Fluctuations in heart rate variability of health care workers during four consecutive extended work shifts and recovery during rest and sleep

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Abstract: The aim of this study was to investigate fluctuations in heart rate variability (HRV), which reflect autonomic nervous system (ANS) function and potential psychological and physical strain, among 24 health care workers during work and sleep during four consecutive extended work shifts. Data included 24/36/12 h of HRV measurements, two logbooks, and a questionnaire. A cross-shift/cross-week design was applied. HRV was measured during work, leisure time, and sleep. The HRV data included time-domain [mean RR, SD of normal to normal R-R intervals (SDNN), and root mean square of the successive differences (RMSSD)] and frequency-domain [low frequency (LF)/high frequency (HF) ratio] parameters. HRV parameters revealed significant differences among work, leisure time, and sleep. Mean RR, RMSSD, and SDNN values were lower and the LF/HF ratio was higher on the first versus last day of the work period; however, the differences were most prominent in the morning hours. The results indicate higher levels of cardiovascular stress on the first versus fourth day of the working period, and measurements at night indicate a satisfactory recovery from the extended shifts.

Key words: Autonomic nervous system, Stress, Health care workers, Extended working hours, Compressed work week

Introduction and Background

Non-standard work schedules are becoming an increasingly frequent aspect of modern society and have become more diverse and irregular, including night shifts, extended daily and weekly working hours, and less time for rest and recovery[1]. Extended working hours may include long working *days*, long working *weeks* (exceeding 40 h)*,* or *compressed* working weeks (long daily hours and normal weekly working hours)[2]. The use of extended daily working hours and extended or compressed working weeks followed by several days off has traditionally been practised in the Norwegian offshore sector[3, 4] and within the aviation sector[5]. The use of similar work schedules has, in recent years, increased in the health care sector, construction sector, and service sector due to production benefits or the clients' or patients' need for continuity in care[4].

While expressing their concern regarding possible

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adverse health effects, the social partners in Norway are granting an increasing number of health institutions exemptions from the minimum daily rest of 11 h[4]. Many nursing homes in Norway have introduced shift schemes, including several extended work shifts, resulting in less daily rest during the work period.

Among both employers and employees, there is an increased request for such work schemes. Perceived positive effects may include increased time off between work periods, more time with their families, less commuting time and cost, and fewer shift handovers[2]. Extended working hours and shift or night work are well-established risk factors for workplace accidents and several negative health effects, including cardiovascular diseases (CVDs)[6]. Several studies of nurses with extended work hours have demonstrated both short-term and long-term detrimental effects on sleep, performance, and safety among both nurses and their patients[7–9].

Shift and night work may be particularly problematic if the time for rest and recovery between the shifts is shortened[10]. Associations between long working hours and an increased risk of CVD have also been described[11]. However, it is unclear to which degree these effects are related to risk factors of CVD, such as psychosocial and physiological strain, or to detrimental behavioural changes with respect to sleep, physical activity, and nutritional or smoking habits[12–14]. Thus, it is important to differentiate between the effects of the psychological and physiological workload and the behavioural changes due to the organization of the working hours[2, 15, 16].

Heart rate variability (HRV) is the variation in the beat-to-beat interval of the heart. It represents a reliable reflection of the many physiological factors modulating heart rate (HR). HR is controlled by the sinoatrial node, which is modulated by both the sympathetic and parasympathetic pathways of the autonomic nervous system (ANS). Sympathetic activity tends to increase HR and decrease HRV, whereas parasympathetic activity decreases HR and increases HRV. Measurements of HRV provide a means of observing the interplay between the sympathetic and parasympathetic pathways of the ANS[17] and may also be regarded as an indicator of current disease or a marker of subclinical cardiac disease[17, 18].

Different external stressors affect HRV by causing increased activity in the sympathetic nervous system, which is reflected in the HR and HRV. Subtle changes in cardiac autonomic function due to potential physical or psychological strain during work and recovery during sleep may be detected by analysing HRV measurements[6, 10].

HRV measurements are non-invasive and a relatively simple procedure for evaluating cardiac autonomic function[19].

Significant differences in the HRV parameters between work and sleep periods have been observed in several studies[20–22]. HRV patterns in nurses during normal-length day and night shifts show similar patterns regardless of the type of shift but are dependent on the activity level. HRV thus seems to be modified by levels of physical activity more than diurnal variations[21, 22].

Studies of HRV among workers with extended working hours have shown that extended hours of night work, in particular, may lead to decreased HRV[10, 23]. However, a Finnish study of HRV among female Finnish nurses with shift schemes including both normal and extended day shifts showed only minor differences in HRV parameters between nurses in normal and extended shifts. This may possible be explained by an individual adaptation to the extended shifts or the more flexible organization of duties that is possible during the extended shifts[15].

Our hypothesis is that four consecutive extended day shifts will increase cardiac strain.

The aim of this study is to assess associations between exposure to consecutive extended workdays and the cardiac stress response, as measured by HRV parameters. This includes comparisons of HRV parameters during work and recovery the actual days and nights.

Material and Methods

When a new nursing home opened on the west coast of Norway in 2012, a new temporary shift scheme was introduced. The shift scheme was to be evaluated after 2 yr. We invited all involved workers to participate in the study. The shift scheme consisted of four consecutive day shifts (D) followed by 7 d off (-) and three day shifts followed by another 7 d off (DDDD -------DDD -------) over a period of three weeks. The duration of the day shifts was 14 h. In addition to the 30-min lunch break, the workers were entitled to a one-hour break in the afternoon during which they could leave the ward and had access to a quiet room where they could lie down to rest. Each participant was followed during the four consecutive extended shifts from Thursday to Sunday. Members of the actual day-teams ended their last day of duty on Sunday evening, and a new day-team started on the following day. The members of every new day-team arrived half an hour before their shift started to read the reports from the previous day and night shifts. The turnover of patients was high, as most of the patients of the somatic wards were short-term (usually 14 d) inpa-

Table 1. Participant characteristics (N=24)

	Registered nurses/social workers (N=8) 33%	Nurses assistants/apprentices (N=16) 67%	All (N=24) 100%
Males	1	2	3
Females	7	14	21
Mean age	40.5 (SD 11.9)	42.6 (SD 13.1)	41.9 (SD 12.5)
Current smokers	1 (13%)	6 (38%)	7 (29%)
Mean BMI (kg m^{-2})	26.0 (SD 4.1)	26.3 (SD 3.7)	26.2 (SD 3.7)
Married/cohabitant	6 (75%)	12 (75%)	18 (75%)
Children <18 yr living at home:	6 (75%)	7 (44%)	13 (54%)
Frequent excessive workload	2 (25%)	4 (25%)	6 (25%)
Physical exercise>1 h/wk	6 (75%)	7 (44%)	13 (54%)
Pain in neck, shoulder, upper back last year	2 (25%)	8 (50%)	10 (42%)
Pain in neck, shoulder, upper back last month	2 (25%)	6 (38%)	8 (33%)
Headache, migraine last year	4 (50%)	4 (25%)	8 (33%)
Headache, migraine last month	4 (50%)	3 (19%)	7 (29%)
Sleep problems last year	2 (25%)	4 (25%)	6 (25%)
Sleep problems last month	1 (13%)	4 (25%)	5 (21%)

tients. One of the four wards was designed specifically for patients with dementia, with increased staffing due to potential aggression and violence.

A total of 51 health care workers were included in this temporary shift plan. Workers taking any medication with known effects on cardiovascular function were excluded from the study (2). Five chose not to participate due to health problems or personal reasons. Only one out of the six workers who left the nursing home during the data collection period stated the shift scheme as a reason. The other five workers were offered permanent employment elsewhere. In addition, three apprentices were relocated during the study period. These nine workers were replaced by new employees, whom were included in the study. The resulting sample consisted of 44 health care workers.

HRV measurements from 20 subjects were excluded due to poor quality of the data. Hence, the final sample consisted of 24 subjects: 3 men and 21 women; 8 registered nurses/social workers; and 16 assistant nurses/apprentices. Table 1 shows the characteristics of the participants.

The study design was a cross-shift/cross-week design where the participants served as their own controls. Information about the study and the invitation to participate in the study were given at a staff meeting. The director of the nursing home encouraged participation and informed that the municipality would compensate for their participation beyond the planned working hours, i.e., the baseline meeting.

Participation started at a baseline meeting the evening before the four workdays began. Each participant completed a questionnaire, which included questions on indi-

vidual characteristics, such as marital status, number of children living at home, age, weight, smoking habits, physical activity, duration of current position, habitual sleep pattern, and self-reported health problems during the previous four weeks and the previous year. The questions were based on validated questionnaires such as the QPS Nordic[24], Karolinska Sleepiness scale[25], and Bergen Insomnia Scale[26] in addition to questions that were developed specifically for this study.

HRV data were collected by eMotion 3D-sensors, which were produced by Mega Electronics Ltd., to assess cardiovascular stress, strain, and recovery during work, leisure, and sleep.

Information and demonstrations regarding the application and activation of the HRV-sensors were given by a member of the research team, whom also activated the first sensor at the baseline meeting. The second HRV measurement (HRV2) was performed from the morning of the first work shift and deactivated the next morning. On the morning of the fourth shift, the participants activated another sensor, which was deactivated the next morning (HRV3). On the third day off, the participants activated the fourth sensor at night before sleep and deactivated it the next morning (HRV4).

Logbooks developed for this study were completed by the participants during the first and fourth days of their working period. The logbooks included questions about sleep length and sleep pattern during the previous night; physical activity during leisure time; commuting time; start and stop times of the shift; episodes of heavy physical workload at work; the number and time/duration of breaks;
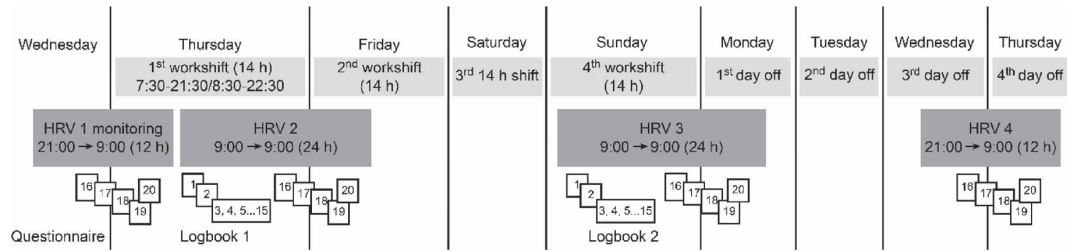
Fig. 1.

Table 2.   Selected heart rate variability measures

Measure	Description
Time–domain	
HR (min^{-1})	Mean heart rate in beats per minute. Measure of physiological and psychological cardiac strain. Lower HR at rest and during physical strain implies more efficient heart function and better cardiovascular function.
Mean RR (s)	Mean of selected beat to beat (RR) interval series inversely proportional to HR.
RMSSD	The root mean square of differences of successive RR intervals. RMSSD evaluates differences between successive RR intervals and reflects short-term variations. Low value indicates high cardiovascular strain.
SDNN	SD of normal heart beat intervals. Gives an estimate of overall HRV not distinguishing between changes due to reduced vagal tone or increased sympathetic activity. Low value indicates high cardiovascular strain.
Frequency-domain	
LF and HF	Low frequency power demonstrates sympathetic and vagal activation. High frequency power is synchronous with respiration and is modulated by the vagal tone. High LF indicates high cardiovascular stress. High HF indicates low cardiovascular strain.
LF/HF ratio	LF/HF ratio describes ratio of LF and HF powers. High LF/HF ratio indicates high cardiovascular strain.

food intake; coffee and tobacco consumption; and self-reported health problems, including perceived stress. The study protocol was approved by the Regional Committee for Medical Research Ethics. Participants provided written informed consent. Data collection occurred from November 2014 to February 2016.

The measured segments represent different time points during the workday, time off, and sleep: time segments 1 to 14 represent the workday; time segments 9–10 represent the one-hour break; time segment 15 is the period before falling asleep; time segments 16 to 19 represent hours of sleep; and time segment 20 indicates the time of awakening the next morning (Fig. 1). The nights were numbered as follows: night 0: the night after baseline; night 1: the night after the first work day; night 4: the night after the fourth work day; night 7: the night after two days off.

HRV parameters

HRV was assessed using three time-domain parameters and one frequency-domain parameter (Table 2). All HRV parameters were computed according to published guidelines[27] (Table 2).

Data preparation and statistical analysis

HRV parameters were investigated during a period of four consecutive 14-h work shifts to evaluate the following:

- Possible differences between work day one and work day four, for each time segment during the whole day.
- Possible differences between the baseline night (night 0) and the nights 1, 4 and 7 respectively, for each of the first four hours of sleep.
- Possible differences between the baseline night (night 0), and the nights 1, 4 and 7 respectively, for the awakening hour.

HRV data were visually inspected to exclude artefacts. Nineteen 10-min time segments that were free of artefacts from each workday were analysed. The HRV data were analysed using Kubios HRV analysis software[28]. SPSS Statistical Package for Windows 24.0 (SPSS Inc, Chicago, IL, USA) was used to analyse the self-reported data from the questionnaire and logbooks. Linear mixed models were applied to each of the HRV measurements, separately analysing the workday, sleep, and awakening hours. All analyses were adjusted for gender, age, body mass index (BMI), and included a random intercept for subjects. Additional analyses adjusted for varying HR, by adding a linear and quadratic term. Linear mixed models were analysed using the lme4 package (version 1.1-12) in R (version 3.3.3) (R-project.org).
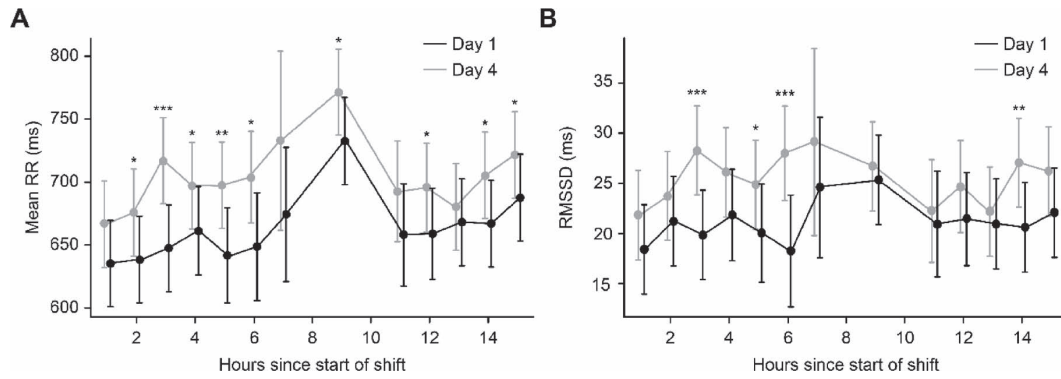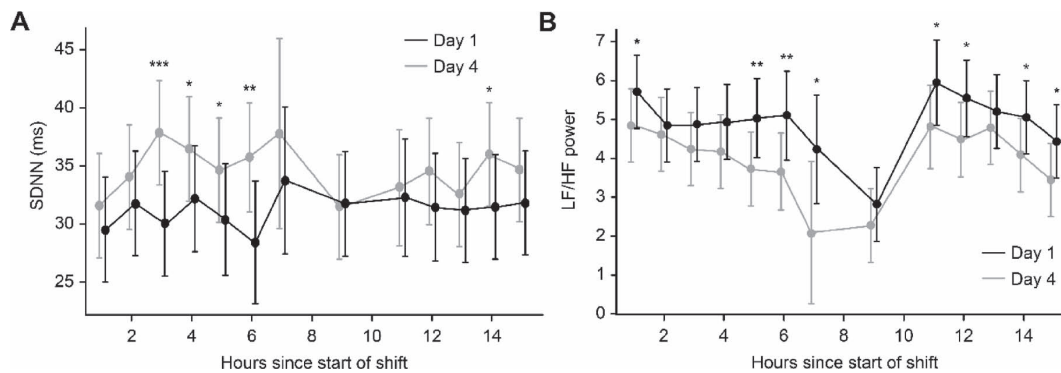
Fig. 2.

Fig. 3.

Results

We found no significant differences between the two groups in age and BMI using Two samples Wilcoxon rank-sum test. Neither did we find any significant differences in any of the other variables in Table 1 using Fishers-exact test. Due to this, the two groups were analysed as one.

The beat to beat interval (RR) was significantly higher on the fourth workday at time segments representing most of the workday compared to the first workday (Fig. 2A). The root mean square of the successive differences (RMSSD) was at its lowest in the morning when the shift starts on both the first and fourth workdays, but it was considerably lower on the first compared with the fourth workday (Fig. 2B).

The SD of normal to normal R-R intervals (SDNN) was lower during the whole first workday compared to the fourth workday (Fig. 3A). The low frequency (LF)/ high frequency (HF) ratio was consistently higher on day 1 compared to day 4 (Fig. 3B). A significant decrease in HR, and a decrease in the LF/HF ratio were observed around the time of the afternoon break compared to the start of the

shift in the morning. When comparing the time segment before the one-hour break with the time segment just after the break, we did not detect any significant differences in RR, RMSSD, or SDNN on neither the first nor the fourth workday. However, we observed a significantly higher LF/ HF ratio after the one-hour break on the fourth workday compared to that on the first workday (Table 3).

HRV parameters during four nights

For all parameters, Table 4 shows only minor differences between the four nights during the first four hours of sleep (time points 16–19) except for a significant increase in SDNN at time point 18 the night after the first work day compared to the baseline night. A significant increase in LF/HF was observed at the time of awakening in the morning (time point 20) of the second workday versus the morning of the first workday (night 1 vs 0). However, a significant decrease in LF/HF was observed at the time of awakening in the morning of the first day off compared to the morning of the first workday (night 4 vs 0). The mean RR, RMSSD and SDNN were significantly increased at the time of awakening on the morning of the first day off.

Table 3. Analyses of differences of mean SDNN, mean RR, RMSSD, and SDNN between workday 1 and workday 4, for each time segment during the day (9–10 is time of rest). N=24.

Hour	LF/HF		MeanRR (ms)		RMSSD		SDNN (ms)	
	B (95 % CI)	p	B (95 % CI)	P	B (95 % CI)	p	B (95 % CI)	p
1	−0.86 (−1.7, −0.048)	0.04	32 (−0.91, 64)	0.06	3.4 (−0.89, 7.6)	0.12	2.1 (−1.5, 5.6)	0.25
2	−0.22 (−1, 0.59)	0.59	37 (4.9, 70)	0.03	2.6 (−1.7, 6.8)	0.24	2.3 (−1.3, 5.8)	0.21
3	−0.64 (−1.5, 0.18)	0.12	70 (37,100)	<0.01	8.4 (4.2,13)	<0.01	7.8 (4.3,11)	<0.01
4	−0.76 (−1.6, 0.07)	0.07	36 (2.5, 69)	0.04	4.2 (−0.13, 8.6)	0.06	4.2 (0.63, 7.9)	0.02
5	−1.3 (−2.2, −0.41)	0.01	56 (20, 92)	<0.01	4.8 (0.13, 9.5)	0.05	4.2 (0.33, 8.1)	0.03
6	−1.4 (−2.5, −0.37)	0.01	56 (13, 99)	0.01	9.7 (4.1,15)	<0.01	7.3 (2.7,12)	<0.01
7	−2.1 (−4.2, −0.1)	0.04	58 (−23,140)	0.16	4.5 (−6.1,15)	0.40	4 (−4.8,13)	0.37
Rest	−0.54 (−1.4, 0.27)	0.19	39 (6.4, 71)	0.02	1.4 (−2.9, 5.7)	0.52	−0.27 (−3.8, 3.3)	0.88
11	−1.1 (−2.2, −0.035)	0.041	35 (−9.2, 78)	0.12	1.3 (−4.4, 7)	0.66	0.86 (−3.9, 5.6)	0.72
12	−1.1 (−1.9, −0.19)	0.02	37 (2.1, 72)	0.04	3.2 (−1.3, 7.8)	0.17	3.1 (−0.68, 6.9)	0.11
13	−0.42 (−1.2, 0.39)	0.31	12 (−21, 45)	0.47	1.2 (−3.1, 5.5)	0.58	1.3 (−2.2, 4.9)	0.46
14	−0.96 (−1.8, −0.15)	0.02	38 (5.7, 71)	0.02	6.4 (2.2,11)	<0.01	4.5 (0.97, 8)	0.01
15	−0.99 (−1.8, −0.18)	0.02	34 (1.2, 66)	0.04	4.1 (−0.16, 8.4)	0.06	2.8 (−0.69, 6.4)	0.12

B: estimate of difference between day 4 and day 1
Linear mixed model analyses with random intercept for subject and adjustment for gender, age and BMI.

Table 4. Analyses of differences of mean SDNN, mean RR, RMSSD, and SDNN between the baseline night (night 0) and nights 1, 4 and 7 respectively, for each of the first hours of sleep (16–19), and for the time of awakening (20). N=24.

Night[*]	Time period	LF/HF		meanRR (ms)		RMSSD		SDNN (ms)	
		B (95 % CI)	p	B (95 % CI)	p	B (95 % CI)	p	B (95 % CI)	p
1 vs 0	16	0.13 (−0.69, 0.94)	0.76	19 (−18, 56)	0.32	1.1 (−5.9, 8.1)	0.75	1.2 (−4.5, 6.8)	0.68
	17	−0.31 (−1.1, 0.51)	0.46	19 (−18, 56)	0.31	2.2 (−4.8, 9.2)	0.53	2.6 (−3, 8.2)	0.37
	18	0.18 (−0.64, 0.99)	0.67	23 (−14, 60)	0.22	5.1 (−1.9, 12)	0.15	6.3 (0.7, 12)	0.03
	19	0.74 (−0.077, 1.6)	0.08	2.5 (−35, 40)	0.90	1.1 (−5.9, 8.1)	0.76	1.6 (−4.1, 7.2)	0.59
	20	2.2 (0.65, 3.8)	<0.01	14 (−58, 85)	0.71	2.3 (−11, 16)	0.74	4.6 (−6.2, 15)	0.40
4 vs 0	16	−0.18 (−0.99, 0.64)	0.67	36 (−1.4, 73)	0.06	3.7 (−3.3, 11)	0.30	1.8 (−3.8, 7.5)	0.52
	17	−0.76 (−1.6, 0.053)	0.07	20 (−17, 57)	0.29	1.2 (−5.8, 8.2)	0.74	1.9 (−3.8, 7.5)	0.52
	18	−0.085 (−0.9, 0.73)	0.84	19 (−18, 56)	0.32	2.7 (−4.2, 9.7)	0.44	4.2 (−1.4, 9.8)	0.14
	19	0.097 (−0.72, 0.91)	0.82	0.48 (−37, 38)	0.98	−1.3 (−8.2, 5.7)	0.73	−2.4 (−8, 3.3)	0.41
	20	−2 (−3.6, −0.46)	0.02	280 (210, 350)	<0.01	19 (5.5, 32)	<0.01	18 (7.6, 29)	<0.01
7 vs 0	16	−0.02 (−1.3, 1.3)	0.98	27 (−33, 87)	0.38	−1.6 (−13, 9.7)	0.78	0.28 (−8.8, 9.4)	0.95
	17	−0.78 (−2.1, 0.54)	0.25	−3.2 (−63, 57)	0.92	0.38 (−11, 12)	0.95	0.95 (−8.1, 10)	0.84
	18	0.022 (−1.3, 1.3)	0.97	30 (−30, 89)	0.33	2.7 (−8.6, 14)	0.65	6 (−3.1, 15)	0.19
	19	0.54 (−0.78, 1.9)	0.42	25 (−35, 85)	0.42	−2.4 (−14, 8.9)	0.68	0.49 (−8.6, 9.6)	0.92
	20	−0.4 (−1.8, 1)	0.59	230 (170, 300)	<0.01	11 (−1.6, 23)	0.09	11 (1.6, 21)	0.02

[*]Night 0: The night after baseline, night 1: The night after the first work day, night 4: The night after the fourth work day, night 7: The night after three day off
B: estimate of difference between day 4 and day 1
Linear mixed model analyses with random intercept for subject and adjustment for gender, age and BMI.

Furthermore the mean RR and SDNN showed a significant increase the morning on the fourth day off compared with the awakening time of the first workday (night 7 vs 0).

HRV parameters of the three men were not statistically significantly different from those of the women. Older subjects had a statistically lower mean RR. Higher BMI was associated with statistically increased mean RR and SDNN.

Reported sleep and health issues

The average duration of sleep was 5.8 h the night before the first workday (min 3, max 7.5 h), and it increased to 6.5 h (min 5 and max 8 h) the night before the fourth workday. Fifteen participants (65%) reported a sleep pattern including one or more of the characteristics described in Table 5 the night preceding the first workday, and 12 participants (50%) reported such a sleep pattern the night preceding the

Table 5.   Reported sleep patterns the nights preceding Day 1 and Day 4. (N=24).

	Night before Day 1	Night before Day 4
≥30 min falling asleep	10 (44%)	8 (33%)
≥30 min awake in between sleep	8 (35%)	4 (17%)
Awakening ≥30 min before wanted	9 (38%)	4 (17%)

fourth workday.

Five (21%) participants reported having general sleep problems the night preceding the first workday, and four (17%) participants reported sleep problems the night preceding the fourth workday. No significant difference was observed in the number of participants reporting little or no stress between the first and the fourth workdays. All 24 participants stated that they were happy with the current shift scheme. However, two participants (9%) reported difficulties in balancing their work and private lives. Six participants (25%) reported that they rarely or never experienced an excessive workload, 12 (50%) reported that they sometimes experienced an excessive workload, and the remaining six (25%) reported that this occurred quite often.

Discussion

The main finding in the present study was the higher level of cardiovascular stress during the first workday compared with the fourth workday, as indicated by the significantly lower values of mean RR, SDNN, and RMSSD and by the significantly higher LF/HF ratio on the first workday. Our findings did not support the contention that consecutive extended day shifts increase cardiac strain under the present work conditions.

HRV parameters at night were analysed by comparing the values of the first four hours of sleep in the night preceding the work period with the corresponding hours after one and four workdays as well as after three days off. Only minor differences were observed in the HRV patterns during sleep between the four nocturnal time points that were evaluated. Greater sympathetic activation of ANS was observed during work than during sleep. These results are in accordance with the study of nurses by Ito and coworkers, which showed significant differences in the HRV parameters between the work and sleep periods[21]. Bilan and coworkers reported a strong influence of physical activity on the circadian changes in HR[29]. HR and HRV are also influenced by posture. Compared with the supine position, the HRV recorded in the standing position shows

LF/HF values that indicated sympathetic augmentation and vagal attenuation[30]. In an attempt to disentangle the effect of HR on HRV, we adjusted for HR in the analyses of RMSSD, SDNN, and LF/HF. The difference between the first and the fourth workday were reduced, but remained statistically significant for RMSSD and SDNN at several timepoints during the day.

If the participants did not achieve sufficient recovery during sleep at night, one would expect to see decreased values of the baseline mean RR, SDNN, and RMSSD and an increased LF/HF ratio during sleep on nights 2 and 3 compared to the baseline nights 1 and 4. However, the minor differences among the HRV-values during the different nights indicate that the participants in this study recover well from the long shifts.

In agreement with previous studies, higher values of the LF/HF ratio were observed upon awakening and during the morning and afternoon hours of both workdays[29, 31]. However, the LF/HF ratio was significantly higher on the first compared with the fourth workday. Mean RR, SDNN, and RMSSD were significantly lower on the mornings the participants had to go to work compared to those on the mornings of their days off. The difference in sympatho-vagal balance between the awakening time of mornings preceding workdays and that preceding days off indicates that the participants are showing more physiological stress during the mornings of workdays, probably due to vagal withdrawal.

HRV and cortisol are two different physiological markers of stress that experience diurnal variation. Cortisol shows variation during the day, and groups with a stressful or high workload often exhibit increased cortisol levels, particularly in the morning[32, 33]. Bilan and coworkers[29] evaluated the diurnal fluctuations of HRV in healthy people and found a peak in the morning when studying frequency-domain HRV parameters. Their study revealed that the ratio between LF and HF peaked between 6 and 9 a.m. and between 4 and 6 p.m., with the smallest values between midnight and 5 a.m. In accordance with this, in the present study, we observed a peak in the early morning and late afternoon on both workdays one and four; however, the peak was more prominent on workday 1 (Fig. 3B).

Åkerstedt[34] claims that feeling stressed is closely related to impaired sleep. Physical stressors, such as sleep deprivation and overtime work, require an immediate systemic reaction. The ANS responds to both psychological and physical stressors and may result in cognitive, emotional or somatic consequences[35]. Åkerstedt[36] notes that the anticipation of high demands or efforts the next day

also seems to be important. He claims that the sleep before early morning shifts is often disturbed. Difficulties of having to rise early in the morning seem to be associated with the anticipation of stressful events[34, 36]. The health workers in the present study start their first morning shifts at 7:30. Although they have a relatively short commuting time to work (average 15 min), the extended shifts provide a rest time between the shifts limited to 10 h. Considering the time spent commuting, winding down, and possibly performing some daily domestic chores, the time left for sleep between the shifts is limited. The difference in sleep length before and after the work period, corresponds to the fact that 65% of participants reported disturbed sleep the night preceding the first workday versus 50% the night preceding the fourth workday.

There was no handover meeting or overlap between teams in the actual nursing home. This, together with other stressful factors mentioned in the methods section, could cause an anticipation of high demands, particularly during the first working day, acting as a psychological stressor that potentially contributes to cardiovascular stress. Mornings and evenings represented the busiest periods of the shifts in all wards due to the morning and night care of the patients. In the morning, patients need assistance to get out of bed, to get washed and dressed, and with morning care in general. Administration of the patients' medications, which occurred during the morning hours of the first workday, may have potentially contributed to additional psychological stress.

The one-hour breaks in the afternoon between 3 p.m. and 5 p.m., or at time segments 9 and 10 in (Fig. 2A and B), seem to lead to reduced levels of cardiovascular stress during both workdays one and four; the positive effects are shown by statistically significant differences; decrease in HR, increase of RR, and increase of RMSSD, and decrease of the LF/HF ratio around the time of the afternoon breaks compared to the start of the shift in the morning. The lower cardiovascular stress in the afternoon coincides with the ability to lie down during their break, which most participants did[21, 37]. When comparing the time segment before the one-hour break with the time segment just after the break, we did not observe any significant differences in RR, RMSSD, and SDNN on any of the actual workdays. The significantly higher LF/HF ratio after the one-hour break on both workdays could potentially reflect greater physical activity and potential mental stress due to work-related tasks in the afternoon and evening, such as dinner serving, the administration of medications, and the general night care of patients, including helping them to bed. The

midday hours before the one-hour break seemed to be quieter than the hours during the morning, late afternoon, and evening.

The elevated level of cardiovascular stress at the time of awakening on the first workday was significantly reduced at awakening time on the second workday and on the first day off; cardiovascular stress appeared to be somewhat increased at awakening time after three days off. Factors outside of work could have also influenced the increase in cardiovascular stress in the morning after three days off. Most of the participants were women, 75% of them were married/cohabited, and 54% had children under the age of 18 living at home. Although only 9% of the participants reported problems in balancing work with family life, one cannot exclude that factors outside of work might represent an issue[38].

When the human nervous system perceives an experience as stressful, physiological and behavioral responses are initiated, leading to allostasis and adaptation. Stressful experiences over time may cause an allostatic load, and such sustained stress could promote a blunted response that is a kind of non-adaptive response to stressor stimuli[39]. A working-time schedule like the one in the present study could possibly represent a chronic stressor, and as such potentially explain the vague physiological response after the first day of work. However, none of the health care workers in our study has had this work schedule for more than two years, and it is questionable if two years represents a relevant time span to produce such effects.

In previous studies, decreased values in HRV parameters are reported from the age of 60[40]. In the present study, however, the mean age was 41.9 yr old with only one individual over 60 yr of age. Age had a significant influence on only mean RR ($p \leq 0.01$).

A strength of this study was the use of a crossover design that eliminates uncontrolled confounding that stems from the use of an external control group[41]. Furthermore, the study was conducted in a real-life situation in which we had detailed exposure information. Limitations include the small sample size and potential uncontrolled confounding of sex hormone levels[21] and the stages of the menstrual cycle among the female participants. Leicht and coworkers found a correlation between oestrogen levels at the time of ovulation and HRV measurements[42]. However, in that study, the normal cyclic variations in endogenous sex hormone levels during the menstrual cycle were not significantly associated with changes in cardiac autonomic control as measured by HRV[42].

HRV measurements from 20 participants had to be

excluded due to poor quality of the data. However, the characteristics of this group did not differ from those of the included participants.

The study demonstrates higher cardiovascular stress during the first versus the last of four consecutive extended work shifts. The difference was most notable in the morning hours. Measurements at night indicate a satisfactory recovery from the extended shifts.

The analyses did not reveal any adverse effects on HRV parameters from a shift scheme consisting of a compressed week in which the shifts include an extra one-hour break with opportunities to rest while lying down.

The results of this study should be interpreted in the context of the favourable physical and organizational determinants of work stress that are offered in the nursing home in question. Little is known about the possible adverse effects from such shift schemes with a considerably higher workload. At the time of the data collection, the shift plan had been in use for only two years; hence, little is known about possible negative long-term effects.

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