The aim of this study was to examine the effects of a nighttime nap and daytime sleep on the heart rates of professional long-distance bus drivers and also a subjective rating of drowsiness through the use of a questionnaire survey on 58 drivers and a heart rate study on 9 drivers during both work and sleep. Of 2 bus drivers, one continued to drive for approximately 2-3 hours while another was alternately able to take a nap during nighttime in the bus cabin for a maximum of around 2 hours during their rest time. In a questionnaire survey, around 80% of 58 drivers reported that they could sleep well for at least one-half of the duration of the nap time reported. The nighttime nap showed a beneficial effect on their sleep debt which results from both night driving as well as from insufficient daytime sleep in local lodgings after duty. Concerning both the nighttime nap and daytime sleep, according to the heart rate measurements of 9 drivers during their duty time, it was found that the average heart rate had higher levels during daytime sleep than during a nighttime nap, presumably due to circadian rhythm. It was disclosed that the duration of a nap in the cabin was very short but the recovery from drowsiness could be effective.

Key Words: Long distance bus driving, Night work, Nap, Drowsiness and fatigue, Daytime sleep

1. INTRODUCTION

In Japan the transportation networks for long-distance buses have led to a rapid growth in night highway bus services, along with railway and jetliner services as a means of passenger transportation from metropolitan to regional cities. On the other hand, professional bus drivers have been exposed to an intensive workload of driving, long distances including night work, and especially sleep in the daytime after night work.

With regards to driving long distances, Horne and Reyner described that 29% of respondents admitted to having felt close to falling asleep at the wheel in the previous year. One of the main concerns of the common factors concerning feeling close to falling asleep during driving tends to be associated with rest time during continuous driving and daytime sleep after night work. The systematic investigations, involving 6,000 respondents, revealed that involuntarily falling asleep at work was significantly related to the independent factors of shift work, solitary work and disturbed sleep.

In EU regulations for working hours of a bus or coach, it is stated that the driver is allowed to drive 4.0 hours without a break irrespective of the time of day. Horne and Reyner described that there is no convincing data on which to base any premise that 4.0 hours is generally a safe length of time for driving a bus or coach, especially on monotonous roads.

Concerning work over-load and under-load, Shaw and Riskind have revealed that work stress is related to the particular characteristics of a job. It may be that the bus driver’s tension and stress arises partly from fixed time schedules that permit little or no lateness. In addition, it has been suggested that one of the main sources of stress for bus drivers is related to the general level of alertness required of them and also the need to work long hours is a source of work-related stress. Hartley et al. from a systematic study on truck drivers reported that drivers attempted to compensate for fatigue by increased mental effort that may result in manifestations of stress, such as increased endocrine catecholamine secretion. The effects of stress resulting from workload lead to physiological and psychological changes in the bus driver’s work during night work. Kroemer and Grandjean described that the driver is allowed to drive 4.0 hours without a break irrespective of the time of day.
describe that measuring the heart rate is one of the most useful ways of assessing workload. Recent investigation has suggested that fatigue is associated with work overload at work. It is known that there is a significant cardiovascular involvement in differences between work and sleep. However, the number of investigations on physiological changes associated with sleep during the daytime for long distance drivers is small. It is important to clarify the difference in heart rates between periods of nap during night work and daytime sleep for a physiological assessment of sleep debt.

This study was to examine the effects of a nighttime nap and daytime sleep on the heart rate and subjective rating of fatigue and drowsiness during night work.

2. METHOD

2.1 Work schedule of long distance driving

The bus drivers studied worked on a work system where drivers rotate on a 1-month shift, driving long distance routes during the night (nighttime work), and suburban routes between local cities (daytime work). In the driving shift for suburban routes, drivers were mainly engaged in driving on general streets in the daytime but were also requested to drive in the early morning or during the night.

In the driving work shift of long distance routes, the drivers worked a 7-day shift schedule as follows; a driver who came to the office from his home in the evening on the first day, left the metropolitan hub terminal between 19:00 and 21:00 and arrived at a terminal in a local city early in the morning on the 2nd day, mainly via highway. After taking a daytime sleep for several hours in a prescribed local lodging, the drivers went to work in the evening on the 2nd day, left the local terminal between 19:00 and 21:00 and arrived at the hub terminal early in the morning on the 3rd day. After taking a daytime sleep for several hours at home, the drivers went to work in the evening on the 3rd day and performed another round-trip shift to a different destination from the last shift. After completing the 2nd round-trip shift early in the morning on the 5th day, the drivers took 2 days off and earned a normal nighttime sleep in their homes for 2 consecutive days. The drivers returned to the office in the evening of the 7th day to work on another scheduled driving shift. In short, the driver was allowed to sleep at home on 2 consecutive nights after completing a duty of driving for 4 consecutive days. The drivers changed to a daytime shift of driving suburban routes. Figure 1 shows the outline of night work for working a 7-day shift.

Fig. 1 Diagram of night work schedule for a 7-day shift of long distance bus drivers

Concerning the details of a nighttime nap in the cabin for the long distance routes which were driven by 2 drivers alternately, one of the drivers took the wheel while the other attended to the passengers in order to provide them with sleeping time after leaving the hub terminal by 22:00. During the next period of time (from midnight to dawn) of the above time zones, while the driver was driving the bus (for 2-3 hours), the other driver had a rest time for a nap in the cabin provided in the bus. The cabin had enough space for the driver to lie down and also air-conditioning. Each driver usually took 3 to 5 naps on average, depending on the destination.

2.2 Questionnaire items on nighttime nap in cabin

The bus drivers filled in a questionnaire concerning 3 items: (1) the sleep quality: “Can you sleep in the cabin during night work?”, (2) the reduction of drowsiness: “How is the reduction of drowsiness through a nighttime nap in the cabin?”, and (3) the recovery from fatigue: “How is the recovery from fatigue through a nighttime nap in the cabin?”, immediately after a nap which was taken at nighttime in the cabin during their duty for long-distance routes. Questionnaire item (1) was answered on a 4 point rating scale of subjective feelings: (a) sleep for 3/4 of nap time, (b) sleep for 1/2 of nap time, (c) sleep for 1/4 of nap time, (d) can hardly sleep. Item (2) was answered on a 5 point rating scale: (a) reduce very well, (b) reduce most of, (c) reduce well, (d) reduce a little, (e) no
reduction. Item (3) was answered on a 5 point rating scale: (a) recover very well, (b) recover most of, (c) recover well, (d) recover a little, (e) no recovery. The drivers also had to note down the times when they went to sleep and awakened in each rest time.

2.3 Physiological measurement of heart rate

Continuous measurements of the heart rates of each of the 9 drivers on a round-trip duty of a long-distance route on different days were taken for a maximum of 40 hours between when they left and returned to the hub terminal. The heart rates were measured by a heart rate monitor-S810 (Polar Electro Oy) in which ECG (Electrocardiogram) signals transmitted from a band with embedded electrodes attached on the chest were wirelessly received and displayed as the heart rate on a watch-style LCD (Liquid Crystal Display) screen which were then saved in the memory. The heart rate was sampled at an interval of 60 seconds, according to the limited settings of capacity. Each driver was required to note down the times when they went to sleep and awakened, and also each time they started and finished driving. The heart rate measurements were analyzed with the reported duration of nap and also with the times in a bed for daytime sleep.

2.4 Subjects

In the questionnaire study subjects consisted of a total number of 58 professional male bus drivers with ages ranging from 31 to 52 years old (average = 40.7 years). They had bus driving experience from 5 to 18 years (average = 10.1 years). In the physiological study, heart rate measurements of 9 drivers were taken, with ages ranging from 31 to 51 years old (average = 41.6 years) and bus driving experience from 2 to 18 years (average = 11.1 years).

3. RESULTS

3.1 Effects of nighttime nap in cabin by questionnaire survey

Figure 2 shows the results of an evaluation of the subjective rating on how long a bus driver was actually able to sleep while taking a rest time in the cabin after rotating with the other driver. It was found that 30% of 58 drivers remained asleep for 3/4 of the napping time and 50% for 1/2 of the period. It was also disclosed that 80% of the drivers were able to sleep to some extent by a nap in the cabin during the night. However, 15% of the drivers remained asleep for only 1/4 of the nap time, and 5% could hardly sleep at all. The results showed that 20% of the drivers were unable to sleep well in reality, despite having the opportunity to nap.

Figure 3 shows the subjective evaluation concerning the extent of recovery from fatigue and reduction of drowsiness through a nighttime nap in the cabin. It was indicated that very few of the drivers evaluated a nap as being very effective in reducing drowsiness. In addition, none of them evaluated a nap as being very effective in recovery from fatigue. Nineteen percent of the drivers found it helpful in avoiding most drowsiness and 7% fatigue, while 25% found it reduced drowsiness well, and 23% fatigue well. The results revealed that nearly 50% of the drivers found a nap effective in removing drowsiness, while only approximately 30% of the drivers found a nap effective in recovering from fatigue.
3.2 Comparison of heart rates during nighttime nap in cabin and daytime sleep in local lodging

As shown in Figure 4, the average heart rates measured from 9 drivers were 71.7 beats/min (sd: 8.05) during a nighttime nap in the cabin and 84.7 beats/min (sd: 10.42) during daytime sleep in local lodging. Heart rates had a higher level of 13 beats/min during daytime sleep than a nighttime nap in the cabin, which was a statistically significant difference (t = 4.62, df = 8, p < .01). The results showed that almost all the drivers had a higher level of heart rate during daytime sleep than during a nighttime nap in the cabin although there were naturally individual differences in the levels of heart rates.

The results showed that the average number of naps was 4.4 times on a long distance route and the average length of the nap time was 107 minutes (sd: 12.7), on the other hand, the average duration of daytime sleep was 351 minutes (sd: 98.6). The average heart rate of the drivers in each duration of the reported times for the naps and the daytime sleep were calculated and were classified into 3 class intervals on reference average values of rest and work of shift workers. In the comparative study of heart rates during rest and work, Inoue et al.7 has shown that the average value of heart rate was 75.3 beats/min during rest and 85.8 beats/min during work. It can be assumed that a heart rate below 75.0 beats/min indicates a state of rest and also an active state is over 90.0 beats/min.

Figure 5 shows the results of heart rates in comparison to nighttime naps and daytime sleep. It was found that in the interval class of heart rates at both 74 or less and 90 or more there were remarkable differences in heart rates between a nighttime nap and daytime sleep. From the total number of 40 examples of naps which were taken by 9 drivers, the results showed that drivers remained asleep for approximately 60% of the nighttime nap with a heart rate of 74 or less, which suggested that they were in the state of sleep.

4. DISCUSSION

According to EEG (Electroencephalography) research, it is known that, though night workers attain deep sleep early during a nighttime nap taken during a night shift, just as in the initial stage of normal sleep during the night, they only attain light sleep during daytime sleep after a night shift8,9. Lower levels of heart rate indicate physical and mental relaxed states, because the heart rates during sleep indicate exactly the workers’ levels of body and mind activity. However, the rates are not a direct physiological index for sleep depth like an EEG. In other words, heart rates during sleep have a meaning as a convenient physiological index for sleep that replaces an EEG. It can be considered possible to use heart rates extensively for studies on break time effects and sleep problems at worksites by making the most of the advantages of greater ease of measurement other than an EEG.

The percentage of naps which were taken by 9 drivers as shown in Figure 5 corresponds to the fact that 80% of the drivers reported in the questionnaire study, concerning their subjective feelings about a nighttime nap, that they had slept to some extent. However, only 25% of them actually remained asleep during the daytime sleep time. On the other hand, drivers with heart rates of 90 or more could remain awake in an active state without sleep. There were about 5% of the drivers who had 90 or more
heart beats/min during the nighttime nap, which corresponds to a percentage of the drivers who reported that they could hardly sleep during the nighttime nap. The fact that there were about 30% of the drivers with 90 or more heart beats/min during the daytime sleep showed that many drivers were not in the state of sleep although being in a period of daytime sleep. Daytime sleep in a local lodging for several hours in a comparatively comfortable sleeping environment had an even lower quality of sleep when compared with a nighttime nap in the cabin which was quite inferior in sleeping environment and duration.

Comparing the driver’s heart rates between a nighttime nap in the cabin and daytime sleep in local lodging, the former showed significantly lower levels than the latter. It is suggested that a nighttime nap allowed an efficient sleep than daytime sleep in a local lodging. The general reason is closely related to the influence of the circadian rhythm. The time zone of nighttime, at which a driver took a nap, corresponds to a period of time when human activation levels were in the lowest state in the time of a day, which resulted in good physiological conditions leading to good sleep. On the other hand, because the driver was requested to sleep in local lodging in the daytime when human activation levels were heightened, this prevented him from achieving deep sleep.

5. CONCLUSION

The effects of nighttime naps in recovering from fatigue, which were taken by 2 drivers alternately resting in the cabin while driving a night highway bus, were investigated. Approximately 80% of 58 bus drivers reported that they had a comparatively good sleep during a nighttime nap. Fifty percent of the drivers answered that a nighttime nap made them feel less drowsy, but only 30% less fatigued. Comparing 9 drivers’ heart rates between a nighttime nap in the cabin and daytime sleep in local lodging, the mean values of heart rates were 71.7 and 84.7 beats/min respectively, which showed that heart rate levels were significantly lower during the nighttime nap than those during daytime sleep, indicating a better state of sleep in the cabin.

It was shown that many drivers recognized a nighttime nap as effective in preventing drowsiness rather than fatigue. However, with relation to the fact that heart rate levels during nighttime naps were apparently lower than those during daytime sleep in local lodging, sleep during the nighttime nap seems to be associated with efficient levels, and a nighttime nap was estimated to be significantly effective in not merely preventing drowsiness temporarily but also related to recovering from fatigue.

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