PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Influence of nocturnal noise on non-restorative sleep: Gender effects

Daniel Y.T. FONG[1]; Sha LI[1]; Janet Y.H. WONG[1]; Bradley MCPHERSON[1]; Esther Y.Y. LAU[2]; Lixi HUANG[1]; Mary S.M. IP[1]

[1] The University of Hong Kong, Hong Kong

[2] The Education University of Hong Kong, Hong Kong

ABSTRACT

Nocturnal noise exposure may affect the sleep of men and women differently. However, evidence remains limited, especially for non-restorative sleep (NRS). Therefore, this study aimed to assess the moderating effect of gender on the effect of nocturnal noise exposure on NRS. This was a household survey of Chinese adults. Participants completed the Chinese Non-restorative Sleep Scale (NRSS), standardized on a 0-100 scale, with a higher score indicating less NRS. Nocturnal noise level was measured by a dosimeter for one week. We recruited 90 subjects (58% female) with average age 37.0 years (range: 18-65). The mean nocturnal noise level was 55.5dBA (SD: 5.5dBA). The mean NRSS domain scores were 57.3 (SD: 17.6) for Refreshment from sleep, 67.0 (SD: 16.7) for Physical/Mental symptoms, 60.5 (SD: 15.4) for Daytime function, and 62.6 (SD: 21.6) for Affective symptoms. The gender-by-nocturnal noise exposure interaction was significant (p=0.043) for the Refreshment from sleep domain. The influence of nocturnal noise exposure on Refreshment from sleep was more profound in women (-1.00, 95% CI: -1.87 to -0.13) than in men (0.22, 95% CI: -0.57 to 1.01). Women may be more vulnerable than men to the adverse impact of nocturnal noise exposure on NRS.

Keywords: Gender, Noise, Non-restorative sleep

1. INTRODUCTION

Noise is often referred to as unwanted sound. The World Health Organization (WHO) has reported that at least one million healthy years of life are lost in Europe each year due to excess exposure to noise (1). The hypothesized pathways of the non-auditory impact of excess noise exposure on health can be both direct and indirect (2). Noise may directly affect our autonomic nervous system (ANS), the reticular nervous system, as well as the cortical and subcortical brain centers. Alternatively, noise may also make influences via annoyance that causes stress hormones resulting in pathophysiological changes. Hence, excess noise exposure may result in various health problems including sleep.

Nonrestorative sleep (NRS) refers to the degree one feels unrefreshed upon waking up even after adequate sleep. It is a defining symptom of insomnia, but it may not be co-morbid with other sleep-related disturbances. Prolonged NRS may lead to the feeling of fatigue during day-time, chronic illnesses, impaired psychological well-being, and even suicidal thought (3). Hence, it has gained much attention as a treatment target. NRS was most previously assessed by a single item, but it can now be assessed using the standardized 12-item Nonrestorative Sleep Scale (NRSS) that is available in both English and Traditional Chinese versions (4, 5).

The effect of environmental noise exposure on NRS has not been well studied. The literature has so far reported people who have lower tolerance to noise have more NRS (3). Efforts have been made to determine moderating factors on the health impacts of environmental noise, including gender. For cardiovascular diseases, there is some evidence showing men are more affected by noise than women but more evidence is needed (6, 7). For sleep or NRS, there is less work as yet on the potential role of gender on the impact of noise. In view of this, the European Network of Noise and Health (ENNAH) recommended more studies on identifying vulnerable groups, e.g. gender, to the effects of noise on

[1] dytfong@hku.hk

health (6).

Despite gender being considered as an important confounder when assessing noise effects on sleep problems (8), its moderating role on NRS has not been examined. Therefore, this study aimed to assess the moderating role of gender on the association between nocturnal noise exposure and NRS in Chinese adults.

2. METHODS

2.1 Design

This was a household survey of Chinese adults in Hong Kong. The study protocol and consent form were approved by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (Reference Number: UW 17-011).

2.2 Subjects

Individuals aged 18 or above who could read and understand Chinese were recruited. Those who were deaf, needed hearing aids, took sleeping pills or other medications for sleep disorders, were pregnant, had psychiatric illness, or had children under 2 years of age were excluded.

We used a representative sampling frame in Hong Kong to randomly identify residential addresses for conducting the household visits. In each household visit, at most one eligible subject was identified. Each eligible subject was explained of study details and written consent was obtained before study participation.

2.3 Measurements

The participants self-completed a battery of questionnaires that included demographics, the 12-item Chinese Non-restorative Sleep Scale (NRSS), the Hospital Anxiety and Depression Scale (HADS) - Depression, and the 10-item Chinese Perceived Stress Scale (PSS). The Chinese NRSS was shown to be reliable and valid for assessing NRS in the Chinese population (5). It comprises a global scale and the four domains: refreshment from sleep, the physical/medical symptoms of NRS, daytime functioning, and affective symptoms of NRS. They were scored on the 0-100 scale, and a high score indicated less NRS. The Chinese PSS has been shown to have good validity and reliability in individuals aged 10 or above (9).

Nocturnal noise level was also measured by asking each participant to place a dosimeter (Spark 706RC, Larson Davis Inc, US) near their bed for one week.

2.4 Statistical Analysis

We conducted multiple linear regression analysis of the domains of the NRSS on nocturnal noise, age, gender, depression and stress, as well as the noise by gender interaction. The interaction term was used to assess the moderating effects of gender on the influence of nocturnal noise on NRS. When an interaction term was insignificant, the interaction term was removed from the regression model before the effect of nocturnal noise was reported. Adequacy of all models was assessed by examining the normal probability plot of residuals and the scatter plot of residuals against predicted values. All estimates were accompanied by 95% confidence intervals (CIs) and 5% nominal level of significance was used in all significance tests. The R package was used for the statistical analysis.

3. RESULTS

3.1 Sample Characteristics

A total of 90 eligible Chinese adults were recruited and completed the assessments. Their demographics are summarized in Table 1. There were 52 (58%) female subjects, and the average age was 37.0 years (range: 18-65). Table 2 summarizes the nocturnal noise level and NRS experienced by the participants.

3.2 Moderating Effects of Gender

Table 3 assesses the moderating effect of gender on the influences of nocturnal noise on NRS. The gender-by-nocturnal noise exposure interaction was significant ($p=0.043$) for the Refreshment from sleep domain of NRSS. The influence of nocturnal noise exposure on Refreshment from sleep was more profound in women (-1.00, 95% CI: -1.87 to -0.13) than in men (0.22, 95% CI: -0.57 to 1.01).

There was no significant gender by noise interaction and nocturnal noise effects on other domains of NRSS.

Table 1 – Demographic characteristics

Characteristics	Female (n = 52)	Male (n = 38)	Total (n = 90)
Age (years), mean	39.5 (SD=13.6)	33.6 (SD=12.4)	37.0 (SD = 13.3)
Marital status			
Single	24 (46.2%)	27 (71.1%)	51 (56.7%)
Married/Cohabitation	22 (42.3%)	11 (28.9%)	33 (36.6%)
Separated/Divorced/Widowed	6 (11.5%)	0 (0%)	6 (6.7%)
Education level			
Primary or below	2 (3.8%)	0 (0%)	2 (2.2%)
Secondary/Diploma/Associate degree	28 (53.8%)	12 (31.6%)	40 (44.4%)
Tertiary or above	22 (42.3%)	26 (68.4%)	48 (53.3%)

Table 2 – Nocturnal noise and nonrestorative sleep

Characteristics	Female (n = 52)	Male (n = 38)	Total (n = 90)
Nocturnal noise (dBA)	56.0 (SD = 4.8)	54.7 (SD = 6.2)	55.5 (SD = 5.5)
Nonrestorative sleep (0-100)			
Refreshment from sleep	58.3 (SD = 18.5)	55.9 (SD = 16.4)	57.3 (SD = 17.6)
Physical/medical symptoms of NRS	67.4 (SD = 17.1)	66.4 (SD = 16.4)	67.0 (SD = 16.7)
Daytime functioning	61.4 (SD = 14.7)	59.4 (SD = 16.4)	60.5 (SD = 15.4)
Affective symptoms of NRS	64.9 (SD = 22.6)	59.3 (SD = 20.1)	62.6 (SD = 21.6)
Global scale	62.9 (SD = 12.7)	60.6 (SD = 11.3)	62.0 (SD = 12.1)
HADS-Depression (0-21)	5.1 (SD = 3.1)	5.7 (SD = 3.2)	5.4 (SD = 3.2)
Perceived Stress Scale (0-40)	15.9 (SD = 5.0)	17.9 (SD = 5.0)	16.8 (SD = 5.0)

Table 3 – Impact of nocturnal noise on nonrestorative sleep

	Estimated effects for 1dBA increase in nocturnal noise (95% CI)		Moderating effect of gender
Nonrestorative sleep (0-100)	Female	Male	p-value
Refreshment from sleep	-1.00 (-1.87, -0.13)	0.22 (-0.57, 1.01)	0.043
Physical/medical symptoms of NRS	-0.03 (-0.65, 0.59)		0.304
Daytime functioning	0.01 (-0.52, 0.54)		0.450
Affective symptoms of NRS	0.32 (-0.42, 1.07)		0.785
Global scale	0.07 (-0.43, 0.56)		0.471

4. DISCUSSION

This was the first study to assess the moderating effect of gender on NRS. Women reacted more to nocturnal noise than men in their feeling of refreshment from sleep. More specifically, increased exposure to nocturnal noise reduced the degree of feeling refreshment from sleep in women but no effect was found in men. There are also epidemiological studies that show women have a longer sleep latency, report more sleepiness, sleep less, and have less non-rapid eye movement (NREM) stages 1 and 2 sleep than men (10). However, there is some evidence showing women have more slow wave sleep than men (11). Slow wave sleep allows our body to restore energy and strengthen the immune system. Yet, women had more complaints of sleep disorders than men (10). Moreover, the vulnerability of women towards noise is consistent to the hypothesized pathway of the influence of noise on ANS. There has been evidence showing that the ANS stress response system in women was more sensitive (12), and thus would make women more vulnerable to the impact of noise.

Several study limitations are worth noting. First, the sample size may preferably be larger to ensure adequate power for assessing the interaction effects. Moreover, the nocturnal noise effect on affective symptoms of NRS may be potentially significant should the sample size be larger. Second, we only assessed nocturnal noise exposure for at most one week. Longer-term assessment for better representativeness of noise exposure and its associated longer-term effect on NRS is desirable.

5. CONCLUSIONS

Women were more vulnerable than men to the adverse impact of nocturnal noise exposure on NRS. There has been research on the gender differences in sleep, but more epidemiological studies remain necessary to develop improved care for both men and women.

ACKNOWLEDGEMENTS

Financial support from the Health and Medical Research Fund (Project No.: 14150801) of the Food and Health Bureau of The Government of the Hong Kong Special Administrative Region is gratefully acknowledged.

REFERENCES

1. WHO. Burden of disease from environmental noise: Quantification of healthy life years lost in Europe. Theakston F, editor. Copenhagen: WHO Regional Office for Europe; 2011.
2. Daiber A, Kroller-Schon S, Frenis K, Oelze M, Kalinovic S, Vujacic-Mirski K, et al. Environmental noise induces the release of stress hormones and inflammatory signaling molecules leading to oxidative stress and vascular dysfunction-Signatures of the internal exposome. Biofactors. 2019.
3. Fong DYT, Wong JYH, Huang L. Effect of noise tolerance on non-restorative sleep: a population-based study in Hong Kong. BMJ open. 2018;8(3):e020518.
4. Wilkinson K, Shapiro C. Development and validation of the Nonrestorative Sleep Scale (NRSS). J Clin Sleep Med. 2013;9(9):929-37.
5. Li S, Fong DYT, Wong JYH, Wilkinson K, Shapiro C, Choi EPH, et al. Nonrestorative sleep scale: reliable and valid for the Chinese population. Quality of life research. 2019;28(6):1685-92.
6. Lekaviciute J, Kephalopoulos S, Stansfeld S, Clark C. Final Report: ENNAH - European Network on Noise and Health. In: Commission JRCotE, editor. Italy2013.
7. van Kamp I, Davies H. Noise and health in vulnerable groups: a review. Noise Health. 2013;15(64):153-9.
8. Basner M, McGuire S. WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Effects on Sleep. International journal of environmental research and public health. 2018;15(3).
9. Leung DY, Lam TH, Chan SS. Three versions of Perceived Stress Scale: validation in a sample of Chinese cardiac patients who smoke. BMC Public Health. 2010;10:513.
10. Mallampalli MP, Carter CL. Exploring sex and gender differences in sleep health: a Society for Women's Health Research Report. J Womens Health (Larchmt). 2014;23(7):553-62.
11. Redline S, Kirchner HL, Quan SF, Gottlieb DJ, Kapur V, Newman A. The effects of age, sex, ethnicity, and sleep-disordered breathing on sleep architecture. Arch Intern Med. 2004;164(4):406-18.
12. Verret B. Gender Differences in Autonomic Nervous System Reactivity to Stress: University of New Orleans; 2012.