Impact of One Year of Shift Work on Cardiovascular Disease Risk Factors

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The purpose of the study was to investigate whether the reported increased cardiovascular disease risk in shift workers could be explained by changes in cardiovascular risk factors. In a cohort of 239 shift and 157 daytime workers, 1-year changes in biological and lifestyle cardiovascular risk factors were monitored between the start of a new job and 1 year later. Both body mass index and low-density lipoprotein/high-density lipoprotein cholesterol ratio decreased significantly in shift workers compared with daytime workers (body mass index change: −0.31 and +0.13 kg/m^2; low-density lipoprotein/high-density lipoprotein ratio change: −0.33 and −0.13 respectively). Cigarettes smoked per day increased significantly in shift compared with daytime workers (+1.42 and −1.03, respectively). Therefore, only for smoking, an unfavorable change was observed. This may explain, at most, only a part of the excess cardiovascular disease risk reported in shift workers. (J Occup Environ Med. *2004;46:699–706*)

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Evidence available so far seems to indicate an elevated cardiovascular disease risk in shift workers. In their review Bøggild and Knutsson[1] presented a relative risk of 1.4 as the most reasonable risk estimate. A proper meta-analysis in the 17 studies on cardiovascular disease endpoints is not considered appropriate because of the diversity of the identified studies in outcome as well as exposure (type of shift schedule, duration of shift work). Whereas most studies so far have been conducted in males, the four studies addressing females suggest that shift-working women have a relative risk similar to men. Several explanations for the elevated risk have been proposed, including disturbance of physiological rhythms, changes in behavior, and disturbed sociotemporal activities.[2] Until now, information favoring the involvement of one or more of these mechanisms was not sufficient to favor one or more of these explanations. In a review on possible mechanisms for cardiovascular disease in shift workers, Knutsson and Bøggild[3] concluded that social factors, stress, and behavioral variables may play a role, but the disturbance of circadian physiological rhythms as a consequence of night work also was regarded as probably relevant. Monitoring changes in cardiovascular disease risk factors in shift workers could provide evidence confirming or refuting some of the explanations. This information might contribute to effective strategies for cardiovascular disease prevention.

Most studies that addressed cardiovascular disease risk factors in shift workers, reviewed in the article of Bøggild and Knutsson,[1] until now have been cross-sectional. Cross-sectional studies are susceptible to bias, especially because of selective dropout (healthy worker effort). Only two longitudinal studies were found comparing changes of cardiovascular disease risk factors between shift workers and daytime workers. The study of Knutsson et al[4] did not show significant different changes in cardiovascular disease risk factors between the 12 shift workers and 13 daytime workers during a 6-month period. This might be a consequence of the relatively small sample size. The study of Morikawa et al[5] displayed an increased 5-year hypertension risk in younger shift workers but not for the older shift workers. No other cardiovascular risk factors were included in this study. To summarize, the information available is not sufficient to confirm or reject the involvement of unfavorable changes in one or more cardiovascular risk factors in the elevated cardiovascular disease risk.

Therefore a 1-year cohort study among 239 shift workers and 157 daytime workers was conducted. The aim of this cohort study was to compare changes in cardiovascular risk factors during a 1-year period between shift and daytime workers to identify possible factors that might explain the elevated cardiovascular disease risk among shift workers. To avoid selection bias, much effort was put in follow up of dropouts and participants who changed jobs.

Subjects and Methods

Study Population

Potential participants were approached during an 18-month period using three strategies to sample from different shift work schedules: (1) persons undergoing a pre-employment medical examination in two occupational health services; (2) all workers in a newly built waste incinerator plant; and (3) nurses, starting with their practical in hospital training. The following inclusion criteria were used: (1) starting in a new job; (2) working at least 32 hours a week; (3) expecting to work next year in the same job; (4) no use of medication or previous hospitalization for a cardiovascular disease; (5) no insurmountable objections against shift work (see data collection); and (6) aged between 18 and 55 years of age.

A total of 707 people were approached for participation in the study; 98 were not eligible (13.8%,) because they did not match the criteria mentioned above, 30 because they worked less than 32 hours a week, 32 because they expected to quit their job within 1 year, 11 because they had a history of cardiovascular disease, 18 because they had "insurmountable objections to shift work" (all day workers), and 7 because they did not match the age criteria. Of the 609 eligible respondents, 213 refused to participate (35%). The major determinant of the nonresponse rate was the time involved in traveling to the research location. For the respondents who were measured close to their workplace ($n = 518$), the response rate was 75%, whereas the response rate for workers who had to travel to participate in the study ($n = 91$) was 8%. The calculated response rates for shift workers and daytime workers were 65% and 63%, respectively. A total of 396 people participated in the baseline measurement. In Table 1 a summary is given of the number of respondents included for the repeated measurement. In total, 364 people were measured for the second measurement. We excluded three respondents because of a pregnancy within the follow-up period. Nineteen observations were excluded from the analysis because of missing values. This study was approved by the ethical committee of the Wageningen Agricultural University.

Data Collection

Measurements were performed between 1 week and 2 months after the start of a new job in day or shift work and were repeated after 1 year. All participants received a questionnaire and were asked to return it by mail after completion. Unclear or missing answers were verified by telephone. Most questions were closed-ended and came from standardized questionnaires.

Current Job Title and Job History. We asked for the current job, including company, department, and shift work schedule. According to social status and job content, all jobs were coded. In total nine different job titles were used. In this study, we defined shift work as working in an alternating work schedule, including nights. Information on all previous

TABLE 1
Number of Subjects During Follow-up

Status	Baseline Work Schedule: Day Work	Shift Work
Total number of participants included at baseline	150	227
Excluded		
Missing data	6	13
Became pregnant during follow-up	0	3
Lost to follow-up		
Discharged & refused further cooperation	9	20
Refused second measurement	1	2
Included		
Remained in same job	105	159
Changed work schedule	32	34
Unemployed	2	4
Sick leave (WAO)*	1	5

* WAO, receiving a benefit according to the Dutch disablement insurance act.

jobs, including job title, employer, starting and ending date, and shift work status, was collected. Shift schedules were coded as backward rotating (nights-afternoons-mornings, advancing schedule) or forward rotating (mornings-afternoon-nights, delaying schedule). We coded rotation as fast when at most three consecutive night shifts were worked. At most, five consecutive night shifts on a row were coded as medium rotation. Irregular shift schedules, often scheduled once per month, were coded as "irregular." These schedules did not display a marked direction of rotation. In total, 32% of the shift workers was coded as working in a fast forward-rotating schedule, 17% in a fast backward-rotating schedule, 35% in a medium backward-rotating schedule, and 15% in a irregular schedule. None of the workers worked fixed nights.

Objections Against Shift Work. To improve comparability between shift workers and daytime workers, only workers with no insurmountable objections against working in shifts were included. The following question was used to assess this: "Would you keep working in your current job if the department would switch to shift work jobs? (1) Yes, without any objections; (2) Yes, but only if there is a financial reward; (3) Only if there are no other jobs available; and (4) On no account." We excluded people who gave answer (4) to this question.

Personal Characteristics. In the questionnaire, educational level was divided in seven categories, from elementary school to university education. In the final analysis, these were categorized in junior education, senior education, and higher education. The physical activity indexes for work, sport, and leisure time were assessed as described by Baecke et al.[6] The ranges of the indexes were 1.1 to 4.3, 1.0 to 5.2, and 1.3 to 4.5 respectively. Current (type, quantity) and past smoking habits (type, years, and quantity) were asked.

Anthropometric Measurements. Measurements were conducted between 1 week and 2 months after the beginning of a new job. Weight, height, and waist and hip circumferences were measured in a standing position. The waist circumference was measured at the level of the umbilicus, and the hip circumference at the widest part over the buttocks. Body mass index (BMI), that is, weight/height^2 (kg/m^2), and the waist-to-hip ratio (WHR), that is, ratio between the waist and hip circumferences, were calculated.

Plasma Cholesterol Measurements. Serum of nonfasting blood samples was obtained by centrifugation and stored at −80°C. The sera were analyzed enzymatically for high-density lipoprotein (HDL) and total.[7] Low-density lipoprotein (LDL) cholesterol was calculated using the Friedewald formula.

Dietary Assessment. A self-administered food-frequency questionnaire that measured the intake of energy, total fat, saturated fat, monounsaturated fat, polyunsaturated fat, and cholesterol was filled out by the respondents.[8]

Blood Pressure. Blood pressure measurements were performed using a tensoplus OSZ2 oscillometric sphygmomanometer. A trained technician read the blood pressure with a stethoscope placed on the brachial artery. All measurements were performed in triplicate, all at least 5 minutes apart. An average of the three readings was used in the data analysis.

Job Strain. Job strain, separated in psychological demands and decision latitude, was assessed using a validated Dutch version of the self-administered Job Content Questionnaire.[9,10]

Data Analysis

Only subjects without missing data were included in the data analysis. Data are presented as mean values or absolute change between the first and second measurement. Chi-square and unpaired *t* test were used to test baseline differences between the day and shift workers. A paired *t* test was used to test different changes within the shift and day workers for the continuous variables. For the class variables, a chi-square test on the status of change (no change, favorable change, unfavorable change) was used. For the test of a different change between the shift and day workers, the mean individual differences between baseline and 1 year of follow-up were tested with the unpaired *t* test or chi-square test. Linear regression and logistic regression was used to evaluate effect modification, to evaluate possible regression to the mean, and to adjust for potential confounders (educational level, gender, age and job strain variables, and the variable under study at baseline). All analyses were performed using the Statistical Analysis System (SAS; Cary, NC).[11]

Results

In Table 2 the mean baseline values are presented. As can be seen from the table, at baseline the shift workers had a slightly higher age and a significantly less favorable cardiovascular risk profile (smoking habits, BMI, WHR, LDL/HDL ratio, and leisure time physical activity, although for the latter two the difference was not significant between the shift and day workers.). Also significantly more shift workers were current or former smokers. They also reported significantly lower psychological job demands and lower decision latitude. Also significantly more of the shift workers were males.

In Table 3 the changes in cardiovascular risk factors from baseline to 1-year follow-up are presented. Compared with baseline, the percentage of smokers and the number of cigarettes smoked per day (in smoker only) increased more in shift workers compared with daytime workers. BMI and WHR decreased significantly in the shift workers compared with their own baseline values. For BMI, this change also was significant when compared with the in-

TABLE 2
Baseline Characteristics According to Work Schedule

	Day Workers		Shift Workers		P value Difference Shift—Day
Background and job related factors					
N	150		227		
Gender (% male)	41.0		55.4		0.005*
Age (years)	24.1	(23.2–25.1)	26.8	(26.0–27.7)	0.0001
Education					
Lower (%)	16.6		38.9		0.001*
Intermediate (%)	54.9		52.3		
Higher (%)	28.5		8.8		
Work time physical activity index	3.00	(2.88–3.13)	3.12	(3.05–3.19)	0.11
Demands	2.30	(2.24–2.36)	2.14	(2.09–2.20)	0.0003
Control	2.20	(1.75–1.85)	1.57	(1.52–1.62)	0.0001
Support	1.82	(1.77–1.88)	1.77	(1.72–1.83)	0.23
Diet					
Energy intake (MJ/day)	11.5	(10.9–12.2)	12.2	(11.6–12.7)	0.16
Energy from fat (% of total energy intake)	38.1	(37.0–39.2)	40.3	(39.4–41.2)	0.002
Alcohol intake (g/day)	6.1	(4.8–7.4)	8.5	(6.5–10.5)	0.05
Cholesterol intake (mg/day)	281	(262–301)	306	(286–324)	0.09
Anthropometry					
Weight (kg)	71.5	(69.6–73.4)	73.8	(72.1–75.6)	0.09
BMI (kg/m^2)	23.1	(22.6–23.5)	24.0	(23.5–24.4)	0.006
Waist-to-hip ratio	0.836	(0.825–0.847)	0.863	(0.854–0.872)	0.0002
Diastolic blood pressure (mm Hg)	76.5	(75.4–78.1)	76.4	(75.3–77.6)	0.9
Systolic blood pressure (mm Hg)	127.7	(125.6–130.0)	126.1	(124.5–128.1)	0.3
Blood lipids					
Total serum cholesterol (mmol/L)	4.85	(4.68–5.02)	4.87	(4.74–5.01)	0.8
HDL cholesterol (mmol/L)	1.34	(1.28–1.34)	1.30	(1.25–1.35)	0.3
LDL cholesterol (mmol/L)	2.86	(2.71–3.00)	2.95	(2.82–3.07)	0.3
LDL/HDL ratio	2.28	(2.11–2.45)	2.44	(2.29–2.59)	0.2
Lifestyle					
Smoking					
Never (%)	68.2		51.6		0.006*
Former (%)	9.3		12.9		
Current (%)	22.5		35.5		
Cigarettes smoked per day (in current smokers)	10.7	(8.5–12.9)	11.7	(10.3–13.1)	0.4
Physical activity during sport (score)	2.66	(2.51–2.81)	2.61	(2.48–1.74)	0.6
Leisure time physical activity (outside sport, score)	2.78	(2.68–2.88)	2.68	(2.60–2.79)	0.15

Difference between day workers and shift workers:
* Chi-square test, *P* value for all categories together.
n.a., not applicable.
95% confidence intervals between parentheses.
HDL, high-density lipoprotein; LDL, low-density lipoprotein.

crease in the employees working in daytime. No different change was found between the shift and daytime workers in diastolic and systolic blood pressure. Comparing the 1-year change in energy intake between the shift and daytime workers, both groups displayed a decrease but the decrease in the daytime workers was significantly higher. Also, the amount of energy from fat and the cholesterol intake were reduced in both the daytime as well as shift workers, but this decrease only reached statistical significance in the daytime workers, whereas the difference between the shift and daytime workers was not significant. Psychological job demands were significantly increased in both shift workers and the daytime workers, but the difference was not significant. Significant decreases in total and LDL cholesterol and an increase in HDL level were found in shift workers, but compared with the 1-year change for daytime workers, this decrease was not significant. The LDL/HDL ratio was significantly decreased in both shift and daytime workers, but the decrease was almost 50% higher in the shift workers compared with the daytime workers ($P < 0.01$). A separate analysis in males and females revealed similar results as presented before (data not shown). Only in males, a significantly decreased level of social support was found in shift workers compared with daytime (shift workers: -0.13, daytime workers: $+0.12$, *P* value difference: 0.001). Analysis of the results with

TABLE 3
One-Year Changes in CVD Risk Factors According to Work Schedule

	Day Workers	Shift Workers	*P* Value Difference Shift−Day
Job-related factors			
Work time physical activity index	0.024	0.084*	0.3
Demands	0.11**	0.17***	0.2
Control	0.003	−0.016	0.6
Support	0.015	−0.071*	0.10
Diet			
Energy intake (kJ/day)	−1306***	−481	0.04
Energy from fat (% of total energy intake)	−0.78	−0.52	0.8
Alcohol intake (g/day)	0.04	−0.03	0.4
Cholesterol intake (mg/day)	−22.4*	−13.8	0.5
Anthropometry			
Weight (kg)	0.43	−0.98**	0.003
BMI (kg/m^2)	0.13	−0.31**	0.004
Waist-to-hip ratio	−0.0052	−0.0093***	0.3
Diastolic blood pressure (mm Hg)	1.07	0.16	0.3
Systolic blood pressure (mm Hg)	−1.26	−1.33	0.9
Blood lipids			
Total serum cholesterol (mmol/L)	0.00	−0.04	0.6
HDL cholesterol (mmol/L)	0.080***	0.11***	0.2
LDL cholesterol (mmol/L)	−0.04	−0.15**	0.15
LDL/HDL ratio	−0.13*	−0.33***	0.004
Lifestyle			
Smoking			
Stopped last year (%)	2.9	2.5	0.5†
No change (%)	93.2	89.9	
Started last year (%)	3.9	7.5	
Cigarettes smoked per day (in current smokers on both time points)	−1.03	1.42	0.03
Physical activity during sport (score)	0.007	−0.09	0.3
Leisure time physical activity (outside sport, score)	−0.05	−0.06	0.9

Only the data from workers not changing work schedule is presented (105 daytime and 159 shift workers).
Significance level 1 year change not equal to 0: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.
† Chi-square test, *P* value for all categories together.

exclusion of respondents with a shift work job before their new job did not yield significant changes in the results. The possibility of different effects for different shift schedules (fast forward, fast backward, slow backward, and irregular shift schedules) was tested by including an interaction term in the model. A significant effect in modification by shift type was not found for any of the outcome parameters. To evaluate possible regression to the mean, regression analysis on level of change (difference between baseline and 1 year of follow-up) was performed with the inclusion of baseline values of BMI or smoking as independent variables. This analysis did not yield a substantial change in the reported results.

Analysis of the respondents changing from a daytime job to a shift work job between baseline and the 1 year of follow-up ($n = 32$) revealed a significantly higher decrease in BMI compared with daytime workers (−0.36 kg/m^2 and + 0.13 kg/m^2, respectively, $P = 0.05$) and an higher increase in number of cigarettes smoked per day in smokers (+2.54 and −1.03 cigarettes per day, respectively, $P = 0.02$), but no considerable difference was found for any of the other cardiovascular risk factors. For the respondents changing from a shift work to a daytime job ($n = 34$) a higher decrease of physical activity during sport (−0.40 vs. −0.09, $P = 0.04$), and higher decrease in amount of cigarettes smoked per day in smokers (−1.17 vs. + 1.42 cigarettes per day, $P = 0.1$) and higher increase in waist to hip ratio (+0.0051 vs. −0.009, $P = 0.04$) was found compared with workers who stayed in their shift work job, but no considerable change in any of the other factors was found. As expected, the workers changing from a shift work and daytime job to unemployment ($n = 6$) or long time sick leave (receiving a benefit according to the Dutch disablement insurance act: W.A.O.) ($n = 6$) did report a significantly decreased physical activity compared with workers who remained in their job. No other significant changes were found for this group. Shift workers had a higher risk of being on sick leave (W.A.O.) after 1 year of work compared with daytime workers (relative risk 2.46; 95% confidence interval 0.57–10.6).

We further conducted an analysis of the 1-year changes according to shift work status at baseline (in analogy to the analysis for intention to treat). This analysis did not reveal considerable changes in the reported changes compared with the results in the respondents who remained in their job.

Discussion

At baseline, significantly more shift workers were smoking, and they had a higher BMI, WHR, and percentage energy intake from fat compared with daytime workers. The change from baseline to 1-year follow-up displayed a significantly larger decrease in BMI and LDL/HDL cholesterol level in shift workers compared with daytime workers. The number of cigarettes smoked per day (in smokers only) increased significantly in shift workers compared with daytime workers. None of the other cardiovascular risk factors displayed a significantly different change between the day and shift workers. Because the reported results may have been biased, we will first discuss the validity of the reported results.

One of the most important sources of bias when investigating shift work related health effects is the selection of people starting in shift work. People who assume that they are not capable of working in shifts are less likely to apply for a shift work job. This self-selection might be influenced by job availability in a specific region. Also, companies may use different criteria when employing shift workers compared with daytime workers. By using a cohort design, where each respondent serves as his or her own control, one might expect that the effect of existing pre-job differences between shift and daytime workers because selection is removed. Moreover, in this study, daytime workers who indicated that they would never work in shifts were excluded from the study ($n = 18$). Also, as indicated in the results section, we conducted a separate analysis, excluding those workers with previous shift work experience. This did not lead to different results. Nevertheless, differences in sensitivity to the effects of shift work might still be present between the shift and daytime workers because self-selection into the job might have occurred. The size of this effect cannot be estimated, but we consider it to have probably led to an underestimation of the relation between shift work and change in cardiovascular risk factors. We assume people who are more sensitive to the effects of shift work are the ones less likely to start working in shifts. When translating the reported results to other populations, one has to consider the possibility of differences in self-selection between different areas because job possibilities might be different between different regions. This might lead to differences in the group of shift workers with regards to their health status before the start of the job and might possibly also have implications for their sensitivity to shift work.

Secondary selection, where shift workers move out of their job, will be a source of bias if the change of job is related with a change in cardiovascular disease risk factors. Analysis of the people moving out of their shift work job, however, did not reveal unfavorable changes in any of the cardiovascular disease risk factors compared with the shift workers. For BMI and smoking, the change in the respondents swapping from a shift-work job to a daytime job resembled the changes encountered in the people working in a daytime job. It is therefore concluded that secondary selection did not bias the reported results. This was further supported by the results of an analysis of the 1-year changes according to shift-work status at baseline (in analogy to the analysis for intention to treat). This analysis did not reveal considerable changes in the reported changes compared to the results in the respondents who remained in their job.

Measurement errors and within person biological variation in the measured cardiovascular risk factors might differ between the shift and daytime workers and cause biased results. If, for example, measurements are performed after a night shift, the levels might be changed not because of shift work but because the measurement was taken in a different phase of the circadian rhythm. Because for most respondents the baseline and repeated measurement were performed on the same time and day of the shift rotation schedule, we assume that the amount of systematic error is comparable between the first and second measurement. When calculating the change between the first and second measurements, this systematic error will level out. A dilution of possible effects of shift work as a result of random errors and biological variation will remain. However, because only within person variation has to be considered, the size of this effect is considered to be small. The random error between the first and second measurement could have been larger as compared to the day workers as the circadian rhythm in day workers is expected to be more robust.

As we conducted the baseline measurements between 1 and 8 weeks (average, 2 weeks) after the start of a new job the possibility exists that changes very early (within 2 weeks) after the start of a new job are missed. For most of the cardiovascular disease risk factor, however, we assume that the duration of this period was too small to have a noticeable effect. Most lifestyle risk factors were assessed using a questionnaire concerning the preceding 3-month period. Therefore, the 2 weeks of exposure to shift work would probably not have a large impact on the questionnaire scores. Also, for the BMI and WHR, a short-term effect within 2 weeks is not very likely. For the blood lipids and blood pressure, a short-term effect of shift work cannot be excluded, although the effect is considered to be low. However, it might explain a part of the baseline differences in cholesterol levels between the shift and day workers. Another issue of concern is that the duration of 1 year of follow-up might be not long enough to show significant changes in cardiovascular disease risk factors. However, the results from other studies conducted so far do not support a long time window without effects. The study of Knutsson et al,[12] for example, already showed a relative risk of 1.5 in subjects working 2 to 5 years in shift work.

Differences in work conditions between the shift and daytime workers may confound the relationship between shift work and the change in cardiovascular risk factors. We assume that this confounding caused an overestimation of the relation between the change in cardiovascular risk factors and shift work and could therefore not explain the reported results. In addition, we performed a correction for the most important work related confounders, workplace noise, job strain and physical activity at work, which did not yield different results. Therefore, work conditions are not considered to be important confounders in this study.

Because the shift workers displayed significantly elevated BMI and smoking levels compared with the daytime workers, regression to the mean might have been responsible for the reported change in BMI and smoking. However, an analysis with the inclusion of baseline values of BMI or smoking as independent variables did not show different results. It is therefore concluded that regression to the mean could not explain the reported results. Overall, although the total amount of bias cannot be estimated precisely, bias of the reported results is considered to be low and nondifferential and lead to a small underestimation of the relation between shift work and change in cardiovascular risk factors.

Comparison of our data with the few cohort studies is difficult because of the difference in number of respondents included in most of these studies. Of the cohort studies on cardiovascular risk factors, the study of Morikawa et al[5] on hypertension risk among shift workers is the largest so far. In this study, a higher 5-year relative risk for hypertension in younger shift workers (ages 18 to 29) but not for the older shift workers was reported. In our data, where most respondents belonged to the 18- to 29-year age group, no changes in blood pressure were found. The shorter time of follow-up in our study might be an explanation for the differences with the study of Morikawa. But another possible explanation might be that the decrease of BMI as found in our data has prevented a possible increase in blood pressure.

Four studies reported a positive relationship between BMI and duration of shift work.[13–16] This is in contrast with the decrease of BMI in shift workers as found in this study. One might hypothesize that the decrease of BMI found in shift workers as compared with the day workers might partially be explained by increased smoking by the shift workers. As in other studies,[17,18] significantly lower BMI levels were found in smokers. However, this relation was not sufficient to explain the total reported effect. Another possible mechanism involved might be a change in the neuro-endocrine secretion of hormones, which can be disturbed by sleep problems[19] and shift work.[20,21] However the discrepancy between the reported increase of BMI with number of years worked in shifts found in several studies and the decrease of BMI found in this study remains puzzling. One might hypothesize that the disturbance of the metabolic system after the start in a shift work job causes a decrease of BMI, which in the long term is compensated by an increased energy intake, leading to a increase in BMI after several years of working in shifts. Another explanation might be a change of behavior of the participants, caused by the inevitable attention on cardiovascular health because of the realization of the study itself. Although this is likely to have occurred in both the shift and day workers, the shift workers might have been more susceptible because a relation between shift work and cardiovascular risk factors might have occurred by entering the study, making the shift workers more health conscious. The decreased levels of energy intake as reported in the shift as well as the daytime workers might be an indication for the latter effect.

Except for the study of Knutsson et al,[4] no cohort studies were found reporting on changes in smoking habits and other lifestyle risk factors in shift workers. In contrast to our data, in this study no different change in smoking habits between the day and shift workers was found. Contrary to our findings regarding the longitudinal changes in blood lipids, Knutsson et al reported a slightly less favorable shift in blood lipid profile in the shift workers as compared with the day workers, although the differences were small and insignificant. This difference can be attributed to the small number of respondents in the study of Knutsson et al as compared with our study population. Results from the cross-sectional studies, reviewed as by Bøggild and Knutsson,[1] revealed 12 studies that reported higher smoking rates among shift workers compared with daytime workers (only one reported a significant difference), one study reported no difference, and one study reported more smokers in the daytime group. Most authors explained this by differences in socioeconomic status between the shift workers and daytime workers. But the results from this study, with an increased change smoking rate in the shift workers, which remained significant even after correcting for educational level, might indicate that other factors might be important in the elevated smoking rate among shift workers. It might be that a shift work-related decreased social support is involved in the increase in smoking because we found a significant negative correlation between staring to smoke and social support at baseline within the shift workers (specific data not shown).

Using the data on the cardiovascular disease risk from the Framingham study[22] a crude estimate of the risk of the increased cigarette smoking in shift workers can be calculated. Assuming that the increase of 2.4 cigarettes per year remains constant over a 20-year working life in the 36% of smoking shift workers, an average excess of 17 pack-years can be calculated. The relative cardiovascular disease risk in the shift workers due to an increased smoking rate is than estimated to be 1.1.

The study of Knutsson et al[4] is the only cohort study published so far reporting on changes in blood lipids in shift workers. As in our study, Knutsson et al reported no significant different changes in cholesterol between 13 day workers and 12 shift workers from the start of employment compared with 6 months at work. Also, most of the cross-sectional studies on biomarkers of cardiovascular disease among shift workers reported no or small differences between shift workers and daytime workers.[13] Another approach regarding the effects of shift work in relation to cardiovascular disease risk factors was taken by Bøggild and Jeppesen.[23] In a quasi-experimental controlled intervention among 101 nurses, they found that when ergonomic shift criteria were applied, favorable changes in blood lipids and lipoproteins occurred. In our study, we did not found significant differences between the different shift schedules included. However, this might be the result of the low numbers in some of the included shift schedules in our study.

To conclude, our results combined with the results from other studies provide no evidence for the hypothesis that working in shifts leads to a substantial unfavorable change in the cardiovascular risk profile. The only factor found in our study that could explain a part of the elevated cardiovascular disease risk for shift workers is smoking. One may speculate that shift workers increase their smoking to compensate for a decreased social support or because of the stress related to working in a shift schedule. Taking the results from our study together with all other available data on the cardiovascular risk factors in shift workers it seems unlikely that lifestyle habits or changes in one or more of the conventional biological risk factors can explain the elevated cardiovascular disease risk in shift workers.

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