The synergetic effect of nocturnal road noise exposure and work-related stress on self-rated sleep quality

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Abstract

Ample evidence exists for adverse health effects, such as sleep disturbance, due to nocturnal transportation noise but also due to other non-acoustic particularly psychosocial stressors, such as work-related strain. However, only very few studies have focused on the synergetic effect of the co-exposure by transportation noise and psychosocial stress. A survey with 3460 working women aged 18-65 years from the Swedish county Västra Götaland investigated the effect of nocturnal road noise exposure, work-related stress and their potential synergetic effect on self-rated sleep quality. Results revealed that sleep quality was not consistently associated with noise exposure (depending on the assessment via modelled nocturnal outdoor noise levels vs. façade of the bedroom) while work-related stress had a significant effect throughout. There was a non-significant trend for a synergetic effect between the façade of the bedroom and work-related stress that warrants consideration in future noise effects research.

Keywords: road noise, sleep quality, work-related stress, synergetic effect

1 Introduction

Chronic exposure to nocturnal transportation noise can have adverse physiological and psychological effects including annoyance, decreased cognitive performance, increased risks for cardiovascular diseases, and sleep disturbance [1]. According to the World Health Organization [2], the latter comprises the highest burden of disease due to environmental noise exposure with road traffic noise considered as the most common source of transportation noise worldwide. Evidence for road noise-induced sleep disturbance come from laboratory and field studies using electro-physiological sleep measurements [3-5], but also from epidemiological studies and cross-sectional surveys using self-assessments of sleep quality and sleep disturbance [6].

An additional source of sleep disturbance is psychosocial stress [7]. Amongst others, work-related stress has shown to be a critical predictor of decreased sleep quality and insomnia in a systematic review [8].

However, the potential for synergetic effects of work-related stress and nocturnal transportation noise exposure on sleep has scarcely been investigated, so far [9]. The present conference paper analyses the effect of work stress and nocturnal road traffic noise exposure on self-rated sleep quality in multivariate models. In addition, a potential synergetic effect of noise exposure and work-related stress is examined. All analyses and results presented here are part of a paper recently published by the same authors (https://doi.org/10.1007/s00420-021-01696-w).

2 Methods

2.1 Sample

Data presented here come from an ongoing cohort of working women in Sweden including women with a preschool teachers' degree and randomly selected women from the general population of the Västra Götaland County of Sweden born between 1943 and 1989 [10]. Data were surveyed via questionnaires sent out between October 2013 and July 2014. Predictor and outcome variables were assessed in parallel using a cross-sectional study design. Response rates were 51% (preschool teachers) and 38% (general population) [10].

Analyses presented in this paper are based on a sample of in total 3460 working women aged 18-65 years. For 2,191 respondents residing in the area of Gothenburg and its neighbouring community Mölndal (= subsample A), data on modelled nocturnal road noise levels and subjective sleep quality were available. For 1,764 respondents from the area of Gothenburg and Mölndal and the whole Västra Götaland County (subsample B) data on the façade of their bedroom and their sleep quality.

The study was approved by the Ethics Committee of Gothenburg Sweden (060-13). All participants received written information and gave their consent by returning a completed questionnaire.

2.2 Outcome variable

Sleep was assessed via a single question on self-rated general sleep quality plus a matrix of four questions on specific sleep problems including problems to fall asleep, early awakenings and problems to fall asleep again, tiredness in the morning, and sleepiness during the subsequent day in line with recommendations by [11]. Answer options were "very good", "rather good", "neither good nor bad", "rather bad", and "very bad" for the question on self-rated sleep quality and "never/seldom", "a few times per month", "once per week", "several times per week", and "every day" for the questions on specific sleep problems. The five questions were condensed and dichotomized as follows: Sleep quality was coded to value 1 (=poor sleep) when three or more of the five questions were answered with the two upper answer options characterizing worse sleep ("rather bad" or "very bad" and "several times per week" or "every day"). Otherwise, sleep was coded to 0 (= no poor sleep).

2.3 Predictor variables, confounders and modifiers

2.3.1 Noise exposure

The nocturnal road noise level (L_{night}) which is the equivalent noise level from 22:00 to 06:00 (standard night time in Sweden) was modelled according to the Nordic prediction method for road traffic noise [12] based on geo coding of the respondent's home address. The method used geometries of roads, buildings, elevation data, ground types and noise barriers as well as traffic counts for standard and heavy vehicles and their distribution during the night. All noise data referred to outdoor levels calculated for the mot exposed façade. Information regarding the floor of the bedroom in the building was not available. We differentiated between three L_{night} categories, i.e. < 45 dB(A), 45-50 dB(A), and > 50 dB(A).

Via the question “Does your bedroom have windows directly facing a street or road?”, we obtained information about the façade of the bedroom. The response options were “no street/road”, “yes, a low-traffic street/road”, “yes, a medium-traffic street/road”, and “yes, a high-traffic street/road”. “No street/road” was considered as a proxy for a quiet façade. Because of very few respondents in the category “high-traffic street/road”, this category was combined with the category “medium-traffic street/road” for the subsequent analyses.

2.3.2 Work-related stress

Work-related stress was operationalized by the concept of *job strain* [13] that describes mental job strain as a result of the interaction between psychological job demands (i.e. workload and task requirements) and job control (i.e. individual control over one’s work activities and work-related decision authority) [14]. We used the Swedish Demand–Control–Support Questionnaire (DCSQ) [15] and assigned respondents to categories of low, medium and high job strain depending on their ratio between job demands and job control applying a method described by [9]. The categorization of job strain was conducted according to a priori defined cut-off values (i.e. sum scores). We considered this method preferable to a categorization based on quantile splits since they and the resulting categorization can vary with study populations and survey waves [16].

2.3.3 Confounders and modifiers

The following demographic and lifestyle factors have *a priori* been selected as potential modifiers or confounders of the association among work-related stress, nocturnal road noise exposure, and poor sleep and have been included in all analyses: current smoking, alcohol consumption, obesity via the Body-Mass-Index, physical activity, educational level, monthly income, self-rated general sensitivity to noise, age, and belonging to either the preschool teacher cohort or the general population.

2.4 Statistical analyses

In a first step, we analysed the effect of the predictor variables separately in univariate logistic regression models. In a second step, we applied multivariate logistic regression models including a noise exposure variable (i.e., either L_{night} or the façade of the bedroom window), job strain, and all a priori selected confounders and modifiers in order to examine their effects on the outcome sleep quality (i.e., poor sleep vs. no poor sleep).

In order to test for potential synergetic effects between job strain and exposure to nocturnal road noise, we assessed interaction effects on an additive scale. Positive departure from additivity in the present analyses means that the number of respondents reporting poor sleep is higher when both risk factors (i.e., nocturnal noise exposure and job train) impact in combination than the sum of the respondents that would be caused by high levels of each risk factor [17]. We quantified the amount of interaction by attributable proportion, AP, that indcates the presence of an interaction for values larger than 0. AP was computed as recommended by [18]. Since this method applies to dichotomous variables and the predictor variables presented in this paper contained three categories, we calculated AP including only the highest and lowest levels of these variables, each.

Synergistic interaction effects between the noise exposure variables and job strain were only examined when the variables showed at least a trend for an increase in the prevalence of poor sleep, i.e. p <.01.

3 Results and discussion

3.1 Association among nocturnal road noise exposure, job strain, and self-rated poor sleep

As shown in Table 1, there was no positive association between the L_{night} and the prevalence of poor sleep neither in the univariate nor in the multivariate model. Contrary to our expectations, respondents in the high L_{night} category reported even slightly lower rates (15.6 %) of poor sleep than respondents in the low L_{night} category (19.6 %) pointing at a rather negative association.

Table 1 – Effect of nocturnal road noise exposure level and job strain on sleep. Odds Ratios (OR) with 95 % Confidence Intervals (CI), subsample A.

Variable and level	*n* with poor sleep	*n* without poor sleep	Univariate Model OR	Univariate Model 95 % CI	Multivariate Model OR	Multivariate Model 95 % CI
Nocturnal road noise						
Low (< 45 dB, reference)	139	570	1.00		1.00	
Medium (45 - 50 dB)	120	544	0.90	0.69-1.19	0.96	0.73-1.28
High (> 50 dB)	112	607	0.76 *	0.58-0.99	0.80	0.60-1.07
Job strain						
Medium (reference)	179	765	1.00		1.00	
Low	94	730	0.55 ***	0.42-0.72	0.62 ***	0.47-0.82
High	98	226	1.85 ***	1.39-2.47	1.83 ***	1.35-2.47

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. The Multivariate Model includes potential confounders and modifiers: age, educational level, monthly family income, type of the cohort, body mass index, BMI, physical activity, current smoking, alcohol, and noise sensitivity.

A plausible explanation for this finding may be limitations in the modelling of the nocturnal road noise exposure at the most exposed façade and without considering the façade of the bedroom. It is assumed that residents of noisy roads are likely to choose more shielded façades of their dwellings for their bedrooms [19]. Hence, our original intention was to analyse the association between the L_{night} and sleep quality while considering the façade of the bedroom. However, due to an unfortunate mishap, the majority of the study population received a questionnaire version that did not include the question on the bedroom façade so that this information could not be considered together with the L_{night}. As a consequence, the modelled L_{night} used in the analyses did not necessarily reflect the actual level at the bedroom façade and this limitation might have led to an underestimation of the true association between the equivalent outdoor level and sleep quality.

Moreover, information on the respondents' window positions at night were not available. When exposed to high nocturnal road noise levels, residents are likely to close their windows [20]. Depending on the window position, outdoor-to-indoor attenuations can vary considerably between 10 dB(A) for open windows and 28 dB(A) for closed windows [21]. Thus, outdoor levels are a per se a rather poor proxy for the noise exposure indoors.

Notwithstanding the above, the explanatory power of equivalent continuous levels for sleep disturbance is generally limited, in particular for rather intermittent and less continuous noise such a road traffic noise [22-23]. A major drawback of equivalent levels is the fact that different noise scenarios can result in the same level [6]. Maximum levels are a more important factor for sleep disturbance and fragmentation [6]. Future studies should therefore apply exposure modelling that considers the bedroom facade, window-opening behaviour, façade insulation as well as maximum levels.

Besides, also the wording of the questions on sleep quality and sleep disturbance may have had an influence as they were neutral and did not name road noise as the source of potential sleep disturbance. Recently, it was concluded that night-time road noise night levels were significantly associated with self-rated high sleep disturbance when questions mentioned road noise as the cause of sleep disturbance. When road noise was not mentioned in the question, only a non-significant, very small association was reported [6]. Moreover, the size of effect of modelled road noise exposure on self-reported sleep quality has been shown to vary depending on the sex with a significant association found in men but not in women [24]. Consequently, the results of the present study should be generalized with caution to the whole population since only women were included in the dataset.

Table 2 – The effect of bedroom window façade and work stress on sleep. Odds Ratios (OR) with 95 % Confidence Intervals (CI), subsample B.

Variable and level	*n* with poor sleep	*n* without poor sleep	Univariate Model OR	Univariate Model 95 % CI	Multivariate Model OR	Multivariate Model 95 % CI
Bedroom façade						
No street (reference)	165	919	1.00		1.00	
Street with low traffic	65	375	0.97	0.71-1.32	0.91	0.65-1.26
Street with medium or high traffic	31	106	1.63 *	1.06-2.51	1.40	0.89-2.22
Job strain						
Medium (reference)	134	521	1.00		1.00	
Low	72	717	0.39 ***	0.29-0.53	0.45 ***	0.33-0.62
High	55	162	1.32	0.92-1.89	1.38 $^{+}$	0.94-2.02

Note. $^{+}$ $p < .1$, * $p < .05$, *** $p < .001$. The Multivariate Model includes potential confounders and modifiers: age, educational level, monthly family income, type of the cohort, body mass index, BMI, physical activity, current smoking, alcohol, and noise sensitivity.

The present results suggest an effect of the façade of the bedroom. Albeit not throughout on a significant level, Table 2 shows a trend for an increase in the prevalence of poor sleep among respondents with a bedroom window facing a medium or high-traffic street compared to those with a bedroom window facing no street. Thus, results suggest a beneficial effect of a quiet bedroom façade on sleep quality as already reported in previous studies [20, 25-26]. We did not find a difference in the prevalence of poor sleep between the no street (=quiet façade) and the low-traffic street condition. Being exposed to a self-reported low-traffic street may be related with low-level night-time noise in the studied areas which may not have caused perceivable sleep disturbance. Moreover, the absence of a street does not necessarily mean a quiet façade such as a garden, green space, a yard or garden, or water, as suggested by [25].

As shown in Tables 1 and 2, job strain was positively related with self-rated poor sleep. The prevalence of poor sleep was lower when job strain was low compared to medium job strain in both the univariate and the multivariate model. The prevalence of poor sleep was higher in the high job strain condition compared to the medium job strain condition, albeit not throughout on a significant level in the multivariate models for subsample A and B. The increasing effect of job strain on self-reported sleep quality has been shown before

[7-9, 27]. In addition, the present results suggest a sleep protecting effect of low job strain, meaning that control exceeds demands. However, the present data came from a cross-sectional study and causality between job strain and sleep quality cannot be proven. Reverse causality is conceivable as well, meaning that chronically poor sleep can lead to decreased performance which, again, may affect the perception of one's demands and control [8].

3.2 Synergetic effects between road noise exposure and job strain

Potential synergetic effects, i.e. the departure from additivity, was examined between the predictors bedroom facade and job strain. Since the L_{night} did not show any positive association to the prevalence of self-rated poor sleep, we did not carry out an analysis of additive interaction. Table 3 shows a positive Attributional Proportion (AP = 0.46, CI -0.09-1.00) suggesting a non-significant trend for an additive interaction. A high level of job strain in combination with a bedroom window facing a medium or high-traffic street showed a more than additive risk for self-rated poor sleep indicting that the number of cases of poor sleep in this combination was higher than the sum of cases of poor sleep that would be caused by high job strain and a bedroom façade to a medium/high-traffic street, each.

Table 3 – Analysis of additive interaction effects between bedroom façade and job strain.

	No street (quiet façade)			
	n with poor sleep	*n* without poor sleep	OR	95 % CI
Low job strain	47	474	1.00	
High job strain	31	98	3.02	1.79-5.09
	Medium-/high-traffic street			
	n with poor sleep	*n* without poor sleep	OR	95 % CI
Low job strain	6	52	1.09	0.43-2.75
High job strain	9	14	5.71	2.24-14.56
	Attributional Proportion			
	AP		95 % CI	
	0.46		-0.09-1.00	

Note. The distribution of levels of bedroom façade and job strain in respondents with vs. without poor sleep refer to crude numbers (n). Estimates for odds ratios (OR) and confidence intervals (CI) are adjusted for the effect of a priori selected confounders and modifiers

A study that focussed on potential synergetic interactions between nocturnal road noise exposure and job strain first [9], did not find an additive interaction in women. However, those findings are not fully transferable to the present results as noise exposure was operationalized by the L_{night} and not by the bedroom facade.

4 Conclusions

Job strain and at least on a trend level also bedroom façade both impacted on self-rated sleep quality in a sample of Swedish working women. Compared to job strain, the impact of the bedroom façade was marginal. A non-significant trend for an additive interaction was found between the bedroom façade and job strain on self-rated sleep quality. Results suggest that work-related stress and potential additive interactions with the noise exposure are important predictors that should be considered more thoroughly in future (epidemiological) studies on the effect of transportation noise on sleep quality. Because of previously reported sex differences in the association between road noise exposure and sleep quality [24], present findings in only women warrant more research in order to establish generalizability on a population level including men.

The nocturnal equivalent road noise level modelled outdoors at the most exposed façade (L_{night}) seem to be a poor predictor of self-reported sleep quality since it does not adequately reflect the sleeper's actually perceived noise exposure. A quiet façade seems to play a more important role as it protects sleep quality at least on a trend level. Future studies on the effect of nocturnal road noise exposure should consider the façade of the bedroom in their modelling of outdoor noise levels.

Since the findings presented in this a paper are based on cross-sectional analyses causality of effect could not be proven. However, the research questions raised in this study with regard to exposure classification and an improved knowledge on health affecting factors warrant following up preferably in longitudinal studies.

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