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COMPENSATION OF REDUCED SLEEP IN A RAPIDLY ROTATING SHIFT SYSTEM

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Sleep characteristics were examined in various phases of a forward rapidly rotating shift cycle in two groups of workers. In view of the fact that age is related to both sleep duration and the incidence of napping the relationships between sleep characteristics were analysed with age statistically held constant. The results showed that reduced sleep duration in one phase of the shift cycle (morning or night shift) was compensated by prolonged sleep in the following phase (afternoon shift and days off). Sleep was not prolonged equally for different workers; those sleeping shorter in the previous phase of the shift cycle prolonged their sleep more while those sleeping longer in the previous phase prolonged their sleep less. There was no relationship between the duration of the main sleep and the incidence of napping. The results are considered to be an additional argument in favour of the rapidly rotating shift system as compared to the permanent or slowly rotating shift systems.

Key terms:
age, main sleep duration, nap, shift work, sleep characteristics

One of the most frequent complaints among the shift workers is that they are unable to sleep adequately. The complaint concerns primarily the sleep following night work when sleep is displaced to a day period which is unfavourable for sleep in respect to both internal 24-hour rhythms and external physical and social influences. As a result, on night shift days workers sleep only five to six hours (1-3). Sleep on morning shift days can also be shortened, especially if work starts early in the morning. In a shift cycle only the conditions on afternoon shift days and days off are favourable for sleep. Napping is a common practice among some shift workers on morning and/or night shift days, but researchers disagree on its effects and role (2-6).

Arh hig rada toksikol, Vol 45 (1994) No 3, pp. 211-218

It is questionable whether sleep characteristics within a shift cycle are related so that reduced sleep in one phase of the cycle is compensated with additional sleep (nap) in the same phase and/or prolonged sleep in the subsequent phase of the cycle. The answer to this question can add some arguments in favour of a certain speed and direction of the shift system rotation (7-10). Our recent longitudinal study conducted in a homogenous group of young shift workers showed that reduced sleep on morning and night shift days was not compensated with napping, but rather with an increase in main sleep duration on afternoon shift days and days off (11). According to earlier studies, which were performed among age heterogenous groups of workers, the napping behaviour was related to the length of the main sleep and results on relationships between sleep durations in various phases of the shift cycle were inconclusive (2-4, 11). However, age is related to both the incidence of napping and duration of main sleep (2-4, 12). In view of this there is a need to control for the effect of age when relationships between sleep characteristics are analysed. In the present study we examined the relationship between sleep characteristics in a rapidly rotating shift cycle of age heterogenous groups of workers with age statistically held constant.

SAMPLE AND METHODS

The data used in the analyses were obtained from the questionnaire studies of two groups of workers: a group of 604 male oil refinery workers (group A)(2) and a group of 104 male petrochemical workers (group B). The group A workers had a mean age of 32.1 years (range from 19 to 61 years) and a mean shift work experience of 9.7 years (range from 0.5 to 38 years). The workers in group B had a mean age of 39.8 years (range from 24 to 56 years) and a mean shift work experience of 16.1 years (range from 4 to 31 years). The groups differed with respect to age ($t=9.22$; $P<0.001$).

Both groups worked in a rapidly rotating three-shift system with shift changes at 06:00, 14:00 and 22:00 hours. The phases of the shift cycle rotated in the order morning-afternoon-night shifts and days off (a forward rotation).

The sleep variables analysed were:

- main sleep duration on morning shift days (SD_MS), afternoon shift days (SD_AS), night shift days (SD_NS), and days off (SD_DO); they were determined by means of questions about the usual time of going to bed and time of waking up;
- increase in sleep duration from morning shift days to afternoon shift days (DELTA_AS_MS);
- increase in sleep duration from night shift days to days off (DELTA-_DO_NS);
- incidence of napping on morning shift days and night shift days.

RESULTS

The timing and duration of sleep in various phases of the shift cycle are presented in Figure 1. If we follow the phase changes we can see that this shift system enabled workers to increase their sleep on the afternoon shift days after they had slept for relatively a short time on the morning shift days (on average 6.6 hours in group A and 6.7 hours in group B). The sleep increased on average 2.3 hours (SD=1.8) in group A and 1.4 hours (SD=1.9) in group B. There was a similar and even more pronounced increase in sleep duration on days off, after a short sleep on night shift days when the workers slept on average 5.3 hours in group A and 4.6 hours in group B. In group A the sleep on days off increased on average by 4.2 hours (SD=1.8) and in group B even by 4.7 hours (SD=2.2).

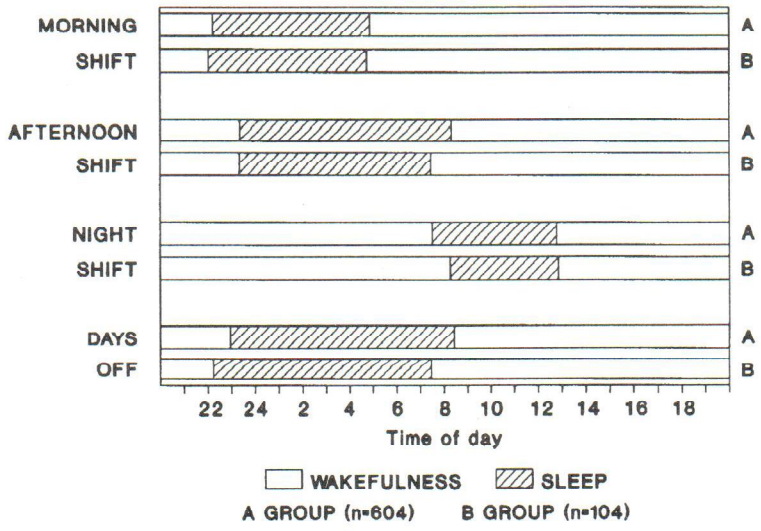

Figure1 *Sleep/wakefulness rhythm in various phases of the rapidly rotating shift cycle*

The notion that increase in sleep duration in favourable conditions compensates for reduced sleep in the preceding unfavourable conditions was investigated using two groups of partial correlations which hold the effect of age constant (Table 1). One group were correlations between the sleep durations in the phase of the shift cycle having unfavourable conditions for sleep (morning and night shifts) and the sleep durations in the following phase having favourable conditions (afternoon shift and days off, respectively). The second group were correlations between the sleep duration in unfavourable phase and increase in sleep duration from unfavourable to the following favourable phase, i.e. between sleep duration on morning shift days and increase in sleep from morning shift days to afternoon

shift days, and between sleep duration on night shift days and increase in sleep from night shift days to days off.

Table 1 *Correlations of sleep duration in one phase of the shift cycle with sleep duration in the following phase and with increase in sleep duration from one phase to another. Zero-order (r) and partial correlation coefficients – the effect of age removed from both variables – (r_{part})*

	SD_AS		DELTA_AS_MS		
	r	r_{part}	r	r_{part}	
SD_MS	−0.14***	−0.02	−0.62***	−0.54***	A
	−0.20*	−0.19*	−0.73***	−0.73***	B

	SD_DO		DELTA_DO_NS		
		r_{part}		r_{part}	
SD_NS	0.31***	0.28***	−0.68***	−0.68***	A
	−0.09	−0.10	0.69***	0.69***	B

* P<0.05 **P<0.001

SD_MS – sleep duration on morning shift days; SD_AS – sleep duration on afternoon shift days; SD_NS – sleep duration on night shift days; SD_DO – sleep duration on days off; DELTA_AS_MS – increase in sleep duration from morning to afternoon shift days; DELTA_DO_NS – increase in sleep duration from night shift days to days off; A group (n=604); B group (n=104)

In both groups of workers partial correlations between sleep duration on morning shift days and increase in sleep from morning to afternoon shift days, as well as between sleep duration on night shift days and increase in sleep from night shift days to days off were high and negative (fourth column in Table 1). Thus, the workers who slept shorter on the morning shift days prolonged their sleep on the following afternoon shift days more than the workers sleeping longer. Similarly, the workers who slept shorter on the night shift days prolonged their sleep more on the following days off than the workers sleeping longer.

However, out of the partial correlations between sleep durations in two phases of the shift cycle (second column in Table 1) only the low negative correlation was found between sleep durations on morning and afternoon shift days in group B and the low positive correlation between sleep durations on night shift days and days off in group A. Thus there were no stable relationships between sleep durations in the two adjoining phases of the shift cycle as were found between sleep duration in one phase and increase in sleep from that phase to the following one.

In both examined groups the workers who usually took a nap were older than the workers who took a nap occasionally or those who usually did not take a nap (in group A: $F(2,601)=9.01$; $P<0.001$ for morning shift and $F(2,601)=75.55$; $P<0.001$ for night shift; in group B: $F(2,101)=3.17$; $P<0.05$ for morning shift and $F(2,101)=5.91$; $P<0.01$ for night shift). The relationship between the incidence of

napping and duration of the main sleep in the same phase of the shift cycle was examined by means of the one-way analysis of variance testing the differences in the main sleep duration between three groups of workers: the workers usually napping, those napping occasionally and those usually not napping. To control for the effect of age the analyses were performed using residuals, i.e. differences between the observed values and the values predicted by age.

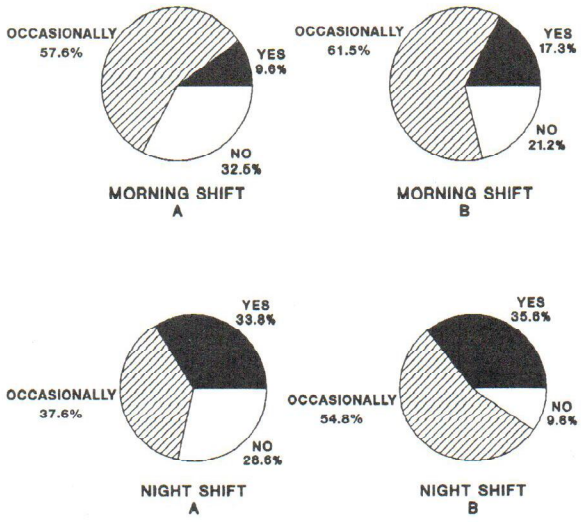

Figure 2 *Percentage of workers usually napping, napping occasionally and usually not napping (A group n=604; B group n=104)*

The analyses showed that the workers differing in napping strategies on morning shift days did not differ in their main sleep duration, either in group A ($F(2,601)=1.58$) or group B ($F(2,101)<1$). Similarly, shift workers differing in napping strategies on night shift days did not differ in the duration of the main sleep on these days, either in group A ($F(2,601)=2.76$) or in group B ($F(2,101)=1.32$).

DISCUSSION

In a rapidly rotating shift system where each phase of the shift cycle having unfavourable conditions for sleep is followed by a phase having favourable conditions for sleep, workers have the possibility to prolong their sleep after it has been shortened for a few days. The results of this study show that in this shift cycle reduced sleep in one phase is compensated with increase in sleep in the

following phase. Moreover, the increase in sleep is not identical in all workers: workers sleeping shorter in the phase with unfavourable conditions for sleep prolong their sleep more while those sleeping longer in the previous (unfavourable) phase prolong their sleep less. These results have been obtained for both examined groups working in different industries. The same relationships have also been found in our longitudinal study of young shift workers of homogenous age (11). The notion that sleep in more favourable conditions makes up for reduced sleep in less favourable conditions was rejected in an earlier shift work study because the correlation between sleep durations on working and non-working days was not negative but positive (12). However, this study as well as the previously mentioned longitudinal study of a homogenous group of young shift workers show that a negative correlation between sleep durations in two phases of the shift cycle could not be a basis for rejecting the compensatory notion. The existence of compensation is revealed through a negative correlation between reduced sleep duration in unfavourable conditions and the amount of sleep increase in more favourable conditions. This correspondence shows that a worker who sleeps shorter on morning or night shift days is also likely to increase his sleep more on the days of the following shift phase, i.e. afternoon shift days or days off, and one who sleeps longer is also likely to increase his sleep less. The possibility to compensate for shortened sleep is especially important after night shift days when a large percentage of workers sleep less than five hours which is considered to be an obligatory quota (13).

The present results show that there is a relationship between the shift worker's age and napping incidence. When the effect of age upon sleep duration was statistically controlled there was no relation between the incidence of napping and the main sleep duration; the workers usually napping, either on morning or night shift days, did not sleep shorter than the workers usually not napping. Likewise, such relationship was not found among young shift workers of homogenous age (11). These data seem to indicate that in shift workers naps do not occur to compensate for reduced main sleep. The question that still requires an answer is whether there is a relationship between the duration of main sleep and the duration of nap, and also whether appetitive and replacement nappers can be identified among workers usually napping (14).

There is a dispute on which shift schedule is superior: permanent shifts in which the hours of work remain the same from day to day, slower rotating shifts with one week or more at one shift timing before moving to a different timing, or quicker rotating shifts with very short round of duty at one shift timing before moving to a different timing (10, 15, 16). In the rapid rotating shift system each phase involves only two or three days in a row and thus results in fewer successive sleeps in unfavourable conditions (night and morning shifts) and eventually in a less cumulative sleep loss which tends to build up after many successive nights (17). This study taking account of the duration of sleep in various phases within the shift cycle forwards the argument of immediate compensation of reduced sleep in favour of the rapidly rotating shift schedule.

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Sažetak

NADOKNADA SKRAĆENOG SPAVANJA U SUSTAVU BRZOROTIRAJUĆIH SMJENA

Ispitane su neke karakteristike spavanja u dvije skupine radnika heterogene dobi. Radnici su radili u brzorotirajućem smjenskom ciklusu s fazama koje se izmjenjuju po redosljedu: jutarnje, poslijepodnevne, noćne smjene te slobodni dani. Svrha ispitivanja bila je utvrditi postoje li pouzdani odnosi između karakteristika spavanja u različitim fazama smjenskog ciklusa koji bi govorili o kompenzaciji skraćenog spavanja u jednoj fazi smjenskog ciklusa s dodatnim spavanjem u istoj fazi i/ili s produljenim spavanjem u narednoj fazi smjenskog ciklusa. Budući da su trajanje spavanja i učestalost dodatnog

Arh hig rada toksikol, Vol 45 (1994) No 3, pp. 211–218

spavanja povezani s dobi odnos između karakteristika spavanja u različitim fazama smjenskog ciklusa ispitan je nakon što je statistički uklonjen utjecaj dobi iz analiziranih variabli. Nije nađena povezanost između trajanja glavnog spavanja i učestalosti dodatnog spavanja. Utvrđeno je da se reducirano spavanje u jednoj fazi smjenskog ciklusa koja je nepovoljna za spavanje (jutarnjoj, odnosno noćnoj smjeni) kompenzira produživanjem spavanja u narednoj fazi koja je povoljna za spavanje (poslijepodnevnoj smjeni, odnosno slobodnim danima). Produživanje nije jednako u svih radnika: oni radnici koji u prethodnoj fazi spavaju krače produžuju svoje spavanje više, a radnici koji u prethodnoj fazi spavaju dulje produžuju svoje spavanje manje. Dobiveni rezultati govore u prilog preporuke brzorotirajućeg smjenskog sustava u odnosu na sustav permanentnih ili sporotirajućih smjena.

Ključne riječi:
dob, dodatno spavanje, karakteristike spavanja, smjenski rad, trajanje glavnog spavanja

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