

Is noise annoyance from neighbours in multi-storey housing associated with fatigue and sleeping problems?

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ABSTRACT

Danish Health and Morbidity Surveys including questions about neighbour noise and traffic noise have been carried out each 3-5 years since year 2000, the latest one in 2017. In all five surveys, the neighbour noise annoyance in multi-storey housing was higher than annoyance from traffic noise. In 2017, 14,022 respondents (response rate 56%) completed the self-administered questionnaire, out of which 3,893 adult Danes lived in multi-storey houses. Noise annoyance was assessed by asking the respondent about noise annoyance from neighbours and traffic, respectively, in their home during the past two weeks. Fatigue and sleeping problems during the past two weeks were assessed with a checklist that included eight different health outcomes (including the two mentioned). In total, 36% reported having been very/slightly bothered by neighbour noise and 22% by traffic noise. Noise annoyance from neighbours was strongly associated with both health outcomes. For example, individuals being very annoyed by noise from neighbours had 2.91 times higher odds of being very bothered by fatigue. Similar associations were also observed for traffic noise annoyance. Although causality cannot be established in the present cross-sectional study, it is concluded that noise annoyance from neighbours is strongly associated with both fatigue and sleeping problems.

Keywords: Housing, Neighbour noise, Fatigue, Sleeping problems

1. INTRODUCTION

The adverse effects of noise has had the attention of WHO for decades, and several reports are published, e.g. an assessment report [1] addressing the environmental health inequalities in Europe and pointing out noise exposure at home as one of the environmental health inequality indicators. Due to the influence of noise on health, the European Environmental Agency (EEA) has analyzed the traffic noise situation and published a report *Noise in Europe 2014* [2] pointing out the severe adverse health implications of traffic noise. A brief summary is found in [3]. The importance of protection from traffic noise sources has been emphasized at the EU level, e.g. by EEA, and the EU Environmental Noise Directive (END), [4], requires national mapping of external noise and action plans every fifth year.

While health implications of traffic noise have been quite thoroughly investigated, neighbour noise has mainly been considered a “social” problem. Nevertheless, sleep disturbances and other activity disturbances by neighbours may be unhealthier than those caused by traffic, since the information contents in neighbour noise is high, implying a high annoyance potential.

In Denmark, national health and morbidity studies have been carried out every 3-5 years since year 2000, see [5]. Comparison between neighbour and traffic noise annoyance is found in [3], and strong associations between neighbour noise annoyance and poor mental health and perceived stress, respectively, are found in [6]. The current paper deals with fatigue and sleeping problems.

2. NEIGHBOUR NOISE ANNOYANCE AND REACTIONS

Based on indications from the field, very low sound insulation between dwellings implies total lack of privacy leading to annoyance and to restraints on own activities. Examples of disturbing noises and disturbed activities are found in Table 1, and reactions may go in different directions, e.g. annoyance may develop to hatred and conflicts, and disturbance to tension, depression and tiredness,

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see e.g. description of the noise reaction process in [7]. Thus, it is necessary to increase awareness on the importance of acoustic conditions for quality of life. In contrast to neighbour noise, traffic noise exposure can be objectively quantified by physical parameters [4], and most studies investigating the impact of noise on health outcomes use traffic noise as the environmental noise exposure. However, the health consequences of neighbour noises have rarely been studied. Neighbour noises are more complex and generally not quantifiable. Thus, individual and subjective perceptions of noise are assessed by means of surveys targeting noise annoyance. Based on results, there are good reasons to suspect that neighbour noise annoyance affects health adversely. Health outcomes from noise are dealt with in the WHO LARES study carried out in eight cities in Europe 2002-2003, see [8] and [9], and it is concluded that that neighbour noise affects health via long lasting severe annoyance, [9]. In [8] sleep disturbance from neighbour noise is reported as almost on the same level as for traffic, while other noise sources are far below. References to various other surveys are found in e.g. [10]. The far most extensive survey has been made in UK, see [11], with very detailed interviews and reporting.

Table 1 – Examples of disturbing/annoying neighbour sounds and own activities being disturbed.

Disturbing/annoying neighbour noises		Own activities disturbed
<ul style="list-style-type: none"> ◆ Voices/shouting/arguments ◆ Dogs ◆ Radio, TV, music ◆ Parties ◆ Neighbours' DYI 	<ul style="list-style-type: none"> ◆ Footsteps ◆ Children jumping/playing ◆ Doors banging ◆ Washing machines etc. 	<ul style="list-style-type: none"> ◆ Sleeping ◆ Using every room in the house ◆ Listening to TV, radio, music ◆ Quiet activities: Reading, resting ◆ Having a conversation

3. MULTI-STOREY HOUSING IN DENMARK

The housing stock in Denmark consists of about 2.7 million dwellings in total, of these almost 1.1 million in multi-storey (MS) housing. In Figure 1 are found graphs for number of dwellings in MS housing according to year of construction. Buildings from different periods have different construction characteristics, and thus expectedly different sound insulation performance. More details are found in [12-13] and [3] and in references in those publications. The building types may here be denoted E1, E2, E3 and NEW, and number of dwellings are ~ 500,000, up to 100,000, ~ 400,000 and ~ 65,000 (incl. estimate for 2019). Figure 1 also includes small sketches of the four building types and expected acoustic classes F, E, D, C according to [14]. The current Danish building regulations are found in [15], which refers to class C in [14] as minimum acoustic performance. Acoustic requirements for other countries are found in e.g. [16], [12] and [17]. Brief indications of constructions in Danish MS housing are as follows:

- E1: Old brick-built buildings with timber floor constructions. Period: ~ 1850 to 1930/1950.
- E2: Brick-built buildings with thin in-situ concrete slabs and wooden floors. Period: ~ 1930 to 1960.
- E3: Concrete elements with wooden floors. Period: ~ 1960 to 2009.
- NEW: Concrete elements with wooden floors (higher performance than E3). Period: From ~ 2010.

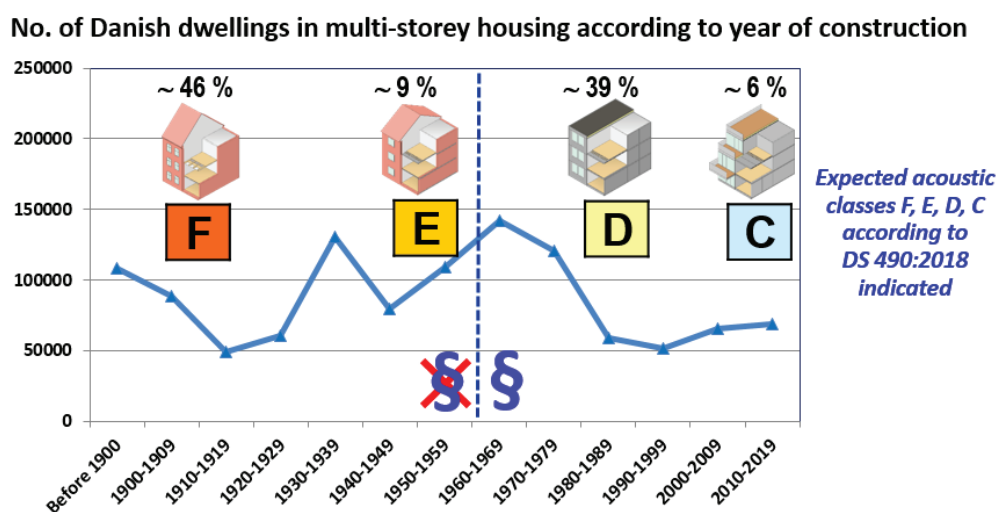


Figure 1 – Dwellings in multi-storey housing according to construction year [18]. Building types for various periods are illustrated and expected acoustic classes indicated. Number of dwellings for 2019 estimated.

4. DANISH HEALTH AND MORBIDITY SURVEYS 2000-2017 – METHODOLOGY

Data derives from the Danish health and morbidity surveys in 2000, 2005, 2010, 2013 and 2017 [19]. The aim of the surveys is to describe the status and trends in health and morbidity in the adult Danish population (16 years or older) and the factors that influence health status, including e.g. health behaviour and environmental and occupational health risks. The results are used in national, regional and municipal planning and monitoring as well as in research and analysis. All samples were drawn at random from the adult Danish population using the Danish Civil Registration System [20]. It is important to notice that the target population in 2010, 2013 and 2017 included all individuals living in Denmark, whereas the target population in 2000 and 2005 only were Danish citizens. Data were in 2000 and 2005 collected via face-to-face interview at the respondent's home. However, in 2010, the mode was changed from face-to-face interviews to self-administered questionnaires, [21]. The letter of introduction invited the selected individuals either to fill in the web questionnaire or to complete the mailed questionnaire. In each survey wave, the questionnaire includes standard topics, e.g. morbidity, health behaviour, health care utilization, consequences of morbidity and background information such as sex, age, cohabitation status and education. In addition, the survey also aims to highlight several specific topics, e.g. teeth status, violence and sexual assault and thought of suicide and suicide attempts. The questionnaires from all waves can be downloaded from the website [5].

In all survey waves (since year 2000), noise annoyance was assessed by asking the respondent whether they had been annoyed by noise from traffic or noise from neighbours, respectively, in their home during the past two weeks. The respondents were also asked about other indoor environment exposures. The possible answer categories were 'Yes, very annoyed', 'Yes, slightly annoyed', and 'No'. Fatigue and sleeping problems (or insomnia) during the past two weeks were assessed with a checklist that included eight different health outcomes. There were three answer categories for each health outcome: 'Yes, very bothered', 'Yes, slightly bothered', and 'No'. This checklist has been included in all survey waves since 1987.

Information on type of housing for each respondent was obtained from the Building and Housing Register at the time of the survey in the latter three waves [22]. In 2000 and 2005, this information was noted by the interviewer.

In all, the questionnaire in 2017 included 98 questions, out of which approximately 50% had underlying items. Table 2 shows a brief overview of the survey waves, e.g. number of invited individuals, response rates and brief indications of noise related questions.

Table 2 – Main characteristics for the Danish Health and Morbidity Surveys 2000-2017 and indication of noise questions.

Year	Survey mode	Sample size	No. of respondents/ response rate (%)	Questions on noise annoyance included in survey
2000	Face-to face interview	22,484	16,688 / 74%	Noise from traffic; Noise from installations (e.g. pipe, radiator, refrigerator); Noise from neighbours; Noise from nearby business activities; Infrasound or low frequency noise.
2005	Face-to face interview	21,832	14,566 / 67%	Noise from traffic; Noise from installations (e.g. pipe, radiator, refrigerator); Noise from neighbours; Noise from nearby business activities.
2010	Self-administered	25,000	15,165 / 61%	Noise from traffic; Noise from service equipment (e.g. pipe, radiator, refrigerator); Noise from neighbours; Noise from nearby business activities.
2013	Self-administered	25,000	14,265 / 57%	Noise from traffic; Noise from neighbours.
2017	Self-administered	25,000	14,022 / 56%	Noise from traffic; Noise from neighbours; If affirmative, the respondents were asked which kind of noise using a multiple-choice question.

The association between traffic noise annoyance and sleep has been examined in several studies, but studies examining the associations between neighbour noise annoyance and fatigue and/or sleeping problems are rare, but is done in the current study. The prevalence of experiencing bothering fatigue and sleeping problems, respectively, is presented as percentages. Multiple logistic regression

models were used to examine the associations between traffic and neighbour noise annoyance, respectively, and very bothering fatigue and sleeping problems, respectively, among individuals living in multi-storey houses. The results are presented as odds ratios (ORs) with 95% confidence intervals (CI). An odds ratio is a measure of effect size, measuring the strength of association between two variables [23]. An odds ratio greater than 1 indicates the group is more likely to report that health outcome (i.e. very bothering fatigue or sleeping problems, respectively), while an odds ratio less than 1 indicates the group is less likely to report the health outcome. The ORs are adjusted for sex, age, education, marital status, degree of urbanisation, owner/tenant status, and ethnic background. The CI of the ORs are used to estimate the precision of the ORs. If the CI interval includes 1, then there is no statistically significant difference between that specific group and the reference group.

Overview results related to housing conditions are found in [24] for the 2013 survey and in [25] for the 2017 survey. Detailed results are published separately.

5. NOISE RELATED SURVEY RESULTS 2017

In the 2017 survey, 3,893 respondents lived in multi-storey houses, cf. Table 3. The distribution by construction year is displayed in Table 3. For example, the table shows that 14.0% of the study population live in multi-storey houses that were constructed between 1960-1969 and 11.9% live in multi-storey houses that were constructed between 1970-1979, i.e. about 1/4 of the study population live in houses constructed during these two decades. Furthermore, the table shows that there were no clear associations between the year of building construction and the self-reported neighbour and traffic annoyance, respectively, among individuals living in multi-storey housing. However, the prevalence of being very or slightly annoyed by neighbour noise were relatively low among individuals living in multi-storey houses constructed in the 2000's.

Table 3 – Number of respondents living in multi-storey houses, distribution by year of building construction and percentage who were very or slightly annoyed in their home during the past two weeks by traffic and neighbour noise, respectively. Results from 2017.

Survey 2017			Traffic noise (%)			Neighbour noise (%)		
Year of building construction	Respondents %	No. of respondents	'Yes, very annoyed'	'Yes, slightly annoyed'	'No'	'Yes, very annoyed'	'Yes, slightly annoyed'	'No'
<1900	9.7	399	4.0	24.5	71.5	7.7	28.7	63.6
1900-1909	8.7	350	4.9	22.6	72.5	6.3	27.4	66.3
1910-1919	4.2	167	3.4	17.2	79.4	5.5	32.7	61.8
1920-1929	6.1	243	2.0	13.8	84.3	4.1	28.0	67.9
1930-1939	11.2	466	4.1	20.5	75.5	7.3	33.4	59.3
1940-1949	6.0	231	1.8	22.3	75.9	5.6	32.7	61.7
1950-1959	9.7	369	5.6	16.7	77.7	11.7	30.1	58.2
1960-1969	14.0	519	1.0	16.9	82.1	7.7	30.9	61.4
1970-1979	11.9	427	1.9	15.8	82.3	5.9	29.6	64.5
1980-1989	5.6	208	2.8	21.9	75.4	8.0	26.1	65.8
1990-1999	4.1	150	2.2	18.4	79.4	6.7	19.4	73.9
2000-2009	6.5	270	1.5	14.3	84.2	1.4	20.8	77.8
≥2010	2.3	94	8.1	14.4	77.4	3.6	21.8	74.6
All	100.0	3.893	3.0	18.6	78.4	6.7	28.9	64.4

Table 4a shows that 2.8% of all respondents in 2017 reported being very annoyed by neighbour noise within the past two weeks, whereas 13.8% had been slightly annoyed. Furthermore, the table shows that 1.8% of the respondents in 2017 reported being very annoyed by traffic noise within the past two weeks, whereas 12.2% had been slightly annoyed. The percentages are substantially higher when the analyses are restricted to individuals living in multi storey housing, see Table 4b.

Table 5 reveals that the prevalence of annoyance is strongly associated with the type of exposure and house types. For example, the prevalence who had been very or slightly annoyed by neighbour noise within the past two weeks was 35.6% among individuals living in multi-storey housing and 5.5% among individuals living one-family houses.

The prevalence of being very or slightly annoyed by traffic noise has increased from 6.3% in 2000 to 14.0% in 2017, see Table 6. Among individuals living in multi-storey houses, the corresponding prevalences were 11.5% in 2000 and 21.6% in 2017. The prevalence of being very or slightly annoyed by neighbour noise among individuals living in multi-storey houses has been stable in the period 2010 (35.8%) to 2017 (35.6%). The change in mode of data collection in 2010 (i.e. from face-to-face interview to self-administered questionnaire) had a large effect on respondents' reported neighbour noise annoyance. Thus, the prevalence estimates for neighbour noise annoyance from 2000 and 2005 are not comparable with the prevalence estimates from 2010 and onwards.

Table 4a – Traffic and neighbour noise: Percentage who were very or slightly annoyed in their home during the past two weeks. All dwellings. Results from 2017.

Type of noise	'Yes, very annoyed'	'Yes, slightly annoyed'	'No'	In all	Total Very or slightly annoyed
Neighbours	2.8	13.8	83.3	100.0	16.7
Traffic	1.8	12.2	86.0	100.0	14.0

Table 4b – Traffic and neighbour noise: Percentage who were very or slightly annoyed in their home during the past two weeks among individuals living in multi-storey housing. Results from 2017.

Type of noise	'Yes, very annoyed'	'Yes, slightly annoyed'	'No'	In all	Total Very or slightly annoyed
Neighbours	6.7	28.9	64.4	100.0	35.6
Traffic	3.0	18.6	78.4	100.0	21.6

Table 5 – Percentage who were slightly or very annoyed in their home by various indoor environment exposures within the past two weeks according to type of dwelling. Results from 2017.

Exposure	One-family houses	Row and double houses	Multi-storey housing	Other*	All housing
Smell of mould	2.3	3.0	4.2	2.6	3.0
Noise from traffic	9.8	10.8	21.6	12.5	14.0
Noise from neighbours	5.5	11.8	35.6	21.8	16.7
Odour from nearby wood stoves	12.5	7.9	3.5	8.0	8.8
Smell of tobacco smoke from neighbours	1.7	4.5	17.3	8.5	7.4

* Other = e.g. nursing homes, institutions

Table 6 – Percentage who were annoyed in their home by traffic and neighbour noise, respectively, during the past two weeks. Results from surveys in 2000-2017.

Year	Traffic noise					Neighbour noise				
	Total	One-family houses	Row and Double houses	Multi-storey	Other	Total	One-Family houses	Row and Double houses	Multi-storey	Other
2000	6.3	4.2	5.7	11.5	5.6	(7.7)*	(2.6)	(9.1)	(19.1)*	(10.9)
2005	8.1	5.2	7.5	15.6	7.2	(9.0)*	(4.4)	(9.8)	(21.2)*	(12.1)
2010	9.6	5.3	4.8	18.4	11.2	15.6	4.2	10.6	35.8	23.8
2013	9.6	5.9	6.4	16.4	11.2	15.4	3.8	12.2	34.4	26.5
2017	14.0	9.8	10.8	21.6	12.5	16.7	5.5	11.8	35.6	21.8

*Change in methodology suggests that pre-2010 survey estimates are not comparable to results from 2010, 2013 and 2017.

The prevalence of being very bothered by *fatigue* was substantially higher among those who have been very annoyed by noise from neighbours (33%) than among those who had not been annoyed by noise from neighbours (14%), see Figure 2. The prevalence among those who had been slightly annoyed was 20%. Correspondingly, the prevalence of being very bothered by *sleeping problems* was substantially higher among those who have been very annoyed by noise from neighbours (25%) than among those who had not been annoyed by noise from neighbours (11%), see Figure 2. The prevalence

among those, who had been slightly annoyed was 16%. The same associations are observed for noise from traffic, see Figure 3. The strong associations remained even after adjustment for potential confounders, see Table 7. For example, individuals who had been very annoyed by noise from neighbours during the past two weeks had 2.62 (95% CI: 1.86-3.69) times higher odds of being very bothered by sleeping problems than individuals who had not been annoyed by noise from neighbours. The corresponding odds ratio for those who had been slightly annoyed was 1.46 (95% CI: 1.16-1.84).

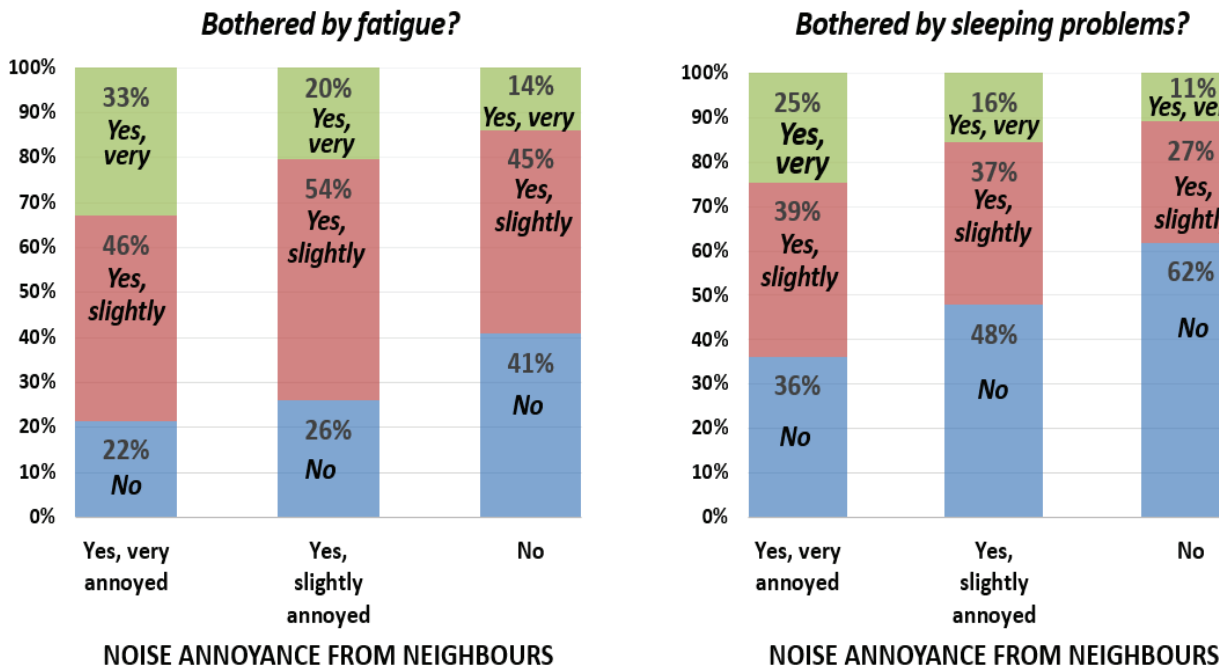


Figure 2 – Prevalence of fatigue and sleeping problems, respectively, within the past two weeks by noise annoyance from neighbours among individuals living in multi-storey housing in 2017. Percentages.

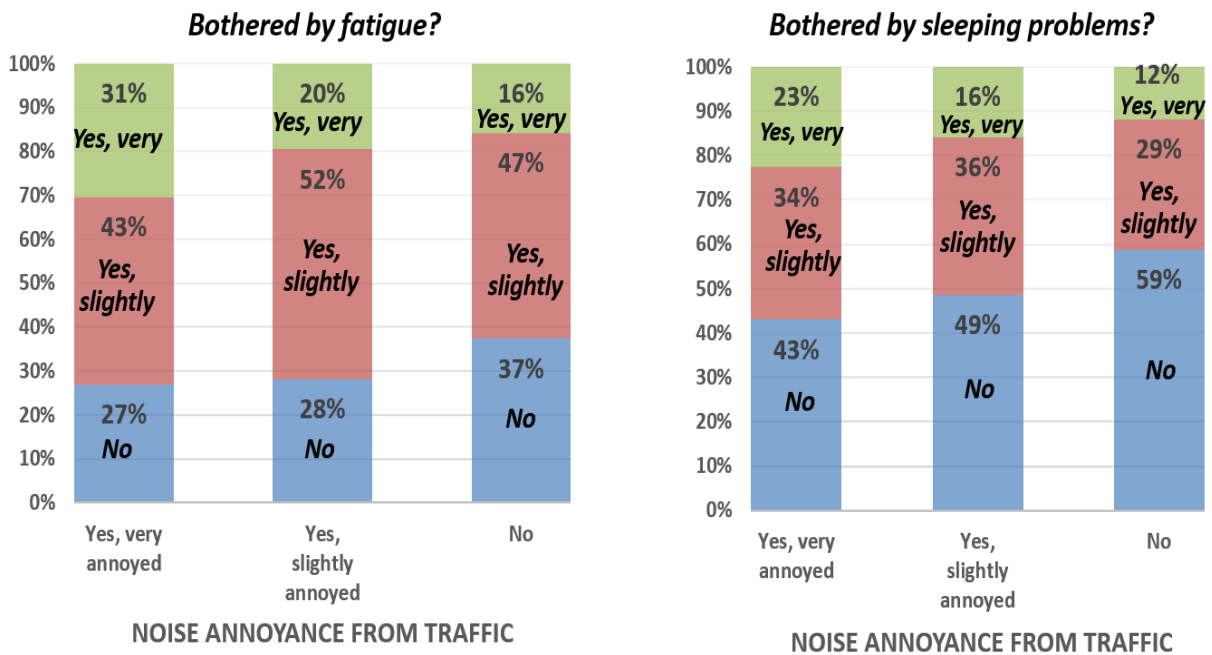


Figure 3 – Prevalence of fatigue and sleeping problems, respectively, within the past two weeks by noise annoyance from traffic among individuals living in multi-storey housing in 2017. Percentages.

Table 7 – The association between noise annoyance from neighbours and traffic, respectively, and very bothering fatigue and sleeping problems or insomnia, respectively, within the past two weeks among individuals living in multi-storey housing in 2017. Adjusted odds ratios¹ (and 95% confidence intervals).

	Annoyed by noise from neighbours		
	Yes, very annoyed	Yes, slightly annoyed	No
Fatigue	2.91 (2.14-3.98)	1.46 (1.18-1.79)	1
Sleeping problems	2.62 (1.86-3.69)	1.46 (1.16-1.84)	1
	Annoyed by noise from traffic		
	Yes, very annoyed	Yes, slightly annoyed	No
Fatigue	2.10 (1.39-3.18)	1.46 (1.11-1.92)	1
Sleeping problems	2.60 (1.73-3.91)	1.58 (1.20-2.09)	1

¹Adjusted for sex, age, marital status, education, degree of urbanization, owner/tenant status and ethnic background

6. CONCLUSIONS

The prevalence of being very or slightly annoyed by traffic noise increased markedly between 2013 and 2017. The reasons are not known, but might partly be increased traffic noise levels, see e.g. [26], partly higher awareness about traffic noise pollution among the general population. The prevalence of being very or slightly annoyed by neighbour noise remained stable in the period 2010 to 2017. The present study also showed that the prevalence of annoyance depends on the type of exposure and housing. For example, as expected, noise annoyance from neighbours were most prevalent among individuals living in multi-storey housing.

The strong associations between neighbour noise annoyance and fatigue and sleeping problems, respectively, among individuals living in multi-storey housing in Denmark seems reasonable due to the unpredictable nature of noise from neighbours (often with a very high informational content) and/or loud noises like e.g. neighbours' footsteps, barking dogs, loud discussions, banging doors. This finding is also in keeping with a previous Danish study, which found strong associations between neighbour noise annoyance and poor mental health and perceived stress, respectively, [6].

The present study highlights the importance of studying the association between noise annoyance, and fatigue and sleeping problems, respectively. However, future prospective studies are needed to determine the direction of causality, since it's not possible in a cross-sectional study to determine, whether people with fatigue and/or sleeping problems are more annoyed by noise, or opposite, if the annoyance leads to fatigue and/or sleeping problems. However, either way is relevant for evaluation of the health situation of the population and the quality of life.

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