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A quantitative general population job exposure matrix for occupational noise exposure

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Abstract

Occupational noise exposure is a known risk factor for hearing loss and also adverse cardiovascular effects have been suggested. A job exposure matrix (JEM) would enable studies of noise and health on a large scale. The objective of this study was to create a quantitative JEM for occupational noise exposure assessment of the general working population.

Between 2001-03 and 2009-10, we recruited workers from companies within the 10 industries with the highest reporting of noise-induced hearing loss according to the Danish Working Environment Authority. We obtained 1343 personal occupational noise dosimeter measurements among 1140 workers representing 100 different jobs according to the Danish version of the International Standard Classification of Occupations 1988 (DISCO 88). Four experts used 35 of these jobs as benchmarks and rated noise levels for the remaining 337 jobs within DISCO 88. To estimate noise levels for all 372 jobs, we included expert ratings together with sex, age, occupational class and calendar year as fixed effects,

while job and worker were included as random effects in a linear mixed regression model. The fixed effects explained 40% of the total variance: 72% of the between-jobs variance, -6% of the between-workers variance and 4% of the within-worker variance. Modelled noise levels showed a monotonic increase with increasing expert score and a 20dB difference between the highest and lowest exposed jobs. Based on the JEM estimates, metal wheel-grinders were among the highest and finance and sales professionals among the lowest exposed. This JEM of occupational noise exposure can be used to prioritise preventive efforts of occupational noise exposure and to provide quantitative estimates of contemporary exposure levels in epidemiological studies of health effects potentially associated with noise exposure.

Search terms

Job exposure matrix for occupational noise exposure, Occupational noise exposure, JEM, Epidemiological studies, Job

Bottom 5 keywords

Noise exposure*, job exposure matrix (JEM)*, occupational*, epidemiology*, mixed effects model*

Introduction

Occupational noise is a known risk factor for hearing loss (Prince, 2002) and other health effects (Selander et al., 2016; Skogstad et al., 2016).

In Europe, 30% of the work force reported that they were exposed to noise so loud that they had to raise their voice and this proportion was unchanged from 2000-10 (Eurofound, 2016). However, in Europe no longitudinal surveillance data are available for occupational noise levels. In order to prioritise preventive efforts of health consequences of occupational noise exposure, there is a need for population-based overviews of the distribution of the relevant exposures across occupations. Such an overview can be provided by a quantitative general population job exposure matrix (JEM).

A JEM also enables estimation of job and calendar year specific exposure levels of occupational noise in community-based epidemiological studies investigating exposure-response relations. Recently, general population JEMs have been developed using quantitative exposure information from a limited number of occupations in combination with expert rating (Friesen et al., 2012; Peters et al., 2011; Vested et al., 2019; Wild et al., 2002). This approach allows calibration of the experts' ratings as well as assignment of exposure level to occupations without measurements.

We describe a quantitative JEM for occupational noise exposure assessment of the general working population combining personal noise exposure measurements with expert ratings.

Methods

Data collection and selection

Companies

During 2001-03 and 2009-10, we recruited workers in companies from the 10 industries reported having the highest frequency of noise-induced hearing loss in Denmark according to the Danish Working Environment Authority: manufacturers of food, wood products, non-metallic mineral products, basic metals, fabricated metal, machinery, motor vehicles, furniture, publishing and printing, and construction (The Danish Working Environment Authority, 2019). For optimizing the range in exposure levels and the between group variability, we also recruited workers of financial services. Finally, children's day care facilities were included as recent measurements in Denmark had indicated that workers of

these units were exposed to high noise levels. Overall, 175 companies were enrolled in the two measurement campaigns, both performed as part of epidemiological studies previously described (Kock et al., 2004; Rubak et al., 2008; Stockholm et al., 2014).

Briefly, Statistics Denmark, a governmental organisation (Thygesen et al., 2011) in 2001 provided a list of 840 eligible companies in 2001, with ≥ 15 workers within the selected industries. During 2001 -2003, we randomly enlisted five companies with 15-49 workers and five companies with ≥ 50 workers from each industry. From each company a maximum of 10 workers were selected by foremen and managers. In 2009-10 we asked these companies to participate again in a new measurement campaign and in case they declined or were closed, we invited other companies within the same industries in order to approach the initial number of companies.

Workers

Furthermore, we re-invited identifiable 2001-03 participants in the subsequent 2009-10 campaign. In total, the study population then included 1140 workers, 203 participated twice contributing 30% of all noise measurements (Table 1).

All workers filled in a questionnaire providing information on job according to DISCO 88, the Danish version of the International Classification of Occupations (ISCO 88) containing 372 occupations on a 4-digit level (DISCO, 2011) , and use of hearing protection devices. During measurement days, the workers also provided information on work schedules. Furthermore, a subgroup of 334 workers filled in a log-book with detailed information on usage of hearing protection devices during the shift. Age and sex were extracted from the civil registration number (Pedersen, 2011).

The study protocol was approved by the local ethics committee (M-20080239) and the Danish Data Protection Agency (2009-41-3072) and participants gave written, informed consent.

Noise exposure measurements

Noise measurements started throughout the day, and not necessarily when work started, and ended about 24 hours later. Only measurements during work were included and not necessarily the complete working time. Sampling time was defined by the research team. We measured noise level as A-weighted equivalent sound level means (L_{EQ}) by personal dosimeters (Brüel & Kjær, model 4443 and 4445) recording every 5 seconds for 24 hours

including one work shift. In the first measurement campaign in 2001-2003, dosimeters were set to a 50-120 dBA range. In the second campaign, dosimeters were set to a 70-140 dBA range. Therefore, all measurements were standardized to a common 70-120 dBA range. For any noise recording falling below the limit of detection, a value of 50 dBA replaced the non-detected level (the $LOD/\sqrt{2}$ for each non-detectable value, where LOD is the limit of detection) (Burns et al., 2016; Hornung and Reed, 1990). All measurements were synchronized with questionnaire information, so each 5 second measurement relative to work, off-work or night time could be identified. All individual noise recordings during work were transformed from dBA to intensity, and an arithmetic mean was computed before transforming back to dBA yielding personal occupational noise intensity levels, hereafter referred to as noise levels according to the following formula: $10 \times \log [\sum (10^{dB(A)/10} \times T)]$. Measurements were obtained on ordinary working days all year round to account for potential seasonal variation in exposure.

Expert assessment

During 2016, four specialists in occupational medicine with at least 10 years of experience evaluating occupational exposures within industries and jobs rated noise levels for jobs included in DISCO 88. In order to qualify ratings, we a priori randomly selected approximately half ($n=35$) of the jobs with ≥ 5 noise measurements (mean of 21 measurements per job) in our database to benchmark their assessments. For these jobs, the experts were informed on mean, median and range of dBA values measured, and the number of underlying measurements. The experts independently rated the expected average exposure intensity for a worker during a standard working day of 7.5 hour for each of the remaining 337 jobs (22 jobs with estimated noise exposure level blinded to the experts and 315 jobs with no or <5 measurements ($n=43$) and classified each job as low level (<80 dBA), medium level (80-84 dBA) or high level (≥ 85 dBA) exposed. The experts discussed discrepancies in ratings; based on relevant literature and sound arguments they reached consensus for all jobs. Before discussing discrepancies and reaching final consensus, 3 or all 4 experts agreed on the ratings in 85% of the cases, with a kappa of 0.77 for the overall agreements between the experts.

Statistical methods

Noise exposure grouping strategy

In order to examine variance components and predictors of noise exposure intensity, we fitted linear mixed effect models in STATA (mixed-command) using restricted maximum likelihood estimation, with mean noise exposure level as the dependent variable and job and worker as random effects including all measurements. We checked the adequacy of the models confirming the normal distribution of the residuals by QQ-plots and linearity/homogeneity by scatterplots of the residuals versus fitted values.

Statistical model

The model structure was:

$$Y = \beta_0 + \beta_{\text{sex}} + \beta_{\text{age}} + \beta (I_{\text{benchmark}} \times I_{\text{rating}}) + \beta_{\text{occupational class}} + \beta (\text{Calendar year} \times I \beta_{\text{occupational class}}) + b_{\text{job}} + b_{\text{worker}} + \varepsilon$$

The model terms were:

Y: noise level in dB

β_0 : model intercept

β_{sex} : categorical variable for sex (woman used as reference)

β_{age} : continuous variable for age (40-year-old as reference)

$\beta (I_{\text{benchmark}} \times I_{\text{rating}})$: categorical interaction term between benchmark (yes, no) and expert rating (low, medium, high exposed)

$\beta_{\text{occupational class}}$: categorical variable for occupational class (blue-, white-collar used as reference)

$\beta (\text{calendar year} \times I \beta_{\text{occupational class}})$: continuous interaction term between calendar year (continuous with 2010 as a reference) and occupational class (blue-, white-collar)

b_{job} : random effect term for job

b_{worker} : random effect term for worker

ε : residual error (within worker)

Information on sampling duration was also assessed but not included in the model because of statistical insignificance (p-value >0.05). P-values were not corrected for model selection or multiple testing.

The random effect terms b_{job} and b_{worker} were assumed statistically independent and normally distributed with means 0 and two different variance components representing the between job variance and the between worker (within job) variance. We obtained best linear unbiased predictions (BLUPs) of the coefficients for each of the jobs with noise measurements (n=100). The BLUPs shrink the estimates toward the overall mean exposure of the expert

score when there are few measurements and pulls the estimates toward the individual measurements when either there are more measurements available or the exposure variability is low.

We aimed at assessing noise exposure levels for each of the 372 jobs described by the DISCO 88. Jobs without measurements were assigned the weighted mean noise exposure level derived from the model for the corresponding category of the expert ratings. For jobs with exposure measurements available, the job specific prediction from the statistical model (BLUP) was added to the noise exposure estimate. Thus, an exposure level for all 372 jobs, sex, age, benchmark and year were estimated.

All analyses were performed using STATA 14.1 (StataCorp LP, College Station, TX, USA).

Results

Noise levels varied between 56 and 107 dBA with an arithmetic mean of 81.7 dBA and a SD of 6.6. Noise level increased through the expert ratings and was higher among blue-collar jobs. Mean noise exposure decreased with increasing calendar year and age and was lower among women than men (Table 2).

Table 3 presents variance components for noise level from the mixed effects model. More than 50% (25.4/46.6) of the total variance was between jobs as can be seen from the null model that only included random effects. By including sex and age as fixed effects, we observed a 6% reduction of the variance between jobs. When we added the interaction term between benchmark and expert rating as fixed effect this value increased to 69%, reaching finally a 71% reduction when we added occupational class and the interaction term between occupational class and calendar year as fixed effects in the final model.

The fixed effects model parameters are presented in Table 4. Noise level was higher among men and blue-collar workers. Noise level decreased with increasing age and showed an 0.1 dBA annual decline by increasing calendar year among blue-collar workers while no such trend was apparent for white-collar workers (test for interaction between occupational class and calendar year, $p=0.012$). While medium exposed benchmark jobs were 1 dBA higher than the medium exposed expert rated jobs (5.99 vs. 4.88 dBA), the corresponding difference was 3 dBA for the high exposed jobs (9.48 vs. 6.41 dBA) (test for interaction between benchmark and expert rated jobs, $p=0.025$).

Table 5 shows model-based mean noise levels (dBA) for the ten highest and the ten lowest exposed jobs as estimated for 40-year old male workers in 2010. Metal wheel-grinders, polishers and tool sharpeners presented the highest level of 88.9 dBA while finance and sales associate professionals showed the lowest noise level of 70.2 dBA.

Among low, medium and high exposed workers, 12%, 24%, and 29% used hearing protection according to log-book information (data not shown).

Supplementary table A presents the number of all 372 jobs as defined at the 4-digit level in DISCO 88 and the number of jobs represented in the dataset for the nine major job categories.

In total, 27% of all jobs were represented in our sample. We prioritized sampling of jobs with expected high noise exposure levels. A total of 46% of all jobs in the major job category 8 "Plant and machine operators and assemblers" were represented in the data. We also included low and medium exposed jobs. The noise JEM will be made freely available at the DOC-X homepage (<http://doc-x.dk/>).

Discussion

We created a general population quantitative JEM with estimates of personal occupational noise intensity level specific for sex, age and calendar year. The model calibrated the expert ratings to a scale (dBA). This enables assessment of job and calendar year specific exposure levels of occupational noise for all jobs represented in Denmark including those with missing quantitative information. The JEM will be applicable to epidemiological studies addressing exposure-response relations between occupational noise exposure and cardiovascular and other health effects hypothesized to be associated with noise exposure in and outside work.

Two JEMs of occupational noise exposure for the general population have previously been described. Sjöström et al. developed a Swedish expert based semi-quantitative 3-level JEM for 321 jobs within the Nordic Occupational Classification system based on ISCO 58. The expert assessment was informed on 569 measurements from 129 jobs. Twenty five percent of the measurements were personal and included both short-time and full-shift measurements from 1970-2004, with most measurements collected during 1995-1999 (Sjöström et al., 2013).

Recently, Roberts et al. reported a quantitative JEM including 753,702 measurements among 443 broad level standard occupational classification groups in the US (Roberts et al., 2018). The measurements were mainly obtained from the US government occupational exposure

databases (85%), private industry (14%), and published literature (1%) and made according to the Occupational Safety and Health Administration's (OSHA) permissible exposure limit of 90 dBA criterion level and threshold, and 5 a dB time-intensity exchange rate. They used imputation statistics for jobs with no available measurements (Roberts et al., 2018) and had previously conducted a meta-analysis to ensure high heterogeneity across different job titles (Cheng et al., 2018). In contrast to this extensive dataset and to the Swedish JEM, we used personal noise measurements collected in accordance with a research protocol, thereby circumventing some problems with hot spot measurements or worst case sampling (Cherrie, 2003).

We observed that women were exposed to less noise than men within the same jobs and we were thus able to capture some of the exposure variation within jobs. Lacking ability to go beyond the job is a major limitation of most JEMs (Greenland et al., 2016; Kauppinen et al., 1992). There have previously been indications of sex differences in occupational exposure levels within the same jobs for assembly workers and janitors (Locke et al., 2014). Some argue that these differences could either be due to differences in either tasks or reporting (Eng et al., 2011; Lacourt et al., 2018), however, this might not always be the case (Heilskov-Hansen et al., 2014). It could be argued that the noise level difference observed is due to sex differences between jobs rather than within jobs, however in 52% of all jobs both men and women are represented. And for up to 62% of blue-collar jobs, measurements on both sexes were available (data not shown).

Interestingly, we also found a decrease of noise exposure by increasing age, which could reflect changes to less exposed tasks over working years within the same job (Cassidy, 2017).

To our knowledge, only few previous JEMs have combined expert ratings with measurements in a statistical model framework (Friesen et al., 2012; Peters et al., 2011; Vested et al., 2019). Applied in epidemiological studies, the use of general population JEMs have recently depicted the shape of the exposure response relation between low level asbestos and silica exposure and lung cancer in a population-based case control study (De Matteis et al., 2012; Olsson et al., 2017).

More than 50% of the total variance of our dataset was between jobs and this is more than often seen in general population or industry specific exposure (Friesen et al., 2012; Kromhout et al., 1993; Peters et al., 2011). Since noise exposure is prevalent in many jobs, this is expected to reflect considerable variation in noise levels across jobs (Kock et al., 2004).

Measurements were performed in companies within industries with high reporting of noise induced hearing loss, which might overestimate noise exposure for the same jobs also represented in industries with lower noise levels and reporting of noise induced hearing loss.

Adding the fixed effects to the model explained up to 72% of the between job variance, mostly attributed to the expert ratings. This proportion was about 43% and 18% in Friesen's and Peters' studies of benzene and quartz exposure, respectively (Friesen et al., 2012; Peters et al., 2011). Hence, most of the variance could be attributed to jobs.

There is a general concern about lack in consistency for expert rating of occupational exposures, and the agreement between experts can vary from poor to very good depending on the exposure (Friesen et al., 2011; Teschke et al., 2002). In order to improve homogeneity between the different experts' ratings, we selected 35 benchmark jobs that permitted the experts to calibrate their estimates to a common scale. This resulted in a very good agreement between the experts ($\kappa=0.77$) before discussing discrepancies and reaching final consensus (Teschke et al., 2002). Noise exposure increased monotonically with increasing expert rating, however, we observed that experts were not able to capture the full exposure contrast in noise exposure level by overestimating low and underestimating high noise levels.

A comprehensive study estimated historical levels and long-term trends in occupational exposures, and found that most exposures declined between 4% and 14% per year, with a median value of 8% per year influenced by exposure factors including type of monitoring, historical changes in the threshold limit values (TLVs), and period of sampling (Symanski et al., 1998). Several other papers have documented the same decreasing trend in occupational noise exposure (Joy and Middendorf, 2007; Middendorf, 2004; Neitzel et al., 2014; Neitzel et al., 2011; Sayler et al., 2019). Roberts et al., also reported decreasing occupational noise exposures in 40.9% of the major classification groups (Roberts et al., 2018). Parallel results have also been seen by others. Likewise, we observed a linear 0.1 dB annual decline of noise level among blue-collar workers. This finding provides the possibility to evaluate exposure changes over time that could be an important source of exposure misclassification if left unaccounted. Our dataset only included noise recordings made between 2001 and 2010. Extrapolating noise levels several years back in time based on the linear trend observed within this rather brief period is however not warranted.

Our elaborated final model provides estimates of personal ambient noise exposure levels that may be significantly attenuated by hearing protection (Arlien-Søborg et al., 2016; Frederiksen et al., 2017; Stockholm et al., 2014). Based on questionnaire information, about 74% of highly exposed workers used hearing protective devices in our cohort. Neitzel et al. reported that workers exposed above 85dBA who reported always using hearing protective devices, actually only wore them one third of the time (Neitzel, Richard and Seixas, 2005), which was also the case in our population according to the log-book reporting. With information on the usage of hearing protection across jobs, it is possible to adjust exposure assessment. Mean noise level declined about 2 dBA when accounting for the use of hearing protection devices in a subsample of this population assuming a reduction of an average 10 dBA when wearing protection (Stockholm et al., 2014).

This study was performed in random samples of small and large companies within a range of selected industries with high reporting of noise induced hearing loss. Some of the reasons for declining participation (such as time lag or organizational changes) may not be related to noise levels, but there is a risk of bias if companies with high noise levels due to limited resources declined to participate, resulting in underestimation of actual noise levels. Still, it is plausible that companies that successfully have solved a noise problem would be less interested in participating. However, neither the participation rate at the industry nor the number of workers per industry was related to the measured noise levels. Workers were mainly selected by foremen and managers so as to have at least one employee from each work area, and this selection might have resulted in bias in an unpredictable direction. Nevertheless, we expect the measurements to be representative of these industries.

We did not have full-shift measurements for all workers, but sampling time was not defined by the participants but by the research team, and we regard the included measurements to be representative of full-shift levels. For that reason, it was not relevant to normalize levels to full shift duration.

We only had repeated measurements from a few workers. This could bias the results if only highly motivated workers chose to participate in both measurement campaigns. Still, about 50% of workers agreed to participate in the second campaign when re-invited. However, only 36% (18 % of all participants) had operational measurements, as the remaining were either performed during days off, or from unemployed or pensioned workers (Frederiksen et al., 2017).

Some non-differential misclassification could also affect the results as 1-minute resolution questionnaire information was synchronized with 5-second resolution noise level data.

It is problematic to compare these model-based noise levels with the two previous published JEMs on noise exposure. In Europe, we use a stricter noise exposure standard than in the US (85 dBA level and a 3 dB time-intensity exchange rate). Thus, US levels are expected to be higher (Roberts et al., 2018). Furthermore, Roberts et al. used 443 jobs according to the broad standard occupational classification (SOC) and Sjöström et al. used 321 jobs classified according to the Nordic Occupational Classification system (NYK) (Sjöström et al., 2013), which likewise makes comparability difficult. However, it is possible to compare few jobs across the three JEMs. In the Swedish JEM most measurements were collected during 1995-99, and based on this assumption butchers, for example, are exposed to a median of 90 dBA, a mean of 90.6 dBA according to Roberts et al. and a mean of 90.3 dBA for a 40-year old male in 1995 according to this JEM. The latter estimate reflected a 2.2 dBA increase from 2010 back to 1995. An increase of 3 dB was observed for the major SOC group in the same period in the American JEM. Likewise, workshop mechanics are exposed to a mean of 82.7 dB in 2010 (reference year), corresponding to 85.0 dBA in 1995 according to this JEM, a median of 88 dBA in the Swedish JEM and 83.7 dBA according to the American JEM.

Conclusion

The noise estimates of this JEM can guide future preventive efforts, not only focusing on specific jobs but also targeting age and sex. Additionally, this occupational noise exposure matrix can be used in epidemiological studies to investigate exposure-response relations between occupational noise exposure and health effects. This quantitative JEM is designed for epidemiological studies of the general population as noise exposure is ubiquitous and not restricted to specific industries. The JEM provides exposure levels by calendar year which is highly relevant for estimating duration of and cumulative contemporary noise exposure retrospectively, which may predict otological, cardiovascular and other non-contagious diseases. Furthermore, we showed the usefulness of applying benchmarks for the calibration of expert assessment.

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Table 1. Number of companies, jobs, workers and noise measurements by calendar year

	Companies		Jobs ^a		Workers		Measurements	
	N	%	N	%	N	%	N	%
2001-03	23	13	16	16	532	47	532	40
2001-03 & 2009-10	62	35	62	62	203	18	406	30
2009-10	90	52	22	22	405	35	405	30
Total	175	100	100	100	1 140	100	1 343	100

^aJobs within the DISCO 88, the Danish version of the International Standard Classification of Occupations (ISCO), revision 1988

Table 2. Number of samples and distribution of noise levels (dBA), overall and by level of selected variables

Variable	N ^a	% ^b	Mean	SD
Overall	1 343	100	81.7	6.6
Sex				
Women	323	24	78.3	7.1
Men	1 020	76	82.8	6.0
Age (tertiles)				
18-37 years	470	35	82.4	6.8
38-46 years	457	34	81.6	6.3
47-65 years	416	31	81.2	6.5
Rating				
Low exposed	250	19	74.2	7.3
Medium exposed	541	40	81.9	4.4
High exposed	552	41	85.0	5.0
Calendar year				
2001	52	4	84.4	5.4
2002	599	45	82.2	6.5
2003	84	6	82.6	6.7
2009	333	25	81.3	6.4
2010	275	20	80.5	6.7
Occupational class				
White-collar	299	22	75.6	7.5
Blue-collar	1 044	78	83.5	5.0

^aNumber of samples; ^bRelative percentages of samples by level

Table 3. Variance components for noise level (dBA) from the mixed effects model (n=1343)

Variance components	Null model ^a	Intermediate model 1 ^b		Intermediate model 2 ^c		Final model ^d	
	Variance (%)	Variance	% ^f	Variance	% ^f	Variance	% ^f
Between jobs	25.4 (54)	24.0	6	7.9	69	7.1	72
Between workers	5.0 (11)	5.0	0	5.1	-2	5.3	-6
Within worker	16.2 (35)	15.9	2	15.9	2	15.5	4
Total	46.6 (100)	44.9	4	28.9	38	27.9	40

^aNull model includes job and subject id as random effects; ^bIntermediate model 1 includes in addition to the previous random effects, sex and age as fixed effects; ^cIntermediate model 2 includes in addition to model 1, the interaction term between benchmark and expert rating as fixed effects; ^dFinal model includes in addition to model 2, occupational class and an interaction term between occupational class and calendar year as fixed effects; ^fPercentage reduction of variance explained by fixed effects when compared with null model

Table 4. Fixed effects model parameters for noise levels (dBA) (n=1343)

	β	SE	<i>P</i> -value
Intercept	72.88	1.22	<0.001
Sex			
Woman	Ref.		
Man	1.25	0.41	0.002
Occupational class			
White-collar	Ref.		
Blue-collar	2.77	1.08	0.011
Age ^a	-0.04	0.01	0.012
Calendar year*occupational class ^b			0.012
White-collar	0.06	0.07	0.357
Blue-collar	-0.14	0.04	<0.001
Benchmark ^c *rating ^d			0.025
Yes			
Low exposed	Ref.		
Medium exposed	5.99	1.48	<0.001
High exposed	9.48	1.71	<0.001
No			
Low exposed	1.87	1.36	0.172
Medium exposed	4.87	1.74	0.006
High exposed	6.41	1.64	<0.001

^aAge is standardised to 40 years (continuous); ^bInteraction term between calendar year standardised to year 2010 (continuous) and occupational class (dichotomous); ^cExpert rating for no benchmark group (low, medium, high exposed); ^dInteraction term between benchmark and ratings

Table 5. Model-based noise level (dBA) for the ten highest and the ten lowest exposed jobs as estimated for a 40-year old male worker in 2010 among 100 estimated jobs

Jobs ^a	Job description	N	Mean
Ten highest exposed jobs			
7224	Metal wheel-grinders, polishers and tool sharpeners	6	88.9
8123	Metal-heat-treating-plant operators	8	88.7
7411	Butchers, fishmongers and related food preparers	11	88.1
8275	Fruit-, vegetable- and nut-processing-machine operators	6	86.8
8240	Wood-products machine operators	37	86.3
8271	Meat- and fish-processing-machine operators	20	85.9
7212	Welders and flame cutters	6	85.8
7423	Woodworking machine setters and setter-operators	35	85.7
7211	Metal molders and core makers	12	85.6
8274	Baked-goods, cereal and chocolate-products machine operators	8	85.5
Ten lowest exposed jobs			
3419	Finance and sales associate professionals not elsewhere classified	<4	70.2
4212	Tellers and other counter clerks	<4	70.3
2441	Economists	<4	70.7
2419	Business professionals not elsewhere classified	17	71.8
4190	Other office clerks	12	71.9
1227	Production and operations department managers in business services	<4	72.0
3411	Securities and finance dealers and brokers	<4	72.8
3118	Draughts persons	<4	73.0
2351	Education methods specialists	<4	73.6
1231	Finance and administration department managers	<4	74.1

^aJobs within the DISCO 88, the Danish version of the International Standard Classification of Occupations (ISCO), revision 1988

Supplementary material

Table A. Number of jobs defined at the 4-digit level within the nine major groups and the number of jobs with noise level measurements

Major groups ^a	Total	Jobs with measurements	
	N	N	%
Overall	372	100	27
1 Legislators, senior officials and managers	32	5	16
2 Professionals	55	6	11
3 Technicians and associate professionals	70	12	17
4 Clerks	22	7	32
5 Service workers and shop and market sales workers	20	<4	15
6 Skilled agricultural and fishery workers	12	<4	8
7 Craft and related trades workers	71	28	39
8 Plant and machine operators and assemblers	70	32	46
9 Elementary occupations	20	6	30

^aMajor groups within the DISCO 88, the Danish version of the International Standard Classification of Occupations (ISCO), revision 1988