SLEEP COMPLAINTS AND POLYSOMNOGRAPHIC FINDINGS:
A STUDY OF NUCLEAR POWER PLANT SHIFT WORKERS

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The literature widely recognizes that shift workers have more health complaints than
the general population. The objective of this study was to describe the prevalence of
sleep complaints and verify the polysomnographic (PSG) variables of shift workers
in two Brazilian nuclear power plants. We carried out a subjective evaluation with a
sleep questionnaire. Based on these results, the interviewees that reported sleep-
related complaints were referred for polysomnographic evaluation. Of the 327
volunteers initially evaluated by the sleep questionnaire, 113 (35%) reported sleep
complaints; they were significantly older, had higher body mass index (BMI), and
worked more years on shifts than those without sleep complaints. Of these 113, 90
met criteria for various sleep disorders: 30 (9%) showed obstructive sleep apnea
(OSA), 18 (5.5%) showed limb movement, and 42 (13%) evidenced both sleep pro-
blems and had a significantly higher proportion of sleep stage 1 and arousals com-
pared with the 23 shift workers that had no indices of sleep problems. The present
study found that 90 (27.5%) of the evaluated participants met the PSG criteria of
some type of clinical sleep disorder. This high proportion should be investigated for
associations with other aspects of work, such as working hours, working schedule,
years performing shift work, and access to health services. Due to the strong association
between sleep disorders and the incidence of fatigue and sleepiness, the evaluation of
the sleep patterns and complaints of shift workers is essential and should be considered
to be one of the basic strategies of industry to prevent accidents. (Author correspon-
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power plant

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INTRODUCTION

Epidemiological studies have demonstrated that chronic sleep deprivation and the presence of sleep disorders, especially obstructive sleep apnea syndrome (OSAS) and insomnia, are estimated to occur in 2–4% of the population (Liu et al., 2000; Young et al., 1993). Furthermore, the consequences of the sleep disorders can be mental and physical fatigue, lapses of attention, loss of concentration, compromised quality of life, and accidents at work or while driving (Costa, 1996; Pandi-Perumal et al., 2006). In this regard, a number of investigators have demonstrated that shift workers have excessive health complaints (Åkerstedt, 2003, 2007; Costa et al., 2006; Fisher et al. 2006; Raediker et al., 2006). The most common complaint is loss of subjective sleep quality. Others have suggested that sleep problems are the most important reason of quitting shift work (Folkard & Tucker, 2003).

Some industrial processes require special characteristics in the way workers must execute their job, such as those in nuclear power plants. To prevent accidents, the maintenance of the security of the operational system depends on precision and attention in performing work-related tasks (Bobko et al., 1998; Folkard et al., 2005; Gillberg et al., 2003). Smith and Folkard (1993) conducted an exploratory survey study to examine the impact of shift work on several general aspects of the health of nuclear power plant workers, such as alertness, fatigue, sleep, and social issues, and concluded that the night shift is the most problematic in terms of decreases in all these variables. Looking for differences between shifts, Smith et al. (1995) carried out a study using hand-held computers to record alertness levels, cognitive task performance, and workload ratings. The authors found significantly lower levels of alertness and poorer performance in night-shift workers.

Recently, Takahashi et al. (2005) demonstrated that shift workers with good adaptation to work on shifts are those who had fewer health problems and who took frequent and long naps. Complementing this work, Smith et al. (2005) used subjective measures to evaluate the health of 609 shift workers in a nuclear power plant in Japan. The results demonstrated that the way the worker perceived his mental and physical fatigue, levels of stress, and general health influenced his tolerance of shift work.

As far as we are aware, no studies have yet used both subjective (questionnaire) and objective (polysomnography [PSG]) to investigate sleep complaints and disorders in shift workers at nuclear power plants. Accordingly, the objective of the present study is to describe the prevalence of sleep complaints and verify sleep problems in shift workers at two Brazilian nuclear power plants.
METHODS

Sample and Experimental Design

This study was approved by the Ethics Research Committee of the Federal University of São Paulo (UNIFESP, process number 1556/03), Brazil, and was conducted according to the ethical guidelines recommended by the journal (Touitou et al., 2006). All participants gave written informed consent for their participation in the research protocol, which was conducted in two consenting Brazilian nuclear power plants. Recruitment of the volunteers was conducted after the presentation of lectures designed to explain the protocol and the importance of sleep hygiene, sleep disorders, and work schedule. After the lectures, the workers were interviewed individually during the first 2 h of the morning or afternoon shift. Approximately 340 workers were on rotating shifts at the two power plants, and a total of 327 (96%) agreed to participate in the study. Only those workers who experienced sleep complaints according to the criteria of the UNIFESP Sleep Questionnaire (Pires et al., 2007) were referred for PSG evaluation. This involved 113 of the workforce. To perform the PSG recordings, a sleep laboratory was specially built in rooms of a hotel located near the power plant, following the standard criteria the American Academy of Sleep Medicine (2005).

Shift System

One shift system was worked at both plants. Each shift lasted 8 h, and the number of successive shifts was the same for all job types: six days on the evening shift (15:00–23:00 h), four days off; six days on the morning shift (07:00–15:00 h), four days off; and six days on the night shift (23:00–07:00 h), six days off.

Questionnaire

The UNIFESP Sleep Questionnaire (Pires et al., 2007) was used, as it was previously validated by the Brazilian Sleep Institute. In its full version, it comprises a number of standard measures typically used in shift work and sleep research.

In this study, the data analyzed consisted of: descriptive data of the sample; questions about socio-demographic characteristics, such as age, marital status, schooling, and salary; and characteristics and complaints related to sleep habits, such as time of going to bed and getting up, the nature of the sleep problems, and the frequency of their occurrence. The interviewees were asked about the frequency with which they experienced these sleep problems and the answers were rated on a seven-point
scale: 1) never; 2) less than once a month; 3) once a month; 4) two to three times a month; 5) one to two times a week; 6) three to six times a week; 7) daily.

Insomnia was assessed through complaints of difficulty initiating and maintaining sleep, or awakening earlier than desired and not being able to resume sleep. Excessive daytime somnolence was assessed through complaints of diurnal sleepiness with impairment of daytime activities and bouts of extreme sleepiness. Snoring and sleep apnea were assessed through complaints of gasping or choking, and limb movements (LM) were assessed by episodes of repetitive, highly stereotyped, limb movements occurring during sleep. Insomnia, excessive daytime sleepiness, snoring, and apnea were considered as sleep complaints when they were described daily or more than three times per week. LM was considered a complaint when described at least one or two times per week. The interviewees were also asked if they had already sought the help of a physician for their sleep problems, and if they had used medication to help sleep (with no distinction being made between prescribed, over-the-counter, or herbal medicines).

**Polysomnographic Records**

Overnight PSG was performed and visually scored by a trained sleep technician according to the method of Rechtschaffen and Kales (1968) using an EMBLA digital system (EMBLA A10, Embla Systems Inc. Broomfield, Colorado, USA). The following variables were monitored: electroencephalogram (C3–A2, C4–A1, O1–A2, O2–A1), electrooculogram (LOC–A2, ROC–A1), electromyogram (submental and anterior tibialis muscles) using surface electrodes, and electrocardiogram. Snoring and body position were detected with EMBLA sensors. Airflow was detected by a thermocouple and by a pressure-flow transducer. Chest and abdominal XactTrace sensors monitored respiratory effort. Arterial oxygen saturation (SaO₂) and pulse were recorded by a pulse oximeter (EMBLA). The following parameters were analyzed from the PSG results: total sleep time (TST, min); sleep latency (min); sleep efficiency (%); wake after sleep onset (WASO, min); stages 1 (S1%), 2 (S2%), 3 (S3% + S4%), and REM sleep (REM%) as the percentage of TST and latency to REM (min). Arousal, abnormal respiratory events, and periodic limb movements (PLM) were scored according to standard criteria (American Academy of Sleep Medicine Task Force [AASMTF], 1999; American Sleep Disorders Association Atlas Task Force, 1992, 1993). The cutoff point for obstructive sleep apnea (OSA) was defined as an Apnea Hypopnea Index (AHI) of 5/h; a AHI of between 5 and 15/h was considered mild OSA, between 16 and 29 moderate OSA, and >30 events severe OSA (AASMTF, 1999). The cutoff point for abnormal LM was 5; a LM between
6 and 25 was considered mild LM, between 26 and 49 was considered moderate, and a LM above 50 was considered severe LM (AASMTF, 1999). All volunteers that met the PSG criteria for some type of sleep disturbance were referred to a sleep specialist for treatment.

**Statistical Analysis**

Based on the questionnaire results, the workers were divided into those with and without sleep complaints. The descriptive data are expressed as the number of workers per group and percentage of the total sample. The PSG results were also used to divide the total sample into two groups, those with and without sleep problems. Statistical comparisons between the groups were achieved by Student’s t or chi-squared tests, with differences of 5% being considered statistically significant.

**RESULTS**

**Questionnaire**

A total of 327 shift workers answered the UNIFESP sleep questionnaire (Pires et al., 2007). Of these, 214 (65%) were classified as without sleep complaints, and 113 (35%) were classified with sleep complaints. Table 1 reports their socio-demographic characteristics. There were statistically significant differences between the two groups (with/without sleep complaints) in terms of age, BMI, and years working shifts.

Of the 113 (35%) that met the questionnaire criteria for sleep complaints, 29 (8.8%) workers reported difficulty initiating sleep, 56 (17.1%) reported difficulty maintaining sleep, and 27 (8.2%) reported early morning awakenings. Thirteen (3.9%) shift workers reported excessive daytime sleepiness, and 11 (3.3%) reported bouts of extreme sleepiness. Seventy-seven (23.5%) reported snoring, and 82 (25.0%) reported gasping or choking. Limb movements were reported by 17 participants (5.1%). Table 2 summarizes the subjective sleep patterns of the shift workers. There were no statistically significant differences between the two groups.

**Polysomnography**

A total of 113 shift workers were referred for PSG: 23 showed normal sleep parameters, and 90 met the criteria for OSA, LM, or both. This latter group of 90 subjects showed a significantly higher proportion of sleep stage 1, arousals, and both indices of OSA and LM, and then could be divided into 30 (9%) individuals with OSA, 18 (5.5%) with LM, and 42
(13%) with both OSA and LM. Table 3 shows the sleep parameters of the 113 subjects who underwent PSG, based on their replies to the sleep questionnaire. Using the indices of sleep disorder severity, 41 shift workers met the criteria for mild, 20 moderate, and 11 severe OSA; 51 shift workers met the criteria for mild, 6 for moderate, and 3 severe LM.

**DISCUSSION**

The objective of this study was to examine sleep complaints among shift workers employed in two Brazilian nuclear power plants using a sleep questionnaire followed by PSG evaluation. The data obtained from the questionnaire showed that 113 (35%) of the 327 shift workers fulfilled the criteria for insomnia, excessive sleepiness, snoring, sleep apnea, and limb movement. Overall, we expected to find that shift workers would report more sleep complaints than the general population. However,
when we compared our findings with those for the general population of São Paulo, Brazil, obtained by Pires et al. (2007), our hypothesis was not confirmed. For example, in this study of nuclear power plant employees, 8.8% of the shift workers reported difficulty initiating sleep vs. 13.1% of the general population; 17.1% vs. 24.6% reported difficulty maintaining sleep, and 8.2% vs. 11.3% reported early awakenings. For excessive daytime sleepiness, the percentages were similar: 3.9% of the shift workers and 3.3% of the general population. The percentages were also similar for the OSA symptom of snoring: 23.5% of the shift workers and 26.3% of the general population. Although these results seem to differ from those reported in the medical literature (Åkerstedt, 2003; De Mello et al., 2000; Menezes et al., 2004), this cannot be attributed to the methods of the respective studies. Perhaps other aspects of shift work, or even the specificity of the study sample of nuclear power plant workers, play a role.

One possibility is the socio-economic characteristics of this sample, such as the number of workers that have a higher degree of schooling (e.g., 150 [46%] had at least some university education) and higher income (e.g., 285 [86%] earned more than five-fold the average monthly salary) compared to the general population studied by Pires et al. (2007), of which 37% had low salary income. Other studies have reported a positive correlation between social problems and sleep

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<th>TABLE 2 Subjective Sleep Patterns</th>
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<tr>
<td>Total n = 327</td>
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<tr>
<td>Without sleep complaints n = 214</td>
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<td>With sleep complaints n = 113</td>
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<td>Sleep time (h)</td>
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<td>7.3 ± 1.3</td>
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<td>Sleep enough?</td>
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<tr>
<td>Yes</td>
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<td>No</td>
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<td>Have 11 h of rest between shifts?</td>
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<td>Yes</td>
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<td>No</td>
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<td>Take naps?</td>
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<td>Yes</td>
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<td>Doze off at the wheel?</td>
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<td>Yes</td>
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<td>Medication used for sleep?</td>
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complaints. Hyppa et al. (1997) demonstrated people who were continuously unemployed during a period of economic recession in Finland suffered more with insomnia and used more hypnotic drugs than those continuously employed. Indeed, Travassos et al. (2002) showed that families with a higher income are more likely to use health services. Furthermore, in our study, 15% of shift workers had consulted a physician for a sleep problem, which is higher than the 6% found in the general population (Pires et al., 2007) and 12% of the shift workers reported using sleeping pills. It is also higher than the findings of previous studies on professional bus drivers, such as the 4% reported by Howard et al. (2004) and 7.5% reported by De Mello et al. (2000).

Based on the sleep questionnaire, we found that shift workers who reported sleep complaints were older, which is consistent with the findings of many other studies (Buysse et al., 2005; Dijik et al., 1999; Young et al., 1993); with aging, the sleep architecture changes, especially showing more fragmented and superficial sleep. Another important result is that shift workers with sleep complaint assessed by the questionnaire had high BMI. Recent studies (Drake et al., 2004; Moreno et al., 2004, 2006; Taheri, 2006; Van Dongen et al., 2003) suggest that subjects who must assume a different sleep-wake cycle from that programmed by their circadian rhythm are more likely to consume fast foods, thereby increasing their BMI, which is related with hypertension, cardiovascular risk, and sleep problems (Stoohs et al., 1994; Viegas & Oliveira, 2006).

The PSG tests and findings enabled us to better characterize the sleep parameters of those 113 shift workers who reported sleep complaints by their answers to the sleep questionnaire. Ninety (27.5%) of these 113 persons met the criteria for a higher proportion of sleep stage 1, increased indices of arousal, OSA, and LM. Interestingly, 23 shift workers who

| TABLE 3 | PSG Sleep Parameters in the Two Groups with and without Sleep Disorders |
|-----------------|-----------------|-----------------|-----------------|
| Without sleep disorder | With sleep Disorder | p    |
| n = 23           | n = 90           |      |
| WASO (min)       | 36.9 ± 29.5      | 52.0 ± 38.9     | ns              |
| Total sleep time (min) | 393.6 ± 50.1    | 381.6 ± 57.8    | ns              |
| Sleep latency (min) | 10.2 ± 9.5       | 10.4 ± 12.3     | ns              |
| Sleep efficacy (%) | 89.1 ± 7.4       | 86.1 ± 9.2      | ns              |
| REM latency (min) | 84.7 ± 32.1      | 87.9 ± 33.4     | ns              |
| % S–1            | 3.3 ± 1.5        | 4.9 ± 3.4       | 0.03            |
| % S–2            | 52.9 ± 10.0      | 54.16 ± 8.1     | ns              |
| % S–3 (S3 + S4)  | 20.7 ± 7.5       | 19.7 ± 6.6      | ns              |
| % REM            | 22.9 ± 6.3       | 21.3 ± 5.3      | ns              |
| Arousal index (h) | 9.6 ± 5.5        | 16.7 ± 9.4      | <0.01           |
| IAH              | 2.3 ± 1.3        | 16.0 ± 15.9     | <0.01           |
| LM               | 2.2 ± 1.3        | 11.8 ± 14.7     | <0.01           |
complained of a potential sleep problem through their responses to the sleep questionnaire showed normal sleep parameters. These results are higher than those reported by Young et al. (1993) for the general population (24%), but lower than those reported by Santos et al. (2004). Santos compared the day and night-time sleep parameters of a small \( n = 32 \) but complete sample of professional bus drivers and concluded that 38% met the criteria for both OSA and LM by a night-time PSG study. Our findings can be attributed to the limited (i.e., 75%) sensibility of the questionnaire when it was first developed by Braz et al. (1987), and/or perhaps (as suggested by Takahashi et al., 2005) the difficulty of shift workers to adequately perceive the quality of their sleep, as they must continuously alter their sleep-wake schedule with each change in the work shift.

The PSG results show that most of the workers who were diagnosed with a sleep disorder met the criteria for mild sleep disorder, either due to OSA and/or LM. Based on these results, we suggest that besides regularly checking the health status of shift workers, it is important to encourage healthy habits, such as physical exercise, healthy eating, and sleep hygiene, to attenuate the consequences of working night-time shifts. In accord with the sleep task force (World Association of Sleep Medicine, 2006), the association among OSA and LM can be explained as a consequence of respiratory events; this suggests that the OSA must be treated first before the LM can be recognized and treated.

The absence of a control group (of day workers) to compare the findings on shift workers is a limitation of the current study. Furthermore, the full evaluation of sleep disorders requires a more exhaustive clinical evaluation that cannot be achieved by a single overnight PSG study alone. Even though the cross-sectional study design cannot determine a causal relationship between some reported aspects found in the questionnaire and the PSG, due to the strong association between sleep disorders and the incidence of fatigue and sleepiness, the evaluation of the sleep patterns and complaints of shift workers is essential and should be considered one of the basic strategies of industry to prevent accidents.

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World Association of Sleep Medicine. (2006). The official World Association of Sleep Medicine (WASM) standards for recording and scoring periodic leg movements in sleep (PLMs) and wakefulness (PLMW) developed in collaboration with a task force from the International Restless Legs Syndrome Study Group (IRLSSG). Sleep Med. 7:175–183.