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EFFECT OF OCCUPATIONAL NOISE ON THE NOCTURNAL SLEEP ARCHITECTURE OF HEALTHY SUBJECTS

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Abstract : Background & objectives : Noise is considered to be a non-specific stressor which generally causes physiological and psychological effects in an individual. Many occupations involve workers being subjected to loud noise levels without adequate protective measures. The study was done to document the changes, if any, in the nocturnal sleep architecture of healthy persons exposed to loud occupational noise during daytime.

Methods : The study was a retrospective cohort design wherein three groups of eight subjects each, exposed to continuous occupational background noise levels of >75dB for 1–2 years, 5–10 years and >15 years were selected. Corresponding age and gender matched healthy controls (eight for each group) who worked in a quiet atmosphere were also recruited. All night sleep polysomnography was done on all subjects. In the morning, subjects rated their quality of sleep on a Visual Analogue Scale.

Results : There is a strong association between occupational exposure to loud noise and poor sleep efficiency (Relative Risk 2.49; Confidence Interval 1.12 to 5.57; P=0.01, Fisher's exact test). The group exposed to noise for 1–2 years had a decrease in Total Rapid Eye Movement Time, Non Rapid Eye Movement Time, Slow Wave Sleep Time, Sleep Onset Latency and Total Sleep Time. The other two groups showed lesser number of changes in sleep architecture. Subjectively there was a decrease for sleep continuity in Group I and an increase for sleep onset in Group II. There is no correlation between loudness of noise in the workplace and sleep efficiency.

Interpretation and conclusion : It can be concluded that workers exposed to loud background occupational noise are at an increased risk of having poor quality sleep but adaptation to this effect probably takes place after a few years.

Key words : noise occupational noise sleep
sleep architecture sleep quality

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INTRODUCTION

Noise is one of the commonest occupational health hazards. Though noise-induced permanent hearing loss is the main concern related to occupational noise exposure, the non-auditory effects of noise on cardiovascular function (1, 2), breathing, sleep, physical and mental health are serious enough to be a cause for concern. The wide range of effects on health caused by noise has led to the belief that noise may act as a general, non-specific stressor since the evidence suggests that the reaction to noise is similar to other stressors (4). Loud noise presented to rodents has been shown to cause an increase corticosterone levels which is a marker of stress (5). Noise stress is one of the well established models for studying stress in animals. Nocturnal sleep is commonly affected in stress (6). Insomnia, early morning awakening, waking up many times at night and having difficulty going back to sleep, sense of feeling unrefreshed after waking up are some of the sleep related effects of stress in individuals (6). Sleep is one of the most important physiological functions which is known to affect daytime activity, vigilance, concentration and performance. Hence an assessment of sleep could be considered an indicator of good health and well being of a worker.

Though many of the non-auditory effects of occupational noise have been documented (7, 8), the effects of it on the nocturnal sleep of workers have not been studied. Noise is a well known stressor, and physical and psychological stressors have been shown to interfere with sleep. Poor quality sleep is well known to interfere with normal day to day activities and decreased work efficiency (10). Many industrial workers in India are exposed to loud occupational noise throughout the length of their workday (11). Whether this constant exposure to loud noise could lead to changes in sleep architecture has not been studied before. Hence this study was planned to document and compare the impact of loud occupational noise on the subjective and objective effects on sleep architecture of individuals who are exposed to loud, continuous noise for an entire workday with those who work in a quiet environment. We also decided to look for any temporal effects of noise exposure on sleep.

METHODS

The study was a retrospective cohort design, conducted in Pondicherry, South India on subjects who were all natives of Pondicherry between April 2000 and March 2001. Twenty four subjects exposed to loud occupational noise [background noise level of >75dB(A)] throughout their workday and an equal number of matched controls were recruited for the study. These subjects were further divided into three groups of eight subjects each working in mills or driving autorickshaws for 1–2 years (Group I), 5–10 years (Group II) and >15 years (Group III). Only healthy adults between 20–45 years were chosen. For each of these groups age and gender matched controls working in a quiet atmosphere were chosen. Quiet atmosphere was defined for the purposes of this study as a workplace where the average sound levels was <45dB(A). Exclusion criteria were those on medication for systemic or metabolic disease, regular alcohol intake, psychiatric illness and those with perceived hearing loss. All subjects were declared healthy after a medical examination. None of the subjects wore ear protective devices at work. The clearance of the institute ethics committee was obtained and all subjects gave written informed consent in Tamil, prior to the study.

Subjects came to the Sleep Disorders Laboratory at JIPMER, Pondicherry after a light meal at 20.00 hrs. Each subject slept for a total of three nights in the sleep laboratory. The first night was an acclimatization night where no recording was done but they slept with all electrodes attached to them. All night sleep polysomnography was done on the successive two nights and the results were an average of two nights' recordings. The polysomnographic montage consisted of electroencephalography, electro-oculography, electromyography and electrocardiography. Standard leads were used for monitoring. Recording was done using computerized polysomnography equipment (Alice 3), from Healthdyne Technologies (USA). Data was stored on magneto-optical disks with a capacity of 640 MB for scoring later. Sleep scoring was done according to established criteria of Rechtschaffen and Kales (12) using an epoch by epoch method. Length of each epoch was 30 sec.

In the morning, after the sleep study was completed, subjects were asked to rate their sleep quality during the previous night on three parameters, i.e. sleep onset latency, sleep continuity and sense of refreshed sleep. These were recorded on three separate 10 cm visual analogue scales (VAS) which recorded the poorest estimates of sleep at zero and the best estimates at 10 cm (13). The VAS were translated into Tamil, a language with which all subjects were familiar. The subjects were allowed to go home after this test.

Sleep onset latency (SOL) was the time taken from lights out to the first epoch of State 1 sleep which is followed by at least five minutes of Stage 1 or other sleep stages. Total Sleep Time (TST) was the time spent in minutes in Non Rapid Eye Movement (NREM) and Rapid Eye Movement (REM) sleep. Time in Bed (TIB) was the time (min) spent in bed from lights out to lights on. Sleep period time (SPT) is the total time spent from sleep onset to the last epoch recorded as sleep. Sleep efficacy was calculated using the formula TIB-TST/TSTX100.

Sound levels at the workplaces of the test and control subjects were measured using a Sound level meter. This was done by field scientists of the Department of Science, Technology and Environment, Govt. of Pondicherry, India.

Statistical analysis was done using Prism 3 for Windows version 3.0, GraphPad Company, USA. Student's unpaired 't' test was done to compare the means between controls and test subjects within each group. Correlation between sleep efficiency and subjective feelings of sleep quality were done by tests of correlation. $P<0.05$ was taken as statistically significant. Contingency tables were prepared using 80% Sleep Efficiency as a cut-off. Relative risk was estimated and significance testing was done by Fischer's exact test. To assess whether noise levels at the workplace correlated with sleep efficiency, test of correlation was done with the average noise level at the workplace as the dependent variable and sleep efficiency as the independent variable.

RESULTS

Control and test groups were equally matched for demographic characteristics with no significant differences (Table I). In each group the number of males was more than the females. The average noise levels (mean ± SD) at the mills were 83.5 ± 8.2 dB(A) and 80.3 ± 8.2 dB(A) in the autorickshaws. At the shops where the shopping assistants worked, the offices of the clerks and in the laboratory the noise levels were 40.6 ± 4.9, 39.3 ± 5.7 and 36.2 dB(A) respectively. Data for the polysomnography parameters were calculated from the manually scored data stored in optical disks. A total of one hundred and three all night recordings were done on forty eight subjects. Five subjects (two each from Groups I and III and one Group II) had three recordings each and two subjects (both from Group I) had four recordings done on them. These extra recordings were done because the data got corrupted in 2, could not be retrieved in 4 and was of poor quality in 1. For the final analysis, forty six pairs of recordings and two single night recordings were taken. For two volunteers only one night recording was taken because both recordings were accidentally stored on a faulty disc and could not be accessed at the time of final analysis.

The polysomnographic data (Table II) reveals a significant decrease in total REM time in Group I and II but not in the third group. Total time spent in Slow Wave Sleep (SWS) is significantly decreased in Group I but not in other Groups. SOL is decreased in Groups I and III but not in II. Five parameters are altered in Group I, three in Group II and only two in Group III. Sleep efficiency is also decreased in Group I which is not seen in the other groups (Table III). The overall sleep efficiency (mean ± SD) was 81.2 ± 6.1 and 79.1 ± 5.9 in control and test groups respectively when all the controls and the test subjects were taken together

TABLE I: Demographic variables of all three groups.

Variables	*Gr I (Cont)*	*Gr I (Test)*	*Gr II (Cont)*	*Gr II (Test)*	*Gr III (Cont)*	*Gr III (Test)*
Age (yr)	25.3±1.0	25.2±2.0	27.7±2.0	28.7±3.9	36.6±2.0	36.2±1.9
Sex (M/F)	8/0	8/0	5/3	5/3	6/2	6/2
Height (cm)	167.2±4.9	166.9±2.9	172.0±2.1	163.3±1.9	164.1±2.5	162.2±2.6
Weight (kg)	57.8±2.8	57.0±1.6	60.0±4.1	57.6±3.1	63.2±2.5	60.1±3.7
Marital status (M/S)	2/6	3/5	3/5	3/5	8/0	8/0
Duration of occupation (yr)	1.5±0.3	1.5±0.2	6.3±0.8	5.8±0.6	15.4±0.4	15.3±0.3
Type of occupation (no.)	Clerks (3) S.A. (4) L.T. (1)	M.W. (5) A.D. (3)	Clerks (3) S.A. (4) R.A. (1)	M.W. (6) A.D. (2)	Clerks (2) S.A. (6)	M.W. (5) A.D. (3)

Values are given as mean ± SD. M/F = Male/Female; M/S = Married/Single; M.W. = Will Worker; A.D. = Auto Driver; S.A. = Shopping Assistant; R.A. = Research Assistant, L.T. = Laboratory Technician.
n=8 in each group.

TABLE II : Sleep polysomnography variables of subjects exposed to loud occupational noise and their matching controls.

Sleep variables (min)	*Group I*		*Group II*		*Group III*	
	Control	*Test*	*Control*	*Test*	*Control*	*Test*
TIB	472.3±39.0	463.8±17.0	431.4±21.8	460.0±28.4*	457.7±15.5	456.5±35.5
SPT	434.3±34.6	446.0±18.4	405.0±30.8	435.8±25.1*	423.2±28.0	439.3±41.2
TST	395.9±36.8	353.0±30.4*	353.6±42.3	356.9±51.0	357.3±11.6	383.2±60.6
Total REM time	71.2±18.9	40.6±15.4**	68.6±35.2	37.3±19.9*	67.5±34.3	45.7±15.3
Total NREM time	284.5±38.9	223.1±23.7**	274.8±27.9	298.5±33.4	288.4±20.8	350.7±16.3#
Total stage 3 & 4	48.8±22.7	21.7±18.4*	55.6±19.9	39.7±20.8	50.8±28.4	53.7±22.3
Sleep onset latency	30.2±12.3	15.4±10.3*	25.4±11.5	18.2±6.8	32.1±11.7	19.3±5.8**
REM onset latency	88.3±20.4	74.2±18.58	79.2±18.58	92.6±27.6	80.7±16.3	91.3±34.6

All values are mean ± SD. *P<0.05; **P<0.01; #P<0.001 compared to controls of same group. n = 8.

and compared. The means were not statistically significant. Using an 80% sleep efficiency as cut-off, contingency tables were made between all test subjects and controls (n=24 in each group). 5 in the Control Group and 14 in the Test group had a Sleep Efficiency <80%. The Relative Risk was 2.49 (Confidence Interval 1.12 to 5.57) with a P value of 0.017 (Fisher's Exact Test). The subjective changes in sleep quality are seen only in Group I for sleep continuity and for sleep onset in Group II but not for any of the other parameters (Table IV). There was no significant correlation between noise levels at the workplace and sleep efficiency.

TABLE III : Sleep efficiency of various groups.

Name of group	*Sleep efficiency (%)*	
	Control	*Test*
Group I	83.6±6.8	76.2±4.2*
Group II	81.9±6.3	77.3±7.6
Group III	78.1±13.4	83.9±6.2

All values are mean ± SD. *P=0.019; when compared with controls of same group.

n = 8 in each group.

TABLE IV : Subjective scores (mm) of sleep quality on visual analogue scales between test and control groups.

Groups		*Global*	*Sleep onset*	*Continuity*	*Refreshed*
Group I	Control	82.3±11.4	65.6±15.3	56.2±14.9	85.2±11.0
	Test	85.4±9.3	85.8±10.7	80.0±9.4#	78.5±13.3
Group II	Control	80.1±12.1	51.2±17.6	55.0±14.1	67.2±31.4
	Test	87.5±7.5	68.3±13.0*	72.6±23.4	76.7±21.9
Group III	Control	84.5±10.6	61.2±15.7	68.6±21.9	73.4±29.9
	Test	88.9±9.9	59.3±20.6	71.5±22.7	76.8±31.3

Values are mean ± SD; n = 8 in each control and test groups.

*P<0.05; #P<0.01 compared to corresponding control group.

DISCUSSION

The results appear to support the hypothesis that workers exposed to loud continuous noise during the daytime will exhibit changes in their nocturnal sleep architecture. Sleep efficiency is one of the important markers of sleep quality (14) and this study proves that workers exposed to loud noise are significantly at risk to have decreased sleep efficiency. The 80% cutoff for sleep efficiency was chosen "*a priori,*" based on other studies of sleep quality (15, 10) and the fact that in elderly subjects, sleep efficiency decreases to about 80% (16). Therefore the possibility of a post-experimental analysis bias does not arise. These findings may be interpreted to mean that young adults exposed to loud occupational noise will have sleep efficiency equal to that of an aging adult. However, it must be stressed that a decrease in sleep efficiency need not necessarily translate to poor work performance (14). Though there is no statistically significant difference between the means of the control and test groups for this parameter (sleep efficiency), a statistically significant proportion of workers exposed to loud occupational noise exhibit poor sleep quality, which we believe is clinically relevant.

The decrease in Total REM time which is seen in Group I and II as not seen in Group III. Probably there is a tolerance which develops with time though we have no evidence to support this speculation. It must also be said that though the values do not reach statistical significance in Group III there is not enough power in this study to substantiate this finding. An increased number of subjects may very well show that there is a decrease in this group too. There is some evidence that loud noise during wakefulness inhibits one of the phasic activities of REM sleep, namely middle ear muscle activity (16). Therefore, it is possible to surmise that noise heard during wakefulness can alter some brain activity which in turn modulates sleep. REM sleep is altered in many conditions (14) such as anxiety, depression, schizophrenia, benzodiazepine intake etc., and this response may not be very specific to loud noise. Studies of continuous and transient noise during sleep have shown that REM sleep is easily affected by noise and its percentage decreases (17). The functions of REM sleep (18) have been hypothesized to include the maintenance of catecholamine systems (19) and an organism's capacity to sustain attention during wakefullness (20), the modulation of mood (21), facilitation of learning and memory (22), consolidation of memory by "unlearning" irrelevant facts (18, 23), neural growth promotion (18) and protein synthesis (20). In experimental subjects who were REM sleep deprived, performance of a perceptual learning task was inferior when compared to those who have had a normal night's sleep (24). Hence the theoretical implications of reduced REM sleep are many and may form the basis for an explanation of some of the symptoms listed by workers exposed to noise stress, such as, changes in mood, difficulty in concentration, irritability, etc. (13, 25).

The primary outcome measures of poor quality sleep is evident in Group I in whom it is evident that many parameters are affected. Obviously, those subjects who have just started working in a noisy environment are subjected to stress to which they have not yet adapted, which is reflected in the quality of sleep. White collar workers complaining of job-stress reported poor quality of sleep (26). However, the stress referred to in that study was psychological and not physical stress. The decreased SOL seen in the test subjects were surprising since one of the common affects of stress on sleep is an increase in SOL (6). Taking a closer look at the nature of occupation of the volunteers, we found that the test subjects were involved in more physical labour than our controls. Unfortunately it was a variable which we did not anticipate and hence did not control. It is logical to ask whether all the findings of the study could be explained based on a difference in physical activity between the control and test subjects. This possibility can be ruled out because increased physical activity has consistently shown increased sleep efficiency in previous studies (27) whereas the majority of test subjects in our study showed a decrease in sleep efficiency.

The fact that only TIB and SPT (and not TST) are decreased in Group II suggests that these subjects may be spending more time during sleep or in movement during sleep. This is because in SPT the time when the subject is not sleeping (after sleep onset) is also included whereas in TST only the time when the subject is asleep is considered. Even though the negative impact of a decreased TST is not present, the other parameters being present suggest that these subjects may be going through a period of development of tolerance to the adverse impact on sleep architecture. Longitudinal studies may throw better light on the nature and type of adaptation.

The apparent changes in the objective parameters are not reflected in the subjective evaluation. One of the explanations could be that the sleep laboratory provides an artificial surrounding for the subjects to sleep and a perceived better sleep quality may be due to the comfortable beds, airconditioned quiet surroundings to which the subjects are not used to, a phenomenon called “reverse first night effect” (28). We have also shown the level of background noise did not correlate with sleep efficiency. This means that the adverse effects of noise on sleep are independent of the loudness. Field studies relating to occupational noise exposure and blood pressure could not record a consistent association between loudness and blood pressure (29).

The study proves that unprotected workers exposed to loud occupational noise are at an increased risk for having poor quality sleep. Adaptations to these changes are seen in workers exposed to noise for many years. Even though a strong association between occupational noise and poor sleep has been made caution should be exercised in extrapolating these results since these effects cannot be distinguished from any other general stressor which the test subjects could have been influenced by (30). However, this does not detract the serious implications of the study.

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