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The Effect of Ehronic Nocturnal Noise Exposure on Subjective Sleep Quality of Hangzhou Citizens

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Abstract

Due to rapid urbanization, noise-related sleep disturbances are particularly prevalent in metropolitan areas. (United Nations Department of Economic and Social Affairs. (n.d.)) sThis study investigates how nocturnal noises in the urbanized city influence sleep quality to provide insights in tackling noise-related sleep disturbances. First, a web-based, cross-sectional survey was conducted with convenience and snowball sampling of 338 residents from five residences in Gongshu District, Hangzhou, China. Later, the objective noise exposure around the periphery of each residence was measured by a decibel meter, the level of nocturnal noise exposure was determined based on the Noise Exposure Questionnaire, and the perceived sleep quality was determined using a combined Pittsburgh Sleep Quality and Insomnia Severity Index questionnaire. Lastly, multiple regression models using stepwise variable selection were fitted to determine associations, adjusting for potential confounders. This study showed a significant negative association between nocturnal noise exposure (measured both objectively via a decibel meter and subjectively through the survey) and sleep quality. In the univariate regression model, participants' perceived level of noise disturbances was significantly negatively associated with perceived sleep quality (β=-0.126, p-value=0.020) in the multiple regression model, participants' perceived level of noise disturbances was significantly negatively associated with perceived sleep quality (β=-0.118, p-value=0.000), adjusted for confounding variables, namely volume of tea intake, time spent on outdoor activities, and other lifestyle factors (cellphone usage, midnight snacks intake) by stepwise method.Volume of tea intake was significantly associated positively with perceived sleep quality (β=0.096 and p-value=0.050). This study provided insights into urban nocturnal noise intervention to ensure qualified sleep. More research is needed to determine how nocturnal noise exposure affects objective sleep quality and threshold noise level.

Keywords: Chronic nocturnal noise exposure, Sleep quality, Hangzhou citizens, General linear modeling

1. Introduction

Due to mechanization, industrialization, transportation, and particularly urbanization, over 50% of the global population is exposed to noise (Public Health and Scientific Information | NCEH | CDC, n.d.). Noise is defined as any acoustic phenomenon that causes an unpleasant or disturbing sensation (Liu, F. F., et al. (2012)). Generally, chronic noise exposure leads to hearing impairment, hypertension, ischemic heart disease, annoyance, sleep disturbance, and decreased academic performance (Vermeer, 2000). Specifically, sufficient evidence has proved that nocturnal environmental noises can cause changes in sleep patterns, sleep stages, number of awakenings, perceived sleep quality, and next-day performance (Vermeer, 2000). Perceived sleep quality comprises perceived deepness of sleep, sleep duration, sleep disturbances, sleep latency, sleep efficiency, satisfaction with sleep, and the extent of being well-rested (Nelson et al., 2021).

Numerous epidemiologic studies have shown a strong association between noise exposure and sleep quality. Noise alters sleep architecture and, thus, perceived sleep quality. Nocturnal noise can lead to sleep fragmentation and redistribution of time spent in different sleep stages, typically increasing wake and stage 1 sleep and decreasing slow wave and rapid eye movement (REM) sleep, resulting in overall shallower sleep (Saremi et al., 2008). Comparative analysis of the effect of noise exposure on sleep quality in Shanghai has revealed that the duration of REM sleep was significantly (correlation coefficient=-0.176, p-value=0.043) shortened with the increase of sound intensity. The duration of deep sleep shortened, and subjective sleep quality worsened significantly (correlation coefficient=-0.191, p-value <0.05) with the increase of acoustic sensation vote (Xu et al, 2023). Thus, nocturnal noise exposure significantly impacts perceived sleep quality.

Nevertheless, many studies haven't considered other confounding variables such as nutrition structure, coffee, tea, and alcohol intake, daytime outdoor activities, and other lifestyle habits. Also, many studies use sound intensity to assess noise exposure without differentiating different noise sources with different frequencies, affecting perceived sleep quality to various extents (Xu et al., 2023). More than that, the sample sizes of current studies are small.

Thus, this study aims to investigate the effects of nocturnal noise exposure and perceived noise exposure on self-reported sleep quality through multiple regression models in Gongshu, Hangzhou district. Also, current studies focus on traffic noise and mediator or intermediate factors affecting subjective sleep quality. Policies and factors in the urban and natural environment that may mitigate or exacerbate exposure to street noise levels, including separation of humans and vehicles and restriction of human gatherings were excluded (McAlexander et al., 2015). This research could provide insights into noise intervention to improve sleep quality and offer suggestions for noise regulation.

The null hypothesis (H0) of this study is that there is no significant association between nocturnal noise exposure and perceived sleep quality. On the other hand, the alternative hypothesis is that there is a significant correlation between the two variables. The higher the level of nocturnal noise exposure, the worse the perceived sleep quality of citizens from five residences in Hangzhou.

2. Methods

2.1 Study design

A web, cross-sectional survey was conducted using a convenience and snowball sample of 338 residents from five residences (Zhong Ye, Wan Jia, Xi Wen, Guang Dian, and Shui Yin) between July 8th, 2023 and July 13th, 2023. Their names are substituted with A, B, C, D, and E, respectively, for convenience. These participants had expressed their willingness to be involved in the study and were contacted via was established through social media (WeChat) online and face-to-face offline. The survey consists of four sections: socio-demographic data, lifestyle data, subjective noise exposure, and sleep quality assessment to provide a comprehensive understanding of the participants. It is also important to note that this study was conducted within the Gongshu district in Hangzhou, which provides valuable insights into Hangzhou citizens living in the Gongshu district, especially the five residences mentioned above under investigation. Specifically, the Noise Exposure Questionnaire (NEQ) (Johnson et al., 2017) is referred to examine the perceived noise exposure, and a decibel meter is used to fathom the objective noise exposure. The assessment of sleep quality was determined using a combination of the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989a) and the Insomnia Severity Index (ISI) (Baghyahi et al., 2013). Associations with social-demographic variables were assessed through linear modeling with both univariant and multivariant models built.

Statistical concepts of standardized coefficients and p-values are incorporated to determine whether nocturnal noise exposure relates to the perceived sleep quality and the significance of this correlation. Standardized coefficients (β) suggest the strength and direction of the relationship between variables. When $\beta=0$, there is no relationship between nocturnal noise exposure and perceived sleep quality, and vice versa. T-test, a statistical significance test, is used in the linear regression model of numerical discrete variables. T-score refers to the number of standard deviations away from the mean in a t-distribution. A p-value in the t-test is the integration (the sum of area) under the t-distribution (Watts, 2022).

The P-value obtained by the t-test refers to the probability of data being equal to or more unlikely than the actual

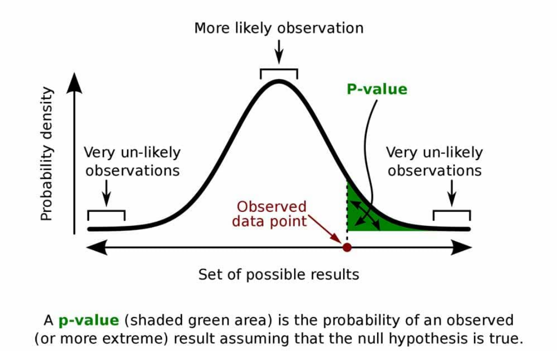

Figure1. Graphical display of the definition of p-value (Simply Psychology, 2023)

observed data under the null hypothesis (Dahiru, 2011). In this case, the p-value refers to the probability of the perceived sleep quality result being equal to or exceeding the observed result, as elucidated in the diagram below. Only when the p-value exceeds 0.05 is the correlation between variables significant.

2.2 Study area

To show the gradation of the noise exposure, five different residences are chosen based on different average decibels of noise, owing to various noise sources and distances between the noise source and residences. Electronic map Gaode's distance measurement function is used to find the shortest straight line to measure the actual distance according to the global positioning system (GPS) (Gaode map, n.d.). Specifically, the periphery of residence A has an average distance from the trestle of around 126m. The periphery of residence B has an average distance from the central business district (CBD) of 98.3m, respectively. The periphery of residence C has an average distance from the main roads of around 43.7 m. For residence D, the average distance from the periphery to the alley is 16.0m. For residence E, the average distance from the periphery to the street and metro station is 33.0m. The calculation processes are summarized in supplementary materials. As shown in the map below, Residence A is mainly affected by transportation noise from the trestle. Noises from transportation and human activities majorly influence residence B. Residence C is mainly affected by transportation noises from the main road and noises from the supermarket. Residence D is mildly affected by noise from a small road. Residence E is impacted by low transportation noise and is protected from dense vegetation and rivers. Noise in these five residences can be classified into five categories: Human activities, transportation, construction, human gatherings, and other noises. Characteristics of five residences are summarized below in the table (Table 1) and the map (Figure 1).

Table 1. Characteristics of five residences and corresponding noise exposure (Garg, 2022)

Residence name	**Main noise sources**	**Average distance from the noise sources**	**Estimated outdoor noises (decibels)**
Residence A	Transportation noise on the highways and public natural park	126.0m	90~110 db
Residence B	Noises caused by human gatherings and activities in central business district	98.3m	80~100 db
Residence C	Transportation noises on the main roads	43.7 m	70~90 db
Residence D	Transportation noises from the small roads	16.0m	60~90 db
Residence E	Natural noises of cicada and noises from the small road.	33.0m	50~70db

2.3 Study population

The population of this study is citizens in Hangzhou of all ages in the five residences mentioned above. Cochran's formula was used to determine the desired sample size (Cochran, W.G., 1963).

$$n = \frac{Z^2 \times P(1-P)}{\varepsilon^2}$$

where z is the z score, ε is the margin of error, N is the population size, and p is the population proportion (use 0.5

when unknown). In this study, the standard score (Z value) with 95% confidence level and 5% margin of error is:

$$invNorm(0.975, 0,1) = 1.95996 \approx 1.96$$

Therefore, the sample size with a finite population of 660 students can be calculated as 385. As a result, the desired sample size was 385 samples.

2.4 Perceived sleep quality

The study uses a combined Pittsburgh Sleep Quality Index (PSQI) and Insomnia Severity Index (ISI) to measure the subjective sleep quality of citizens in Hangzhou. PSQI measures sleep latency, duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. The time spent to complete this questionnaire is typically 5 minutes. Besides, it has high reliability and validity. Also, the psychometric properties of PSQI are widely assessed; the developers suggested that the internal reliability is α=0.83, a test reevaluate reliability of 0.85 for the global scale, a sensitivity of 89.6%, and a specificity of 86.5%. However, the original age range is 24–83 for a comprehensive clinical span. A current study has shown that PSQI is reliable among the elder centenarians in China. The Cronbach's α coefficient of the PSQI was 0.68, which increased to 0.78 after two components (medication use and daytime dysfunction) were removed (Zhang et al., 2020). Since the research subjects are of all age groups, PSQI was chosen.

The reason why ISI was adopted is the pooled prevalence of insomnia in China is 15.0% (95% Confidence interval [CI]: 12.1%-18.5%) (Baghyahi et al., 2013). Therefore, it's an important factor to be considered. Besides, ISI measures the severity of symptoms and the respondent's satisfaction with sleep patterns. Only people with insomnia will be asked questions in the ISI scale to determine how seriously their sleep qualities are harmed. Moreover, the internal consistency determined by designers is α= 0.74 and found item-total correlations that were quite variable, ranging from 0.36 to 0.54. According to the study related to the reliability and validity of the Chinese translation version, the Cronbach-α coefficient of the Chinese version for the clinical group, control group, and both was 0.72, 0.75, and 0.91, respectively. The total scores of C-ISI (Chinese Insomnia Index) were significantly correlated with its related components and total scores in the retest ($P < 0.05$). Since there are significant correlations between the C-ISI component and total scores and the C-PSQI component and total scores in related items, similar questions were ruled out to make sure that the two sections of the questionnaire are independent, avoiding the problem of collinearity.

2.5 Noise exposure assessment

Noise level can be quantified using decibels, a measure of sound intensity. The data collection involves gathering information on nocturnal noises emitted by various noise sources within a 1-kilometer radius from 8:00 p.m. to 10:00 a.m. the next day. The noise sources are summarized above in Table 1. The noise level in decibels is measured using a decibel meter. REED 8080 was used to record decibels of noises and store the data using its internal memory function. Before measuring noises, the decibel meter is calibrated using a standardized 94dB sine wave played by a calibrator directly, and the sound level meter is adjusted until it shows a reading of precisely 94 dB. Press the red "turn-on" button to open the device, point the device's probe toward the direction of noise sources, and record the maximum noise data (Blake, 2022).

2.6 Covariates

Covariates included in the analysis were selected based on current knowledge of potential confounders associated with perceived sleep quality. Demographic characteristics considered were sex (male or female) current ages(from below 18 to beyond 60); education background (classified as below middle school, high school or secondary school, specialty university, bachelor degree, master degree, and higher), height (ranging from below 140cm to beyond 185cm) weight (varied from below 20kg to beyond 100kg); jobs (classified as marketing management, procurement and logistics, administration, human resources management, art and design, lawyers, finance and accounting, service industries, doctors and nurses, teachers, housewives, governmental servants, farmers, retired workers, freelancers, and students).

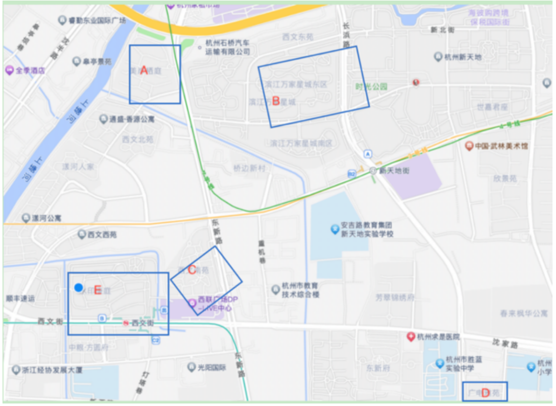

Figure 2. Map of five residences (A, B, C, D, and E) (Gaode map, n.d)

Dietary habits included were (self-reported eating or not eating dinner; time; nutritional structure; coffee and tea intake frequency, volume, and time). Other lifestyle-related characteristics were daytime outdoor activities and digital devices used before sleep. Besides, sleep-related diseases are screened, including Insomnia, Obstructive Sleep apnea, Parasomnias, Narcolepsy, and Restless Leg disorder (Karna, 2023).

2.7 Statistical analysis

In this study, Pearson's correlation analysis was done to examine the correlation between nocturnal noise exposure and subjective sleep quality. The detailed models were constructed hierarchically, starting with Model 1 (simple regression model), which included only subjective nocturnal noise disturbance and subjective sleep quality rating of the participants. Subsequently, Model 2 (regression model) was developed, incorporating confounding variables such as social-demographic data, including ages, jobs, dietary habits, and daytime activities.

To assess the associations between nocturnal noise exposure and sleep quality, the study computed relative risk along with 95% confidence intervals (CIs). Differences were considered statistically significant if $p < 0.05$ (two-sided). Multiple regression models made were considered significant if $p < 0.05$. Adjustments were made for potential confounders, and beta values were analyzed to determine whether the association is negative or positive. The covariates considered in the analysis included (coffee, tea, and alcohol drinking, day-time activity, dietary habits, occupations, and other factors affecting perceived sleep quality). The results of the univariate model for nocturnal noise exposure and perceived sleep quality, as well as the stepwise regression model with confounders, were reported.

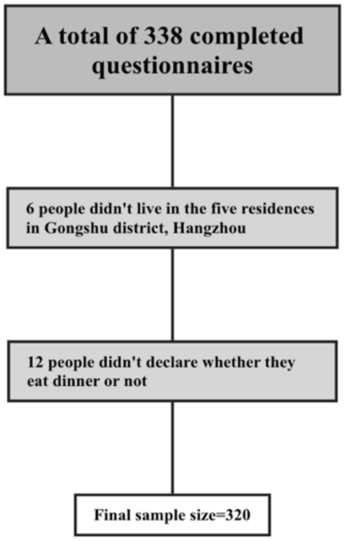

Figure 3. Numbers of residents excluded based on fulfillment of various eligibility criteria

Descriptive statistics summarize the data, providing numerical information on the effect of nocturnal noise levels on subjective sleep quality. Data management and analysis were conducted using SSPSAU (version 23.0) (SPSSAU_correlation|regression_factors|standard deviation_SPSS download-online SPSS analysis application, n.d.).

3. Results

3.1 Participant characteristics

A final sample size of n=320 effective questionnaires was collected, with 18 invalid responses excluded and a sample size response rate of 94.7%, according to the participant eligibility criteria demonstrated in Figure 2.

Among 320 eligible participants, 35.21% (n=113) of data was collected in residence E, where the researcher lived, 11.83% (n=38) was organized in residence A, 23.37% (n=75) was collected in residence B, 19.60% (n=63) was collected in residence C, and 10.00% (n=31) was organized in residence D. Based on the field research, residence A has only 30% occupancy, and residence D is of a small-size, so fewer data were obtained.

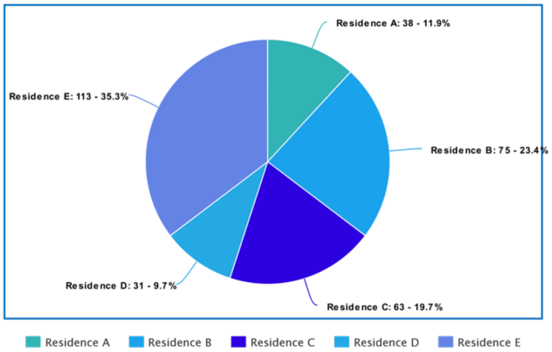

Figure 4. Number of participants recruited in different residences

3.2 Noise exposure

In Table 2, nocturnal noise exposures of households were measured as the sum of frequency, seriousness, and protective measures in five residences. Percentage and number of residents affected by noises over 50% of a month in different residences is compared. In residence A, among 40 residents, 20.0% (n=8) were affected by noise 16~30 days within the last month. In residence B, among 79 individuals, 11.4% (n=9) were affected by noise 16~30 days a month. In residence C, among 64 samples, 23.45% (n=15) were affected by noise 16~30 days a month. In residence D, among 30 samples, 23.33% (n=7) were affected by noise 16~30 days within the last month. In residence E, among 119 individuals, 7.00% (n=6) were affected by noise for 16~30 days within the previous month. Related data are summarized below.

Table 3. Perceived sleep quality with respect to residences from A to E

Frequency	**Extremely severely**	**Seriously**	**Generally**	**Mildly**	**Not at all**	**Total**	**Average score**
A	9(22.50%)	15(37.50%)	8(20.00%)	5(12.50%)	2(5.00%)	1(2,50%)	2.62
B	5(6.33%)	12(15.19%)	29(36.71%)	18(22.78%)	14(17.72%)	1(1.27%)	1.69
C	7(10.94%)	13(20.31%)	28(43.75%)	10(15.63%)	4(6.25%)	2(3.13%)	2.15
D	5(6.67%)	8(26.67%)	7(23.33%)	5(16.67%)	3(10.00%)	2(6.67%)	2.25
E	6(5.04%)	18(15.13%)	40(33.61%)	47(39.50%)	7(5.88%)	1(0.84%)	1.74

Therefore, residence A has the largest range of 26.7 dB, while residence E has the smallest range of 18.6 dB. Thus, the differences between the building with maximum noise exposure and that with minimum noise exposure are relatively large, suggesting that distance from the noise source plays a key role in determining the level of noise exposure. As shown in the diagram below, among 320 residents, with 6 people who left the question blank, 23.08% living 10-39 meters away, and 20.12% living 220 meters away. Also, residence C has the highest IQR, the central 50% calculated using Q3-Q1, indicating the highest level of dispersion of data. Factors including the size of the residence, the density of the building, policies, etc. can affect the distribution of data. Also, since the lower the IQR, the more reliable and consistent the data are, statistics about residence E demonstrate better reliability and consistency.

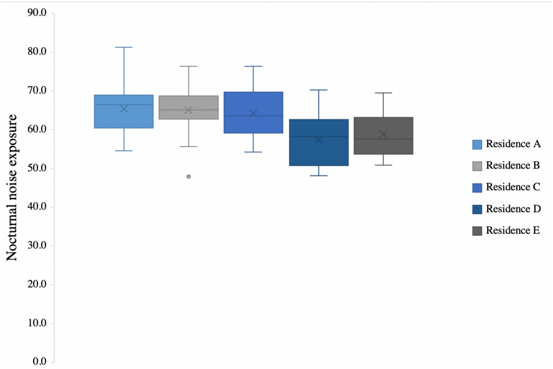

Figure 5. Box-whisker diagram of objective nocturnal noise exposure from 20:00 p.m~8:00 a.m of five residences

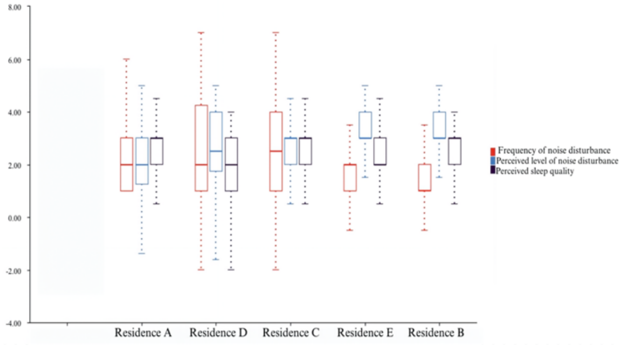

Figure 6. Box-whisker diagram of objective and perceived nocturnal noise exposure and perceived sleep quality of five residences

3.3 Model1 (univariate regression model)

Model 1 is the basic model displaying the relationship between the perceived level of nocturnal noise disturbances (exposure) and perceived sleep quality (health outcome) using linear regression.

The model R^2 is 0.016 means that nocturnal noise disturbances can explain the 1.6% change in perceived sleep quality in the last month, overall. An F-test of the model found that the model passed the F-test (F=5.441, p=0.020), which means that, as a whole, the degree of noise disturbance will have a statistically significant impact on the subjective sleep quality in the previous month. The value of the regression coefficient is 0.126 (t=2.333, $p=0.020<0.05$), which means that, on balance, subjective nocturnal noise disturbances have a significant negative impact on perceived sleep quality in the latest month. (The higher the score of perceived sleep quality, the worse the sleep quality) Parameters of model 1 are presented in Table 4.

Table 4. Linear regression of the relationship between noise exposure and sleep quality (n=320)

	unstandardized coefficient	standardized coefficient	t	p
	B	Beta (β)		
Constants	1.97	-	12.962	0.000**
Subjective nocturnal noise disturbances	0.111	-0.126	2.333	2.333*
R^2		0.016		
Adjusted R^2		0.013		
F		F (1, 336) =5.441, p=0.020		

Health outcome: perceived sleep quality in the previous month; * $p<0.05$ ** $p<0.01$

3.4 Model 2 (multivariant regression model)

Model 2 incorporates confounding variables, including dietary structure, coffee and tea intake, and lifestyle factors besides noise disturbances and distance of residences from noise sources. step-wise regression is used to select variables, which avoids potential collinearity problems.

According to the F test (F=19.081, $p=0.000<0.05$), the model is statistically effective. Based on the correlation coefficient, only the average volume of tea intake positively correlates with perceived sleep quality (=0.096). All other variables negatively correlate with sleep quality (Higher scores in PSQI and ISI represent worse sleep quality) (Forouzanfar et al., 2021). Parameters of model 2 are summarized in Table 5 and visualized in Figure 4. Specifically, Confounding variables are average outdoor time (β=-0.160, p-value=0.001), frequency of noise exposure (β=-0.326, p-value=0.000), Subjective nocturnal noise disturbances (β=-0.118, p-value=0.023), and other factors, including nocturnal screen exposure and snacks intake (β=-0.233, p-value=0.000) were included to build the final model explaining the relationship between time spent on practicing musical instruments and the intensity of jitteriness.

Moreover, based on the collinearity test, VIF values are all smaller than 5 and tolerance values are all larger than 0.2. These data mean that there is no collinearity problem. Therefore, the model can explain the relationship between nocturnal noise exposure and subjective sleep quality.

Table 5. Step-wise regression of the relationship between noise exposure and sleep quality (n=320)

<table>
<tr><th colspan="2" rowspan="2"></th><th>Unstandardized coefficient</th><th>Standardized coefficient</th><th rowspan="2">t</th><th rowspan="2">p</th><th colspan="2">Collinearity</th></tr>
<tr><th>B</th><th>Beta (β)</th><th>VIF</th><th>Tolerance</th></tr>
<tr><td colspan="2">Constants</td><td>1.136</td><td>-</td><td>6.655</td><td>0.000**</td><td>-</td><td>-</td></tr>
<tr><td colspan="2">Average volume of tea intake</td><td>-0.049</td><td>0.096</td><td>-1.97</td><td>0.050*</td><td>1.02</td><td>0.981</td></tr>
<tr><td colspan="2">Average time spent on outdoor activities</td><td>0.094</td><td>-0.160</td><td>3.243</td><td>0.001**</td><td>1.047</td><td>0.955</td></tr>
<tr><td colspan="2">Frequency of noise exposure</td><td>0.205</td><td>-0.326</td><td>6.538</td><td>0.000**</td><td>1.064</td><td>0.94</td></tr>
<tr><td colspan="2">Subjective nocturnal noise disturbances</td><td>0.103</td><td>-0.118</td><td>2.29</td><td>0.023*</td><td>1.127</td><td>0.887</td></tr>
<tr><td colspan="2">Nocturnal screen exposure and snack intake</td><td>0.190</td><td>-0.233</td><td>4.691</td><td>0.000**</td><td>1.054</td><td>0.949</td></tr>
<tr><td>R^2</td><td>0.223</td><td colspan="3">Adjusted R^2</td><td colspan="3">0.212</td></tr>
<tr><td>F</td><td>F (5,332) =19.081, p=0.000</td><td colspan="6">Health outcome: perceived sleep quality in the previous month; * $p<0.05$ ** $p<0.01$</td></tr>
</table>

4. Discussion

In this cross-sectional study, the relationship between nocturnal noise exposure and perceived sleep quality is analyzed through multiple linear regression. The study specifically focused on assessing, Gongshu district, Hangzhou, China. Both online and face-to-face recruitment methods were used to distribute the web-based questionnaire utilizing convenience sampling and snowball sampling. The quantitative data was gathered quickly, between July 8th 2023 and July 13th 2023.

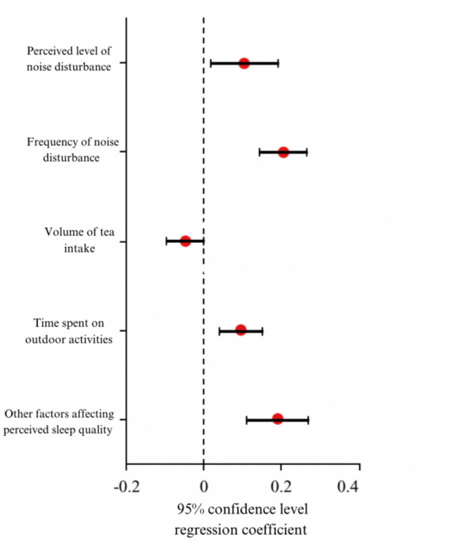

Figure 7. 95% regression coefficient about the effect of perceived noise disturbance, frequency of noise disturbance, volume of tea intake, time spent on outdoor activities, and other factors (nocturnal screen usage and mid-night snack intake) affecting perceived sleep quality on perceived sleep quality

This study shows a similar relationship between nighttime noise exposure and perceived sleep quality. Other research suggests that noise harms perceived sleep quality. In particular, among 160 families, 19% of the children (n = 31) and 30% of the parents (n = 48) reported that road traffic noise "often or always" disturbed their sleep, in the general population (n=18000) (Öhrström et al., 2006b), chronic exposure to road traffic noise is also associated with an increased risk of morning tiredness. Logistic regression shows a significant positive association between exposure to road traffic noise at home and the likelihood of feeling not well rested in the morning (De Kluizenaar et al., 2009).

The study has several advantages. First, the questionnaire contains many possible confounders, including heights, weights, ages, occupations, dietary patterns, outdoor activities, and other factors affecting the perceived sleep quality. Second, both objective levels of noise exposure and perceived noise disturbance are measured to ensure a holistic picture of nocturnal noise exposure. Third, participants were recruited swiftly to make sure that they had similar perceived noise disturbance.

The study has several limitations. First, the research only used subjective sleep quality as an indication instead of using a combination of subjective and objective measurements. As suggested by other studies, Objective sleep quality comprises not only the total sleep duration but also the sleep architecture (time spent on different sleep stages), the amount of wakefulness during the sleep episode, and the number of awakenings during the night (O'donnell et al., 2009). Although subjective sleep quality questionnaires such as PSQI and ISI contain both quantitative and qualitative, including sleep-rating measures, estimation of sleep duration, latency, waking during the night, and medications, subjective sleep quality was related more to sleep efficiency and continuity (Buysse et al., 1989b). Furthermore, polysomnography (PSG), often used in objective sleep quality analysis, collects physiologic parameters during sleep. This measurement incorporates electroencephalogram (brainwave detection), electrooculogram, electromyogram, electrocardiogram, pulse oximetry, airflow, and respiratory effort to evaluate for underlying causes of sleep disturbances and disorders (Rundo & Downey, 2019). As a further improvement, more advanced devices like PSG should be used to elevate the study's accuracy and reduce systematic error.

Second, on average, the questionnaire containing four sections and 50 questions takes average of 600.02 seconds (10 minutes). Recruiting participants by convenience and snowball sampling took a lot of work, because most of the participants complained that the questionnaire was too long. Specifically, 976 people had accessed the link, but only 338 people had completed it, with a completion rate of 34.63%. For future improvement, a questionnaire should be more concise. The study can combine some questions like frequency, volume, and time of coffee drinking as one.

This study also implies some future research needs. Short-term noise monitoring in three categories: source, pathway, and receptor sites, was conducted in this study. However, chronic exposure to noises should be measured over a more extended period for more accurate results. Long-term noise exposure measurement describes the overall "total noise environment," including estimates of individual, group, community, and total population exposures. At the same time, more advanced technologies can be used to measure the average noise exposure level (LEQ) and the maximum noise level (LMAX) in a-weighted decibels (dBA) (Proposal for Monitoring Worldwide Noise Exposure and Assessing the Effectiveness of National Noise Control Policies and Regulations. | NPL Publications, n.d.). Also, ambient noise tomography using abundant microseisms of different frequency bands for multiscale seismic imaging is a promising technique with high social acceptance and low economic cost to effectively and directly measure chronic noise exposure. Furthermore, replication of this research among a large representative sample of Hangzhou citizens would be appropriate to draw a more precise conclusion. Also, longitudinal research is needed to investigate how a particular population gets accustomed to chronic noise exposure (Thompson et al., 2022).

Overall, this study emphasizes the importance of noise intervention such as separation of people and vehicles and the restriction of construction at certain times. Furthermore, smoking as a confounding variable interfering with sleep quality was excluded from the study. Research data have shown that poorer sleep quality at baseline was associated with increased smoking cessation (p-value=0.0043), craving (p-value=0.2471), and total urges to smoke (p-value=0.0118). So, lower withdrawal, craving, and entire smoking urge lead to better sleep quality. More specifically, compared to individuals who do not smoke, those who smoke cigarettes are more likely to experience sleep problems such as sleep-disordered breathing, sleep apnea, insomnia, and poor sleep quality, characterized by sleep disturbances such as shorter sleep duration, increased sleep latency, and daytime sleepiness (Purani et al., 2019).

5. Conclusion

In conclusion, the null hypothesis is rejected, and chronic nocturnal noise exposure is associated negatively and significantly with subjective sleep quality ($\beta=-0.126$, p-value=0.020). Confounding variables, including overall nocturnal noise disturbances, volume of tea intake, time spent on daily outdoor activities a day, and other factors affecting sleep quality, are included to build the final model explaining the relationship between nocturnal noise exposure and perceived sleep quality. Within these confounders, the volume of tea intake was significantly associated positively with perceived sleep quality ($\beta=0.096$ and p-value=0.050). For a holistic evaluation of the research, the research has its benefits of incorporating confounders, measuring both objective and subjective noise exposure using a decibel meter and Noise Exposure Questionnaire (NEQ), respectively, and surveying participants within a short period. Nonetheless, the research can be improved by measuring objective and perceived sleep quality separately, shortening the length of the questionnaire to maintain participants' focus, and expanding the time for a nocturnal noise exposure monitor.

References:

68% of the world population projected to live in urban areas by 2050, says UN | UN DESA | United Nations Department of Economic and Social Affairs. (n.d.). https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html

Baghyahi, S. B. A., et al. (2013). 2738 – Reliability and validity of the chinese translation of insomnia severity index (C-ISI) in chinese patients with insomnia. *European Psychiatry*, *28*, 1. https://doi.org/10.1016/s0924-9338(13)77338-3

Blake, J. (2022). Best sound level meter (That actually records data) — acoustic nature. *Acoustic Nature*. https://acousticnature.com/journal/best-sound-level-meter-for-recording

Buysse, D. J., et al. (1989a). The Pittsburgh sleep quality index: A new instrument for psychiatric practice and research. *Psychiatry Research-neuroimaging*, *28*(2), 193–213. https://doi.org/10.1016/0165-1781(89)90047-4
Cochran, W.G. (1963) *Sampling Technique. 2nd Edition, John Wiley and Sons Inc., New York. - References - Scientific Research Publishing*. (n.d.). https://www.scirp.org/(S(i43dyn45teexjx455qlt3d2q))/reference/ReferencesPapers.aspx?ReferenceID=1837525

Dahiru T. (2008). P - value, a true test of statistical significance? A cautionary note. *Annals of Ibadan postgraduate medicine*, *6*(1), 21–26. https://doi.org/10.4314/aipm.v6i1.64038

De Kluizenaar, Y., et al. (2009). Long-term road traffic noise exposure is associated with an increase in morning tiredness. *Journal of the Acoustical Society of America*, *126*(2), 626–633. https://doi.org/10.1121/1.3158834

Forouzanfar, F., et al. (2021). The beneficial effects of green tea on sleep deprivation-induced cognitive deficits in rats: the involvement of hippocampal antioxidant defense. *Heliyon*, *7*(11), e08336. https://doi.org/10.1016/j.heliyon.2021.e08336
Gaode map. (n.d.). https://www.amap.com/

Garg, N. (2022). Noise sources: Characteristics and control. In *Springer eBooks* (pp. 27–62). https://doi.org/10.1007/978-3-030-87828-3_2

Johnson, T. A., et al. (2017). Noise Exposure Questionnaire: A Tool for Quantifying Annual Noise Exposure. *Journal of the American Academy of Audiology*, *28*(01), 014–035. https://doi.org/10.3766/jaaa.15070

Karna, B. (2023, January 26). *Sleep disorder*. StatPearls - NCBI Bookshelf. https://www.ncbi.nlm.nih.gov/books/NBK560720/

Liu, F. F., (2022). On the definition of noise. Humanities & Social Sciences Communications, 9(1). https://doi.org/10.1057/s41599-022-01431-x

McAlexander, T., Gershon, R. R., & Neitzel, R. L. (2015). Street-level noise in an urban setting: assessment and contribution to personal exposure. Environmental Health, 14(1). https://doi.org/10.1186/s12940-015-0006-y

Nelson, K. L., Davis, J. E., & Corbett, C. F. (2021). Sleep quality: An evolutionary concept analysis. Nursing Forum, 57(1), 144–151. https://doi.org/10.1111/nuf.12659

O'donnell, D., et al. (2009). Comparison of subjective and objective assessments of sleep in healthy older subjects without sleep complaints. Journal of Sleep Research, 18(2), 254–263. https://doi.org/10.1111/j.1365-2869.2008.00719.x

Öhrström, E., et al. (2006). Effects of road traffic noise on sleep: Studies on children and adults. Journal of Environmental Psychology, 26(2), 116–126. https://doi.org/10.1016/j.jenvp.2006.06.004

Passchier-Vermeer, W., & Passchier, W. (2000). Noise exposure and public health. Environmental Health Perspectives, 108(suppl 1), 123–131. https://doi.org/10.1289/ehp.00108s1123

Proposal for monitoring worldwide noise exposure and assessing the effectiveness of national noise control policies and regulations. | NPL Publications. (n.d.). https://eprintspublications.npl.co.uk/2268/

Public Health and Scientific Information | NCEH | CDC. (n.d.). https://www.cdc.gov/nceh/hearing_loss/public_health_scientific_info.html

Purani, H., Friedrichsen, S., & Allen, A. M. (2019). Sleep quality in cigarette smokers: Associations with smoking-related outcomes and exercise. Addictive Behaviors, 90, 71–76. https://doi.org/10.1016/j.addbeh.2018.10.023

Rundo, J. V., & Downey, R. (2019). Polysomnography. In *Handbook of Clinical Neurology* (pp. 381–392). https://doi.org/10.1016/b978-0-444-64032-1.00025-4

Saremi, M., et al. (2008). Effects of nocturnal railway noise on sleep fragmentation in young and middle-aged subjects as a function of type of train and sound level. International Journal of Psychophysiology, 70(3), 184–191. https://doi.org/10.1016/j.ijpsycho.2008.08.002

Simply Psychology. (2023, October 13). *Understanding P-Values and statistical significance*. https://www.simplypsychology.org/p-value.html
SPSSAU_correlation|regression_factors|standard deviation_SPSS download-online SPSS analysis application, n.d.

Thompson, R., et al. (2022). Noise pollution and human cognition: An updated systematic review and meta-analysis of recent evidence. *Environment International*, *158*, 106905. https://doi.org/10.1016/j.envint.2021.106905

Watts, V. (2022, September 1). 13.6 Testing the regression coefficients. Pressbooks. https://ecampusontario.pressbooks.pub/introstats/chapter/13-6-testing-the-regression-coefficients/

Xu, X., et al. (2023). The effect of noise exposure on sleep quality of urban residents: A comparative study in Shanghai, China. Building Simulation, 16(4), 603–613. https://doi.org/10.1007/s12273-022-0972-2

Zhang, C., et al. (2020). Reliability, Validity, and Factor Structure of Pittsburgh Sleep Quality Index in Community-Based Centenarians. *Frontiers in Psychiatry*, *11*. https://doi.org/10.3389/fpsyt.2020.573530