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Original Article

Differences in Heart Rate Variability of Female Nurses between and within Normal and Extended Work Shifts

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Abstract. The aim of this study was to investigate differences in heart rate variability (HRV) reflecting the function of autonomic nervous system (ANS) and psycho-physiological strain associated with normal and extended work shifts in nursing work. Complete data were available from 51 female nurses with a mean age of 40 yr, and based on two comparable 36-h HRV measurements supplemented with a questionnaire. Time-domain (meanRR, SDNN, RMSSD) and frequency-domain (LF power, HF power) parameters represented the HRV data, and were analyzed by linear mixed models. The differences between the compared work shifts were minor, revealing mainly increased sympathetic activity at the beginning of the normal work shift. The HRV parameters detected significant differences between work and leisure-time during the normal and extended work shifts in female nurses. During work shifts, an increase in sympathetic and a decrease in parasympathetic control of HRV was observed when compared to the leisure-time situation. Older subjects had overall lower HRV than younger subjects indicating increased sympathetic activation of ANS, especially during work. HRV parameters revealed significant differences between work, leisure-time and sleep of female nurses, but there were few differences between normal and extended work shifts in HRV parameters. This lack of differences between work shifts may be a consequence of the adaptation of nurses to the extended shifts or the more flexible organization of work duties possible during extended work shifts.

Key words: Heart rate variability, Autonomic nervous system, Shift work, Extended work shift, Female, Nurse

Introduction

In the past decade, working time patterns have become more diversified, flexible and irregular and sometimes can even be unhealthy for the workers[1, 2]. Irregular working

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times and shift work with long working hours are common in the health care professions[1, 2]. As shift work refers to a system of non-standard working hours where the daily working hours are split into at least two sets of work periods, or shifts, over the 24-h day. Shift work with scheduled and rotating shift work system is common in health care[3], and about one third of workers work shift in health care sector[4]. Long working hours refer to a work shift that differs from the normal work time of eight hours per day, for example, due to overtime working or an extended work shift in the work schedule[2]. In general, extended work shifts are combined with "compressed work weeks", i.e., longer working hours each day but fewer days worked each week[5]. In previous studies, long working hours have been shown to be associated with cardiovascular diseases, self-rated health problems, work-related stress and fatigue[6, 7]. Long working hours have also displayed a direct relationship with an increase in the rate of occupational accidents and injuries[8–10], and with a higher risk of motor vehicle accidents[11]. In addition, long working hours can decrease safety in patient care[2]. The negative effects of long working hours may include reduced duration and quality of sleep, sleepiness and fatigue, reduced alertness, adverse effects on performance and health, prolonged toxic exposure, absenteeism and problems in communication[5].

The negative effects of long working hours such as the increased rate of accidents at work, decreased duration or quality of sleep, or increased fatigue are well reported, but the associations are not fully consistent[5]. Moreover, long working hours reduce the time available for recovery and lead to difficulties in unwinding after work[1, 12]. Furthermore, long working hours may affect health through impaired physiological recovery mechanisms. Insufficient recovery disturbs many physiological processes such as blood pressure, and increases the activity of the sympathetic part of the autonomic nervous system (ANS), that may lead to potential psycho-physiological and physical health complaints. Long working hours are also associated with unhealthy life-style factors such as a lack of exercise, poor diet, excessive caffeine intake, and increased alcohol consumption and smoking[6]. Despite these adverse consequences of long working hours, many shift workers prefer to undertake extended work shifts, because of their positive effects on individual time regulation, i.e., less travel time and costs, more time available for family and social life and for domestic duties, increased satisfaction with working hours, fewer shift handovers and less overtime[5]. Thus, information about psychophysiological strain related to extended work shift is needed to supplement previous knowledge.

The estimation of heart rate variability (HRV) from long-term electrocardiographic recordings is a non-invasive method for the assessment of cardiovascular autonomic regulation at work, and for long working hours in particular, since it may provide information about cardiovascular health[13]. HRV is the normal variation in the time intervals between consecutive heart beats (R-R intervals). This method is useful since it reflects the balance of the cardiovascular system controlled by the sympathetic and parasympathetic parts of the ANS. Therefore, changes related to psychophysiological strain and recovery of the ANS can be evaluated by HRV analyses. In any analyses of HRV, age[14, 15], gender[14, 15], cardiorespiratory fitness[16], health[14], medication[14], and smoking[14] should be considered, because they all influence HRV.

With respect to HRV, in particular, shift work and night work have been shown to be associated with reduced HRV. Decreases in specific HRV parameters which represent the parasympathetic activity of the ANS have been observed among night shift workers[17, 18]. These unfavourable changes in HRV might explain the increased cardiovascular morbidity and mortality in shift workers[17–19]. To the best of our knowledge, previous research of HRV in the context of work has focused on shift work[13, 17–20] and not examined the impact of extended working hours.

The aim of this study was to investigate differences in HRV reflecting the function of ANS and psychophysiological strain associated with normal and extended work shifts in nursing work. The differences were detected by examining selected time periods which included work, leisure-time and sleep during two comparable 36 h measurements.

Subjects and Methods

The data were gathered from 60 female nurses from a University Hospital who volunteered to participate in this study. They worked on a three-shift schedule (including M=morning shift, from 07:00 a.m. to 03:00 p.m.; E=evening shift, from 01:00 to 09:00 p.m.; and N=night shift, from 09:00 p.m. to 07:00 a.m.). The subjects were from different acute care wards, where physical and mental work load was comparable.

Due to missing questionnaire or inadequate HRV recordings, the data of nine subjects had to be excluded from the analyses. Hence, the final sample comprised 51 subjects. The nine excluded subjects were similar to the

Table 1. Description of the time-domain and frequency-domain HRV parameters based on the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996)[23]

HRV parameter (unit)	Description
Time- domain parameters	
MeanRR interval (ms)	Mean of the selected beat-to-beat (RR) interval series, inversely proportional to mean heart rate
SDNN (ms)	Standard deviation of all normal RR (normal-to-normal intervals, NN) intervals, the square root of variance demonstrates both sympathetic and parasympathetic activation
RMSSD (ms)	The square root of the mean of the squares of differences between consecutive RR intervals, describes short-term variations and demonstrates parasympathetic activation
Frequency-domain parameters	
LF (ms^2)	Low-frequency power (frequency range 0.04–0.15 Hz) demonstrates both sympathetic and vagal activation
HF (ms^2)	High-frequency power (frequency range 0.15–0.4 Hz) is synchronous with respiration and demonstrates vagal activation

subjects in the final sample with respect to age, gender, experience in current position and sickness absence during the past year. The subjects had no diagnosed cardiac disease or hypertension by a physician. Almost half of the subjects (44%) were using at least one medication regularly, but none was taking cardiovascular medication. Three of the subjects were regular smokers (average nine cigarettes per day). Each subject filled in a written informed consent form. The study protocols were approved by the Ethical Committee of the Kuopio University Hospital. The study was conducted according to the ethical standards of the Declaration of Helsinki.

Two 36-h HRV measurements supplemented with a questionnaire were performed at the worksite. The subjects were measured with the same recording procedure twice, once during normal and once in extended work shifts. The extended work shift consisted of combined morning and evening shift. As the normal work shift, the morning shift was chosen as being most comparable to the extended shift considering the circadian rhythm. By using a repeated study design each subject served as their own control. The measurements were carried out in a random order, i.e. a subject could be measured first during either the normal or the extended shift. Within this study, the day before the recorded work shift was a holiday for all nurses. Thus, all subjects had a comparable baseline situation.

The beat-to-beat heart rate (HR) was measured from each subject with a Suunto Memory Belt HR monitor[21]. The measurement of HRV with heart rate monitor has been shown to be valid and reliable during physically and mentally stressful conditions, especially when chest electrodes are used[22]. The two recording periods included morning shift (from 7:00 a.m. to 3:00 p.m.) and extended work shift (from 7:00 a.m. to 9:00 p.m.). Both recording periods started in the evening before the work shift (at 9:00 p.m.) and ended in the morning of the day after the work shift (at 8:00 a.m.). Thus, the recording periods included the night before the work shift, the actual work shift, and then leisure-time and the night after the work shift. Throughout both 36-h recording periods, the subjects were instructed to work in a habitual manner and to maintain their normal life style. During the 36-h recording subjects filled a diary. Information such as the beginning and the end of sleep, and the beginning and the end of the work day needed in the analysis was obtained from the diary.

Three time-domain and two frequency-domain HRV parameters were selected for the study (Table 1) as a way having of obtaining overall view of HRV with a minimum set of standardized parameters[23].

In the first part of the HRV analyses, the raw HRV data of both measurements were carefully visually inspected by the researcher in order to exclude artefacts. Eight artefact-free 10-min time periods from both 36-h recordings were systematically selected for the analyses of each subject (Fig. 1).

Then the HRV data were analyzed using Kubios (version 2.0) software[24] for advanced HRV analysis[25, 26]. Prior to computation of the HRV parameters, the very low frequency trend components (frequencies below 0.04 Hz) were removed from the selected phases of HRV data by using the smoothness priors method[27]. Time-domain parameters SDNN and RMSSD were computed from the detrended data, whereas meanRR interval was naturally computed from non-detrended data. Furthermore, prior to spectrum estimation, HRV data were interpolated (4 Hz cubic spline interpolation) in order to have equidistantly sampled data. The spectrum estimates were then computed by Welch's periodogram method[28] (window width 256 s

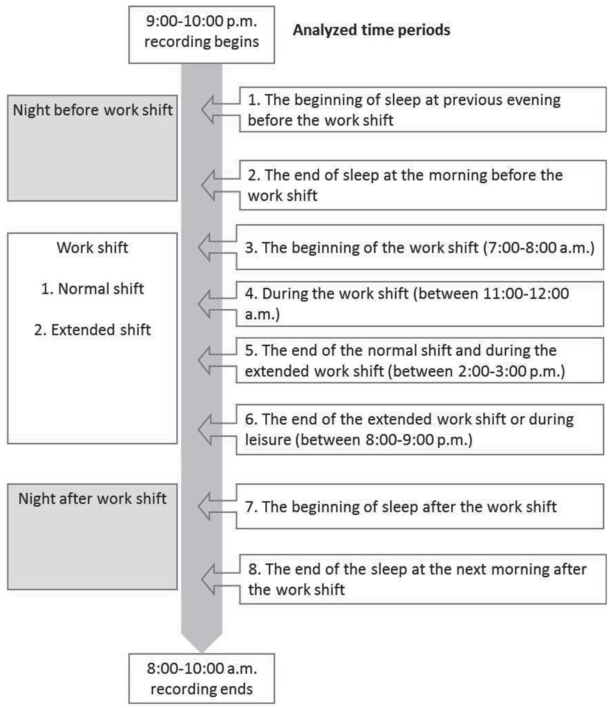

Fig. 1. Eight analysed time periods from the HRV recordings.

with 50% overlap).

The subjects filled in a self-administered questionnaire which included questions about individual characteristics (e.g., age, height, weight, social status, regularly used medication and smoking), occupational stress[29], experience in current position in years[30] and number of sick leaves during the last 12 months[31, 32]. Although the questionnaire was developed specifically for this study, most of the included questions were based on validated questionnaires such as the Occupational stress questionnaire[29] and the Work ability index[30] with known acceptable reliability[31, 32].

Statistical analyses were performed using SPSS (version 19.0 SPSS, Chicago IL, USA). Descriptive statistics (frequency, mean, standard deviation, ranges) were calculated. The linear mixed models[33] were used to examine associations between HRV parameters and work shifts (normal and extended work shifts). Each HRV parameter (meanRR, SDNN, RMSSD, LF power, HF power) was used as a dependent variable and analysed separately. Age (in years) was used as a covariate and time periods (1–8), work shifts (normal or extended work shift) and the interaction between work shift and time period were used as factors in all analyses. The number of sick leaves during the past 12 months was also used as a covariate. The number of extended work shifts during the last six weeks (dichotomized into six (median) or less versus seven or more), children living at home (dichotomized into no children living at home versus one child/children living at home), and perceived occupational stress (dichotomized into no stress versus stress) were included as separate factors in the analyses to test the effect of each factor separately. Since there was no major influence of any of these factors, they were excluded from the further analyses. The distribution of residuals was verified in the analyses. $p<0.05$ were considered as statistically significant.

Results

The mean age of the final sample was 42 yr (SD 11, range 24–56), and average employment duration in their current position was 11 yr (SD 10, range 0–32) (Table 2). The mean length of the normal work shift was 8.0 h and the length of the extended shift 13.9 h (p<0.001). There were no significant differences in the duration of the sleep before or after work shifts (Table 2).

Differences between the work shifts

There were no differences in meanRR interval, RMSSD and HF power between the normal and the extended work shifts (Table 3).

A significant difference between normal and extended work shifts was detected in SDNN in time periods 3 and 6. In time period 3 (at the beginning of work) SDNN was 2.4 ms higher during the normal work shift. In time period 6 (at 8.00–9.00 p.m.), SDNN was 2.6 ms lower in the normal work shift measurement (Table 3).

Another significant difference between normal and extended work shifts was observed in LF power in time periods 3, 4 and 6. In the time periods 3 (at the beginning of work) and 4 (at 11.00–12.00 a.m.), the LF power was higher during normal work shift. In time period 6 (at 8.00–9.00 p.m.), the LF power was 135.2 ms^2 lower during the normal work shift (Table 3).

HRV parameters indicated an increase in sympathovagal balance during both work shifts (time periods 3–5 and 3–6, respectively) when compared to leisure time. This was reflected in the increase in SDNN and LF power, and the decrease in meanRR, RMSSD and HF power during the work shifts compared to leisure-time or sleep (Figs. 2 and 3).

Differences within the work shifts

In both work shifts, the meanRR interval was significantly lower in almost all time periods (1, 3–7) compared

Table 2. Means, standard deviations (SD) and ranges of the demographic, health, and work shifts characteristics

Characteristic	mean (SD, range)	n (%)
Age (yr)	42 (11, 24–56)	
Body Mass Index (kg/m^2)	24.8 (4.2, 19.6–37.8)	
Sickness absence during past 12 month (days)	11.6 (27.4, 0.0–170.0)	
Experience in the current position (years)	11 (10, 0–32)	
Number of extended work shifts during past six weeks	7.3 (4.9, 1–17)	
Duration of work shift (hours)[a]		
Normal	8.0 (0.5, 7.0–8.0)	
Extended	13.9 (0.9, 11.0–15.00)	
Duration of sleep before work shift (hours)[b]		
Normal	6.6 (1.0, 4.0–9.5)	
Extended	6.8 (1.1, 4.0–9.5)	
Duration of sleep after work shift (hours)[c]		
Normal	8.4 (1.8, 5.0–11.5)	
Extended	8.0 (1.5, 4.0–11.0)	
Children living at home		
No children		28 (55)
One child/Children		23 (45)
Perceived occupational stress		
No stress		41 (80)
Stress		10 (20)

[a] Paired samples *t*-test, [a] $p<0.001$, [b] $p=0.142$, [c] $p=0.229$.

Table 3. Mean difference in HRV parameters between normal and extended work shifts in time periods 1-8

Time period	meanRR		SDNN		RMSSD		LF Power		HF Power	
	Mean difference[a]	p^b	Mean difference[a]	p^b	Mean difference[a]	p^b	Mean difference[a]	p^b	Mean difference[a]	p^b
1	8.8	0.587	–0.7	0.525	–0.5	0.690	1.2	0.974	8.8	0.587
2	–10.9	0.511	–0.4	0.697	0.2	0.850	–16.9	0.652	–10.9	0.511
3	0.1	0.995	2.4	**0.026**	0.6	0.636	75.8	**0.046**	0.1	0.995
4	26.1	0.124	1.8	0.093	1.3	0.287	77.3	**0.043**	26.1	0.124
5	1.4	0.933	0.2	0.862	0.2	0.842	27.9	0.455	1.3	0.933
6	14.3	0.397	–2.6	**0.016**	1.3	0.288	–135.2	**0.000**	14.3	0.397
7	6.4	0.702	–0.9	0.408	0.5	0.708	–43.4	0.249	6.4	0.702
8	–10.7	0.527	–1.6	0.139	–1.4	0.244	–30.7	0.421	–10.7	0.527

[a]Mean difference between Normal − Extended work shift, [b]Linear Mixed Model.

to the time period 8 (the end of sleep) with the exception of time period 2 (the end of sleep before the work shift) (Table 4). Overall every one year increase in age increased the meanRR interval by 3.3 ms (95% CI 0.4, 6.1, p=0.026).

During the normal work shift, the value of SDNN was significantly higher in time period 4 (at 11.00–12.00 a.m.) compared to time period 8 (the end of sleep after work). In time period 7 (the beginning of sleep) the SDNN value was significantly lower as compared to time period 8.

During the extended work shift, the SDNN value was significantly lower in time periods 3 (the beginning of work), and 7 (at 8:00–9:00 p.m.) as compared to time period 8 (the end of sleep after work) (Table 4).

In both work shifts, the RMSSD of the time periods 3–6 (during work) were significantly lower (Table 4) than those in time period 8 (the end of sleep after work).

In both work shifts, LF power was significantly lower in time periods 1 (the beginning of the sleep before work) and 7 (the beginning of the sleep after work) compared to that in time period 8 (the end of sleep after work) (Table 5). LF power values were significantly higher in the time periods 3–6 (during work) than in time period 8 (the end of sleep after work) (Table 5). There was an interaction between time period and age. The effect of age on LF power values was highest during time periods 3–5 (during work). Overall, each one year increase in age increased the LF power values by 7.3 ms^2 (95%CI −10.6, −0.3, p=0.040), 11.1 ms^2 (95%CI −14.3, −4.0, p=0.001) and 9.0 ms^2 (95%CI −12.3, −2.1, p=0.006) in time periods 3–5, respectively.

In both work shifts, HF power values in time period 1 (the beginning of the sleep before work) and in the time periods during work shift (3–6) were significantly lower than in time period 8 (Table 5). Overall one year increase in age decreased HF power value 2.5 ms^2 (95%CI −5.0, −0.1, p=0.045).

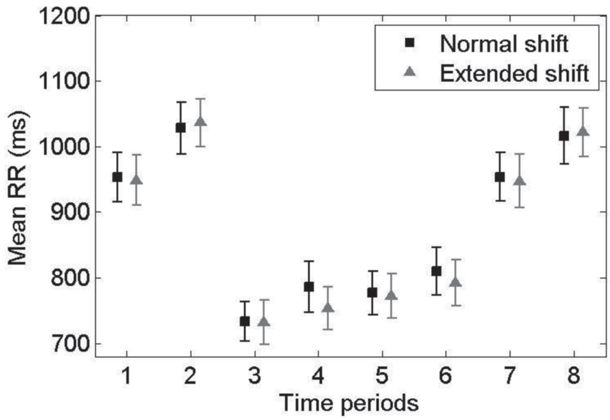

Fig. 2. MeanRR intervals (mean and 95%CI) during the normal and extended work shift in time periods 1–8.

Discussion

This study of 51 nurses aged 24–56 yr aimed to examine their differences in HRV which reflect the function of ANS and psycho-physiological strain associated with normal and extended work shifts. Differences were investigated by using selected time periods which included work, leisure-time and sleep during two comparable measurements of 36 h. As expected, the sympathetic activation of ANS was higher during the work shifts than during leisure-time or sleep[20]. This was reflected by the lower meanRR, RMSSD and HF power, and higher LF power values during the work shifts. This finding is in agreement with the study of Ito *et al.*[20] with 10 female nurses aged 24–49 yr. Furthermore, similar results have been observed among men at the age of 32–46 yr[34].

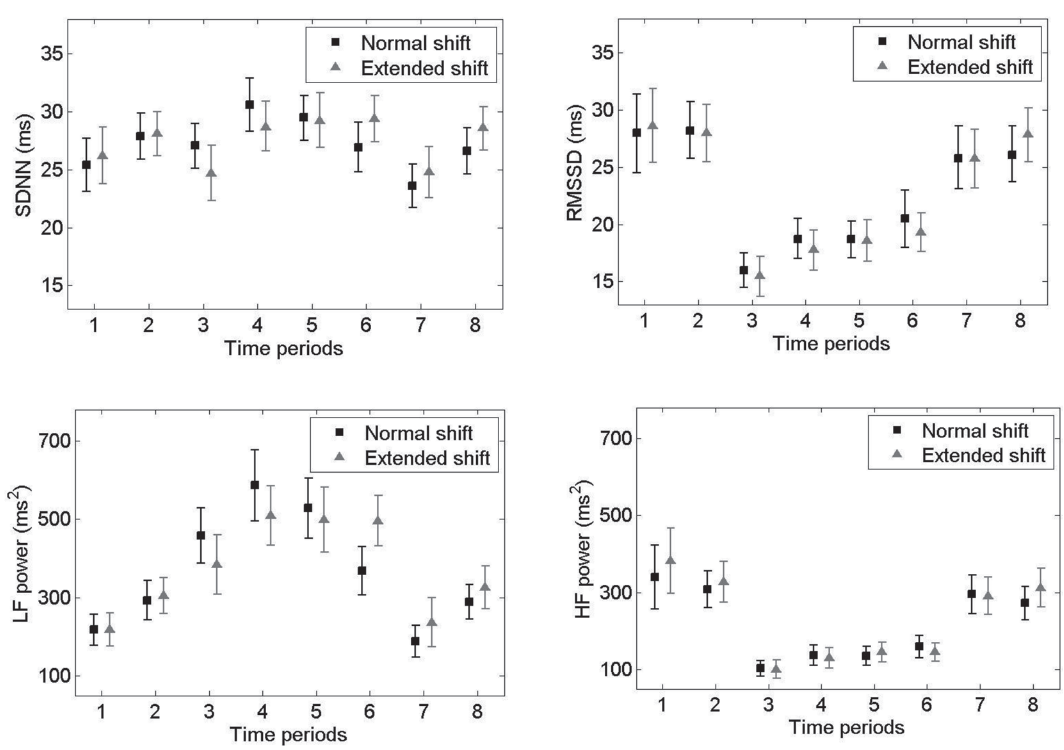

Fig. 3. Time domain (SDNN and RMSSD) and frequency-domain (LF and HF power) HRV parameters (mean and 95%CI) during the normal and extended work shifts in time periods 1–8.

Table 4. Comparison of meanRR interval, SDNN and RMSSD between time periods in the normal and extended work shifts

Time period	Normal work shift		Extended work shift		Normal work shift		Extended work shift		Normal work shift		Extended work shift	
	meanRR(F=97.2, *p*<0.001)		meanRR (F=109.3, *p*<0.001)		SDNN (F=8.6, *p*<0.001)		SDNN (F=7.2, p<0.001)		RMSSD (F= 31.6, *p*<0.001)		RMSSD (F=39.5, *p*<0.001)	
	B[1] (95 %CI)	p[2]	B[1] (95 %CI)	p[2]	B[3] (95 %CI)	p[2]	B[3] (95 %CI)	p[2]	B[3] (95 %CI)	p[2]	B[3] (95 % CI)	p[2]
1 vs 8	–57.6 (–90.8, –24.4)	**0.001**	–77.2 (–109, –45.3)	**0.000**	–1.4 (–3.5, 0.7)	0.196	–2.3 (–4.4, –0.3)	**0.025**	1.8 (–0.6, 4.2)	0.150	0.8 (–1.5, 3.1)	0.494
2 vs 8	13.3 (–19.9, 46.5)	0.431	13.5 (–19.1, 46.1)	0.417	1.0 (–1.1, 3.2)	0.341	–0.2 (– 2.2, 1.9)	0.882	1.9 (–0.4, 4.4)	0.108	0.3 (–2.0, 2.7)	0.796
3 vs 8	–275 (–309, –242)	**0.000**	–287 (–319, –253)	**0.000**	0.4 (–1.7, 2.6)	0.710	–3.6 (–5.7, –1.5)	**0.001**	–10.1 (–12.6, –7.7)	**0.000**	–12.1 (–14.5, –9.8)	**0.000**
4 vs 8	–227 (–260, –194)	**0.000**	–264 (–297, –231)	**0.000**	3.9 (1.7, 6.0)	**0.000**	0.4 (–1.7, 2.5)	0.686	–7.4 (–9.8, –5.0)	**0.000**	–10.1 (–12.5, –7.7)	**0.000**
5 vs 8	–238 (–271, –205)	**0.000**	–250 (–283, –217)	**0.000**	2.6 (0.5, 4.7)	0.015	0.8 (–1.3, 2.9)	0.432	–7.5 (–9.9, 5.1)	**0.000**	–9.2 (–11.6, –6.8)	**0.000**
6 vs 8	–202 (–236, –168)	**0.000**	–227 (–259, –194)	**0.000**	0.2 (–1.9, 2.3)	0.861	1.1 (–0.9, 3.3)	0.262	–5.7 (–8.1, –3.2)	**0.000**	–8.4 (–10.7, –6.0)	**0.000**
7 vs 8	–60.2 (–93.5, –26.9)	**0.000**	–77.3 (–110, –44.7)	**0.000**	–3.2 (–5.3, –1.0)	**0.004**	–3.9 (–6.0, –1.8)	**0.000**	–0.4 (–2.8, 2.0)	0.727	–2.3 (–4.7, 0.05)	0.055

B[1] parameter estimate reported as s, p[2] Linear Mixed Model, B[3] parameter estimate reported as ms.

Table 5. Comparison of LF power and HF power between time periods in the normal and extended work shifts

Time period	Normal work shift		Extended work shift		Normal work shift		Extended work shift	
	LF power (F=30.4, *p*<0.001)		LF power (F= 20.8, *p*<0.001)		HF power (F=97.2, *p*<0.001)		HF power (F=109.3, *p*<0.001)	
	B[1] (95 %CI)	p[2]	B[1] (95 %CI)	p[2]	B[1] (95 %CI)	p[2]	B[1] (95 %CI)	p[2]
1 vs 8	–75.4 (–150.2, –0.5)	**0.049**	– 107.3 (–179.2, –35.3)	**0.004**	–57.6 (–90.8, –24.4)	**0.001**	–77.2 (–109.1, –45.3)	**0.000**
2 vs 8	– 1.5 (–76.4, 73.3)	0.968	–15.4 (–88.9, 58.2)	0.682	13.3 (–19.9, 46.5)	0.431	13.5 (–19.1, 46.1)	0.417
3 vs 8	170.4 (94.7, 246.1)	**0.000**	63.9 (–9.6, 137.4)	0.088	–275.0 (–308.6, –241.5)	**0.000**	–285.8 (–318.4, –253.3)	**0.000**
4 vs 8	293.9 (218.8, 369.1)	**0.000**	186.0 (111.5, 260.4))	**0.000**	–227.1 (–260.4, –193.8)	**0.000**	–263.9 (–296.9, –230.9)	**0.000**
5 vs 8	234.3 (159.9, 308.8)	**0.000**	175.8 (102.2, 249.4)	**0.000**	– 237.8 (–270.8, –204.8)	**0.000**	–249.9 (–282.6, –217.3)	**0.000**
6 vs 8	77.5 (1.5, 153.5)	**0.046**	181.9 (108.4, 255.5)	**0.000**	–201.8 (–235.5, –168.1)	**0.000**	–226.8 (–259.4, –194.2)	**0.000**
7 vs 8	–102.4 (–177.5, –27.3)	**0.008**	–89.7 (–163.2, –16.2)	**0.017**	–60.2 (–93.5, –26.9)	**0.000**	–77.3 (–109.9, –44.7)	**0.000**

B[1] parameter estimate reported as ms^2, p[2] Linear Mixed Model.

The main interest of the study was to quantify HRV based differences between normal and extended work shifts. However, it was found that a difference between normal and extended work shifts existed only in SDNN and in LF power, whereas RMSSD and HF power reflecting parasympathetic activity did not reveal any differences between the shifts. At the beginning of the work shifts (time period 3), SDNN and LF power were higher for the normal shift than for the extended shift. This indicates an increased sympathetic control of heart rate at the beginning of the normal work shift. It could be argued that the duration or quality of sleep[35] before the work shift could explain this result. However, in this study, the duration of sleep was identical before work shifts as controlled by the questionnaire data which detected no difference in the quality of sleep. The comparison between time periods 3 (the beginning of work shift), 4 (at 11.00–12.00 a.m.) and 5 (at 2.00–3.00 p.m.) showed higher sympathetic activity during normal work shift than during extended (Table 3). Higher sympathetic activity may indicate more busyness or work-related stressful events during normal work shift than during extended work shift.

At time period 6 from 8.00–9.00 p.m. (leisure-time for normal work shift and the end of extended work shift), SDNN and LF power were lower during the normal work shift compared to the extended shift indicative of a increase in the sympatho-vagal balance on HRV for normal shift. This is probably due to the recovery of ANS during the leisure-time after normal work shift. In comparison between the ends of the works shifts (time periods 5 for normal shift and period 6 for extended shift) there were no significant difference indicating no difference between accumulated work load at the end of work shifts.

There were no other differences in the HRV parameters between normal and extended work shifts, or if present, the differences were minor. One can postulate that this lack of differences may be attributable to the adaptation of the nurses to the extended work shifts and shift work or by the healthy-worker effect[36]. Another potential explanation may be that the content of extended work shifts actually includes a similar amount of duties than normal shifts. In earlier studies, workers doing extended work shifts were also more satisfied with their working-time arrangements[5]. Moreover, one potential explanation can be the more flexible work duty organization of extended work shifts, resulting in more time to perform work tasks during the shifts. In addition, it may be assumed that nurses had a whole day off after an extended work shift, but not after a normal work shift. The day off after the extended work shift is an ergonomic recommendation regarding the duration and distribution of working time[37]. Thus, the nurses may have had a better opportunity to recover after the extended work shift over the long term although there were no differences in the length of the sleep after the work shifts.

In this study, one single extended work shift was no more stressful than normal work shift. It was found that work load was somewhat higher during normal work shift. Higher sympathetic activity may indicate more busyness or work-related stressful events during normal work shift compared to extended work shift. This somewhat differs from previous findings that the extended working hours may have harmful effects on the long run. Instead this study suggests that maybe the negative effects of extended working hours more likely start to emerge only after few repeated extended shifts. Therefore, it would be important in the future studies to pay attention to adequate recovery and health of nurses who do extended work shifts regularly.

Age is a well known factor affecting HRV[14, 15], therefore all the analyses in this study were controlled for age. However, a closer examination of the impact of age showed that when age-stratified analyses were perform then the older subjects had lower HRV values than their younger counterparts. These lower HRV values are believed to indicate increased sympathetic activation of ANS, especially during work. Hence this difference seems to be attributable to normal physiological changes (i.e., decreased maximal heart rate and stroke volume resulting in lowered cardiac volume) due to the ageing process[38].

In this study, each nurse served as her own control. This was done to eliminate confounding effects of individual factors on HRV, such as age or health status. The potential confounding factors for HRV were taken into account in the statistical analysis (e.g., the number of sick leaves during the past year, number of extended work shifts during past six weeks, number of children living at home and perceived occupational stress). However, the effect of these confounding factors, including perceived occupational stress or fatigue symptoms, was very minor, and, therefore, it may be assumed that the changes in HRV seem to be mainly work related. In our study group, the variability in the perceived stress was minor. This might explain that the association between occupational stress and HRV was not observed in this study. Fatigue symptoms can be result from burnout, for example. In this study, perceived burnout was assessed using Maslach Burnout Inventory − General survey (MBI-GS) -questionnaire[39, 40] and none of the subjects had severe burnout. The MBI score was used as a separate factor in analyses (results not shown in manuscript), and since there was no major influence of perceived burnout, it was excluded from the further analyses.

To the best of our knowledge, previous studies of HRV in the context of work has focused on shift work[13, 17–20] and not examined the impact of extended working hours. In addition, in the literature review of Togo and Takahashi[13], there were three previous research of HRV during 24 h shift with ambulance personnel (n=9 men), fire fighters (n=12 men) and truck drivers (n=6 men), but no studies about extended working hours. At the same time, previous studies have paid more attention to male workers than females. Therefore, less is known about the influence of extended work shifts on HRV and the health of female nurses[7, 13]. In literary search about heart rate variability and shift work and nurses demonstrated that there were only four previous studies about this topic[20, 41–43]. In these studies, comparison has been done between shift female workers and non-shift workers[41] or comparison between day or morning and night shifts[20, 42, 43], and the influence of extended work shifts (e.g. combined morning and evening shifts) on HRV has not been evaluated.

Women are an interesting and important study group because more of their leisure-time is spent doing non-paid work such as child care and domestic responsibilities, which may reduce their time available for sleep and recovery from work[7]. In this study, there was no association detected between the number of children living at home and HRV parameters. However, we cannot exclude the influence of sex hormones effects on HRV[44] since no data was available on the stage of the menstrual cycle of the nurses. Larger longitudinal studies with both genders and various occupational groups would be needed to account for the individual variation in HRV.

One limitation of the present study was the relatively small sample size. However, a comparison with the earlier HRV studies[13] shows that the final sample size of this study can be considered as adequate. A strength of this study was that the HRV measurements were obtained under actual working conditions. On the other hand, a limitation of the study is that there may have been unidentified confounding factors. In addition, the results cannot be generalized to men, other occupations or age groups. However, it may be assumed that the data gathered from long-term HRV recordings at work may help in developing the concept of capability balanced work in ergonomics. Long-term HRV recordings are also a promising method to quantify the state of the ANS, but they need to be supplemented with subjective methods such as questionnaires in order to control for individual factors influencing HRV, e.g., age[14, 15], gender[14, 15], health[14], cardiorespiratory fitness[16] and heredity[14–16]. These supplementary methods provide valuable information which help in the interpretation of the HRV results.

The current technology for the registration of HRV permits a reliable long-term (24–48 h) data collection[22] in different real life circumstances such as during work, leisure-time and sleep. Some practical problems may be encountered in the measurements like weak skin contact or skin irritation which may disturb and limit data collection. Some practical problems may be encountered in the measurements like weak skin contact or skin irritation which may disturb and limit data collection. In the analyses of this study, we observed that sleep time included most artifacts which is probably explained by the weak skin-electrode contact (e.g. when lying on your side the chest belt can easily loose the contact). The movements of the chest belt during physical activity cause artifacts typically, but on the other hand, sweating related to physical activity can improve the skin-electrode contact. Practically, in this study, we were able to select as short as 10 min artefact free samples for analysis for all subjects. It should be noted that the use of an ambulatory ECG system compared to HR monitors, would have clear benefits in relation to artefact identification and overall signal quality. However, the measurement accuracy of the used HR monitors have been shown to be equivalent to ambulatory ECG systems[45], and therefore, the selected measurement devices are not expected to produce any bias to the HRV results. Despite these limitations, the present study showed that HRV parameters can clearly differentiate psychophysiological strain resulting from work, leisure-time and sleep. There are still important issues to be solved in HRV analyses. The main problem is that the reference values of HRV parameters are not yet defined since HRV can be influenced by many factors, although attempts have been made to define reference values[15]. Hence, longitudinal observations of the individual changes of HRV are essential to advance the reliability of the HRV method and its applications in occupational health care.

In general, the analyses of HRV have been used to assess the state of the ANS as a way of evaluating stress and recovery[17]. By monitoring the increase of HRV parameters reflecting parasympathetic activity and the decrease in the parameters reflecting sympathetic activity, the level of recovery after work can be evaluated[17, 46]. One practical implication would be that the indicators of recovery from work would be useful for use in occupational health care in the early identification and prevention of stress. In particular, the information of work load and recovery obtained by HRV would help in planning working time schedules and strategies for the assessment and promotion of health at work.

In conclusion, HRV parameters detected the significant differences between work, leisure-time and sleep during work shifts. The sympathetic control of heart rate was higher during the work shifts than during leisure-time or sleep. Older subjects had overall lower HRV than younger subjects indicative of elevated sympathetic activation of ANS, especially during work. However, the differences between the two different types of work shifts in these female nurses were minor, and revealed mainly increased sympathetic activity at the beginning of the normal work shift. This lack of differences between work shifts may be a consequence of an adaptation by the nurses to the extended shifts or the more flexible organization of work duties possible during extended work shifts.

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