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Original Article

Sleep fragmentation and sleep-disordered breathing in individuals living close to main roads: results from a population-based study

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ABSTRACT

Background: Nighttime traffic noise is associated with sleep disturbances, but sleep fragmentation and sleep-disordered breathing (SDB) have not been demonstrated in individuals living near busy roads.
Methods: We asked 1383 participants to answer a health questionnaire and to undergo 24-h electrocardiogram (ECG). Nocturnal ECG records were used to calculate the very low frequency index (VLFI) interval, a surrogate marker of sleep fragmentation. Distances of participants' addresses to roadways were calculated using the VECTOR25© Swisstopo roads classification, a traffic noise proxy. Distances of homes within 100 or 50 m of major roads defined proximity to busy roads. Adjusted multivariate logistic regressions analyzed associations between the distance of home to main roads and VLFI or self-reported SDB.
Results: Distance of participants' homes to main roads was significantly associated with the VLFI in women (odds ratio [OR], 1.58 [confidence interval {CI}, 1.03–2.42]; $P = .038$) but not in men (OR, 1.35 [CI, 0.77–2.35]; $P = .295$). Women under hormonal replacement therapy (HRT) were at higher risk for increased VLFI when living close to main roads (OR, 2.10 [CI, 1.20–3.68]; $P = .01$) than untreated women ($P = .584$). Associations with self-reported SDB were not statistically relevant.
Conclusions: In our large population, women living close to main roads were at significantly higher risk for sleep fragmentation than men. The 2-fold higher risk for menopausal women under HRT underscores the vulnerability of this group.

1. Introduction

Ambient noise is a well-established cause of nuisance. A large body of evidence gathered in the recent years consistently shows that persistent exposure to noise adversely impacts health, and its detrimental effects can vary from subjective symptoms (e.g., tiredness, irritability) to the development of systemic disease (e.g., hypertension, cardiovascular morbidity) and decrease in quality of life [1–6].

Road traffic during the night is a main source of noise affecting the quality of sleep in exposed individuals [7]. Changes in the sleep architecture induced by noise often have been reported to modify sleep stages, induce frequent arousals, and increase the duration of nocturnal awakenings. Sleep fragmentation reduces the total time of effective sleep resulting in chronic sleep deprivation, a disorder which frequently has been associated with daytime fatigue and decreased neurocognitive capacity [8,9]. Early experimental studies have shown that noise-induced sleep fragmentation impacts on daytime alertness [10]. In addition, it increases upper airway collapsibility [11]. Increased upper airway resistance and inspiratory efforts during sleep may lead to multiple arousals and are associated with sleep-disordered breathing (SDB), a large spectrum condition including patients with regular snoring to those with more severe disease such as those affected by obstructive sleep apnea–hypopnea syndrome (OSAS) [12]. Recurrent sleep fragmentation and obstruction of the upper airways leading to transitory oxygen desaturation and nocturnal arrhythmias frequently are present in patients with SDB [13].

The cardiovascular effects of exposure to traffic noise have been widely documented [3,14–17]. Traffic noise during sleep was

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related to autonomic arousals and increased heart rate [18]. Moreover, altered nocturnal heart rate variability (HRV) has been reported in individuals with SDB [19,20]. Analyzing the frequency domain of the 24-h electrocardiogram (ECG), Roche et al. [21] showed that the very low frequency segment of the spectrum reflects sympathetic activity, thus offering a relatively simple tool to assess the cardiac autonomic function. Further clinical studies by the same group have indicated that the very low frequency index (VLFI) derived from the frequency domain of the 24-h ECG is a surrogate marker of sleep fragmentation, notably when its value exceeds 4% [22,23]. In addition, the VLFI has been validated in a population of elderly individuals [24]. However, the potential link between living in close proximity to busy roads and the VLFI marker of sleep fragmentation has not been investigated.

The SAPALDIA (Swiss Study of Air Pollution and Health in Adults) cohort study has collected data on several health parameters including a 24-h ECG. The study also has maintained a long-term registry of participants' home addresses, which permits the calculation of the distance of individuals' dwellings to main roads and indirectly estimate the potential exposure to traffic noise during the nighttime. Therefore, the SAPALDIA database offered a unique opportunity to investigate the impact of living close to a main road on sleep fragmentation and self-reported SDB in a large population-based sample.

2. Methods

2.1. Design and study population

SAPALDIA is an adult population-based cohort study initiated in 1991 (SAPALDIA 1) and was designed to investigate the effects of air pollution on the respiratory and cardiovascular health of the Swiss population. The cohort started with 9651 participants randomly selected from the population registry including eight representative areas of the climatic, geographic, and cultural diversity of Switzerland. A follow-up survey (SAPALDIA 2) was conducted 11 years later with 8047 participants. Details on the study and the health assessments have been previously published [25,26]. Briefly during a 2-h visit to the SAPALDIA centers, participants answered a comprehensive standardized online questionnaire administered by a trained fieldworker. The questionnaire assessed, among other aspects, the general health status, risk factors (e.g., smoking, regular alcohol intake), systemic diseases, sleep-related disorders (e.g., OSAS), and sleep habits (e.g., keeping windows open in bedroom during the night), as well as perception of traffic density at home vicinity and noise annoyance. At the same occasion, a 24-h ECG holter monitor was conducted.

Our study included 1721 participants of the SAPALDIA 2 cohort (ages, $\geqslant$50 years), who answered the health questionnaire and underwent a 24-h ECG recording. After excluding participants reporting cardiovascular disease ($n = 91$), treatment of OSAS ($n = 14$), or regular use of β blockers ($n = 233$), the analyses comprised 1383 participants. Written informed consent was obtained from all study participants. The study was approved by the Swiss Academy of Medical Sciences and by the ethics committees of the regional study sites.

2.2. Assessment of distance of participants' homes to main roads

Participants' addresses recorded between SAPALDIA 1 and 2 were geocoded by matching the addresses to the building registry of the Swiss Federal Statistical Office. The length of street segments within a 200-m perimeter around the home coordinates of the study participants was determined using the VECTOR25© Swisstopo (Swiss Federal Office of Topography) classification [27]. Geographic information data obtained on participants' home addresses were used to determine the distance of individuals' homes to the upper three classes of roadways (freeway, highway, and cantonal roads) out of five different main classes. Consistent with previous work by our group, categorical variables were built combining these three upper classes of roadways further using critical distances of 100 m or 50 m of a main road. The distance within 100 m or 50 m of individuals' home address coordinated to the closest three classes of roadways identified by VECTOR25© was used to define proximity to a main road [28]. Details on the SAPALDIA assignment of individuals based on participants' home addresses were published before in the context of air pollution [29].

2.3. 24-h ECG monitoring and %VLFI measurement from HRV analysis

Participants who agreed to a 24-h ECG measurement received detailed instructions from trained fieldworkers who also placed the electrodes and started the ECG recording. The ECG recordings were performed using digital devices (Aria, Del Mar Medical Systems, Irvine, CA, USA) having a frequency response of 0.5–40 Hz and a resolution of 128 samples per second. Three leads were recorded: a V_1, a modified V_3 with the electrode placed on the intersection between the left midclavicular line and the lowest rib, and a modified V_5 with the electrode placed on the intersection of the left anterior axillary line and the lowest rib. Participants were asked to continue daily routine activities and to document their medication intake and daily activities by completing a standardized time-activity diary handed by the fieldworker, during the whole recording period. Overall, the mean duration of holter recordings was 22.3 ± 2.1 h. Full details on the HRV variables measurements and their interpretation have been previously published [30]. For the purpose of our study, only holter-recorded tracings comprised between approximately 10:00 pm and 6:00 am were considered for analyses. The average duration of sleep was estimated at 8.1 ± 1.0 h considering the individual's steady decrease of the heart frequency in the beginning of the night period and its increase in early morning as a proxy indicator of sleep status, also assuming that our participants were mostly night sleepers. HRV analyses were conducted by independent scorers blinded to other results obtained from participants included in the study.

Details on the calculation of the HRV domain variables were previously published [22]. Briefly, the HRV analysis was based on validated QRS segments and the calculation of the length of RR intervals. Only regular frequency beats and normal-to-normal beats were considered for analyses. Power spectral analysis of the interbeat interval increment was used to identify the very low frequency oscillations, which are mainly related to sympathetic activation. The frequency-domain component of the 24-h ECG was considered for analysis and the very low frequency power (0.00–0.04 Hz) was calculated. The VLFI generally is expressed as the percent ratio between the power spectral in the very low range over the total power spectral density; in other words, it corresponds to the percent increment interval calculated over the total power spectral density.

2.4. Variables of interest and covariates

The independent variable was the distance of cohort participants' addresses to a main road, as described above. The two main outcomes were VLFI as measured from the 24-h ECG and self-reported SDB using information provided by the health questionnaire. Self-reported SDB was defined by a composite variable combining participants' positive answers to questions addressing respiratory pauses during sleep identified by the partner or diagnosed by the doctor as untreated OSAS. In accordance with