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Intervention in shift scheduling and changes in biomarkers of heart disease in hospital wards

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Objectives The effect of introducing regularity, few consecutive night shifts, more weekends off, and only 2 different types of shifts (day-evening or day-night) into shift scheduling on biomarkers of heart disease was studied.

Methods Ergonomic shift criteria were introduced in a quasi-experimental controlled intervention in 4 hospital wards. Six wards participated as controls. Altogether 101 nurses and nurses' aides were followed for 6 months with measurements of cholesterol and triglycerides. The intervention led to more regular schedules and more staff having 2 shifts in 2 of the intervention wards 1 year after the intervention. The schedules among the controls became less regular and less predictable. The number of consecutive night shifts remained unchanged.

Results After 6 months the high-density lipoprotein (HDL) cholesterol level had increased in the intervention group, and the total cholesterol and low-density lipoprotein (LDL) cholesterol levels and the total:HDL cholesterol ratio had decreased. Regardless of the intervention, changes in regularity were associated with the triglyceride and HDL cholesterol levels and also with the total:HDL cholesterol ratio. More ergonomic changes were associated with lower LDL cholesterol levels, a lower total:HDL cholesterol ratio, and higher HDL cholesterol levels.

Conclusions Increased ergonomic scheduling was possible. Lipids and lipoproteins changed as predicted, both when the changes were assessed in respect to the changes in schedules that resulted from the intervention and the changes that occurred regardless of the intervention. The study suggests that scheduling based on ergonomic criteria is a possible means for reducing the risk of heart disease among shift workers.

Key words cardiovascular diseases, epidemiology, intervention studies, lipids, lipoproteins, occupational exposure, prevention, risk factors, tolerance, work, work schedule.

Shift work has been regarded as a risk factor for ischemic heart disease (IHD) for the last decade, although some studies have failed to find such an association (1, 2). The risk is probably mediated through life-style factors, psychosocial stress, and circadian desynchronization (3, 4).

It has been shown that the outline of a shift schedule may modify the impact on well being. Several proposals for ergonomic criteria have been suggested (5,6), using knowledge about circadian rhythmicity and sleep to propose fast forward rotation with few nights in a row, regularity, and delayed morning shift start as some of the principles for roster design.

The impact of shift work is also related to personal and social factors, and this relationship helps explain why the same schedule may be suitable for one shift worker and demanding for another. This situation supports the need for more weekends off and for the introduction of some flexibility allowing for the planning of interaction between work and social life.

It was anticipated that changing the shift schedule according to these ergonomic principles would lead to a lower risk of IHD. This hypothesis has been examined in 2 small studies on the direction of rotation (7) and the number of consecutive night shifts (8) on biochemical risk factors for IHD.

In this study we examined lipids and lipoproteins as biomarkers of IHD risk during intervention in shift scheduling that introduced several ergonomic principles simultaneously.

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Subjects and methods

The study was a controlled intervention comparing participants before and 6 months after a change in shift schedules.

Selection of wards

In a questionnaire all 112 wards with 24-hour coverage at 7 somatic hospitals in the county of Northern Jutland, Denmark, were asked to indicate interest in participating in a study with the aim of introducing ergonomic criteria into shift scheduling (9). Participation in the discussion would not oblige the wards to change their scheduling procedures. Of the 50 wards indicating interest, 12 were selected according to the number of nurses and nurses' aides working in the ward and the applied schedules. At the 6 wards that accepted an introductory meeting, all at the same regional hospital, the staff voted for participation. Through a participatory approach, the principles of shift scheduling, problems related to shift work, preferences, and the possibilities for changing the applied schedules were discussed. Proposals for new schedules were set up in a year-long process with ward personnel, and in project groups with representation of staff, ward supervisors and researchers. During the 1-year set-up one of the wards was divided in half, giving a total of 7 wards, and, of the 7, the staff of 4 eventually decided to change schedules according to ergonomic criteria. The implementation process has been described in detail elsewhere (10).

Principles of shift scheduling

Prior to the intervention, scheduling was done for 4 weeks in all the wards and presented to the staff at least 4 weeks in advance. The schedules comprised a mixture of staff on permanent evening or night shifts and full- and part-time staff which rotated between 2 or 3 shifts. Scheduling was very flexible for the rotating staff, giving the staff the opportunity to request special shifts and, in some instances, spells of shifts and days off. This type of planning meant that each of the rotating staff had a unique irregular shift schedule of her own.

Selected principles of ergonomic criteria were introduced that emphasized night shift scheduling. Finally, an agreement was reached that scheduling should respect the following principles:

- Maximum of 3—4 consecutive night shifts followed by an extra day off for catching up on sleep deficit. All 4 wards intended to plan according to this principle.
- More regular and predictable schedules with maintained but reduced flexibility to allow staff to choose special arrangements. Three wards intended to follow this principle. It was partly achieved by going from 3 to 2 shifts, but 1 ward also planned to schedule weekends, 1 ward scheduled days off, and 1 extended the scheduled period from 4 to 12 weeks.
- Rotating staff choosing either day and evening or day and night shifts, and therefore going from 3 different shift types to 2, but still with a shift length of approximately 8 hours. Staff members were allocated according to their preferred option. Three wards planned according to this principle.
- Minimizing weekend work. Two wards planned for maximizing the number of weekends off, 1 achieving 4 extra weekends per year and 1 finding 1 extra per 12 weeks through scheduling.

In none of the wards did the staff with permanent shifts or fixed schedules want their schedules to be changed. Therefore the changes affected only staff with rotating shifts. In the wards (a pediatric unit and a neurosurgery ward) using all 4 principles, all the rotating staff was included. In a neonatal unit using 3 of the principles, all the permanently employed rotating staff was included in the changes, and, in an intensive-care unit introducing only one of the principles, only the staff who wanted to work according to the principles were included.

Two of the remaining 3 wards, both intensive-care units, chose not to change schedules, but agreed to participate as intervention control wards. Four outpatient clinics, having day work only, were also included as control wards (figure 1). Staff at the 4 intervention wards that did not have schedules changed were asked to participate as controls. The participants were individually approached and gave their informed consent to participate. The study was approved by the regional ethics committee.

Data collection

Data were collected in the intervention and intervention control wards from April 1997 to April 1998 (figure 1). In the day-working control wards collection was done 1 year later, in April and September of 1998. Information on shift schedules in the intervention and intervention control wards was collected as copies of 8 weeks of shift scheduling for March and April 1997 (time 1), just before the intervention, and in March and April or April and May of 1998 (time 3), 1 year after the implementation of the agreed principles of shift scheduling.

In September 1996, during the discussion in the intervention and intervention control wards (time 0), a questionnaire on attitudes toward shift scheduling, social parameters, and symptoms was distributed. In this study the results were used for comparing the participants with the nonparticipants.

In April 1997 (time 1) a questionnaire partly based on the Standard Shiftwork Index (11) was distributed. The questionnaire requested information on age, personality factors, attitudes towards shiftwork scheduling, life-style factors, social factors, work environment, sleep, symptoms, and stress symptoms. In order to obtain information on day-to-day changes in diet (12) and sleep (13), a diary to be used on 5 days was also distributed, but it was only modestly filled in. The answers were not used in this publication.

After 6 months (time 2) and again after 12 months (time 3), a shorter version of the same questionnaire and the same diary was distributed (figure 1).

Blood samples were collected between 0800 and 1000 after at least 8 hours of fasting and at least 72 hours after the end of the last night shift. Total cholesterol, high-density lipoprotein (HDL) cholesterol and triglyceride concentrations were measured as biomarkers of IHD risk (14—16). The low-density lipoprotein (LDL) cholesterol concentration and the total:HDL cholesterol ratio were calculated. All the measurements were done by the Department of Biochemistry, Aalborg Regional Hospital, according to standard procedures.

Exposure assessment

Only some of the participants in the intervention wards were supposed to have their schedules changed. They were identified through a question in the second questionnaire. The participants stating that their schedule had been changed due to the intervention were considered "exposed". They were further divided so that the exposed staff at the 2 wards that agreed to all 4 principles formed 1 group (I4) and those exposed at the wards agreeing to 1—3 principles formed another (I3), while the participants indicating no changes in their schedule constituted the reference group regardless of ward, together with the participants from the intervention control wards and the outpatient clinics (figure 1). This way of defining exposure was chosen because the aim of the study was to examine whether the introduction of ergonomic principles at the ward level would lead to changes in biomarkers among the staff.

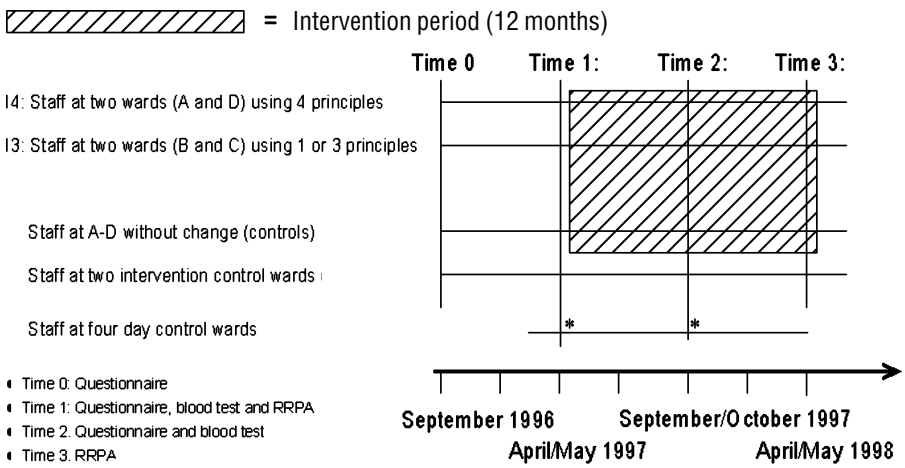
During the intervention period the wards had some problems in maintaining scheduling according to the introduced principles due to staff shortage, sickness and maternity leave, new rules for handling overtime work, and the like.

As the scheduling was also flexible after the intervention, the schedules among the controls could also change, and we defined another criterion for exposure assessment that was independent of the intervention; namely, changes in schedule characteristics divided according to whether, from an ergonomic point of view, they were judged to be less strainful.

Participants and nonparticipation

Altogether 172 nurses and nurses' aides of the 254 in the wards at time 1 agreed to participate in the study (67.7%) (figure 2). In the first 6-month period 17 left the wards, and among the remaining 155 that had participated in the first data collection, 101 participated in the second (time 2) data collection (65.2% of those eligible, 39.8% of the 254 employed at time 1). In the intervention wards, one-third of the data collection was done (time 3), but the participation rate was only 36% of those eligible, and therefore these data are not presented.

The reasons for nonparticipation were not examined. The nonparticipation rate at time 1 was significantly higher among the nurses' aides, but it did not differ between the wards and the type of shift (rotating versus fixed). Altogether 45 of the 82 nonparticipants had completed the questionnaire at time 0, and a tendency for nonparticipation was found among the personnel not wanting more regular scheduling (P=0.06). No differences were found for attitudes towards other principles of shift work



* Data collection was made in the day control wards 1 year later (in April and September 1998)

Figure 1. Collection of data in the intervention study. Questionnaire and blood sample data from time 1 (preintervention) and time 2 (6-month postintervention) are used, along with the Rota Risk Profile Analysis (RRPA) data from time 1 and time 3 (1-year postintervention). The questionnaire data from time 0 were used to describe nonparticipation.

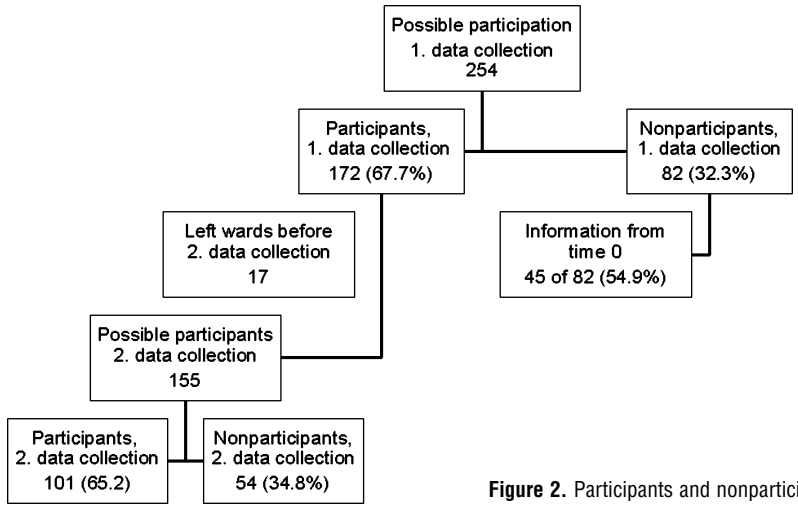


Figure 2. Participants and nonparticipants in 10 hospital wards.

scheduling, age, social parameters, general job satisfaction, symptom scores, and scores for locus of control.

The dropout rate between time 1 and time 2 was significantly higher in the intervention control wards and lower in the day-working control wards. No differences were found between the participants and nonparticipants with regard to the questionnaire data and the biomarker levels at time 1.

Description of the shift schedules

The description of the shift schedule characteristics and the validation of the shift schedule changes were done with the Rota Risk Profile Analysis (RRPA), version 3e (17), a computerized mathematical algorithm that scores shift schedules. The algorithm is based on knowledge of circadian disruption, ergonomic criteria, and social desirability, and it calculates 9 different scores. The scores are transformed into a figure from 0—10, with higher numbers for the ergonomically preferable situations. The basic score is a mean of every week in the schedule, and it is corrected with a constancy score that takes into account the constancy between weeks. Only the corrected scores are reported. Among the dimensions used in our study were (i) regularity (RE), changes in start and stop hours over the schedule, (ii) periodicity (PE), circadian disruption with accumulation of shift hours and with the direction of rotation taken into account, (iii) predictability (PR), counts of clusters of different shifts, and the length of the shift schedule.

The program also calculated the total number of hours worked between 2200 and 0600 and the number of Sundays off, and we further counted the maximum number of consecutive night and evening shifts and the total number of night and evening shifts in each of the 8-week periods. The differences over 1 year were then calculated by subtracting the scores. A 1-year period was used to minimize the influence of differences due to sickness and holidays, although it meant that the change in individual schedule assessment was judged over 1 year, while the outcome variables (biomarkers) were measured over half a year.

Analysis

The differences between the data collections before the intervention and 6 months later were calculated. The main analytic strategy was to examine the relation between "exposure" to a change in shift schedule (intervention) and changes in the biomarkers.

First, whether there were differences between the groups at baseline (time 1) and whether the 3 groups each differed from time 1 to time 2 (6 months after the intervention) were determined. Paired analyses comparing, for instance, the I4 at time 1 with the I4 at time 2 were used for this purpose. Finally, whether the within-subject differences from time 1 to time 2 were larger in the intervention groups than in the control group was examined by comparing the change between time 2 and time 1 in the 3 groups with a trend analysis.

The 2nd analytic strategy was to analyze the observed intraindividual differences in shift characteristics independent of the intervention. Changes in the RRPA scoring were calculated and divided into "better", "unchanged", and "worse" values according to ergonomic criteria. For regularity (RE), predictability (PR), and periodicity (PE) the cut-off level between the groups was set at ± 0.1 units. As more changes could be present simultaneously, we further examined the effect of one or several of the ergonomic changes made. As regularity and predictability were highly correlated (Kendal's tau 0.405 at baseline), we did not include predictability in this count. Staff of the outpatient clinics was included and labeled as "unchanged". The analyses followed the same principles already presented, with baseline comparisons of the RRPA measurements among the 3 groups, paired analyses of the change between time 1 and 2, and finally a comparison across the 3 groups.

The relation between intervention group affiliation and the change in the RRPA score was as follows: 9 had 1 ergonomic change and 12 had ≥2 changes among the 23 participants in I4; 5 had 1 ergonomic change and 7 had ≥2 changes among the 15 participants in I3; 13 had 1 ergonomic change in the RRPA score and 6 had ≥2 such changes among the 52 in the control group. For the intervention groups taken together versus the control, the result was highly significant ($P<0.0000$).

Nominal scales were compared with chi-square or Fisher's exact tests, ordinal scales, and nonparametric interval scales with Mann-Whitney and Jonckheere-Terpstra [a nonparametric test for trend (18)] tests, and with the Wilcoxon test for paired comparisons. For interval scales that followed a normal distribution, linear regression analyses were used to control for the effect of age.

As the level of several of the biomarkers for IHD are related to life-style factors (19), adjustment was made for exercise (none versus some), smoking (nonsmoking versus currently smoking), alcohol consumption (drinks/week), and an item chosen from several items on dietary habits as a proxy for fat consumption (normally avoids or normally does not avoid using margarine on bread), as the dietary diaries were not judged to be of acceptable quality.

All the analyses were conducted with the SPSS (Statistical Package of the Social Sciences) for Windows, version 8.

Baseline characteristics

The characteristics of the participants and the schedules at baseline (time 1) are displayed in tables 1—3. The participants who did not take part in the intervention were older and more satisfied with both their shift system and their general work conditions. They had given less consideration to finding another job. The groups did not differ with regard to family situation, personality factors, sleep quality, symptom scores or stress (not shown in the tables).

At time 1 the schedules in the I4 group were less regular and predictable. The I3 group had a higher load per week, corresponding to a higher number of hours/week, and more often had less than 36 hours between shift clusters.

Change in scheduling

The changes in the shift schedules during the intervention period (from time 1 to time 3) are shown at the group level in table 4. The shift schedules of the I4 group changed towards a higher regularity score and towards a higher degree of having 2 types of shifts. No differences occurred with regard to the maximum number of consecutive night shifts or circadian disruption. In the control group the schedules became less regular and less predictable with fewer Sundays off. The weekly workhours were also lower in the control group at time 3. There was a tendency towards more consecutive evening shifts in the I4 group than in the other groups. When the subtracted figures were compared across all 3 groups, there was a change in regularity and predictability, and the number of shift types also decreased with the intervention.

Results

Concurrent with the RRPA change in schedules, the questionnaire data showed (table 5) that the perceived predictability increased and flexibility decreased in the I4 group from time 1 to time 2. Although the intervention did not result in better sleep, fewer symptoms, or less feeling of stress, satisfaction with the schedules increased in group I4 (not shown in tables). Self-rated health was slightly higher in the I4 group, and the judgment of impact on family life was worse with the new schedule. In the other intervention group (I3) somatic and emotional stress symptoms were lower and mental health better at time 2. Life-style factors (smoking, exercising, and alcohol consumption) did not change with the intervention.

The I4 group showed an increase in HDL cholesterol and a decrease in total and LDL cholesterol and also a decrease in the total:HDL cholesterol ratio. In the I3 group the changes were in the same direction, but they were not statistically significant. The control group showed a significant increase in the total:HDL cholesterol ratio.

When age differences were adjusted for between the groups, the changes in the LDL cholesterol levels and the total:HDL cholesterol ratio were still significantly different in the I4 group when it was compared with the control group (table 6), and the I3 group had changes in between. The inclusion of life-style factors did not change the estimates.

For the other set of analyses we used each of the principles agreed upon for schedule planning as an exposure variable, regardless of whether it changed as part of the intervention or not, and thus was not related to ward (table 7). The ergonomic change in regularity was related to a decrease in triglyceride level and a decrease in the total:HDL cholesterol ratio and also to a higher HDL cholesterol level. The LDL cholesterol level and total:HDL cholesterol ratio decreased with lower predictability and increased with unchanged predictability. The HDL cholesterol level and total:HDL cholesterol ratio increased with lower periodicity and decreased with unchanged periodicity. With fewer consecutive night shifts there was a lower total:HDL cholesterol ratio. With more ergonomic changes the LDL

Table 1. Selected baseline characteristics of the groups. (IHD = ishemic heart disease, IQR = interquartile range, I4= intervention with 4 principles, I3=intervention with 1—3 principles)

Group	Age (years)		Family with IHD (%)	Married or living together (%)	Children at home (%)	Positive attitude toward shift work (%)	All in all satisfied with schedule[a]		Perceived regularity[a]		Perceived predictability[a]		Perceived flexibility[a]		No exercise (%)	Smoker (%)	Weekly alcohol consumption (number of drinks)	
	Median	IQR					Median	IQR	Median	IQR	Median	IQR	Median	IQR			Median	IQR
I4 (N=26)	35	10	62	73	65	50	3	1	3	2	3	1	2	1	12	27	4	6
I3 (N=15)	34	8	53	87	80	67	2	1	3	1	3	2	3	2	7	7	3	5
Control (N=60)	42	11	58	83	62	84	1	1	2	3	2	3	2	2	7	27	4	5

[a] Scales 1—5, low = satisfied, regular, predictable or flexible, depending on the scale in question.

Table 2. Baseline characteristics of the groups with respect to the blood samples. (HDL = high-density lipoprotein, LDL = low-density lipoprotein, IQR = interquartile range, I4 = intervention with 4 principles, I3=intervention with 1—3 principles)

Group	Total cholesterol (mmol/l)		Triglycerides (mmol/l)		HDL cholesterol (mmol/l)		LDL cholesterol (mmol/l)		Total:HDL cholesterol ratio	
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR
I4 (N=26)	4.8	1.2	0.8	0.4	1.7	0.5	2.7	1.2	2.7	1.0
I3 (N=15)	4.6	0.8	0.9	0.6	1.5	0.4	2.7	0.8	3.1	1.0
Control (N=60)	5.0	1.0	0.8	0.5	1.8	0.6	2.9	1.2	2.9	1.3

Table 3. Baseline characteristics of the groups with respect to the Rota Risk Profile Analyses (RRPA) score. (IQR = interquartile range, I4 = intervention with 4 principles, I3=intervention with 1—3 principles)

Group	Regularity		Predictability		Periodicity		Maximum number of consecutive night shifts		Types of shifts (1—3)		Number of Sundays off in 8 weeks	
	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR	Median	IQR
I4 (N=32)	7.55	0.59	4.44	1.44	7.55	1.81	3	4	2	1	5	1
I3 (N=25)	8.38	0.29	6.20	2.15	6.80	3.41	3	4	2	0	4	1
Control (N=55)	8.49	1.94	6.03	2.74	8.61	2.82	1	4	2	1	4	1

Table 4. Change in the scores of the Rota Risk Profile Analysis (RRPA) and the number of different shifts from time 1 to time 3 in the groups. The change (comparing the time 1 and time 3 measurements) was assessed using the Wilcoxon paired test (exact values < 0.05 given in footnotes, otherwise P>0.05) and the trend in change across the groups according to the Joncheere-Terpstra test for trend. (I4 = intervention with 4 principles, I3=intervention with 1—3 principles,IQR =interquartile range,)

RRPA scores[a]	Change from time 1 to time 3						P-value[b]
	I4 group (N=32)		I3 group (N =25)		Control group (N =55)		
	Median	IQR	Median	IQR	Median	IQR	
Regularity	0.11	0.78	0.00	0.12	0.00	0.34	0.003
Predictability	0.20	2.80	0.00	2.19	-0.54	1.87[c]	0.040
Periodicity	-0.10	0.89	-0.05	1.59	-0.03	0.70	0.943
Maximum numbers of night shifts	0	0	0	2.5	0	0	0.911
Number of Sundays off in 8 weeks	0	1	0	2	0	1[d]	0.516
Number of different shifts (1—3)[e]	0	1	0	0	0	0	.

[a] Features agreed upon.
[b] Joncheere-Terpstra test for trend.
[c] P=0.005 (Wilcoxon paired test).
[d] P=0.025 (Wilcoxon paired test).
[e] P=0.00015 (χ^2 test for I4 versus I3+control).

Table 5. Change from time 1 to time 2 in the groups. The change (comparing the time 1 and time 2 measurements) was assessed using the Wilcoxon paired test (exact values < 0.05 given in footnotes, otherwise P>0.05) and the trend in change across the groups according to the Joncheere-Terpstra test for trend. (I4 = intervention with 4 principles, I3 = intervention with 1—3 principles, HDL = high-density lipoprotein, LDL = low-density lipoprotein, IQR = interquartile range)

Variable	Change from time 1 to time 2						P-value[a]
	I4 (N=26)		I3 (N =15)		Control (N=60)		
	Median	IQR	Median	IQR	Median	IQR	
All in all satisfied with schedule (1-5, low=satisfied)	0	1	0	1	0	0	0.156
Perceived regularity (1-5, low=regular)	0	2	0	1.25	0	2	0.410
Perceived predictability (1-5, low=predictable)	-1	3[b]	0	1	0	0	0.023
Perceived flexibility (1-5, low=flexible)	1	2[c]	0.5	2	0	1	0.036
No exercise	0	1	0	1	0	0	0.268
Smoker	0	0	0	0	0	0	0.994
Weekly alcohol consumption (number of drinks)	0	3	0	3	0	2	0.659
Total cholesterol concentration (mmol/l)	-0.1	0.7[d]	0.2	1.0	0.0	0.8	0.184
Triglyceride concentration (mmol/l)	-0.1	0.3	0.0	0.3	0.0	0.5	0.372
HDL cholesterol concentration (mmol/l)	0.1	0.2[e]	0.0	0.5	-0.1	0.3	0.001
LDL cholesterol concentration (mmol/l)	-0.2	0.7[f]	0.0	0.9	0.1	0.7	0.003
Total:HDL cholesterol ratio	-0.3	0.3[g]	-0.3	0.8	0.1	0.7[h]	0.000

[a] Joncheere-Terpstra test for trend. [b] P= 0.041 (Wilcoxon paired test). [c] P=0.003 (Wilcoxon paired test). [d] P=0.043 (Wilcoxon paired test). [e] P=0.004 (Wilcoxon paired test). [f] P=0.005 (Wilcoxon paired test). [g] P=0.000 (Wilcoxon paired test). [h] P=0.041 (Wilcoxon paired test).

level and total:HDL cholesterol ratio decreased, and the HDL cholesterol level increased significantly.

Discussion

Intervening in shift scheduling by introducing ergonomic criteria succeeded in changing the schedules toward higher regularity, including going from 3 to 2 types of shifts. At the same time the control group changed toward lower scores in regularity and predictability. These changes led to favorable changes in risk factors for IHD for the group "exposed" to the highest number of new principles. With 4 principles agreed upon, there was an 8% decrease in total cholesterol, a 15% decrease in LDL cholesterol, a 9% increase in HDL cholesterol, and a 14% decrease in the total:HDL cholesterol ratio. In the intervention group in which 1—3 changes were introduced, smaller insignificant changes occurred in the same direction, but the only significant change occurred for the total:HDL cholesterol ratio, with an 11% decrease.

In addition, when the changes in the RRPA scoring regardless of the intervention were analyzed, a significant relation between changes in schedules and the lipids and lipoprotein biomarkers was found. The same biomarkers (HDL, LDL and total:HDL cholesterol ratio) changed in the same direction whether analyzed groupwise (four principles introduced, table 5) or as the number of changes (table 7). Higher regularity and a reduction in the number of consecutive night shifts were related to the biomarkers. In addition, a reduction in weekend work was related to changes for >1 lipids.

The changes are comparable to the findings in 2 previous studies that assessed the impact of ergonomic changes in shift schedules on biomarkers of IHD risk.

Table 6. Change in lipids in the intervention groups in comparison with the lipid values of the control group — linear regression, adjusted for age and for age and life-style factors at baseline. (I3=intervention with 1—3 principles, I4 = intervention with 4 principles, 95% CI = 95% confidence interval, HDL = high-density lipoprotein, LDL = low-density lipoprotein)

Lipid	Adjusted for age		Adjusted for age and life-style[a]	
	Coefficient	95% CI	Coefficient	95% CI
Total cholesterol				
I3 intervention	0.00	-0.37 — 0.36	0.05	-0.31 — 0.41
I4 intervention	-0.23	-0.52 — 0.06	-0.22	-0.51 — 0.08
Triglycerides				
I3 intervention	-0.02	-0.26 — 0.22	-0.03	-0.29 — 0.21
I4 intervention	-0.13	-0.33 — 0.06	-0.14	-0.34 — 0.06
HDL cholesterol				
I3 intervention	0.14	-0.01 — 0.30	0.16	0.01 — 0.33
I4 intervention	0.12	-0.01 — 0.25	0.13	0.00 — 0.26
LDL cholesterol				
I3 intervention	-0.22	-0.56 — 0.13	-0.17	-0.52 — 0.18
I4 intervention	-0.39	-0.67 — -0.12	-0.40	-0.68 — -0.11
Total:HDL cholesterol ratio				
I3 intervention	-0.39	-0.68 — -0.10	-0.36	-0.66 — -0.07
I4 intervention	-0.40	-0.63 — -0.16	-0.40	-0.64 — -0.16

[a] Current smoking, no exercise, alcohol consumption (continuous variable), dietary habits ("avoid use of margarine on bread").

A change in the direction of rotation (7) was followed by a 4% reduction in triglyceride levels in the clockwise rotation period, and a corresponding 15% increase in the counterclockwise rotation. Cholesterol fell 4% and 6% in the 2 periods. One explanation for the smaller change could be that the experiment lasted only 8 weeks. In a study (8) examining the effect of reducing the consecutive number of night shifts from 7 to 4, an 8% increase in HDL and a 13% reduction in the LDL:HDL cholesterol ratio were obtained.

Table 7. Individual changes in schedule characteristics from time 1 to time 3 and the within-subject change in the biomarkers (time 1 to given in footnotes (otherwise P>0.05). The differences between the time 1 and time 2 measurements were assessed by the Wilcoxon paired

Characteristic	Number of workers	Total cholesterol (mmol/l)				Triglycerides (mmol/l)			
		Baseline	Change	Paired[a]	Trend[b]	Baseline	Change	Paired[a]	Trend[b]
Regularity									
Worse	16	5.0	-0.2	0.157	0.460	0.9	0.1	0.290	0.016
Unchanged	48	5.0	0.0	0.847		0.8	0.0	0.352	
Better	15	4.8	0.0	0.900		0.8	-0.1	0.032	
Predictability									
Worse	25	4.8	-0.1	0.778	0.607	0.9	-0.1	0.666	0.653
Unchanged	29	5.0	0.1	0.336		0.8	0.1	0.171	
Better	25	4.9	0.0	0.442		0.9	0.0	0.895	
Periodicity									
Worse	20	4.7	0.0	0.952	0.255	0.9	-0.1	0.250	0.211
Unchanged	39	5.0	0.0	0.904		0.8	0.0	0.176	
Better	18	5.0	-0.1	0.140		0.9	0.0	0.707	
Maximum number of consecutive night shifts									
More	9	4.6	0.1	0.397	0.765	0.7	0.1	0.473	0.076
Unchanged	57	5.1	-0.1	0.331		0.8	0.0	0.316	
Fewer	14	4.7	0.1	0.916		0.9	-0.2	0.172	
Number of Sundays off									
Fewer	12	4.7[c]	-0.1	0.422	0.510	0.7	0.1	0.839	0.802
Unchanged	48	5.1	0.0	0.643		0.9	0.0	0.907	
More	19	4.7	-0.1	0.248		0.8	0.0	0.381	
Number of positive changes									
0	35	5.0	0.1	0.410	0.203	0.8	0.0	0.224	0.172
1	23	5.0	0.0	0.198		0.9	0.0	0.952	
>1	22	4.6	-0.1	0.400		0.8	-0.1	0.444	

[a] P-value, paired difference (Wilcoxon). [b] P-value, trend (Jonckheere-Terpstra). [c] P=0.045 (Mann-Whitney). [d] P=0.020 (Mann-Whitney). [e] P=0.030 (Mann-Whitney).

No studies have compared such schedule design characteristics as regularity, number of consecutive nights, or flexibility with the incidence of IHD, and our study also relied on proxy measures. It has been shown that a cholesterol reduction of 0.6 mmol/l would correspond to a 54% reduction at 40 years of age (20). This intervention led to a reduction in cholesterol of about half this figure. It suggests that ergonomic changes in shift schedules may reduce the incidence of IHD. It is, however, not known whether the changes that occurred in the biomarkers are lasting.

The changes were apparently not accompanied by changes in the questionnaire data. We adjusted for smoking, alcohol consumption, and exercise at baseline, and the intervention was not related to changes in these life-style factors. We also attempted to adjust for dietary factors by using a question on dietary habits as a proxy marker for the use of saturated fat. We do not know whether this factor actually measured the use of fat. More important, we do not know whether the participants' diet changed during the intervention. As noted, we had included dietary diaries for obtaining information on changes in diet, but had to refrain from using them due to the large number of blanks. This is a drawback of the study, as the diet of shift workers is known to change according to type of shift. On the other hand, dietary changes should be narrowly related to, for instance, regularity and predictability in order to explain the results. It is also not clear whether or not differences in diet should be regarded as confounders and adjusted for, as the change could be seen as an intermediate factor linking shift work, shift work scheduling, and IHD. This question warrants further study.

The regularity score of the schedules at time 2 was lower than those of time 1 in the control group. This finding was not anticipated, and it influences the interpretation of the results of the intervention. Several possible explanations can be proposed. The resulting schedule for the ward is the sum of individual schedules, and changes in the intervention group would necessarily mean that some of the control group members had their schedules changed for the worse, as fewer possibilities for individual scheduling were given for this group. Another explanation is that the external framework for planning could have changed during the intervention period. The nurses had, in fact, a new agreement on the handling of overtime work put into effect during the period. Prior to the new agreement (during time 1) overtime was to be foregone, while according to the new set of regulations (put into effect before time 2), overtime could also be paid out. This change should have tended to increase the number of hours worked, but the opposite occurred in the control group. However, the use of the new regulations was reported by the wards to have a negative effect on the possibilities for scheduling, as the number of staff was not changed accordingly, the result being extra work for the existing staff, which led to more changes being made during the scheduling

time 2). The differences between the groups at baseline were assessed by the Mann-Whitney test. The statistically significant differences are test and the trends by the Jonckheere-Terpstra test. (HDL = high-density lipoprotein, LDL = low-density lipoprotein)

HDL cholesterol (mmol/l)				LDL cholesterol (mmol/l)				Total:HDL cholesterol ratio (mmol/l)			
Baseline	Change	Paired[a]	Trend[b]	Baseline	Change	Paired[a]	Trend[b]	Baseline	Change	Paired[a]	Trend[b]
1.9	0.0	0.758	0.280	2.7	-0.2	0.068	0.382	2.7	-0.1	0.131	0.408
1.7	-0.1	0.022		2.8	0.1	0.437		3.1	0.1	0.252	
1.7	0.2	0.042		2.6	-0.2	0.470		2.7	-0.3	0.045	
1.6	0.1	0.079	0.720	2.8	-0.2	0.020	0.430	3.1	-0.3	0.005	0.451
1.9	-0.2	0.001		2.7	0.2	0.023		2.6	0.3	0.001	
1.6	0.0	0.172		2.8	-0.1	0.193		2.9	-0.2	0.056	
1.6	0.1	0.007	0.075	2.9	0.0	0.396	0.288	3.0	-0.2	0.016	0.876
1.9	-0.1	0.001		2.7	0.1	0.198		2.7	0.1	0.013	
1.7	0.1	0.583		2.9	-0.2	0.038		3.2	-0.3	0.049	
1.7	0.1	0.765	0.117	2.3	-0.1	0.671	0.975	2.7	-0.3	0.953	0.249
1.9	-0.1	0.044		2.9	0.0	0.680		2.9	0.1	0.695	
1.5	0.1	0.058		2.8	0.0	0.529		3.4	-0.3	0.032	
1.6[d]	0.1	0.237	0.414	2.8	-0.2	0.141	0.265	3.0	-0.3	0.036	0.590
1.9	-0.1	0.017		2.8	0.1	0.135		2.7	0.1	0.062	
1.5	0.1	0.094		2.8	-0.4	0.047		3.3	-0.3	0.028	
1.9[e]	-0.1	0.001	0.000	3.0	0.1	0.040	0.000	2.8	0.1	0.008	0.000
1.9	0.0	0.568		2.8	-0.1	0.085		2.7	-0.1	0.045	
1.5	0.2	0.035		2.7	-0.3	0.086		3.1	-0.3	0.012	

process. With this situation it could be argued that the comparison be made "across" all 3 groups instead of with the use of a paired analysis, as these new external frameworks covered all the staff. The intervention counteracted the negative effect of the new regulations on regularity for all participants (seen in the control group) before leading to more regular schedules in the intervention groups.

Some methodological problems deserve comment. Both the questionnaire and biomarker data were obtained half a year apart; and there could have been some impact on the values, as, for instance, cholesterol has an annual pattern with the highest values occurring in the coldest month (19). This is probably a minor problem, as the samples were taken 3 months before and after this peak. In addition, all the groups had the sampling done at the same time of year, and, as the comparisons were made between the groups, the annual variation in cholesterol should not pose a problem. The direction of change at 12 months was the same as after 6 months of follow-up (not shown).

Contrary to the time frame used for the questionnaire and biomarker data collection, the RRPA measurements were done with schedules 1 year apart to ensure that the impact of holidays and sick leave would be less. On the other hand, this schedule meant that, while the baseline data were obtained at the same time as the first schedule, the second schedule did not correspond with the second data collection. This lack of correspondence would probably lead to a misclassification of exposure, as the schedules were flexible and changed between the 2 4-week periods. The schedules at 1 year were therefore only a proxy of the 6-month schedule (that was not obtained), and the misclassification would probably tend to lower the estimates, both in the individual RRPA assessment and in the "intention-to-change" assessment.

The biomarkers have a circadian rhythm, amounting to up to 38% for triglycerides (21). If the night-working participants had had their blood samples drawn after a night shift, the measurement could have simply been from a different circadian window and thus have led to artificially high values. This possibility was dealt with by making the measurements at least 72 hours after the last night shift. Whether or not this period is long enough for the biomarkers to return to a day-oriented circadian rhythm has, to our knowledge, not been studied, but most circadian rhythms of the body have a fast synchronization to the day-oriented rhythm (22).

We had a large dropout rate. Therefore the participants could have had a more positive attitude towards the changes. However, the available information indicated that the nonparticipants did not differ substantially from the participants.

The participating wards had selected themselves for the project. They were not a random sample of wards (9), being more often intensive care units than the background wards were. It was also possible that the baseline schedules of the wards differed from those of

other hospitals, being more irregular than the majority of Danish hospital wards. In addition the schedules in use at hospitals differ between countries. It would therefore be important to repeat the intervention in other types of shift systems to examine the external validity of changes in regularity and predictability.

The comparisons included (table 7) several shift characteristics and biomarkers and therefore provided an opportunity for significant results to occur by chance. We did not formally test for this possibility, but, as we had a priori theoretically based hypotheses of the association, the direction of the results suggests that they were not due to mass significance. Furthermore, the similar results from using 2 different exposure characteristics also supported the validity of the results.

Within the actual shift schedules, it was possible to obtain a combination of flexibility and regularity in scheduling that resulted in lower biomarkers and therefore suggested possibilities for prevention. The flexibility was maintained through the possibility to choose between day-evening and day-night shift systems, whatever was most relevant for the staff member, and the change at the same time made the system more regular. In recent years, shift work has been met with demands for more flexibility (23), from both employees and employers. This study raises the question of whether flexibility without regularity is desirable in relation to health, but it points also to the possibilities of prevention through scheduling.

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References

1. Bøggild H, Knutsson A. Shift work, risk factors and cardiovascular disease. Scand J Work Environ Health 1999; 25:85—99.
2. Steenland K. Shift work, long hours, and cardiovascular disease: a review. In: Schnall P, Belkic K, Landsbergis P, Baker D, editors. The workplace and cardiovascular disease. Philadelphia (PA): Hanley & Belfus, Inc, 2000:7—17.
3. Knutsson A. Shift work and coronary heart disease. Scand J Soc Med Suppl 1989;44:1—36.
4. Knutsson A, Bøggild H. Shiftwork and cardiovascular disease: review of disease mechanisms. Rev Environ Health 2000;15:359—72.
5. Wedderburn A. Guidelines for shiftworkers. Dublin: European Foundation for the Improvement of Living and Working Conditions, 1991:1—56. Bulletin of European shiftwork topics (BEST), no 3.
6. Knauth P. Designing better shift systems. Appl Ergon 1996;27:39—44.
7. Orth-Gomér K. Intervention on coronary risk factors by adapting a shift work schedule to biologic rhythmicity. Psychosom Med 1983;45:407—15.
8. Kecklund G, Åkerstedt T, Göranson B, Söderberg K. Omläggning av skiftschema: konsekvenser för välbefinnande, hälsa, sömn/vakenhet och arbetstrivsel. Resultatrapport 2: frågeformulär, dagbok och hälsoundersökning [Changing shift schedule: effects on well-being, health, sleep/wake behaviour and work satisfaction. Report of results 2: questionnaire, diary data and health examiniation]. Stockholm: Statens Institut för psykosocial miljömedicin, 1994. Stressforskningsrapport, no 242.
9. Jeppesen HJ, Bøggild H, Larsen K. Regulation as prevention strategies for shiftwork problems. Int J Occup Environ Health 1997;3 suppl 2:82—7.
10. Jeppesen HJ, Bøggild H. Redesigning shift schedules through a participatory intervention method approach. In: Hornberger S, Knauth P, Costa G, Folkard S, editors. Shiftwork in the 21st century: challenges for research and practices. Frankfurt: Peter Lang, 2000:363—8.
11. Barton J, Spelten E, Totterdell P, Smith L, Folkard S, Costa G. The Standard Shiftwork Index: a battery of questionnaires for assessing shiftwork-related problems. Work Stress 1995;9:4—30.
12. Lennernäs M, Åkerstedt T, Hambræus L. Nocturnal eating and serum cholesterol of three-shift workers. Scand J Work Environ Health 1994;20:401—6.
13. Kecklund G, Åkerstedt T. The psychometric properties of the Karolinska Sleep Questionnarie [abstract]. J Sleep Res 1992;1 suppl 1:113.
14. WHO scientific group on cardiovascular disease risk factors. Cardiovascular disease risk factors: new areas for research. Geneva: World Health Organization, 1994.
15. Meade TW. Fibrinogen and other clotting factors in cardiovascular disease, with particular reference to smoking. In: Poulter N, Sever P, Thom S, editors. Cardiovascular disease: risk factors and intervention. Oxford: Radcliffe Medical Press, 1993:185—99.
16. Nieto FJ. Cardiovascular disease and risk factor epidemiology: a look back at the epidemic of the 20th century [editorial]. Am J Public Health 1999;89:292—4.
17. Jansen B, Kroon H. Rota-risk-profile-analysis. Work Stress 1995;9:245—55.
18. Hollander M, Wolfe DA. Nonparametric statistical methods. New York (NY): John Wiley & Sons, 1973.
19. Evans K, Laker MF. Intra-individual factors affecting lipid, lipoprotein and apolipoprotein measurement: a review. Ann Clin Biochem 1995;32:261—80.
20. Law MR, Wald NJ, Thompson SG. By how much and how quickly does reduction in serum cholesterol concentration lower risk of ischaemic heart disease? BMJ 1994;308: 367—72.
21. Rivera-Coll A, Funtes-Arderiu L, Diez-Noguera A. Circadian rhythmic variation in serum concentrations of clinically important lipids. Clin Chem 1994;40:1549—53.
22. Knauth P, Rutenfranz J. Experimental shift work studies of permanent night, and rapidly rotating, shift systems. Int Arch Occup Environ Health 1976;37:125—37.
23. Kogi K. Improving shift workers' health and tolerance to shiftwork: recent advances. Appl Ergon 1996;27:5—8.

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