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Original Article

Autonomic nervous system activity under rotational shift programs: effects of shift period and gender

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Abstract: Rotational shifts perturb homeostatic mechanisms in a sexually dimorphic way and may compromise the activity of the autonomic nervous system during day- and night-shifts. Heart rate variability (HRV) is a non-invasive measure to assess autonomic control of the heart. Our aim in this study was to assess HRV by short-term continuous electrocardiogram in female (n=40, average age: 31, average working year: 7) and male (n=40, average age: 29, average working year: 6) nurses under rotational shift programs, HRV is derived from short-term electrocardiogram recordings, carried out both at day- and night -shifts, and included time-domain [e.g., standard deviation of NN intervals, SDNN (ms); percentage of successive RR intervals that differ by more than 50 ms, pNN50 (%); root mean square of successive RR interval differences, RMSSD (ms)] and frequency-domain [very low frequency, VLF; low frequency, LF; high frequency, HF; LF/HF] parameters. Heart rates were similar across the groups but males had lower SDNN (p=0.020), RMSSD (p=0.001). pNN50 (p=0.001), VLF (p=0.048) and HF (p=0.001) but had higher LF/HF ratio (p=0.000) than females. In general, these parameters did not differ between day- and night-shifts (p>0.05). Lower HRV parameters and higher LF/HF in males suggest that they may be under greater threat for disease progression.

Key words: Rotating-shift, Gender, Autonomic nervous system activity, Heart rate variability, Stress

Introduction

Shift work has become an integral and inevitable part of the modern societies[1)]. According to the latest research in USA and Europe, approximately 15 and 30% of adults work in shift system, respectively[2)]. Shift work is associated with numerous negative effects[3)]. The most obvious reason for these negative effects is impaired sleep[4, 5)]. As a result, it has been shown that night shifts have negative effects on biological homeostasis[6)], digestion[7)], reproductive functions[8)] and social life[9)]. Shift work, especially rotating shift and night shift, has also been associated with increased risk of disease progression, including cancer[10, 11)] and cardiovascular diseases (CVD)[3, 12–15)]. The underlying problem of the pathophysiological mechanism appears to

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include an impaired circadian rhythm and lack of sleep[16].

The autonomic nervous system (ANS) plays an important role in the control of a variety of physiological systems, including cardiovascular system, digestive system, nervous system, respiratory system, blood clotting and inflammatory functions. In terms of cardiovascular system, the sympathetic nervous system accelerates the heart whereas parasympathetic (vagal) nervous system decelerates it. Thus, heart rate is the balance between these two simultaneously functioning branches of the ANS. The conflict between these two branches causes beat-to-beat variation in heart rate, called as heart rate variability (HRV). Determination of HRV includes calculation of time- and frequency-domain parameters. Time domain measures include standard deviation (SD) and root mean square of the successive R-R-intervals (RMSSD), whereas frequency-domain parameters include spectral analysis of the HRV power in low frequency (LF, around 0.04–0.15Hz) and high frequency (HF, around 0.15–0.4Hz) bands[17]. The ratio of LF/HF has been reported to be a sign for sympathovagal balance[17]. It has been reported that in healthy people, the heart rate is not monotonous, showing beat-to-beat variation[18]. Studies show that decreased heart rate variability is associated with perturbed ANS activity, and in turn, with increased risk for CVD[13, 19], end-stage renal disease[20], diabetes[21], cancer[22] and with poor health status[23, 24]. HRV has been considered as a surrogate parameter of the complex interaction between ANS and cardiovascular system[25]. Moreover, low HRV has also been associated with above mentioned diseases. In fact, low HRV indicate disease severity or progression but also it appears to predict cardiac morbidity and mortality[19, 26] and all-cause mortality[27, 28] in healthy subjects[29].

Rotational shift programs places great pressure on bodily functions and it appears that there are gender differences in coping and resilience strategies[30]. It has been reported that man and women have substantial differences in their autonomic control of the heart and women are characterized by a relative dominance of vagal activity despite greater heart rate[31]. Continuous weekly changes in cardiac sympathetic and vagal autonomic control may play a role in the incidence of cardiovascular diseases in shift system workers who constantly change their schedule[32]. Books *et al*. (2017) emphasized in their study that there is a strong consensus that nurses prefer to work in straight night shifts instead of rotating shifts and that working rotating shift has a negative effect on health[33]. In a literature-based meta-analysis evaluating the risk of being hypertensive in relation to rotation and night shift work, a strong relationship was found between rotational shift work and hypertension[16]. In addition, irregular work schedules for healthcare personnel may further increase work stress[34]. Cardiovascular disease is the leading cause of death for both men and women worldwide[35]. However, male have an earlier onset of CVD and higher CVD-related mortality and morbidity compared to female[31, 36]. Studies have emphasized that women show more vagal activity than men[31]. On the other hand, women have been reported to experience higher levels of job stress than men[37]. They also have greater responsibilities in doing housework and raising children after work[38]. Therefore, the combined effects of work stress and home stress may possibly have negative impact on health[39–41].

HRV has been reported to be an effective method for determining the effect of gender on autonomic control[31]. This suggests that HRV might be used to assess whether there is a sexually dimorphic response to rotational shift programs. Moreover, during rotational shifts, the same person has not generally been followed at night- and day-shifts. In our literature review, we did not find any study evaluating autonomic nervous system activity in day and night shifts in female and male nurses working in rotational shifts. Studies show shifts are harmful for the health but it seems rotational shifts places greater pressure on body functions[42]. It has been reported that rotational shift works perturbs circadian rhythm more[42]. Moreover, the performance of female and male nurses may differ in night and day shifts. Information on the interaction of gender with rotational shifts is scarce but studies on this area are necessary for better management of the health of the shift workers. In our study, we hypothesized that male nurses working in the rotational shift program in the hospital will have a lower HRV compared to female nurses and this will be more obvious during night shifts. In order to test this hypothesis, we investigated the effects of rotational shift programs on short-term HRV in male and female nurses during night and day shifts. For that purpose, we have utilized short-term (5 min) electrocardiogram recordings. Although a 24-h Holter recording is thought to be superior, a 5-min recording is much widely used to determine HRV[17].

Methods

Ethical consent and participants

The study was carried out in Turgut Ozal Medical Center (TOTM, Malatya, Turkey), in accordance with the ethical guidelines of the 1964 Declaration of Helsinki following ethical approval from the local ethics committee (Malatya Clinical Ethics Committee, No: 2019/20). Turkish people

Table 1. Distribution and demographic characteristics of the participants in the study groups

Subject characteristic	Female nurses (n=40)	Male nurses (n=40)	*p*-value
Age (years)	31(26–35)	29(28–32)	$p>0.05$
Weight (kg)	60(58–66)	78(72–86)	$p<0.001$
Height (m)	163(157–165)	173(171–178)	$p<0.001$
BMI (kg/m^2)	23(22–25)	26(24–29)	$p<0.001$
Working year	7(3–11)	6(4–9)	$p>0.05$

Data presented as the interquartile range [median(Q1–Q3)]. $p<0.05$ was considered as level of significance. *BMI: Body Mass Index

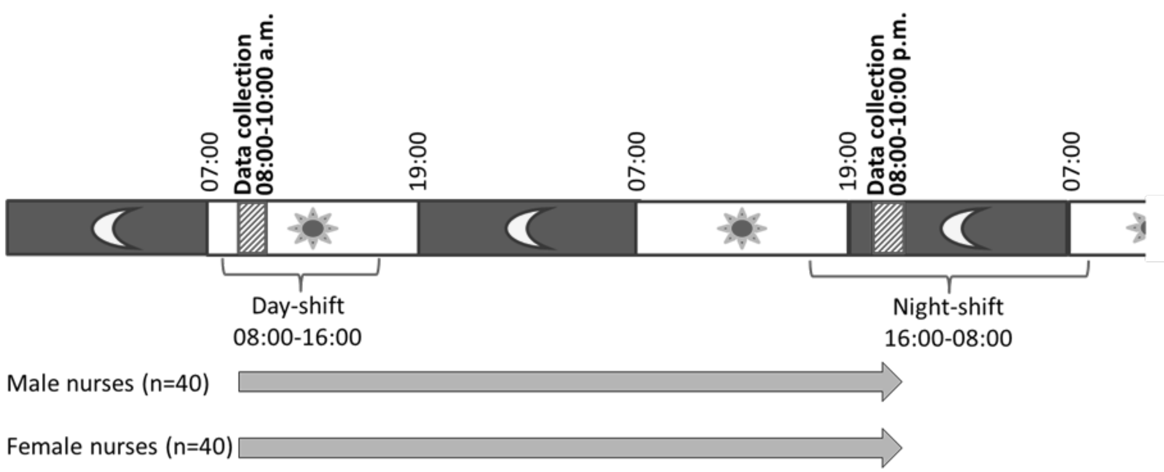

Fig. 1. Experimental protocol. Male (n=40) and female (n=40) nurses who were under rotational shift program were sampled twice (once in the day-shift between 08:00-10:00 h a.m. and again in their night shift between 08:00-10:00 h p.m.) for blood pressure and heart rate variability (HRV, by 5 min continuous electrocardiogram). They also filled in questionnaires once about sleep parameters (Pittsburgh Sleep Quality Index, PSQI) and perceived stress level (State and Trait Anxiety Inventory-Trait, STAI-T) related to the last month.

(Caucasians) were included in the study. The first author PC was also a nurse working in TOTM and participants were all her colleague and therefore, she asked to the potential contributors only (i.e., non-obese, non-smokers etc.) to participate to the study. The participants were informed about the study and written consent was obtained from them. The study included 40 female nurses [age 31 (26–35) years old, weight 60 (58–66) kg, height 163 (157–165) cm] and 40 male nurses [age 29 (28–32) years old, weight 78 (72–86) kg, height 173 (171–178) cm] working in a rotating-shift system [Values are shown as interquartile range, i.e., Median (Q1–Q3)]. The inclusion criteria were; being healthy, being in the 18–45 age range, not smoking and not being in menstruation period. Individuals using any medication including painkillers were not included in the study. All participants were asked not to consume stimulating drinks such as tea and coffee for approximately 2 hours before HRV exposure. Female participants were matched for menstrual phase, as follicular or luteal, by taking into account the lengths of the preceding 3 cycles by self-reported onset of menses[43]. Luteal and follicular phases were confirmed in the individual by the length of the last cycle. Participants were apparently healthy and regularly cycling. They reported that they were not using any medications, including contraceptives, during the study period and this was also in line with their report of regular cycling.

Experimental protocol is shown in Fig. 1. Rotating-shift system consisted of daytime shifts between 08:00–16:00 and night shifts between 16:00–08:00. Both female and male nurses were sampled for blood pressure and HRV twice, e.g., once at day shift and once at night shift. They were also asked to fill in questionnaires once about their sleep parameters (Pittsburgh Sleep Quality Index, PSQI) and perceived stress level (State and Trait Anxiety Inventory-Trait, STAI-T) about the last month. It took approximately two months to collect data from the participants and

Table 2. Frequencies (‰) and the non-parametric analysis of the various cell types in exfoliated epithelial cells of control and exposed subjects as well as of non-smoker and smokers

Variable	Female			Male					
	Day-shift (n=40)	Night-shift (n=40)	*p*-value	Day-shift (n=40)	Night-shift (n=40)	*p*-value	Females (n=40)	Males (n=40)	*p*-value
Blood pressure indicates									
Systole (mm/Hg)	101(92–107)	100(95–108)	0.681	114(105–122)	115(109–125)	0.413	100(94–107)	114(108–122)	0.000
Diastole (mm/Hg)	69(63–77)	69(65–80)	0.960	75(68–83)	78(71–83)	0.903	69(65–78)	76(70–83)	0.000
Time domain parameters									
HR (bpm)	101(92–107)	79(72–88)	0.879	79(74–89)	83(75–90)	0.932	79(72–86)	81(74–90)	0.439
SDNN (ms)	38(33–49)	39(32–49)	0.999	39(26–49)	38(27–43)	0.845	38(32–49)	38(26–45)	0.020
RMSSD (ms)	28(21–38)	28(23–38)	0.963	23(16–33)	22(14–36)	0.974	28(22–38)	23(15–34)	0.001
pNN50 (%)	7(3–17)	7(2–19)	1.000	3(1–11)	3(1–13)	0.998	7(2–18)	3(1–11)	0.001
TP (ms²)	1,377(1,027–2,199)	1,424(968–2,311)	1.000	1,466(661–2,289)	1,321(702–1,673)	0.851	1,377(980–2,239)	1,392(672–1,974)	0.073
Frequency domain parameters									
VLF (ms²)	557(406–733)	602(363–895)	0.962	561(269–852)	449(215–636)	0.979	566(385–822)	499(238–791)	0.048
LF (ms²)	558(306–714)	489(321–764)	0.064	575(240–960)	478(223–746)	0.052	529(321–753)	514(232–784)	0.064
HF (ms²)	312(143–659)	306(162–547)	0.999	217(87–390)	162(84–386)	0.004	307(157–556)	514(232–784)	0.001
LF norm	62(50–74)	61(53–74)	1.000	73(54–81)	78(64–83)	0.960	62(52–74)	77(59–82)	0.000
HF norm	38(26–50)	39(26–47)	1.000	27(19–46)	22(18–37)	0.0097	38(26–49)	23(18–41)	0.000
LF/HF (ms²)	1.6(1.0–2.9)	1.6(1.1–2.8)	0.984	2.7(1.2–4.3)	3.6(1.7–4.7)	0.939	1.6(1.1–2.9)	3.3(1.5–4.6)	0.000
STAI							43(41–48)	43(37–46)	0.923
PSQI							8(4–12)	7(5–9)	0.154

Data presented as the interquartile range [median(Q1–Q3)]. $p<0.05$ was considered as level of significance.
Abbreviation: HR, heart rate; SDNN, standard deviation of NN intervals; RMSSD, root mean square of successive RR interval differences; pNN50, percentage of successive RR intervals that differ by more than 50 ms; TP, total power; VLF, absolute power of the very–low–frequency band; LF, absolute power of the low–frequency band; HF, absolute power of the high–frequency band; LF/HF, ratio of LF–to–HF power; STAI, The State–Trait Anxiety Inventory; PSQI, the Pittsburgh Sleep Quality Index questionnaires

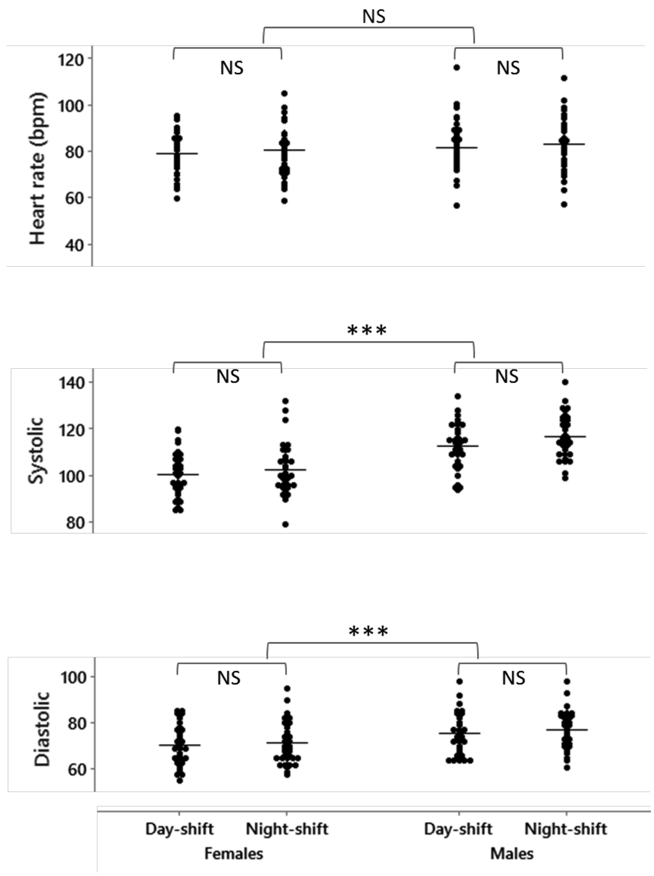

Fig. 2. Individual plots and median values (vertical lines) for heart rate (beats per minute), systolic blood pressure (mmHg) and diastolic blood pressure (mmHg) recorded at day-shifts and night-shifts in males and females who were working under rotational shift regiments. Heart rate did not differ between the genders and between the shifts (*p*>0.05). Males had higher systolic and diastolic pressures than females (*: *p*<0.001) but there was no difference between the shift periods. NS, non-significant.**

1:1 rule was applied, in other words, if one female nurse was added to the study in a particular day, a male participant was also added for the same day. On the other hand, both questionnaires always questioned the last month of each participant. Rotating-shift system employees were given at least 16 hours to rest after day and night shifts. The locations of the day and night shifts were constantly changing, with work schedules arranged at two-week intervals. Demographic characteristics of the study population are represented in Table 1. Body mass indexes [BMI; (weight in kilograms/height in meter^2)] of the subjects are also calculated.

The State-Trait Anxiety Inventory (STAI) and Pittsburgh Sleep Quality Index (PSQI)

The State-Trait Anxiety Inventory (STAI) and the Pittsburgh Sleep Quality Index (PSQI) questionnaires were used in this study. STAI was developed in 1970 by Speilberger *et al*. and the adaptation of the scale to Turkish and its validity and reliability studies were carried out by Öner and Le Compte in 1983[44–46]. PSQI was developed in 1989 by Buysse *et al*. and the adaptation of the scale to Turkish and its validity and reliability studies were carried out by Ağargün *et al*. in 1996[46–48]. The Turkish version was used in this study. The STAI is a self-assessment questionnaire that uses to find out how participants felt at a particular time or under a specific condition. It has two subscales, the State Anxiety Scale (S-Anxiety) and the Trait Anxiety Scale (T-Anxiety). We used the Trait Anxiety Scale (T-Anxiety) in our study. The STAI helps professionals differentiate between feelings of anxiety and depression by making a clear distinction between the transient state of anxiety and the more general and prolonged persistent anxiety[46]. The information about the sleep quality of the participants in the last month was assessed with PSQI[47]. The study took about 2 months. However, care was taken to collect data from an equal number of female and male participants each month. The total score in PSQI is between 0–21[47]. The higher the total score, the higher the sleep quality[47].

Heart Rate Variability and Arterial Blood Pressure

Electrocardiogram (ECG) recording in participants was taken for 5 minutes in supine positions with eyes open. ECG recordings were taken from each participant twice in total, once during the day shift and once during the night shift. Poly-Spectrum 8-E was used for ECG record and HRV analysis was made with the HRV software program of the same device (Neurosoft, Ivanovo, Russia). HRV measurements are widely used to evaluate ANS function[49]. All inter-beat intervals were visually checked to ensure that the program recognized them accurately. Time domain parameters (HR, SDNN, RMSSD and pNN50) and frequency domain parameters (TP, LF, HF, LF/HF, LF norm and HF norm) were evaluated by using the program developed by Inonu University Biostatistics and Medical Informatics Department. Time domain parameters: Heart rate, HR (bpm); standard deviation of NN intervals, SDNN (ms); root mean square of successive RR interval differences, RMSSD (ms); percentage of successive RR intervals that differ by more than 50 ms, pNN50(%) and total power, TP (ms^2). Frequency domain parameters: Low-frequency, LF(ms^2); high-frequency, HF(ms^2); ratio of LF-to-HF power, LF/HF; relative power of the low-frequency band (0.04–0.15 Hz) in normal units, LF norm and relative power of the high-frequency band (0.15–0.4 Hz) in normal units, HF norm[17].

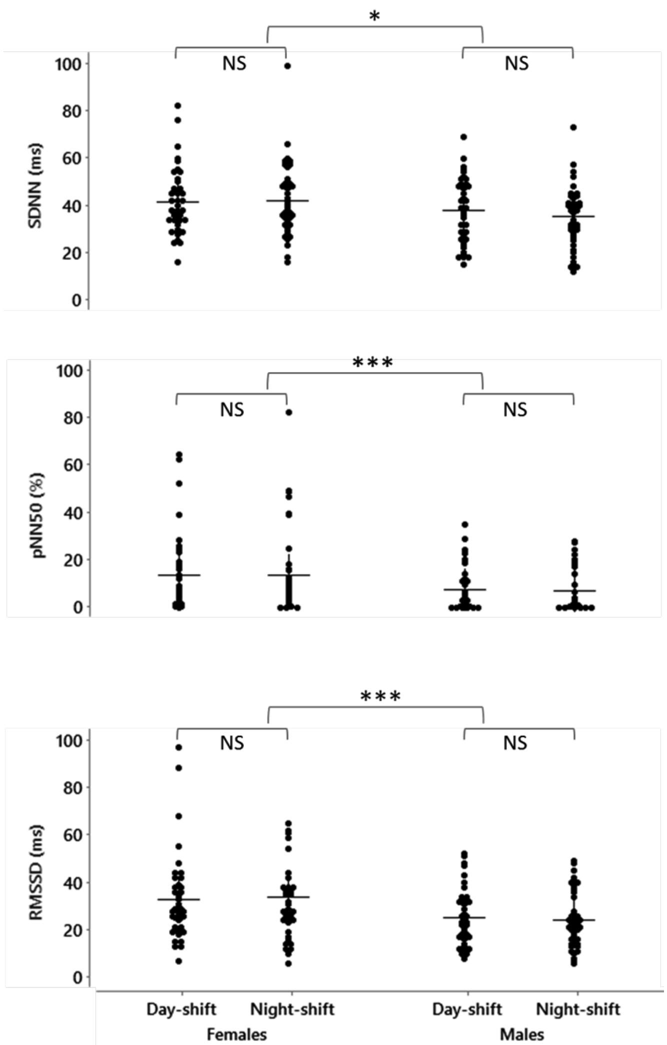

Fig. 3. Individual plots and median values (vertical lines) for time domain parameters of the heart rate variability (HRV). Males had significantly lower SDNN (ms), pNN50 (%) and RMSSD (ms) values than the females but shift time did not have any significant effect (*p*>0.05). NS, non-significant, *$p<0.05$, ***$p\leq0.001$.

Arterial blood pressure (BP) was measured indirectly using an automated digital BP monitor (Omron, M6 comfort, China)[15].

Statistical analyses

Statistical analyzes were carried out by using Minitab statistical package (Version 19.2020, PA, USA). Normal distribution of the data was checked by the Anderson-Darling test (similar to Shapiro-Wilk test). In general, the data did not have normal distribution. Generalized linear model (GLM) was used to analyze the data in a 2 (females and males) x 2 (day-shift and night-shift) factorial design. Within GLM, optimal λ was selected in order to have an ideal distribution of the data. Significance was set at $p<0.05$ and the results are shown as interquartile range [median (Q1–Q3)].

Results

Arterial Blood Pressure

In female nurses, mean systolic blood pressure (SBP) (mmHg) was not statistically different between the night shifts [100(95–108)] and day shifts [101(92–107), p=0.681]. In male nurses, mean SBP was higher in night shifts [115(109–125)] than the day shifts [114(105–122), p=0.413]. SBP was higher in male nurses [114(108–122)] than female nurses [100(94–107), p=0.000]) (Fig. 2, Table 2.). In female nurses, mean diastolic blood pressure (DBP) (mmHg) was not statistically significant in night shifts [69(65–80)] compared to day shifts [69(63–77), p=0.960). In male nurses, DBP was not statistically significant in night shifts [78(71–83)] compared to day shifts [75(68–83), p=0.903). DBP was higher in male nurses [76(70–83)] than female nurses [69(65–78), p=0.000] (Fig. 2, Table 2.).

The State-Trait Anxiety Inventory (STAI) and Pittsburgh Sleep Quality Index (PSQI)

STAI did not differ between male nurses [43(37–46) points] and female nurses [43(41–48) points, $p>0.05$]. PSQI did not differ between male nurses [7(5–9)] and female nurses [8(4–12), $p>0.05$].

Time Domain Parameters of HRV

Time domain parameters of the HRV are shown in Fig. 3, and Table 2. In female nurses, HR was not statistically significant in night shifts [79(72–88)] compared to day shifts [101(92–107), p=0.879]. In male nurses, HR was not statistically significant in night shifts [83(75–90)] compared to day shifts [79(74–89), p=0.932]. Mean HR was not different in male nurses [81(74–90)] than female nurses [79(72–86), p=0.439]. In female nurses, SDNN was not statistically significant in night shifts [39(32–49)] compared to day shifts [38(33–49), p=0.999]. In male nurses, SDNN was not statistically significant in night shifts [38(27–43)] compared to day shifts [39(26–49), p=0.845]. SDNN was lower in male nurses [38(26–45)] than female nurses [38(32–49), p=0.020]. In female nurses, RMSSD was not statistically significant in night shifts [28(23–38)] compared to day shifts [28(21–38), p=0.963]. In male nurses, RMSSD was not statistically significant in night shifts [22(14–36)] compared to day shifts [23(16–33), p=0.974]. RMSSD was lower in male nurses [23(15–34)] than female nurses

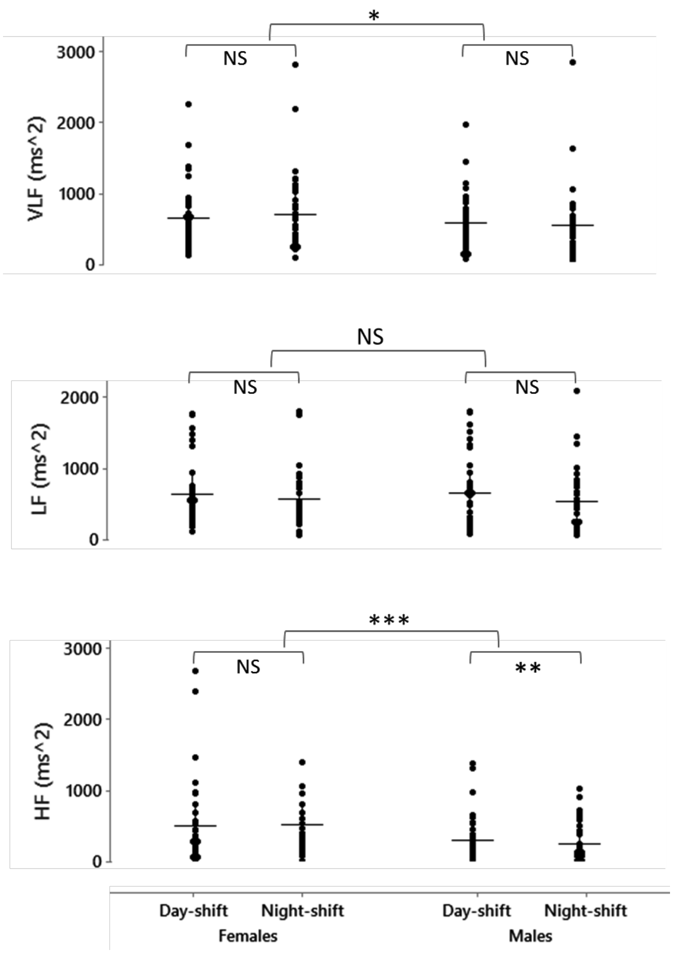

Fig. 4. Individual plots and median values (vertical lines) for frequency domain parameters of the heart rate variability (HRV). Males had significantly lower VLF (ms^2) and HF (ms^2) values than the females but shift time did not have any significant effect except in males for HF (p<0.01). NS, non-significant, *p<0.05, ***p≤0.001.

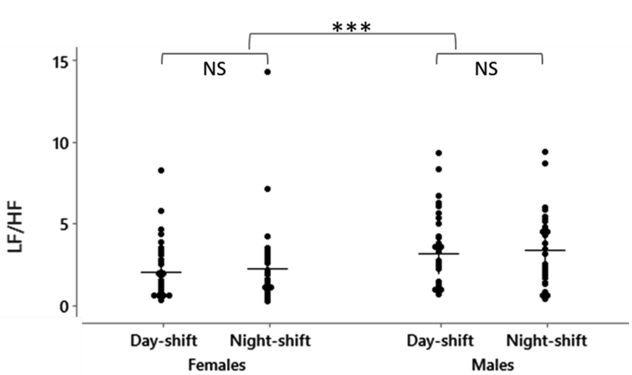

Fig. 5. Individual plots and median values (vertical line) for LF/HF values. Males had significantly higher LF/HF levels than females but there was no statistically significant difference between the shift types. NS, non-significant, ***p≤0.001.

[28(22–38), p=0.001]. In female nurses, pNN50 was not statistically significant in night shifts [7(2–19)] compared to day shifts [7(3–17), p=1.000]. In male nurses, pNN50 was not statistically significant in night shifts [3(1–13)] compared to day shifts [3(1–11), p=0.998]. pNN50 was lower in male nurses [3(0.50–11.40)] than female nurses [6.85(1.85–17.85), p=0.001].

HRV Frequency domain parameters

Frequency domain parameters of the HRV are shown in Fig. 4, Fig. 5, and Table 2. In female nurses, TP was not statistically significant in night shifts [1424(968–2311)] compared to day shifts [1,377(1,027–2,199), p=1.000]. In male nurses, TP was lower in night shifts [1,321(702–1,673)] than day shifts [1,466(661–2,289), p=0.851]. Mean TP was not different in male nurses [1,392(672–1,974)] than female nurses [1,377(980–2,239), p=0.073]. In female nurses, LF/HF was not statistically significant in night shifts [1.6(1.1–2.8)] compared to day shifts [1.6(1.0–2.9), p=0.984]. In male nurses, LF/HF was higher in night shifts [3.6(1.7–4.7)] than day shifts [2.7(1.2–4.3), p=0.939]. Mean LF/HF was higher in male nurses [3.3(1.5–4.6)] than female nurses [1.6(1.1–2.9), p=0.000]. In female nurses, LF (ms^2) was lower in night shifts [489(321–764)] than day shifts [558(306–714), p=0.064]. In male nurses, LF (ms^2) was lower in night shifts [478(223–746)] than day shifts [575(240–960), p=0.052]. Mean LF (ms^2) was not different in male nurses [514(232–784)] than female nurses [529(321–753), p=0.064]. In female nurses, HF (ms^2) was not statistically significant in night shifts [306(162–547)] compared to day shifts [312(143–659), p=0.999]. In male nurses, HF (ms^2) was lower in night shifts [162(84–386)] than day shifts [217(87–390), p=0.004]. Mean HF (ms^2) was lower male nurses [514(232–784)] than female nurses [307(157–556), p=0.001]. In female nurses, LF norm was not statistically significant in night shifts [61(53–74)] compared to day shifts [62(50–74), p=0.100]. In male nurses, LF norm was not statistically significant in night shifts [78(64–83)] compared to day shifts [73(54–81), p=0.960]. LF norm was higher in male nurses [77(59–82)] than female nurses [62(52–74), p=0.000]. In female nurses, HF norm was not statistically significant in night shifts [39(26–47)] compared to day shifts [38(26–50), p>0.05]. In male nurses, HF norm was lower in night shifts [22(18–37)] than day shifts [27(19–46), p=0.0097]. Mean HF norm was lower male nurses [23(18–41)] than female nurses [38(26–49), p=0.000].

Discussion

Results of the current study supported our hypothesis that the males under rotational shift programs have lower HRV parameters. This suggests that they are under greater threat to perturbation of their body functions than that of the female nurses. Moreover, HRV parameters did not differ between night- and day-shifts, suggesting that rather than shift-time, gender is the main determinant of HRV if the workload of shifts is comparable.

Arterial Blood Pressure

SBP and DBP were found to be higher in males than that of the female nurses in the rotating system. Shift work is a risk factor for hypertension and CVD[50)]. The autonomic nervous system affects BP through adjustments in parasympathetic and sympathetic activity[51, 52)]. Studies have shown that ANS dysfunction is associated with BP changes[53)]. BP is seen as a sensitive marker of biological responses to work stress[54)].

Epidemiological studies have highlighted the presence of a circadian profile at the onset of adverse cardiovascular events that occur most frequently in the morning hours[55)]. Blood pressure follows a clear circadian rhythm, which is characterized by a drop during sleep and a sharp rise when awakening[56)]. The exact mechanisms underlying the circadian profile of adverse vascular events are still unknown. However, the sympathetic nervous system is believed to be an important contributor for the morning onset of most cardiovascular diseases[56)]. Mental and postural changes accompanying arousal increase sympathetic nervous system activity[57)]. This probably contributes significantly to the sharp rise in blood pressure in the hours after waking up[56, 57)]. In addition, studies have shown that catecholamine hormones have a direct effect[56)]. Therefore, sympathetic activity and blood pressure, which are higher in men compared to women in the current study, seem to be compatible with the literature.

Heart Rate Variability

In the current study, heart rate was similar between male and female nurses and between night- and day-shifts. Even so, HRV, that is beat-to-beat variation in the rhythm, was lower in males. Specifically, male nurses had significantly lower SDNN and RMSSD than female nurses. These HRV parameters reflect decreased function of sympathetic, parasympathetic, and overall components of the ANS[13, 58)]. Weakening of the ANS can be interpreted as a weakening of the ability to adapt to internal and external environmental challenges, a decrease in the ability to cope with emotional / physical stress factors, and a negative situation for health in general[13, 58)]. Lower SDNN is associated with both morbidity and mortality[17, 59)]. Classification within a higher SDNN category is associated with a higher probability of survival[18)]. Therefore, the lower SDNN in males compared to females suggests that males working in a rotating shift system may be at higher health risk than females.

Male nurses had lower pNN50, RMSSD and HF power and all of these parameters constitute the parasympathetic components of HRV[58)]. Modulation of the vagal (parasympathetic) tone is important for cardiovascular health[18)]. Decreased parasympathetic activity may increase the risk of stroke by increasing the risk of arrhythmia[60)]. Higher vagal activity is considered cardio-protective and is associated with better health[61)] and longevity[31)]. The current study reveals that males who work in the shift system have a more dominant sympathetic activity compared to females. Hence, it can be speculated that males working in rotating shifts are more likely to experience cardiac problems than females. In their study, Lee *et al*. (2015) emphasized that circadian rhythm-mediated changes in the autonomic regulation of the cardiovascular system decreased in night shift male workers, and this may contribute to an increased risk of cardiovascular disease in night shift workers[62)]. Hulsegge *et al*. (2017) reported that shift work is associated with lower HRV during sleep, especially among males, and this may increase the risk of cardiovascular diseases[13)].

LF/HF ratio does not have a diagnostic value and it does not always represent sympathovagal balance[63)]. On the other hand, HF power is reported to be produced by parasympathetic nervous system and the LF power is reported to be produced by sympathetic nervous system[17)]. A low LF/HF ratio reported to reflect parasympathetic dominance, and this is seen at times of energy conservation[17)]. In contrast, a high LF/HF ratio reported to indicate parasympathetic withdrawal and sympathetic dominance[17)]. Autonomic imbalance (relatively higher sympathetic activity and relatively lower parasympathetic activity) is a risk factor for diseases such as CVD and hypertension[24, 31)]. The excessive dominance of the sympathetic nervous system can trigger cardiac arrhythmia and sudden death[64, 65)]. Also, sympathetic chronic stimulation is harmful to health in the long term[65–67)]. Thus, men appear to have higher SVB, which is likely to make them prone to the diseases outlined above. In our study, parasympathetic activity (HF) was found to be lower in men compared to women. In addition, parasympathetic activity (HF) during the night shift was found to be lower in men compared to the day shift. These findings are in line with the results of meta-analysis carried out by Koenig and Thayer[31]. They proposed that the gender difference might be due to[1] estrogens as both ovariectomy and vagotomy reversed these effects, to[2] oxytocin as stimulation of oxytocin neurons slows down the heart and increase parasympathetic activity, and to[3] increased perfusion and function of amygdala in women. It has also been reported that estrogens have a facilitating effect on cardiac parasympathetic control[68, 69].

Cardiac autonomic regulation follows a circadian rhythm[70]. During the night, cardiac parasympathetic control markers increase and sympathetic control decreases[70]. Autonomic imbalance in the form of a hyperactive sympathetic system and a hypoactive parasympathetic system is associated with various pathological conditions[24]. Over time, excessive energy demands in the system can cause illness[24]. Thus, autonomic imbalance may increase morbidity and mortality due to diseases (e.g., cardiovascular diseases) and other conditions[24].

Continual weekly changes in the cardiac sympathetic and vagal autonomic control may have a role in the high rate of cardiovascular diseases in shift workers[32]. Rotational night shifts across shift patterns have been shown to be associated with greater health risks than permanent night shifts[71]. Efferent sympathetic and parasympathetic activity integrates with the activity that occurs in the inner nervous system of the heart[58]. Studies have shown that gender and diurnal variation have effects on cardiac autonomic function[72]. The male population generally has a higher sympathetic drive and therefore has a higher susceptibility to fatal arrhythmia and coronary artery disease[73]. Studies have shown that men have higher sympathetic tone with increased number of neurons and have higher muscle sympathetic activity in the sympathetic ganglion[72].

Impaired HRV indices are usually a state of autonomic dysfunction characterized by depression of parasympathetic activity and / or an increase in sympathetic activity[74]. It can be interpreted that a decrease in HRV can lead to a weakening of the autonomic nervous system's ability to adapt to internal and external environmental difficulties, reduced ability to cope with emotional / physical stress, and overall poor health[58].

Perceived stress and sleep quality

There was no statistically significant difference in self-reported perceived stress (STAI-T scores) between male and female nurses. STAI-T scores are commonly classified as no or low anxiety (20–37), moderate anxiety (38–44), and high anxiety (45–80)[75]. Therefore, the median value of 43 for both male and female nurses indicates that both genders experience similarly upper moderate levels of anxiety. Work-related stress is recognized as an important risk factor for health problems such as CVD, cancer, depression and cognitive impairments[54, 76]. There was no statistically significant difference between male and female nurses in terms of the PSQI about the last month's sleep parameters. A total PSQI score below 5 indicates good sleep quality and a score above 5 indicates poor sleep quality[47]. Although there was no statistically significant difference in sleep quality between males and females in this study, sleep quality was found to be poor in both genders. Therefore, it can be speculated that the rotating shift system affects sleep quality negatively at a similar magnitude both in male and female nurses.

Biological variables such as cortisol and body temperature, which are associated with stress, are characterized by maximum values during the day and lower values at sleep hours at night due to the circadian pattern[32]. In studies related to catecholamine, it was observed that sympathetic nerve activity was higher during the day and decreased at night[77]. It is thought that working in shifts may cause stress, increase catecholamine and glucocorticoid secretion, and activate the sympathetic nervous system[78]. In studies, spectral indices of cardiac sympathetic modulation were found to be lower when subjects worked at night compared to morning and evening work periods[32]. Circadian rhythms are also seen in the sleep-wake cycle[79]. Shift work disrupts workers' circadian rhythms[80]. This is characterized by psychological symptoms including sleep disturbance, cardiovascular disease, anxiety, and irritability[80, 81]. Sleep deficits cause excessive activity in stress response systems, and this deficiency may lead to changes in autonomic control[82]. Researchers have shown that poor quality sleep and sleep deprivation can cause a decrease in vagal tone and therefore impair the ability of the ANS to inhibit sympathetic dominance[83].

Strength and limitations of the study

The participants were of similar age groups and were under similar working environment and under similar managerial administration. Working hours were determined by taking into account the participants' availability due to their busy working schedule. The data were collected between 08:00 and 10:00 a.m. during the day shift, and between 08:00 and 10:00 p.m. during the night shift. While this may seem appropriate for comparing the effects of different shifts, findings will be confounded by the circadian changes. However, there was no difference between the HRV data (except HR) for both female and male in day and night shifts. Moreover, most of the differences were observed between females and males, suggesting that differences were due to gender rather than to shift period.

Conclusions

Current study shows that males have higher blood pressure and lower HRV parameters under rotating shift work, suggesting that males are more prone to deterioration of health by time under rotational shift programs. On the other hand, similar HRV parameters between night- and day-shifts suggest that rather than shift period, gender is the main determinant of the HRV. These findings highlight the need for organizing shift work programs and strategies to improve overall health and cardiovascular health among shift workers.

Poor sleep quality and moderate perceived stress (upper end, closer to high stress) in rotational shift programs imposes that these shift programs must not be implemented for long periods of time. However, as these shift programs are inevitable in all modern societies, rotation of personnel or implementation of sufficient rest periods might be evaluated and health of the personnel must be closely monitored by subjective or objective means. In that regards, findings of the present study and that of previous studies collectively shows that potential of regular monitoring of HRV needs to be explored as it is a cheap, practical, non-invasive, and low-cost alternative technique[84]. The current study also provides evidence for observing the male nurses for medium- to long-term effects of rotational shifts in larger cohorts.

Conflict of Interest

The authors declare that they have no conflict of interest.

Financial Disclosure

There are no financial supports.

Ethical approval

Malatya Clinical Ethics Committee, No: 2019/20

Informed consent

Informed consent was obtained from all individual participants included in the study.

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