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Effects of alternating 8- and 12-hour shifts on sleep, sleepiness, physical effort and performance

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Objectives The aim of the present study was to compare 12-hour shifts during weekends with 8-hour shifts during weekdays with respect to sleep, sleepiness, physical effort, and performance.

Methods Thirty-one subjects at a power plant participated. Sleep, sleepiness, and physical effort were measured with a diary. About half of the subjects carried out a reaction-time test during both 8- and 12-hour morning and night shifts. The remaining subjects carried out a vigilance task.

Results Sleepiness was higher and physical effort lower on the 12-hour night shift than on the 8-hour night shift. However, the subjects who had the same level of physical effort on 8- and 12-hour night shifts did not differ with respect to sleepiness. During the 12-hour morning shift, sleepiness was lower and the sleep length was longer than on the 8-h morning shift. The subjects who had the same amount of sleep for 8- and 12-hour morning shifts showed no difference in sleepiness. Sleep did not differ between 8- and 12-hour night shifts. There was no difference between 8- and 12-hour shifts with respect to performance.

Conclusions It was suggested that the difference in sleepiness between 8- and 12-hour shifts is related to differences in sleep length for the morning shift, and to differences in physical effort for the night shift, rather than to shift duration. Thus the most likely conclusion is that 12-hour shifts do not cause increased sleepiness or impaired performance or disturbed sleep.

Key terms fatigue, reaction time, shift work, subjective ratings, vigilance.

Recently there has been a growing interest in long workhours, and, in particular, 12-hour shifts. One benefit of extended workshifts is that they permit longer and more frequent blocks of free time. On the other hand, there is also a potential risk that extended shifts cause excessive fatigue and sleepiness, which may result in higher risks of accidents and injuries or in a deterioration of health (1, 2). Previous results are inconclusive. For example, Rosa and his co-workers have found increased sleepiness, shorter sleep, and performance decrements after changes to 12-hour shift schedules (3, 4). In contrast, other studies have reported improved sleep, alertness, and well-being as a result of changes to 12-hour shift schedules (5, 6). The reason for the inconsistent results may, at least partly, be methodological. Thus many studies have used a pre- and posttest design, but often without a reference group. Thus it may be that factors other than the change in shift schedule have influenced the results. Another concern is that the evaluation has not extended beyond the initial "Hawthorne" period, when the act of change in itself can be viewed as positive, regardless of content (2).

The aim of the present study was to examine how 12-hour shifts (on weekends), alternating with 8-hour shifts in the same schedule, affect sleep, physical effort, sleepiness, and performance. To our knowledge, this kind of schedule has not been evaluated before. The schedule offers a compromise between the social benefits of having 12-hour shifts on weekends (and not working more than 2 weekends out of 6), but minimizing the risk of accumulating fatigue, since only six 12-hour shifts are worked in a 6-week period. Furthermore, the design also avoids some of the methodological problems of previous studies because the subjects are their own referents, and there is no "Hawthorne effect" since the shift schedule has not changed.

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Subjects and methods

All shift workers (N=76) at a power plant in Stockholm were invited to participate in the study. Twenty-seven abstained or could not participate (changed to day work, changed employment, or pregnancy). Of the remaining 49 subjects another 18 had to be excluded from the analysis because of incomplete data or because of too many deviations from the schedule (changed shifts with colleagues, much overtime, holidays and sick leave). Thus the present study included 31 experienced 3-shift workers, 27 men [mean age 38 (standard error of the mean=SE 2) years] and 4 women [mean age 29 (SE 2) years], who completed a shift cycle. They worked as control room operators, shift engineers, machinists, and shift supervisors.

The shift cycle (comprising 42 days and 6 shift teams) is presented in table 1. The present shift system was introduced more than 1 year before the study.

Eight-hour shifts were worked from Mondays to Thursdays and 12-hour shifts from Fridays to Sundays (the 3rd 12-hour night shift finished at 0700 on Monday morning). The analyses compared the 1st three 8- and 12-hour morning (M) shifts, and, for night (N) shifts, the three 12-hour shifts were compared with the 1st two 8-hour shifts and the 4th 8-hour shift. Since the sleep episode after the last 8- and 12-hour N shifts, respectively, was reduced by about 1.5 hours when compared with the other day sleep episodes, the 4th (and last) 8-hour N shift was considered more appropriate for the present analyses (comparing 8- and 12-hour shifts) than the 3rd shift. Furthermore, there was no significant difference in rated sleepiness [mean KSS between 2400 and 0600; shift 3=5.1 (SE 0.2) versus shift 4=4.9 (SE 0.2), P=0.42)] or physical effort [mean CR-10 between 2400 and 0600; shift 3=1.9 (SE 0.1) versus shift 4=1.8 (SE 0.1), P=0.35] between the 3rd and the 4th 8-hour N shifts. The last days off before the 8- and 12-hour M shifts were also analyzed to investigate the level of recuperation and alertness before the work periods.

The subjects completed the Karolinska Sleep Diary (KSD) (7) and a wake diary across the entire shift cycle. The sleep diary was collected daily after each main sleep period, and it had questions about bed times, wake-up times, napping, and different aspects of sleep quality. A sleep quality index was computed (as a mean across items), containing the items "sleep quality" (phrased "How was your sleep?"), "ease of falling asleep", "calm sleep" and "slept throughout". In previous studies the sleep quality index showed a significant covariation with objective measures of sleep (8). The analysis also included the items "well-rested and refreshing sleep" and "ease of awakening". The response alternatives ranged from 1 ("problems" or "very poor") to 5 ("no problems at all" or "very good").

In the wake diary the subjects were instructed to rate their sleepiness and physical effort every 2nd hour on the Karolinska Sleepiness Scale (KSS) (9) and on the Borg CR-10 scale (10) both during work and free time. The KSS is a 9-point verbally anchored scale that ranges from 1 ("very alert") to 9 ("very sleepy, fighting sleep, an effort to keep awake") . The CR-10 scale ranges from 0 ("none at all") to 10 ("extremely exerted") and has shown a significant covariation with such physiological measures as heart rate and blood lactate (11).

The shift workers were instructed to carry out a performance test at the beginning and end of the M and N shifts (both 8- and 12-hour shifts), respectively. Two tests were used. Half the group did a serial simple reaction-time test and the other half did a vigilance task (VT). The reaction-time test (length=10 minutes) (12) was presented on a handheld computer (Psion Organizer) and was carried out in the normal work environment. Sixteen signals per minute were presented at random intervals (interstimulus interval 2—7 seconds). The present analysis was based on the mean and the 10% longest reaction times across tests. The vigilance task (also 10 minutes) was presented on a computer and was carried out close to the control room. The test was a shorter version of a previously validated 28-minute vigilance task (13).

Table 1. Shift schedule. [A-F=shift teams, D=day shift (0700-1600), A=afternoon shift (1500-2300), M=morning shift (0700-1500), **M**= morning shift (0700-1900), N=night shift (2300-0700), **N**=night shift (1900-0700), blank=day off, bold letters=12-hour shifts, Mo = Monday, Tu = Tuesday, We = Wednesday, Th = Thursday, Fi = Friday, Sa = Saturday, Su = Sunday]

	1							2							3						
	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
A	D	D	D	D	D			A	A	A	A				M	M	M	M	**N**	**N**	**N**
B								D	D	D	D	D			A	A	A	A			
C	N	N	N	N											D	D	D	D	D		
D					**M**	**M**	**M**	N	N	N	N										
E	M	M	M	M	**N**	**N**	**N**					**M**	**M**	**M**	N	N	N	N			
F	A	A	A	A				M	M	M	M	**N**	**N**	**N**					**M**	**M**	**M**

	4							5							6						
	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su	Mo	Tu	We	Th	Fr	Sa	Su
A					**M**	**M**	**M**	N	N	N	N										
B	M	M	M	M	**N**	**N**	**N**					**M**	**M**	**M**	N	N	N	N			
C	A	A	A	A				M	M	M	M	**N**	**N**	**N**					**M**	**M**	**M**
D	D	D	D	D	D			A	A	A	A				M	M	M	M	**N**	**N**	**N**
E								D	D	D	D	D			A	A	A	A			
F	N	N	N	N											D	D	D	D	D		

The signal (total=21 signals) that had to be detected was a clockwise rotating dot that jumped a step at random intervals. Some subjects had to be excluded from the analysis, since the tests had interfered too much with their work task. Altogether 13 subjects produced complete data (for at least one 8-hour and one 12-hour N and M shift, respectively) on the reaction-time test, and 15 subjects completed the vigilance task.

The data were analyzed with a repeated-measures analysis of variance (ANOVA) using 2, 3 or 4 within-group factors. The main effects were shift type (N shifts versus M shifts), shift length (8-hour shifts versus 12-hour shifts), shift sequence (1st, 2nd, and 3rd shift in a row) and, when appropriate, time of day. The Huynh-Feldt epsilon correction method was used to correct for sphericity (14). However, for clarity, the unadjusted degrees of freedom are given in the tables. When appropriate (and after a significant main effect), pairwise tests (orthogonal contrasts) were carried out to investigate the simple effects. For the test of relations between variables, correlation coefficients (pooled) were calculated using a least-squares dummy-variable regression model according to the method of pooled time series presented by Totterdell et al (15). The alpha level was set at 0.05.

Results

The means (across shifts) and a summary of the ANOVA procedures are presented for the sleep and wake data in table 2. The time-of-day results for the KSS

Table 2. Means, standard errors (SE), and P-values [3-way analysis of variance (ANOVA) with shift, length and sequence as factors] for ratings of sleep, alertness, and physical exertion on 8- and 12-hour morning and night shifts. [S = shift; L = length; Se = sequence; TST=total sleep time (for the main sleep episode, naps not included); KSS=Karolinska Sleepiness Scale (1 very alert, 9 very sleepy); CR-10=category ratio scale of physical exertion (0=none at all, 10=extremely exerted)]

	Night shifts		Morning shifts		S	L	Se	SxL	SxSe	LxSe	SxLxSe
	Mean	SE	Mean	SE							
TST (h+min)											
8-hour shifts	5:29	12	6:05	8	0.005	0.31	0.06	0.06	0.0002	0.13	0.04
12-hour shifts	5:18	10	6:27	7							
P-value	0.36		0.04								
TST for the last day off (h+min)											
8-hour shifts	8:49	16	7:48	19	0.02	0.37	-	0.16	-	-	-
12-hour shifts	8:42	22	8:26	13							
P-value	0.80		0.04								
Individuals taking naps (%)											
8-hour shifts	48	5	13	4	0.0001	0.04	0.01	0.14	0.002	0.53	0.74
12-hour shifts	46	5	0	0							
P-value	0.66		0.02								
Sleep latency (min)											
8-hour shifts	11.6	2	17.4	2	0.006	0.53	0.23	0.79	0.37	0.39	0.88
12-hour shifts	10.5	1	15.5	2							
P-value	0.64		0.55								
Sleep quality index (1 poor-5 good)											
8-hour shifts	4.1	0.1	3.9	0.1	0.16	0.37	0.40	0.58	0.59	0.08	0.35
12-hour shifts	4.0	0.1	3.9	0.1							
P-value	0.12		0.85								
Well-rested (1 no-5 yes)											
8-hour shifts	3.1	0.1	2.7	0.1	0.38	0.62	0.04	0.07	0.09	0.63	0.18
12-hour shifts	2.9	0.1	3.0	0.1							
P-value	0.35		0.04								
Ease awakening (1 difficult-5 easy)											
8-hour shifts	3.1	0.1	2.6	0.1	0.03	0.04	0.01	0.27	0.64	0.55	0.93
12-hour shifts	3.2	0.1	2.9	0.1							
P-value	0.39		0.03								
KSS (N=2400-0600h, M=0800-1400)											
8-hour shifts	5.1	0.1	4.1	0.1	0.0001	0.19	0.18	0.0002	0.34	0.74	0.17
12-hour shifts	5.7	0.1	3.7	0.1							
P-value	0.001		0.02								
CR-10 (N=2400-0600h, M=0800-1400)											
8-hour shifts	1.8	0.1	2.4	0.1	0.0001	0.001	0.01	0.58	0.60	0.41	0.28
12-hour shifts	1.6	0.1	2.1	0.1							
P-value	0.04		0.03								
Degrees of freedom	1/30		1/30		1/30	1/30	2/60	1/30	2/60	2/60	2/60

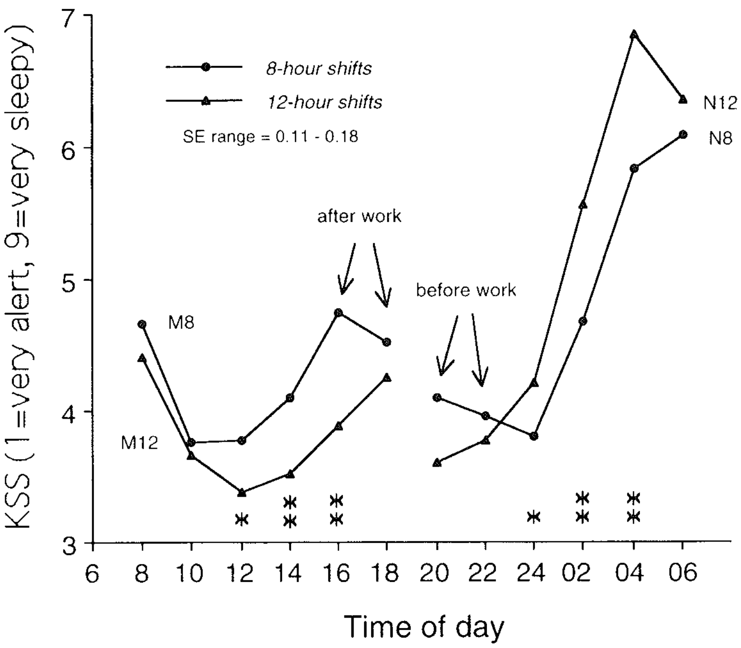

Figure 1. Mean ratings of sleepiness on the Karolinska Sleepiness Scale (KSS) every 2nd hour on 8-hour morning shifts (M8), 12-hour mornings shifts (M12), 8-hour night shifts (N8), and 12-hour night shifts (N12). Two ratings after M8 and before N8 are also plotted. Asterisks indicate significant (*P<0.05, **P<0.01) pairwise differences between 8- and 12-hour shifts.

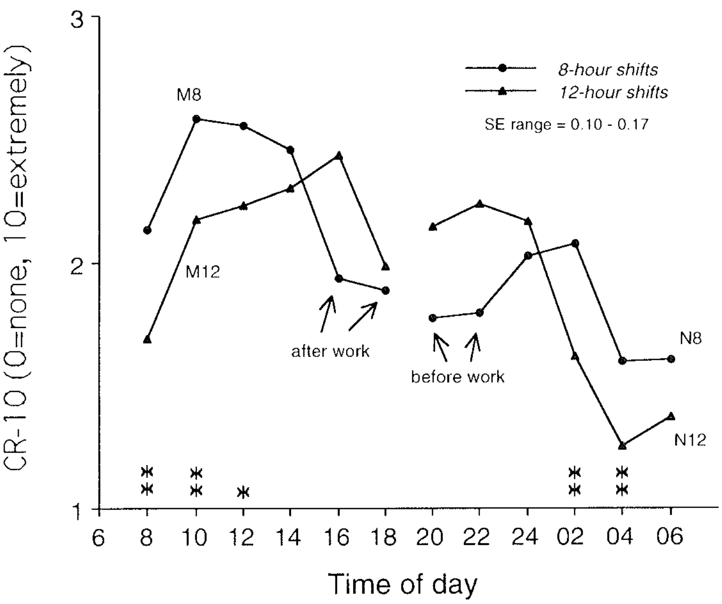

Figure 2. Mean ratings of physical effort on the Borg's category ratio scale (CR-10) every 2nd hour on 8-hour morning shifts (M8), 12-hour mornings shifts (M12), 8-hour night shifts (N8), and 12-hour night shifts (N12). Two ratings after the M8 and before N8 are also plotted. Asterisks indicate significant (*P<0.05, **P<0.01) pairwise differences between 8- and 12-hour shifts.

(sleepiness) and CR-10 (physical effort) are also given in figures 1 and 2. The variables total sleep time, "total sleep time prior to the last day off before shifts" (for the night shifts the last night sleep before the shift sequence was used), sleep latency, ease of awakening, napping (both during free time and on the shift), KSS and CR-10 showed a significant main effect for shift (M versus N shifts). The sleep prior to the last day off before the shift sequence was longer in connection with the N shifts. However, the total sleep time during day sleep (N shifts) was shorter (about 30 minutes) than sleep in connection with the M shifts. The sleep latency was longer in connection with the M shifts. Naps were more frequently taken in connection with N shifts. The rating ease of awakening indicated more difficulties in connection with the M shifts. The M shifts also showed higher alertness and physical effort. Frequency of naps, ease of awakening, and the CR-10 were the only variables that showed a significant difference due to length of shift (8-hour versus 12-hour shifts). It was easier to wake-up in connection with 12-hour shifts than in connection with 8-hour shifts, and more naps were taken in connection with the 8-hour shifts. The physical effort was also lower for the 12-hour shifts. Frequency of naps, well-rested, ease of awakening, and CR-10 also showed significant effects due to sequence (1, 2, and 3 or 4 shifts). The frequency of naps [1 shift (32%) versus 3 or 4 shifts (20%)], as well as the physical effort (about 0.2 scale units), decreased across shifts. The problems with difficulties awakening and unrefreshing sleep accumulated across shifts (decreased by about 0.3 scale units between the first and the last shift). The sleep quality index showed no significant effects at all.

Among the interaction effects, total sleep time and the frequency of naps showed a significant shift-by-sequence effect. The last-day sleep was about 1.5 hours shorter than the other day sleeps, whereas there was no such change for the M shift. The frequency of naps decreased across N shifts (1st 60%, 2nd 48%, 3rd 34%), whereas the occurrence of napping in connection with the M shifts was stable across shifts (~6%). The KSS showed a significant shift-by-length interaction. Thus sleepiness was higher for 12-hour N shifts than for 8-hour N shifts but lower for 12-hour M shifts when compared with 8-hour shifts. The other interactions, except for total sleep time, which showed a significant 3-way interaction, were nonsignificant.

The variables were also subjected to repeated ANOVA procedures for the N and M shifts, separately (2 factors: length of shift and sequence). The P-values for the factor length of shift are listed in table 2 (below the means). For the N shift, significantly higher sleepiness and lower physical effort was found for the 12-hour shift. For the M shifts, significant effects due to length of shift were obtained for the variables total sleep time, total sleep time prior to the last day off, frequency of naps, well-rested, ease of awakening, sleepiness and physical effort. Sleep in connection with the 12-hour shifts was longer and involved no napping; in addition the subjects felt more refreshed and rated the awakening as easier. Furthermore, the sleep prior to the last day off before the 12-hour M shift sequence was about 40 minutes longer. The 12-hour M shift also involved lower ratings of sleepiness and physical effort.

The ANOVA for the KSS and CR-10 ratings also included a 4th factor — time of day. (See figures 1 and 2.) Time of day was significant only for KSS (P=0.0001), and it also showed the expected interaction with shift (P=0.0001). The ratings of sleepiness and physical effort between 2000 and 2200 for the N shifts, and between 1600 and 1800 for the M shifts were also analyzed with respect to length of shift. The mean KSS for the N shifts was 4.0 (SE 0.1) for the 8-hour shifts and 3.7 (SE 0.1) for the 12-hour shifts, and it did not differ between conditions (P=0.13), nor was there a difference in the ratings of CR-10 [8-hour: 1.8 (SE 0.1); 12-hour: 2.2 (SE 0.1), P=0.09] between the N shifts. The CR-10 ratings did not differ for the M shifts [8-hour: 2.0 (SE 0.1); 12-hour: 2.2 (SE 0.1), P=0.26], but the 8-hour M shift was associated with more sleepiness [4.6 (SE 0.1) versus 4.1 (SE 0.1), P=0.005] during the free time between 1600 and 1800.

The KSS and the CR-10 ratings were also subjected to pairwise testing for each time point (figures 1 and 2). Significantly lower sleepiness for the 12-hour shifts was found at 1200, 1400, and 1600, and significantly higher sleepiness was found for the 12-hour shifts at 2400, 0200h and 0400. The analysis for CR-10 showed significantly lower effort for the 12-hour shift at 0800, 1000, 1200, 0200, and 0400.

The difference in physical effort between the 8- and 12-hour N shifts, and in sleep length between the 8- and 12-hour M shifts, may have biased the comparison with respect to sleepiness. In order to control for the bias, some additional analyses were carried out. For the N shift, a subgroup (N=13) was created with subjects with the same level of physical effort (CR-10) during both 8-hour [mean CR-10 1.4 (SE 0.2)] and 12-hour [mean CR-10 1.6 (SE 0.3)] shifts. This subgroup showed no difference in sleepiness between 8- and 12-hour N shifts [KSS: 8-hour

Table 3. Means, standard errors (SE), and P-values (3-way analysis of variance (ANOVA) with shift, length and timing as factors) for performance data [reaction times, degrees of freedom (df)=1/12, and vigilance performance, df=1/14].

	Night shifts				Morning shifts				3-way ANOVA			
	Start		End		Start		End		Shift (S)	Length	Timing (T)	SxT
	Mean	SE	Mean	SE	Mean	SE	Mean	SE				
Reaction times												
Mean (ms)												
8-hour shifts	255	9	284	12	283	11	289	13	0.38	0.83	0.04	0.0002
12-hour shifts	260	9	299	19	280	11	267	11				
10% longest												
8-hour shifts	351	20	411	25	417	32	424	25	0.23	0.38	0.11	0.03
12-hour shifts	368	18	462	52	428	36	402	36				
Vigilance (% misses)												
8-hour shifts	10	2	12	2	6	1	9	2	0.31	0.97	0.85	0.87
12-hour shifts	10	3	8	1	10	2	9	2				

shift=5.2 (SE 0.1), 12-hour shift=5.6 (SE 0.1), P=0.12]. In contrast, the remaining subjects (N=18), who rated their physical effort as lower on the 12-hour N shift, showed significantly higher sleepiness on the extended shift [KSS: 8-hour shift=5.0 (SE 0.1), 12-hour shift=5.8 (SE 0.1), P=0.0001]. A similar analysis was made for the M shift, but the subjects were stratified with respect to prior sleep length. The subgroup (N=14) who obtained the same amount of sleep for both the 8- and 12-hour M shifts [2 subjects actually had slightly less sleep prior to the 12-hour shifts, total sleep time: 8-hour shift=6 hours 40 minutes (SE 14 minutes); 12-hour shift=6 hours 20 minutes (SE 12 minutes)] showed no difference in mean sleepiness [8-hour shift=3.8 (SE 0.1); 12-hour shift=3.6 (SE 0.1), P=0.51]. The group who slept longer in connection with the 12-hour M shift [N=17, 8-hour shift: 5 hours 48 minutes (SE 16 minutes), 12-hour shift=6 hours 34 minutes (SE 14 minutes)], rated lower sleepiness for the 12-hour M shift [8-hour shift=4.3 (SE 0.1); 12-hour shift=3.9 (SE 0.1), P=0.02].

The mean ratings (between 1200 and 2000) of KSS was also computed for the last day off before the first 8-hour and 12-hour M shifts. However, there was no significant difference in sleepiness between the days [8-hour shift: 3.8 (SE 0.1), 12-hour shift: 3.5 (SE 0.1), P=0.27].

The apparent negative covariation between the KSS and CR-10 ratings was tested with a least square dummy variable regression model (all ratings pooled, number of data points=1791), and a correlation coefficient was calculated. A set of n-1 dummy variables represented each participant; the procedure eliminated the difference in level between different subjects. The correlation coefficient for the entire data set was -0.34 [P=0.0001, degrees of freedom (df)=1760, df being calculated as the number of data points minus the number of subjects]. When only N shift data were included, the correlation coefficient became -0.36 (P=0.0001, df=862).

Table 3 shows the results for the performance tests. None of the tests showed any significant main effects for length of shift (8- versus 12-hour shifts) or shift (M versus N). However, the mean reaction time showed a significant main effect for timing (start versus end of shift). The reaction time at the end of the shift was longer than at the start of the shift. Both the mean and the 10% longest reaction times showed a significant interaction between shift and timing. This interaction indicated that the reaction times increased towards the end of the N shift, whereas there was almost no difference between the start and end times for the M shift. No other interactions reached significance. The data were also subjected to a separate comparison between 8- and 12-hour shifts within the M and the N shifts. The analyses did not reveal any significant differences between 8- and 12-hour shifts, although there was a trend towards longer reaction times (10% longest) for the 12-hour N shifts (P=0.08).

Discussion

The comparison between alternating 8- and 12-hour shifts within the same shift system showed higher sleepiness for the extended (12-hour) N shift, but lower sleepiness for the extended M shift. However, there was no difference between 8- and 12-hour shifts with respect to performance on 2 tests (simple reaction time and vigilance) known to be sensitive to variations in sleepiness (16). The 12-hour shifts during the weekend were also, unexpectedly, associated with decreased physical effort; this may indicate a lower physical work load during the extended shifts.

The results partly support the hypothesis that 12-hour workshifts cause more sleepiness. However, it is likely that the shifts during the weekend (and especially during the N shift) involved more passive monitoring of the process than shifts between Monday and Thursday. Thus it may be that a decreased (physical) work load is associated with increased sleepiness during 12-hour N shifts. This suggestion was supported by a subgroup analysis controlling for physical work load, which eliminated the difference in sleepiness. It was also supported by the negative (pooled) correlation found between ratings of sleepiness and physical effort during the night shift. Furthermore, physical work load is also believed to be a strong determinant of sleepiness, although the empirical evidence for this conclusion is rare (17). Clearly, work load requires further investigation in relation to workhours and fatigue.

Among other factors that may explain the difference between 8- and 12-hour shifts during the night, sleep can be ruled out, since no differences were found between conditions for duration of sleep or quality of sleep. However, a possible exception may be the difference in napping behavior between the 8-hour and the 12-hour shifts. The naps did, of course, occur earlier in connection with the 12-hour shift [mean starting (clock)time: 12-hour shift=1454, 8-hour shift=1735, P=0.003], although there was no difference with respect to nap length or frequency. The fact that the naps occurred earlier in connection with the 12-hour shift may imply that their beneficial alertness-enhancing effect had diminished when the critical early morning hours were reached and sleepiness may have increased more during the 2nd half of the 12-hour N shift.

The decreased level of sleepiness during the 12-hour M shift, when compared with the 8-hour M shift, was unexpected. One reason may be that sleep prior to the 12-hour shift was longer and the subjects felt more refreshed and rated the awakening as easier. This possibility was supported by the subgroup analysis controlling for prior sleep length, which eliminated the differences in sleepiness. The duration of sleep and whether sleep is refreshing also seem to be important determinants of (rated) sleepiness in connection with daytime work (18). The reason for better sleep during the weekend is not clear, but commuting time is usually shorter then (the subjects reported a mean commuting time to work of about 40 minutes), permitting a later wake-up time. Another speculation is that sleep was less disturbed by environmental (noise, etc) and psychosocial (stress, mood, etc) factors during the weekend. In addition, the subjects also reported longer sleep in connection with the day off prior to the 12-hour shift sequence. This result suggests that the subjects may have been better prepared and more recuperated before they started the 12-hour shifts. The 12-hour M shifts were also preceded by an additional day off (4 days instead of 3) when compared with the 8-hour shifts.

Among the previous work on extended shifts, the studies by Rosa and his co-workers (3, 4, 19) may be the most relevant to use for comparison because of a similar methodology. Consistent with the present findings, these studies also demonstrated an increase in subjective sleepiness during 12-hour N shifts. In contrast to the present study, they also found performance decrements and disturbed sleep for the 12-hour shifts. In the present study there was only a tendency towards worse performance during the 12-hour N shifts. A possible explanation for these inconsistencies may be related to the differences in schedules. Thus it may be that alternation between 8- and 12-hour shifts, and hence the lower exposure for extended shifts in the present study, did not permit any accumulation of sleepiness and made it easier to tolerate the 12-hour shifts. Another explanation for the difference between the studies may be that, in the Rosa studies, performance was measured more intensively and the measurement included a battery of different tests; in addition it is possible that these factors increased the sensitivity to subtle differences in performance.

In conclusion, the present results showed no indications of 12-hour shifts being worse than 8-hour shifts with respect to sleep, sleepiness, and performance, except for subjective sleepiness during the N shift, which was higher for the extended shift. However, when confounding (lower work load during the extended N shifts) was controlled, the differences in sleepiness between the 8-hour and the 12-hour N shifts became nonsignificant.

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