Day shifts (n=19) were measured between 7 a.m. and 3:30 p.m. (8.5 h), evening shifts (n=12) between 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 day and evening shifts were measured during separate weeks so as not to overlap. A convenient sample of ten employees per shift each wore a personal dosimeter (Larson Davis 705+) with the microphone attached to the right shoulder and kept a written log documenting work activities during the measured shift. A total of 610 separate measurements were collected. However, due to technical errors a few faulty measurements were excluded leaving 529 (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. The equivalent levels reported refer to the full-shift length and will hence vary between 7.25 – 10 hours, hereinafter denoted as $LAeq_{(7\text{-}10h)}$. 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. 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 in delivery care, number of years worked in alternative birth care, work allocation (delivery care, postpartum care or both), two separate items on frequency of current work-related noise exposure (one assessing how often the sound levels are so high that the person has to speak with raised voice and one assessing how often the person have trouble hearing what is said) and finally one item on frequency of hearing protection use. A higher noise index indicates a higher noise exposure dose. The scoring for each items contribution to the index is presented in detail in supplementary table 1. Work-related stress and noise annoyance were analysed as additional explanatory variables. Work-related stress was assessed using two separate questionnaire items asking responders to report how often they experience high degree of

stress and how often they feel unwell due to stress at work. Participants were defined as having work-related stress if answering often or always/almost always on one or both of the items. These stress-related items have previously been used in noise-related research.[21] Noise annoyance was assessed by the item 'Are you annoyed by sounds/noise at your workplace?', which is based on the International standard ISO/TS 15666, adapted for a workplace survey as opposed to community surveys. The hearing-related outcome variables included are hearing loss (yes), tinnitus, sound sensitivity and sound fatigue (a few times each week or more often), general hearing status (poor or very poor) and difficulty perceiving speech (yes both at work and in leisure time). Variables considered as possible moderators for the association between exposure and outcome were smoking (previous or current) and leisure-time noise exposure (once a month or more often). Age (in years) was considered a possible confounder. 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 logistic regressions and relative risk (RR) was calculated from predictive values derived from model 1. Goodness of fit for the regression models were assessed using the Hosmer-Lemeshow test and a non-significant p-value (>0.05) was used to indicate adequate fit.

## RESULTS

### Sound levels in the labour ward

Overall, the dosimeter measurements from the labour ward showed moderately high sound levels, as presented in table 1. The levels reached or exceeded both the action and limit levels. The lower action level 80 dB LAeq was exceeded in 30 different dosimeter measurements during 28 different work shifts, which corresponds to 46% of all measured shifts or 6% of all dosimeter measurements. The upper exposure action level and exposure limit 85 dB LAeq

was reached or exceeded in three measurements from three different shifts, corresponding to 5% of all measured shifts or 0.6% of all measurements. The limit 115 dB LAFmax was reached or exceeded at 50 different occasions. However, of these 9 separate events could not be verified by the written logs and were therefore excluded. The remaining 41 events occurred in 17 different shifts corresponding to 28% of all measured shifts or 8% of all dosimeter measurements. There were no statistical differences in arithmetic mean equivalent nor in maximum levels when comparing measurements from different work-shifts nor measurements from dosimeters worn by midwifes compared to assistant nurses. Due to incomplete written logs however, we were unable to categorise a third of the measurements into professional group. A segment sample from a dosimeter measurement is shown in figure 1, where high maximum levels (119 dB LAFmax) was recorded during a delivery, which according to the written log occurred between 10:30 and 11:05 pm. The equivalent level in this particular measurement was 84 dB $LAeq_{(10h)}$ for the measured shift length. As exposure limits should be 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, $LAeq_{(7\text{-}10h)}$ 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 $LAeq_{(7\text{-}10h)}$ | 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) | | | |
| Midwifes | 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.

Associations between occupational noise exposure dose (continuous noise index), work-related stress, noise annoyance and hearing-related symptoms were evaluated in manual sequential binary logistic regression models, results of which are presented in table 3. The calculated noise index ranged from 4.5 to 64 in the study sample. The proportional contribution of years worked in obstetrics care to the index, as a proxy for cumulative exposure, is shown in figure 2 A. The percentage of participants over the range of noise index also conveys the skewness in the distribution of the index, e.g. less than 25% of the participants have noise index values in the upper half of the range.

**FIGURE 2**

Occupational noise exposure as a single explanatory variable was significantly associated to tinnitus and sound fatigue, but not to the other hearing-related symptoms. Work-related stress and noise annoyance were both significantly associated to sound fatigue in separate models, but not to tinnitus. For sound fatigue, including all three significant explanatory variables (noise, stress and annoyance) in model 5 resulted in marginal changes in point estimates for noise exposure and noise annoyance. It did however affect the estimates for work-related stress, which just missed statistical significance (p=0.053). No significant statistical interactions were found between explanatory variables. Neither work-related stress nor noise annoyance were significantly correlated to noise exposure index, there was however a weak yet significant correlation between stress and noise annoyance (r=0.249, $p$=0.008). The point estimates for noise exposure was comparable with or without adjustment for smoking and leisure-time noise exposure in model 2, and neither one of the adjustment variables were themselves significant. Hence, they were not included in the subsequent multivariable models. All reported models had an acceptable goodness of fit.

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

Due to the cumulative property of the noise index, the index was assumed to be correlated to age, which was also confirmed in the analysis ($r=0.706$, $p<0.001$) with $R^2=0.498$, as shown in figure 2 B. Multi-collinearity issues therefore precluded the assessment of both variables in one regression model. Notably and importantly though, age was not significantly associated to any of the hearing-related symptoms when assessed as a single explanatory variable in separate regression models.

**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** | | | | |
| *Model 1* | Noise exposure index | 0.04 (0.02) | 1.04 (1.00 – 1.07) | **0.031** |
| *Model 3* | 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** |
| *Model 4* | 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** |
| *Model 5* | 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** | | | | |
| *Model 1* | Noise exposure index | 0.04 (0.02) | 1.04 (1.00 – 1.09) | **0.049** |
| *Model 3* | 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 |
| *Model 4* | 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 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 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.

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

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

developed over a long period of time, usually becoming apparent after the age of retirement, and that mild deterioration in hearing may not be easily detected via self-assessment. As the study was cross-sectional, the fact that hearing loss was most prevalent in the third noise exposure group lower prevalence in the highest exposure group may have influenced the analysis. This in turn is possibly due to a healthy worker effect as individuals with hearing loss may not be able to continue working in obstetrics care. Similarly but in the opposite direction, as difficulty perceiving speech was reported by many young individuals it may have influenced the analysis of the effect of occupational noise exposure. It is in any case alarming with such a high prevalence of difficulty perceiving speech. Compared to prevalence data from the Swedish National Board of Health and Welfare from 2000-2005, using a similar survey item as in this study,[26] our data indicate higher age and gender matched prevalence. Between the ages 25-64 years the prevalence in our sample ranged from 26-35%, while the prevalence in the same age range among women in the reference material was 5-15%. Sound sensitivity is less researched, but one previous study from Sweden reports prevalence in the general population of 8-9%.[27] No gender-specific prevalence was reported, making direct comparisons to our data somewhat problematic; yet our data indicate slightly higher prevalence. In addition to the significant association between occupational noise exposure and both tinnitus and sound fatigue, our data also shows that having one or more hearing-related symptom is most common among those with highest cumulative noise exposure dose as seen in table 2. However, this variable was not significantly associated to noise exposure in the regression model, probably due to the variable difficulty perceiving speech having a large influence with the high prevalence in the lower noise exposure group. Again, it is staggering to find that more than half of the participating personnel group report one or more hearing-related symptom. The risks of acquiring hearing-related symptoms in this work environment should also be seen in the light of recent animal studies, showing that noise contribute to

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

**Work-related stress and noise annoyance**

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

**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]

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

## CONCLUSION

This study presents new results regarding risk of noise-induced hearing-related symptoms among obstetrics personnel, which to the best of our knowledge has not been described before. The results show that obstetrics personnel are at times exposed to sound levels above regulated limits and that more than half of the participants report one or more hearing-related symptom. Furthermore, a statistically significant association was found between cumulative occupational noise exposure and the hearing-related symptom tinnitus and sound fatigue. Noise annoyance was a common complaint and in addition to noise exposure also an important factor for sound fatigue. 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.

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**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.

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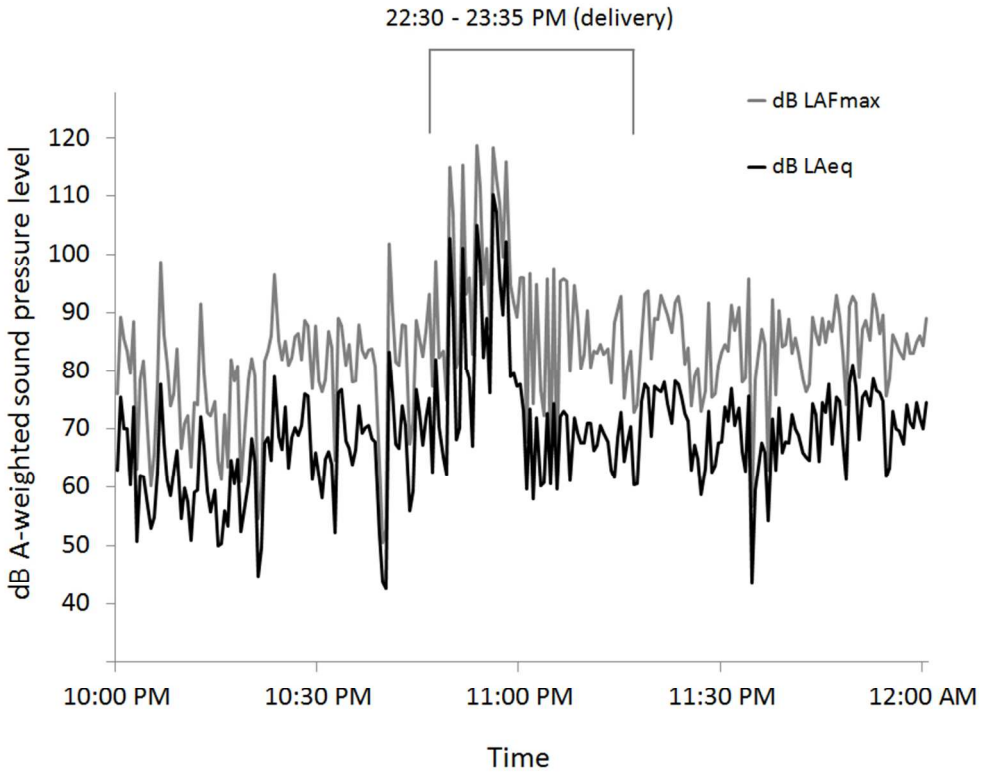
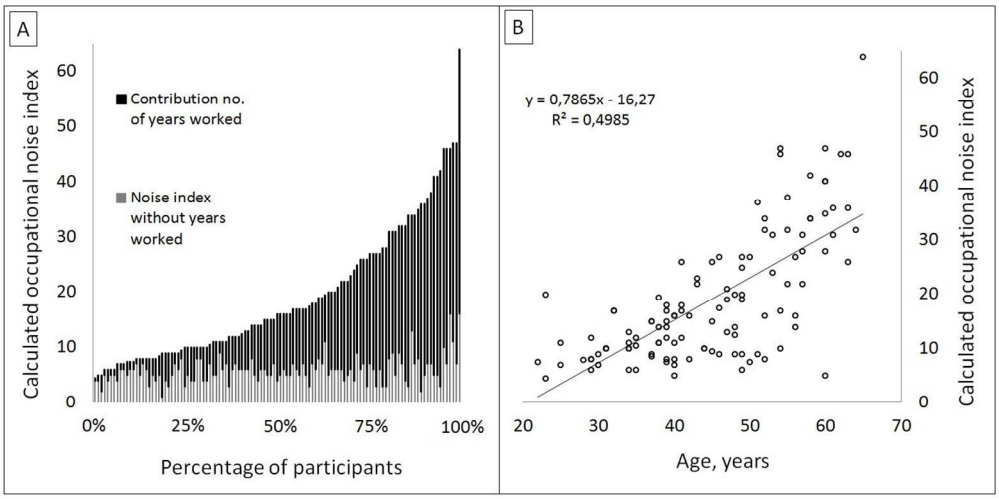
## FIGURE LEGENDS

**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)




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)

**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<br>1 point<br>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<br>25% of time<br>50% of time<br>75% of time<br>Always/almost always | 0 points<br>1 point<br>2 points<br>3 points<br>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<br>25% of time<br>50% of time<br>75% of time<br>Always/almost always | 0 points<br>1 point<br>2 points<br>3 points<br>4 points |
| Do you use hearing protective devices (such as ear-plugs) at your current workplace? | Never/almost never<br>Seldom<br>Often<br>Always/almost always | 3 points<br>2 points<br>1 point<br>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**<br>Do you have a hearing loss? | Yes<br>No<br>Don't know | Hearing loss was defined as reporting yes. |
| **Tinnitus, Sound sensitivity and Sound fatigue** [a]<br>Do you during or after work experience any of the following symptoms:<br>- Tinnitus?<br>- Sound sensitivity?<br>- Sound fatigue? | Never/rarely<br>A few times each month<br>Once or twice a week<br>Several times each week<br>Every day | Having either symptom was defined as reporting once a week or more often. |
| **Poor hearing**<br>How do you think your hearing is? | Very good<br>Good<br>Normal<br>Bad<br>Very bad | Poor hearing was defined as reporting bad or very bad hearing. |
| **Difficulty perceiving speech**<br>Do you have trouble hearing what is said in an environment where several people are talking at the same time<br>- At work?<br>- In leisure time? | Yes<br>No | Difficulty perceiving speech was defined as reporting yes to both work and leisure time. |
| **Explanatory variables** | **Response alternatives** | **Derived variables** |
| **Work-related stress**<br>How is your work typically?<br>- I experience high degree of stress.<br>- I feel unwell due to stress at work. | Never/seldom<br>Sometimes<br>Often<br>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**<br>Are you annoyed by sounds/noise at your work place? | Not at all<br>Some<br>Pretty much<br>Very<br>Extremely | Noise annoyance was defined as reporting if pretty much, very or extreme annoyance. |
| **Smoking**<br>Do you smoke? | Yes<br>Yes, but only occasionally<br>No, but I have smoked previously for ___ years<br>No | Ever smokers were defined as those reporting yes, yes occasionally or previously smoked. |
| **Leisure time noise exposure**<br>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<br>Yes, every day<br>Yes, a few times each week<br>Yes, once or twice each week<br>Yes, a few times each month<br>Yes, once or twice a month<br>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.

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

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

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## 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-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. 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 midwifes 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, midwifes report a high degree of work-related stress and burnout,[11] and according to a recent report burnout

syndrome have doubled among midwifes 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 interaction effects between noise exposure, noise annoyance and work-related stress. Therefore, the aim of this study was to assess the risk of noise-induced hearing-related symptoms among obstetrics personnel by measuring sound levels in the labour ward of a general obstetrics ward and by analysing the effect of and interaction between occupational noise exposure, noise annoyance and work-related stress on hearing-related symptoms among obstetrics personnel.

## METHODS

### Sound level measurements

Sound level measurements were carried out during 61 work shifts in the labour ward of a general obstetrics ward at the Sahlgrenska University Hospital in Gothenburg. Out of the 61 shifts 19 day shifts were measured between 7 a.m. and 3:30 p.m. (8.5 h), 12 evening shifts 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). The day and evening shifts were measured during separate weeks so as not to overlap. A convenient sample of ten employees per shift each wore a personal dosimeter (Larson Davis 705+) with the microphone attached to the right shoulder and kept a written log documenting work activities during the measured shift. A total of 610 separate measurements were collected, as 10 individuals each wore a dosimeter during the 61 shifts measured. However, due to technical errors a few faulty measurements were excluded leaving 529 (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 begun. The equivalent levels reported refer to the full-shift length and will hence vary between 7.25 – 10 hours, hereinafter denoted as $LAeq_{(7\text{-}10h)}$. 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

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

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

## RESULTS

### Sound levels in the labour ward

Overall, the dosimeter measurements from the labour ward showed moderately high sound levels, as presented in table 1. The levels reached or exceeded both the action and limit levels. The lower action level 80 dB LAeq was exceeded in 30 different dosimeter measurements during 28 different work shifts, which corresponds to 46% of all measured shifts or 6% of all dosimeter measurements. The upper exposure action level and exposure limit 85 dB LAeq was reached or exceeded in three measurements from three different shifts, corresponding to 5% of all measured shifts or 0.6% of all measurements. The limit 115 dB LAFmax was reached or exceeded at 50 different occasions. However, of these 9 separate events could not be verified by the written logs and were therefore excluded. The remaining 41 events occurred in 17 different shifts corresponding to 28% of all measured shifts or 8% of all dosimeter measurements. There were no statistical differences in arithmetic mean equivalent nor in maximum levels when comparing measurements from different work-shifts nor measurements from dosimeters worn by midwifes compared to assistant nurses. Due to incomplete written logs however, we were unable to categorise a third of the measurements into professional group. A segment sample from a dosimeter measurement is shown in figure 1, where high maximum levels (119 dB LAFmax) was recorded during a delivery, which according to the written log occurred between 10:30 and 11:05 pm. The equivalent level in this particular measurement was 84 dB $LAeq_{(10h)}$ for the measured shift length. As exposure limits should be

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, $LAeq_{(7\text{-}10h)}$ 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 $LAeq_{(7\text{-}10h)}$ | 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) | | | |
| Midwifes | 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.

Associations between occupational noise exposure dose (continuous noise index), work-related stress, noise annoyance and hearing-related symptoms were evaluated in manual sequential binary logistic regression models, results of which are presented in table 3. The calculated noise index ranged from 4.5 to 64 in the study sample. The proportional contribution of years worked in obstetrics care to the index, as a proxy for cumulative exposure, is shown in figure 2 A. The percentage of participants over the range of noise index also conveys the skewness in the distribution of the index, e.g. less than 25% of the participants have noise index values in the upper half of the range.

**FIGURE 2**

Occupational noise exposure as a single explanatory variable was significantly associated to tinnitus and sound induced auditory fatigue, but not to the other hearing-related symptoms. Work-related stress and noise annoyance were both significantly associated to sound induced auditory fatigue in separate models, but not to tinnitus. For sound induced auditory fatigue, including all three significant explanatory variables (noise, stress and annoyance) in model 5 resulted in marginal changes in point estimates for noise exposure and noise annoyance. It did however affect the estimates for work-related stress, which just missed statistical significance (p=0.053). No significant statistical interactions were found between explanatory variables. Neither work-related stress nor noise annoyance were significantly correlated to noise exposure index. There was however a weak yet significant correlation between stress and noise annoyance (r=0.249, *p*=0.008). The point estimates for noise exposure was comparable with or without adjustment for smoking and leisure-time noise exposure in model 2, and neither one of the adjustment variables were themselves significant. Hence, they were not

included in the subsequent multivariable models. All reported models had an acceptable goodness of fit.

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

Due to the cumulative property of the noise index, the index was assumed to be correlated to age, which was also confirmed in the analysis ($r=0.706$, $p<0.001$) with $R^2=0.498$, as shown in figure 2 B. Multi-collinearity issues therefore precluded the assessment of both variables in one regression model. Notably and importantly though, age was not significantly associated to any of the hearing-related symptoms when assessed as a single explanatory variable in separate regression models.

**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** | | | | |
| *Model 1* | Noise exposure index | 0.04 (0.02) | 1.04 (1.00 – 1.07) | **0.031** |
| *Model 3* | 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** |
| *Model 4* | 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** |
| *Model 5* | 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** | | | | |
| *Model 1* | Noise exposure index | 0.04 (0.02) | 1.04 (1.00 – 1.09) | **0.049** |
| *Model 3* | 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 |
| *Model 4* | 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

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

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

No significant associations between noise exposure and the other hearing related symptoms were detected in this study. This may be explained partly by the fact that hearing loss is developed over a long period of time, usually becoming apparent after the age of retirement, and that mild deterioration in hearing may not be easily detected via self-assessment. As the study was cross-sectional, the fact that hearing loss was most prevalent in the third noise exposure group lower prevalence in the highest exposure group may have influenced the analysis. This in turn is possibly due to a healthy worker effect as individuals with hearing loss may not be able to continue working in obstetrics care. Similarly but in the opposite direction, as difficulty perceiving speech was reported by many young individuals, whom to a larger extent was classified in the lowest noise index quartile, it may have influenced the analysis of the effect of occupational noise exposure such that no significant effect was seen. It is in any case alarming with such a high prevalence of difficulty perceiving speech. Compared to prevalence data from the Swedish National Board of Health and Welfare from 2000-2005, using a similar survey item as in this study,[26] our data indicate higher age and gender matched prevalence. Between the ages 25-64 years the prevalence in our sample ranged from 26-35%, while the prevalence in the same age range among women in the reference material was 5-15%. Sound sensitivity is less researched, but one previous study from Sweden reports prevalence in the general population of 8-9%.[27] No gender-specific prevalence was reported, making direct comparisons to our data somewhat problematic; yet our data indicate slightly higher prevalence. In addition to the significant association between occupational noise exposure and both tinnitus and sound induced auditory fatigue, our data also shows that having one or more hearing-related symptom is most common among those with highest cumulative noise exposure dose as seen in table 2. However, this variable was not significantly associated to noise exposure in the regression model, probably due to the variable difficulty perceiving speech having a large influence with the high prevalence in the

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

**Work-related stress and noise annoyance**

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

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

**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 induced auditory 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]

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

## CONCLUSION

This study presents new results regarding risk of noise-induced hearing-related symptoms among obstetrics personnel, which to the best of our knowledge has not been described before. The results show that obstetrics personnel are at times exposed to sound levels above regulated limits and that more than half of the participants report one or more hearing-related symptom. Furthermore, a statistically significant association was found between cumulative occupational noise exposure and the hearing-related symptom tinnitus and sound induced auditory fatigue. Noise annoyance was a common complaint and in addition to noise exposure also an important factor for sound induced auditory fatigue. 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.

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**Footnotes**

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

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## 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-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. 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 midwifes are women. ~~To the best of our knowledge, only~~ ~~o~~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, midwifes report a high degree of work-related stress and burnout,[11] and according to a recent report burnout

syndrome have doubled among midwifes 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 interaction effects between noise exposure, noise annoyance and work-related stress. Therefore, the aim of this study was to assess the risk of noise-induced hearing-related symptoms among obstetrics personnel by measuring sound levels in the labour ward of a general obstetrics ward and by analysing the effect of and interaction between occupational noise exposure, noise annoyance and work-related stress on hearing-related symptoms among obstetrics personnel.

## METHODS

### Sound level measurements

Sound level measurements were carried out during 61 work shifts in the labour ward of a general obstetrics ward at the Sahlgrenska University Hospital in Gothenburg. Out of the 61 shifts 19 ~~D~~day shifts ~~(n=19)~~ were measured between 7 a.m. and 3:30 p.m. (8.5 h), 12 evening shifts ~~(n=12)~~ between 1:45 p.m. and 9 p.m. (7.25 h) and 30 nightshifts ~~(n=30)~~ between 9 p.m. and 7 a.m. (10 h). The day and evening shifts were measured during separate weeks so as not to overlap. A convenient sample of ten employees per shift each wore a personal dosimeter (Larson Davis 705+) with the microphone attached to the right shoulder and kept a written log documenting work activities during the measured shift. A total of 610 separate measurements were collected, as 10 individuals each wore a dosimeter during the 61 shifts measured. However, due to technical errors a few faulty measurements were excluded leaving 529

(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 begun. The equivalent levels reported refer to the full-shift length and will hence vary between 7.25 – 10 hours, hereinafter denoted as $LAeq_{(7\text{-}10h)}$. 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

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

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

## RESULTS

### Sound levels in the labour ward

Overall, the dosimeter measurements from the labour ward showed moderately high sound levels, as presented in table 1. The levels reached or exceeded both the action and limit levels. The lower action level 80 dB LAeq was exceeded in 30 different dosimeter measurements during 28 different work shifts, which corresponds to 46% of all measured shifts or 6% of all dosimeter measurements. The upper exposure action level and exposure limit 85 dB LAeq was reached or exceeded in three measurements from three different shifts, corresponding to 5% of all measured shifts or 0.6% of all measurements. The limit 115 dB LAFmax was reached or exceeded at 50 different occasions. However, of these 9 separate events could not be verified by the written logs and were therefore excluded. The remaining 41 events occurred in 17 different shifts corresponding to 28% of all measured shifts or 8% of all dosimeter measurements. There were no statistical differences in arithmetic mean equivalent nor in maximum levels when comparing measurements from different work-shifts nor measurements from dosimeters worn by midwifes compared to assistant nurses. Due to incomplete written logs however, we were unable to categorise a third of the measurements into professional group. A segment sample from a dosimeter measurement is shown in figure 1, where high maximum levels (119 dB LAFmax) was recorded during a delivery, which according to the written log occurred between 10:30 and 11:05 pm. The equivalent level in this particular measurement was 84 dB $LAeq_{(10h)}$ for the measured shift length. As exposure limits should be

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, $LAeq_{(7\text{-}10h)}$ 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 $LAeq_{(7\text{-}10h)}$ | 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) | | | |
| Midwifes | 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.

Associations between occupational noise exposure dose (continuous noise index), work-related stress, noise annoyance and hearing-related symptoms were evaluated in manual sequential binary logistic regression models, results of which are presented in table 3. The calculated noise index ranged from 4.5 to 64 in the study sample. The proportional contribution of years worked in obstetrics care to the index, as a proxy for cumulative exposure, is shown in figure 2 A. The percentage of participants over the range of noise index also conveys the skewness in the distribution of the index, e.g. less than 25% of the participants have noise index values in the upper half of the range.

**FIGURE 2**

Occupational noise exposure as a single explanatory variable was significantly associated to tinnitus and sound induced auditory fatigue, but not to the other hearing-related symptoms. Work-related stress and noise annoyance were both significantly associated to sound induced auditory fatigue in separate models, but not to tinnitus. For sound induced auditory fatigue, including all three significant explanatory variables (noise, stress and annoyance) in model 5 resulted in marginal changes in point estimates for noise exposure and noise annoyance. It did however affect the estimates for work-related stress, which just missed statistical significance (p=0.053). No significant statistical interactions were found between explanatory variables. Neither work-related stress nor noise annoyance were significantly correlated to noise exposure index.~~,~~ ~~t~~There was however a weak yet significant correlation between stress and noise annoyance (r=0.249, *p*=0.008). The point estimates for noise exposure was comparable with or without adjustment for smoking and leisure-time noise exposure in model 2, and neither one of the adjustment variables were themselves significant. Hence, they were not

included in the subsequent multivariable models. All reported models had an acceptable goodness of fit.

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

Due to the cumulative property of the noise index, the index was assumed to be correlated to age, which was also confirmed in the analysis ($r=0.706$, $p<0.001$) with $R^2=0.498$, as shown in figure 2 B. Multi-collinearity issues therefore precluded the assessment of both variables in one regression model. Notably and importantly though, age was not significantly associated to any of the hearing-related symptoms when assessed as a single explanatory variable in separate regression models.

**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** | | | | |
| *Model 1* | Noise exposure index | 0.04 (0.02) | 1.04 (1.00 – 1.07) | **0.031** |
| *Model 3* | 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** |
| *Model 4* | 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** |
| *Model 5* | 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** | | | | |
| *Model 1* | Noise exposure index | 0.04 (0.02) | 1.04 (1.00 – 1.09) | **0.049** |
| *Model 3* | 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 |
| *Model 4* | 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

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

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

No significant associations between noise exposure and the other hearing related symptoms were detected in this study. This may be explained partly by the fact that hearing loss is developed over a long period of time, usually becoming apparent after the age of retirement, and that mild deterioration in hearing may not be easily detected via self-assessment. As the study was cross-sectional, the fact that hearing loss was most prevalent in the third noise exposure group lower prevalence in the highest exposure group may have influenced the analysis. This in turn is possibly due to a healthy worker effect as individuals with hearing loss may not be able to continue working in obstetrics care. Similarly but in the opposite direction, as difficulty perceiving speech was reported by many young individuals, whom to a larger extent was classified in the lowest noise index quartile, it may have influenced the analysis of the effect of occupational noise exposure such that no significant effect was seen. It is in any case alarming with such a high prevalence of difficulty perceiving speech. Compared to prevalence data from the Swedish National Board of Health and Welfare from 2000-2005, using a similar survey item as in this study,[26] our data indicate higher age and gender matched prevalence. Between the ages 25-64 years the prevalence in our sample ranged from 26-35%, while the prevalence in the same age range among women in the reference material was 5-15%. Sound sensitivity is less researched, but one previous study from Sweden reports prevalence in the general population of 8-9%.[27] No gender-specific prevalence was reported, making direct comparisons to our data somewhat problematic; yet our data indicate slightly higher prevalence. In addition to the significant association between occupational noise exposure and both tinnitus and sound induced auditory fatigue, our data also shows that having one or more hearing-related symptom is most common among those with highest cumulative noise exposure dose as seen in table 2. However, this variable was not significantly associated to noise exposure in the regression model, probably due to the variable difficulty perceiving speech having a large influence with the high prevalence in the

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

**Work-related stress and noise annoyance**

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

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

**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 induced auditory 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]

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

## CONCLUSION

This study presents new results regarding risk of noise-induced hearing-related symptoms among obstetrics personnel, which to the best of our knowledge has not been described before. The results show that obstetrics personnel are at times exposed to sound levels above regulated limits and that more than half of the participants report one or more hearing-related symptom. Furthermore, a statistically significant association was found between cumulative occupational noise exposure and the hearing-related symptom tinnitus and sound induced auditory fatigue. Noise annoyance was a common complaint and in addition to noise exposure also an important factor for sound induced auditory fatigue. 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.

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**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.

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**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**.**

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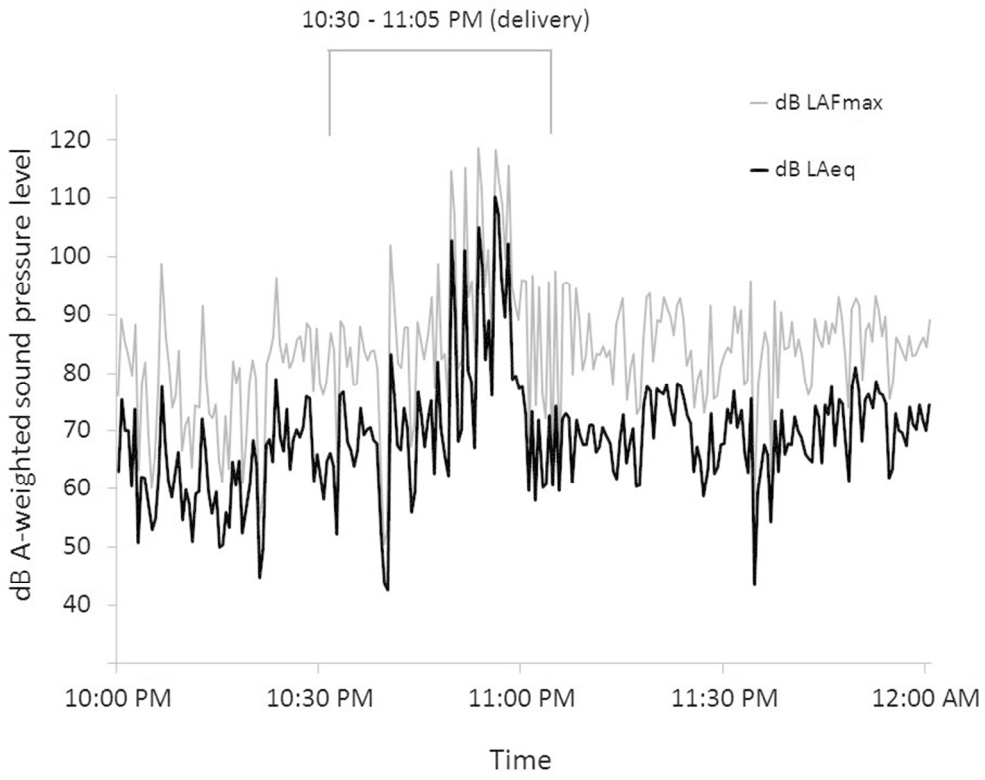
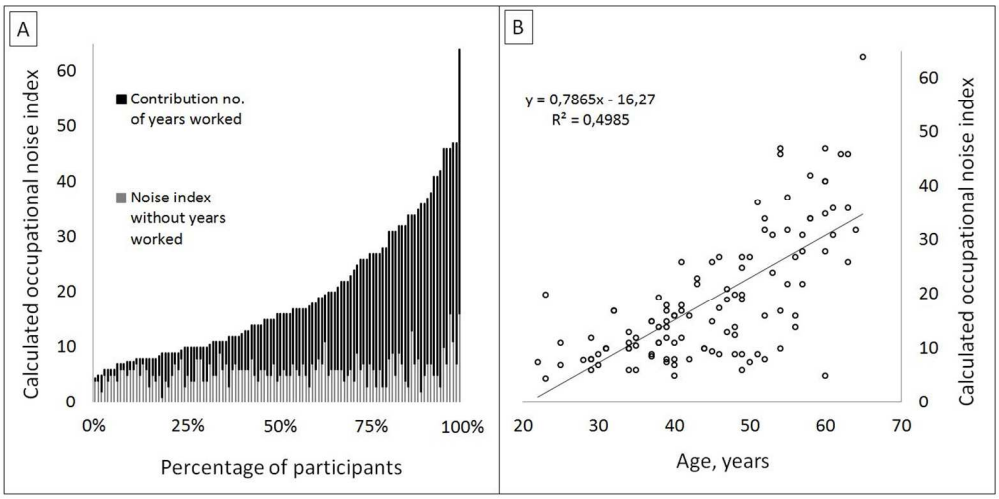



Figure 1. Two hour section of a time history graph from sound level measurement with dosimeter carried by a midwife during a sample night shift in the obstetrics ward. Equivalent sound level during the entire shift was 85 dB LAeq(approx. 9 hours) and 118.7 dB LAFmax was the highest recorded during the 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)

**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<br>1 point<br>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<br>25% of time<br>50% of time<br>75% of time<br>Always/almost always | 0 points<br>1 point<br>2 points<br>3 points<br>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<br>25% of time<br>50% of time<br>75% of time<br>Always/almost always | 0 points<br>1 point<br>2 points<br>3 points<br>4 points |
| Do you use hearing protective devices (such as ear-plugs) at your current workplace? | Never/almost never<br>Seldom<br>Often<br>Always/almost always | 3 points<br>2 points<br>1 point<br>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**<br>Do you have a hearing loss? /hearing disorder?<br>(Swe. "hörselnedsättning/hörselskada") | Yes<br>No<br>Don't know | Hearing loss was defined as reporting yes. |
| **Tinnitus, Sound sensitivity and Sound fatigue** [a]<br>Do you during or after work experience any of the following symptoms:<br>- Tinnitus?<br>- Sound sensitivity? (discomfort, pain from normal sounds)?<br>(Swe. "ljudkänslighet, obehag eller smärta av normala ljud")<br>- Sound fatigue? (Swe. "ljudtrötthet") | Never/rarely<br>A few times each month<br>Once or twice a week<br>Several times each week<br>Every day | Having either symptom was defined as reporting once a week or more often. |
| **Poor hearing**<br>How do you think your hearing is?<br>(Swe. "Hur tycker du att din hörsel är?") | Very good<br>Good<br>Normal<br>Bad<br>Very bad | Poor hearing was defined as reporting bad or very bad hearing. |
| **Difficulty perceiving speech**<br>Do you have trouble hearing what is said in an environment where several people are talking at the same time<br>(Swe. "Har du besvär att höra vad som sägs i en miljö där flera talar samtidigt?")<br>- At work?<br>- In leisure time? | Yes<br>No | Difficulty perceiving speech was defined as reporting yes to both work and leisure time. |
| **Explanatory variables** | **Response alternatives** | **Derived variables** |
| **Work-related stress**<br>How is your work typically?<br>- I experience high degree of stress.<br>- I feel unwell due to stress at work. | Never/seldom<br>Sometimes<br>Often<br>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**<br>Are you annoyed by sounds/noise at your work place? | Not at all<br>Some<br>Pretty much<br>Very<br>Extremely | Noise annoyance was defined as reporting if pretty much, very or extreme annoyance. |
| **Smoking**<br>Do you smoke? | Yes<br>Yes, but only occasionally<br>No, but I have smoked previously for ___ years<br>No | Ever smokers were defined as those reporting yes, yes occasionally or previously smoked. |
| **Leisure time noise exposure**<br>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<br>Yes, every day<br>Yes, a few times each week<br>Yes, once or twice each week<br>Yes, a few times each month<br>Yes, once or twice a month<br>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.

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[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.

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

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| | |

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

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## 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-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. 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 midwifes 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, midwifes report a high degree of work-related stress and burnout,[11] and according to a recent report burnout

syndrome have doubled among midwifes 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 interaction effects between noise exposure, noise annoyance and work-related stress. Therefore, the aim of this study was to assess the risk of noise-induced hearing-related symptoms among obstetrics personnel by measuring sound levels in the labour ward of a general obstetrics ward and by analysing the effect of and interaction between occupational noise exposure, noise annoyance and work-related stress on hearing-related symptoms among obstetrics personnel.

## METHODS

### Sound level measurements

Sound level measurements were carried out during 61 work shifts in the labour ward of a general obstetrics ward at the Sahlgrenska University Hospital in Gothenburg. Out of the 61 shifts 19 day shifts were measured between 7 a.m. and 3:30 p.m. (8.5 h), 12 evening shifts 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). The day and evening shifts were measured during separate weeks so as not to overlap. A convenient sample of ten employees per shift each wore a personal dosimeter (Larson Davis 705+) with the microphone attached to the right shoulder and kept a written log documenting work activities during the measured shift. A total of 610 separate measurements were collected, as 10 individuals each wore a dosimeter during the 61 shifts measured. However, due to technical errors a few faulty measurements were excluded leaving 529 (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 begun. The equivalent levels reported refer to the full-shift length and will hence vary between 7.25 – 10 hours, hereinafter denoted as $LAeq_{(7\text{-}10h)}$. 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

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

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

## RESULTS

### Sound levels in the labour ward

Overall, the dosimeter measurements from the labour ward showed moderately high sound levels, as presented in table 1. The levels reached or exceeded both the action and limit levels. The lower action level 80 dB LAeq was exceeded in 30 different dosimeter measurements during 28 different work shifts, which corresponds to 46% of all measured shifts or 6% of all dosimeter measurements. The upper exposure action level and exposure limit 85 dB LAeq was reached or exceeded in three measurements from three different shifts, corresponding to 5% of all measured shifts or 0.6% of all measurements. The limit 115 dB LAFmax was reached or exceeded at 50 different occasions. However, of these 9 separate events could not be verified by the written logs and were therefore excluded. The remaining 41 events occurred in 17 different shifts corresponding to 28% of all measured shifts or 8% of all dosimeter measurements. There were no statistical differences in arithmetic mean equivalent nor in maximum levels when comparing measurements from different work-shifts nor measurements from dosimeters worn by midwifes compared to assistant nurses. Due to incomplete written logs however, we were unable to categorise a third of the measurements into professional group. A segment sample from a dosimeter measurement is shown in figure 1, where high maximum levels (119 dB LAFmax) was recorded during a delivery, which according to the written log occurred between 10:30 and 11:05 pm. The equivalent level in this particular measurement was 84 dB $LAeq_{(10h)}$ for the measured shift length. As exposure limits should be

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, $LAeq_{(7\text{-}10h)}$ 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 $LAeq_{(7\text{-}10h)}$ | 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) | | | |
| Midwifes | 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.

Associations between occupational noise exposure dose (continuous noise index), work-related stress, noise annoyance and hearing-related symptoms were evaluated in manual sequential binary logistic regression models, results of which are presented in table 3. The calculated noise index ranged from 4.5 to 64 in the study sample. The proportional contribution of years worked in obstetrics care to the index, as a proxy for cumulative exposure, is shown in figure 2 A. The percentage of participants over the range of noise index also conveys the skewness in the distribution of the index, e.g. less than 25% of the participants have noise index values in the upper half of the range.

**FIGURE 2**

Occupational noise exposure as a single explanatory variable was significantly associated to tinnitus and sound induced auditory fatigue, but not to the other hearing-related symptoms. Work-related stress and noise annoyance were both significantly associated to sound induced auditory fatigue in separate models, but not to tinnitus. For sound induced auditory fatigue, including all three significant explanatory variables (noise, stress and annoyance) in model 5 resulted in marginal changes in point estimates for noise exposure and noise annoyance. It did however affect the estimates for work-related stress, which just missed statistical significance (p=0.053). No significant statistical interactions were found between explanatory variables. Neither work-related stress nor noise annoyance were significantly correlated to noise exposure index. There was however a weak yet significant correlation between stress and noise annoyance (r=0.249, *p*=0.008). The point estimates for noise exposure was comparable with or without adjustment for smoking and leisure-time noise exposure in model 2, and neither one of the adjustment variables were themselves significant. Hence, they were not

included in the subsequent multivariable models. All reported models had an acceptable goodness of fit.

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

Due to the cumulative property of the noise index, the index was assumed to be correlated to age, which was also confirmed in the analysis ($r=0.706$, $p<0.001$) with $R^2=0.498$, as shown in figure 2 B. Multi-collinearity issues therefore precluded the assessment of both variables in one regression model. Notably and importantly though, age was not significantly associated to any of the hearing-related symptoms when assessed as a single explanatory variable in separate regression models.

**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** | | | | |
| *Model 1* | Noise exposure index | 0.04 (0.02) | 1.04 (1.00 – 1.07) | **0.031** |
| *Model 3* | 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** |
| *Model 4* | 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** |
| *Model 5* | 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** | | | | |
| *Model 1* | Noise exposure index | 0.04 (0.02) | 1.04 (1.00 – 1.09) | **0.049** |
| *Model 3* | 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 |
| *Model 4* | 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

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

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

No significant associations between noise exposure and the other hearing related symptoms were detected in this study. This may be explained partly by the fact that hearing loss is developed over a long period of time, usually becoming apparent after the age of retirement, and that mild deterioration in hearing may not be easily detected via self-assessment. As the study was cross-sectional, the fact that hearing loss was most prevalent in the third noise exposure group lower prevalence in the highest exposure group may have influenced the analysis. This in turn is possibly due to a healthy worker effect as individuals with hearing loss may not be able to continue working in obstetrics care. Similarly but in the opposite direction, as difficulty perceiving speech was reported by many young individuals, whom to a larger extent was classified in the lowest noise index quartile, it may have influenced the analysis of the effect of occupational noise exposure such that no significant effect was seen. It is in any case alarming with such a high prevalence of difficulty perceiving speech. Compared to prevalence data from the Swedish National Board of Health and Welfare from 2000-2005, using a similar survey item as in this study,[26] our data indicate higher age and gender matched prevalence. Between the ages 25-64 years the prevalence in our sample ranged from 26-35%, while the prevalence in the same age range among women in the reference material was 5-15%. Sound sensitivity is less researched, but one previous study from Sweden reports prevalence in the general population of 8-9%.[27] No gender-specific prevalence was reported, making direct comparisons to our data somewhat problematic; yet our data indicate slightly higher prevalence. In addition to the significant association between occupational noise exposure and both tinnitus and sound induced auditory fatigue, our data also shows that having one or more hearing-related symptom is most common among those with highest cumulative noise exposure dose as seen in table 2. However, this variable was not significantly associated to noise exposure in the regression model, probably due to the variable difficulty perceiving speech having a large influence with the high prevalence in the

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

**Work-related stress and noise annoyance**

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

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

**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 induced auditory 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]

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

## CONCLUSION

This study presents new results regarding risk of noise-induced hearing-related symptoms among obstetrics personnel, which to the best of our knowledge has not been described before. The results show that obstetrics personnel are at times exposed to sound levels above regulated limits and that more than half of the participants report one or more hearing-related symptom. Furthermore, a statistically significant association was found between cumulative occupational noise exposure and the hearing-related symptom tinnitus and sound induced auditory fatigue. Noise annoyance was a common complaint and in addition to noise exposure also an important factor for sound induced auditory fatigue. 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.

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**Footnotes**

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

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## 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-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. 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 midwifes 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, midwifes report a high degree of work-related stress and burnout,[11] and according to a recent report burnout

syndrome have doubled among midwifes 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 interaction effects between noise exposure, noise annoyance and work-related stress. Therefore, the aim of this study was to assess the risk of noise-induced hearing-related symptoms among obstetrics personnel by measuring sound levels in the labour ward of a general obstetrics ward and by analysing the effect of and interaction between occupational noise exposure, noise annoyance and work-related stress on hearing-related symptoms among obstetrics personnel.

## METHODS

### Sound level measurements

Sound level measurements were carried out during 61 work shifts in the labour ward of a general obstetrics ward at the Sahlgrenska University Hospital in Gothenburg. Out of the 61 shifts 19 day shifts were measured between 7 a.m. and 3:30 p.m. (8.5 h), 12 evening shifts 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). The day and evening shifts were measured during separate weeks so as not to overlap. A convenient sample of ten employees per shift each wore a personal dosimeter (Larson Davis 705+) with the microphone attached to the right shoulder and kept a written log documenting work activities during the measured shift. A total of 610 separate measurements were collected, as 10 individuals each wore a dosimeter during the 61 shifts measured. However, due to technical errors a few faulty measurements were excluded leaving 529 (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 begun. The equivalent levels reported refer to the full-shift length and will hence vary between 7.25 – 10 hours, hereinafter denoted as $LAeq_{(7\text{-}10h)}$. 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

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

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

## RESULTS

### Sound levels in the labour ward

Overall, the dosimeter measurements from the labour ward showed moderately high sound levels, as presented in table 1. The levels reached or exceeded both the action and limit levels. The lower action level 80 dB LAeq was exceeded in 30 different dosimeter measurements during 28 different work shifts, which corresponds to 46% of all measured shifts or 6% of all dosimeter measurements. The upper exposure action level and exposure limit 85 dB LAeq was reached or exceeded in three measurements from three different shifts, corresponding to 5% of all measured shifts or 0.6% of all measurements. The limit 115 dB LAFmax was reached or exceeded at 50 different occasions. However, of these 9 separate events could not be verified by the written logs and were therefore excluded. The remaining 41 events occurred in 17 different shifts corresponding to 28% of all measured shifts or 8% of all dosimeter measurements. There were no statistical differences in arithmetic mean equivalent nor in maximum levels when comparing measurements from different work-shifts nor measurements from dosimeters worn by midwifes compared to assistant nurses. Due to incomplete written logs however, we were unable to categorise a third of the measurements into professional group. A segment sample from a dosimeter measurement is shown in figure 1, where high maximum levels (119 dB LAFmax) was recorded during a delivery, which according to the written log occurred between 10:30 and 11:05 pm. The equivalent level in this particular measurement was 84 dB $LAeq_{(10h)}$ for the measured shift length. As exposure limits should be

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, $LAeq_{(7\text{-}10h)}$ 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 $LAeq_{(7\text{-}10h)}$ | 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) | | | |
| Midwifes | 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.

Associations between occupational noise exposure dose (continuous noise index), work-related stress, noise annoyance and hearing-related symptoms were evaluated in manual sequential binary logistic regression models, results of which are presented in table 3. The calculated noise index ranged from 4.5 to 64 in the study sample. The proportional contribution of years worked in obstetrics care to the index, as a proxy for cumulative exposure, is shown in figure 2 A. The percentage of participants over the range of noise index also conveys the skewness in the distribution of the index, e.g. less than 25% of the participants have noise index values in the upper half of the range.

**FIGURE 2**

Occupational noise exposure as a single explanatory variable was significantly associated to tinnitus and sound induced auditory fatigue, but not to the other hearing-related symptoms. Work-related stress and noise annoyance were both significantly associated to sound induced auditory fatigue in separate models, but not to tinnitus. For sound induced auditory fatigue, including all three significant explanatory variables (noise, stress and annoyance) in model 5 resulted in marginal changes in point estimates for noise exposure and noise annoyance. It did however affect the estimates for work-related stress, which just missed statistical significance (p=0.053). No significant statistical interactions were found between explanatory variables. Neither work-related stress nor noise annoyance were significantly correlated to noise exposure index. There was however a weak yet significant correlation between stress and noise annoyance (r=0.249, *p*=0.008). The point estimates for noise exposure was comparable with or without adjustment for smoking and leisure-time noise exposure in model 2, and neither one of the adjustment variables were themselves significant. Hence, they were not

included in the subsequent multivariable models. All reported models had an acceptable goodness of fit.

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

Due to the cumulative property of the noise index, the index was assumed to be correlated to age, which was also confirmed in the analysis ($r=0.706$, $p<0.001$) with $R^2=0.498$, as shown in figure 2 B. Multi-collinearity issues therefore precluded the assessment of both variables in one regression model. Notably and importantly though, age was not significantly associated to any of the hearing-related symptoms when assessed as a single explanatory variable in separate regression models.

**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** | | | | |
| *Model 1* | Noise exposure index | 0.04 (0.02) | 1.04 (1.00 – 1.07) | **0.031** |
| *Model 3* | 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** |
| *Model 4* | 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** |
| *Model 5* | 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** | | | | |
| *Model 1* | Noise exposure index | 0.04 (0.02) | 1.04 (1.00 – 1.09) | **0.049** |
| *Model 3* | 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 |
| *Model 4* | 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

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

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

No significant associations between noise exposure and the other hearing related symptoms were detected in this study. This may be explained partly by the fact that hearing loss is developed over a long period of time, usually becoming apparent after the age of retirement, and that mild deterioration in hearing may not be easily detected via self-assessment. As the study was cross-sectional, the fact that hearing loss was most prevalent in the third noise exposure group lower prevalence in the highest exposure group may have influenced the analysis. This in turn is possibly due to a healthy worker effect as individuals with hearing loss may not be able to continue working in obstetrics care. Similarly but in the opposite direction, as difficulty perceiving speech was reported by many young individuals, whom to a larger extent was classified in the lowest noise index quartile, it may have influenced the analysis of the effect of occupational noise exposure such that no significant effect was seen. It is in any case alarming with such a high prevalence of difficulty perceiving speech. Compared to prevalence data from the Swedish National Board of Health and Welfare from 2000-2005, using a similar survey item as in this study,[26] our data indicate higher age and gender matched prevalence. Between the ages 25-64 years the prevalence in our sample ranged from 26-35%, while the prevalence in the same age range among women in the reference material was 5-15%. Sound sensitivity is less researched, but one previous study from Sweden reports prevalence in the general population of 8-9%.[27] No gender-specific prevalence was reported, making direct comparisons to our data somewhat problematic; yet our data indicate slightly higher prevalence. In addition to the significant association between occupational noise exposure and both tinnitus and sound induced auditory fatigue, our data also shows that having one or more hearing-related symptom is most common among those with highest cumulative noise exposure dose as seen in table 2. However, this variable was not significantly associated to noise exposure in the regression model, probably due to the variable difficulty perceiving speech having a large influence with the high prevalence in the

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

**Work-related stress and noise annoyance**

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

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

**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 induced auditory 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]

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

## CONCLUSION

This study presents new results regarding risk of noise-induced hearing-related symptoms among obstetrics personnel, which to the best of our knowledge has not been described before. The results show that obstetrics personnel are at times exposed to sound levels above regulated limits and that more than half of the participants report one or more hearing-related symptom. Furthermore, a statistically significant association was found between cumulative occupational noise exposure and the hearing-related symptom tinnitus and sound induced auditory fatigue. Noise annoyance was a common complaint and in addition to noise exposure also an important factor for sound induced auditory fatigue. 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.

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**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.

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**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**.**

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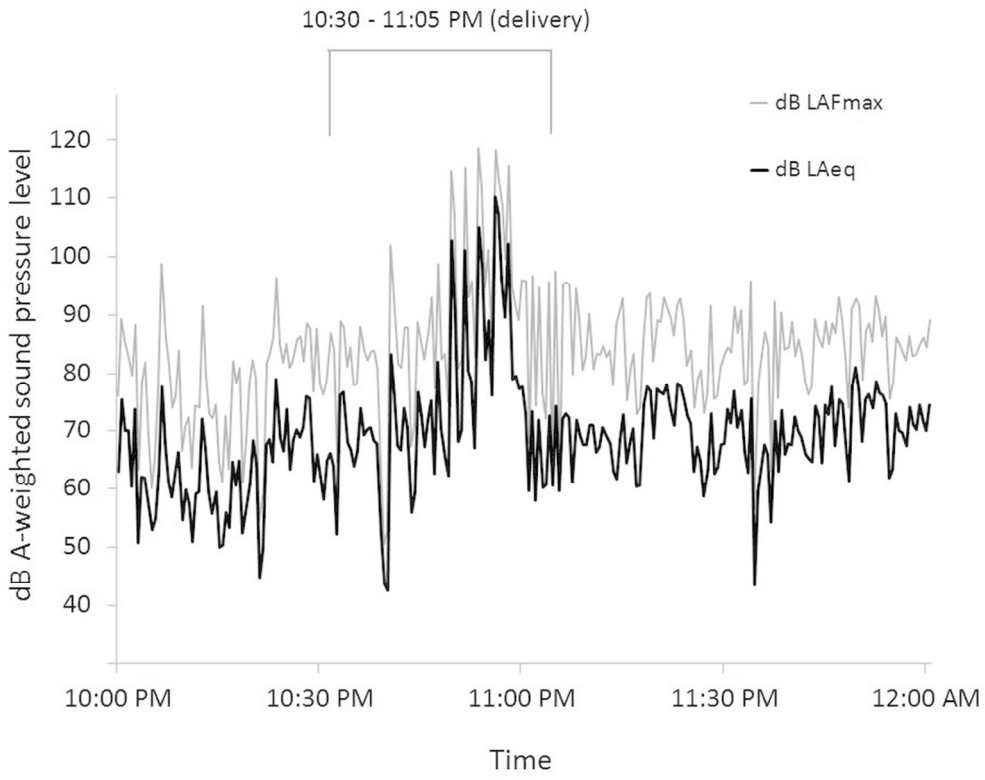


Figure 1. Two hour section of a time history graph from sound level measurement with dosimeter carried by a midwife during a sample night shift in the obstetrics ward. Equivalent sound level during the entire shift was 85 dB LAeq(approx. 9 hours) and 118.7 dB LAFmax was the highest recorded during the 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)

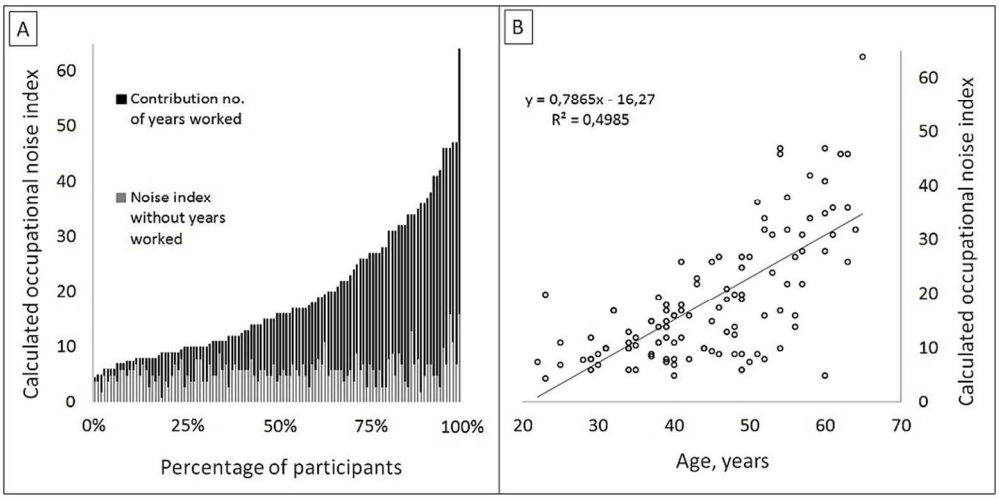


Figure 2. Calculated occupational noise index for obstetrics personnel. Figure 2 A to the left, shows the contribution of the variable number of years worked in obstetrics (in black) to the noise index for each participant, each bar representing one participant. The light grey bars represent the index 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)

**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<br>1 point<br>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<br>25% of time<br>50% of time<br>75% of time<br>Always/almost always | 0 points<br>1 point<br>2 points<br>3 points<br>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<br>25% of time<br>50% of time<br>75% of time<br>Always/almost always | 0 points<br>1 point<br>2 points<br>3 points<br>4 points |
| Do you use hearing protective devices (such as ear-plugs) at your current workplace? | Never/almost never<br>Seldom<br>Often<br>Always/almost always | 3 points<br>2 points<br>1 point<br>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**<br>Do you have a hearing loss? /hearing disorder?<br>(Swe. "hörselnedsättning/hörselskada") | Yes<br>No<br>Don't know | Hearing loss was defined as reporting yes. |
| **Tinnitus, Sound sensitivity and Sound fatigue** [a]<br>Do you during or after work experience any of the following symptoms:<br>- Tinnitus?<br>- Sound sensitivity? (discomfort, pain from normal sounds)?<br>(Swe. "ljudkänslighet, obehag eller smärta av normala ljud")<br>- Sound fatigue? (Swe. "ljudtrötthet") | Never/rarely<br>A few times each month<br>Once or twice a week<br>Several times each week<br>Every day | Having either symptom was defined as reporting once a week or more often. |
| **Poor hearing**<br>How do you think your hearing is?<br>(Swe. "Hur tycker du att din hörsel är?") | Very good<br>Good<br>Normal<br>Bad<br>Very bad | Poor hearing was defined as reporting bad or very bad hearing. |
| **Difficulty perceiving speech**<br>Do you have trouble hearing what is said in an environment where several people are talking at the same time<br>(Swe. "Har du besvär att höra vad som sägs i en miljö där flera talar samtidigt?")<br>- At work?<br>- In leisure time? | Yes<br>No | Difficulty perceiving speech was defined as reporting yes to both work and leisure time. |
| **Explanatory variables** | **Response alternatives** | **Derived variables** |
| **Work-related stress**<br>How is your work typically?<br>- I experience high degree of stress.<br>- I feel unwell due to stress at work. | Never/seldom<br>Sometimes<br>Often<br>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**<br>Are you annoyed by sounds/noise at your work place? | Not at all<br>Some<br>Pretty much<br>Very<br>Extremely | Noise annoyance was defined as reporting if pretty much, very or extreme annoyance. |
| **Smoking**<br>Do you smoke? | Yes<br>Yes, but only occasionally<br>No, but I have smoked previously for ___ years<br>No | Ever smokers were defined as those reporting yes, yes occasionally or previously smoked. |
| **Leisure time noise exposure**<br>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<br>Yes, every day<br>Yes, a few times each week<br>Yes, once or twice each week<br>Yes, a few times each month<br>Yes, once or twice a month<br>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.