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Assessment of cardiovascular risk in shift working telephone operators

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Abstract

Background: There is evidence for an increased cardiovascular risk of shift work from epidemiologic and field studies. The aim of the present study was to assess the health risk by studying cardiovascular autonomic control and screening of supraventricular and ventricular extrasystoles (SVE/VE), and to determine whether a functional association exists between cognitive work-related factors and cardiovascular autonomic control in shift workers. **Methods:** Heart Rate Variability (HRV), SVE/VE were assessed based on 10 minutes Electrocardiogram recordings, work-related factors were measured by NIOSH Job Stress Questionnaire in 99 telephone operators. **Results:** The comparison of the mean values of HRV indices between operators on non-shift and shift schedules did not show significant changes in the autonomic cardiovascular control. No significant changes were found in myocardial activity. The study of the relationship between autonomic cardiovascular control, and work-related factors revealed significant dependence of mean heart rate on skill utilization and significant dependence of Short-Term Variability on cognitive skills and skill utilization. **Conclusions:** The results of our study did not reveal a pattern of an increased cardiovascular risk in shift working telephone operators. Functional dependencies revealed that skill utilization and cognitive skills might exert a stress generating effect and affect the parasympathetic cardiac function.

Keywords: shift work, cardiovascular risk, autonomic cardiovascular control, heart rate variability, psychological and social factors

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1. Introduction

Early detection and prevention of cardiovascular diseases (CVD) is a current national problem in Bulgaria and worldwide. The determination of pre-morbid indicators of health risks is an important task of preventive medicine. One of the main non-invasive methods for the determination of a potential risk for developing a CVD is the assessment of cardiovascular autonomic control through analysis of the consecutive time- and frequency-domain based characteristics and indicators of cardiointervals (Analysis of Heart Rate Variability (HRV) – AHRV).

At the workplace the individuals are exposed to the effect of various factors. The most frequently encountered factors are high work load, low extent of control, noise and shift work (Virtanen, Notkola 2002).

It has been shown that in developed countries cardiovascular mortality associated with shift work has a negative correlation with socioeconomic status (De Gaudemaris et al. 2002). The same researchers outline the significance of the occupational environment, psychological stress at the workplace, lack of physical activity, active and passive smoking and shift work for the development of CVD. Shift work could affect the gastrointestinal and cardiovascular function, alter the hormonal balance, disturb sleep mode, interfere with behavioral and social activity and increase the risk for accidents and incidents (Garbarino et al. 2002).

The results provided by the majority of studies of CVD in shift workers support the hypothesis for higher cardiovascular risk (Knutsson et al. 1986; McNamee et al. 1996; Spurgeon et al. 1997; Adams et al.1998; Iwasaki et al. 1998; Morikawa et al. 1999; Steenland 2000). The triggering factors responsible for the increased cardiovascular risk could be desynchronized circadian rhythm, changes in behavioral and social activity. Some studies consider the relationship of lifestyle characteristics and biological risk factors (Boggild, Knutsson 1999).

Although several studies revealed a significant relationship between CVD risk and shift work, it is considered that there are other risk factors and neural and autonomic mechanisms mediating cardiovascular risk in shift workers (Van Amelsvoort et al. 2001). Such factors are elevated myocardial arrhythmogenic activity and disturbed cardiovascular autonomic control (Van Amelsvoort 2000). A prospective monitoring of shift workers elucidates the greater risk by changes in the rhythmogenesis manifesting in disturbed rhythmic myocardial activity and induction of greater rate of ventricular extrasystoles (Van Amelsvoort et al. 2001). Similar results have been obtained in other study (Harenstam et al. 1987). These comprehensive studies accentuate the increased myocardial susceptibility to arrhythmia as risk factor for CVD in shift workers.

Numerous studies revealed a relationship between altered or disturbed autonomic function studied by HRV and cardiovascular morbidity (Bigger et al. 1992; Willich et al. 1993; Maggioni, Zuanetti 1994; Kautzner, Camm 1997; Liao et al. 1996a; Liao et al. 1996b; Liao et al. 1997). HRV indices are used for: screening studies of groups of individuals at elevated cardiovascular risk; determination of individuals at significant risk for development of coronary diseases; prediction of the progress of coronary heart disease (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996; Saul et al. 1988).

Shift work is associated with significant changes in the cardiovascular autonomic control and in the circadian characteristics of HRV – indicator of the autonomic function. Several studies on the impact of shift work on HRV indices establish strong reduction of the high-frequency component of HRV (Van Amelsvoort et al. 2001) which corresponds to the clinical findings at post-myocardial infarction state and advanced stage of arterial hypertension in a study on shift workers revealing significant decrease of the respiratory component of HRV (Matsuzaki et al. 1996).

In a study of nurses an increased ratio of the low-frequency to high-frequency component of HRV was found (Matsuzaki et al. 1997). In another study evidence for changes of cardiovascular regulation indicated by differences in the standard deviation (SD) of cardiointervals in shift workers as compared to regular day workers was found (Van Amelsvoort et al. 2000).

The increased cardiovascular risk of shift workers was attributed to disturbed circadian patterns of the cardiovascular control expressed by dominating sympathetic activity (Furlan et al. 2000; Van Amelsvoort 2000). These disturbances may be associated with performance deficits and individual complaints (drowsiness, fatigue, difficult concentration) (Furlan et al. 2000).

A study of 16-hour and 8-hour shift schedules showed more pronounced individual complaints for the 16-h shift (Fukuda et al. 1999; Takahashi et al. 1999). According to other researchers accumulation of sleep deficits could cause decreased sympathetic activity especially during shifts with increased length (Sasaki et al. 1999). Most important in this context is the study of the circadian rhythm of HRV and the effect of the day-night cycle and the activity periods – work, sleep, and leisure time (Freitas et al. 1997; Ito et al. 2001). These studies revealed a relationship between the circadian rhythm of HRV and the activity period and underlined the clinical importance of studying HRV in shift workers.

Van Amelsvoort et al. (2001b) suggested that the increased cardiovascular risk possibly associated with some shift schedules is associated with changes in the myocardial rhythmogenesis and maybe not due to changes in cardiovascular autonomic control. Sasaki et al. (1999) found no significant differences in HRV indices between night and day shifts; also other aspects of the schedule were not associated with cardiovascular risk factors: HRV, arterial hypertension, serum cholesterol (Sasaki et al. 1999).

The occupational-physiological significance of AHRV is emphasized by the possibility to implement and use it as a reliable method and indicator for health risk assessment, for evaluation of work load, for the individual assessment and prediction of cardiovascular risk, for the assessment of interventions at the work place for health promotion (Danev 1989; Nikolova 1993; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology 1996; Schnall et al. 2000; Theorell 2000; Goldenhar et al. 2001; NIOSH 2002). It was successfully applied for the assessment of work schedules and other work place interventions (see e.g. Kristal-Boneh et al. 1995; Kobayashi et al. 1997).

The aim of the present study was to assess cardiovascular health through studying the cardiovascular autonomic control and screening of supraventricular and ventricular extrasystoles, and to determine whether a functional association exists between cognitive work-related factors and cardiovascular autonomic control in telephone operators working in shifts at the Bulgarian telecommunication company.

2. Methods

For this study of the variability of heart rhythm and supraventricular and ventricular extrasystoles 99 female telephone operators, working a non-shift schedule: 37 individuals, mean age 43.04 (SD 8.23 yr) or within a shift schedule: 62 individuals, mean age 43.24 (SD 8.81 yr) at the Bulgarian Telecommunication Company were selected. Inclusion criteria for individuals working a shift or non-shift schedules were the following:

- Shift schedule: exposure to day and night shift work; low intensity of physical work; work with videodisplays; job tenure with exposure to night shift work at least

0.33 years (observed: mean 15.38, SD 9.14 years); overall job tenure – mean 22.24, SD 9.04 years;

- Non-shift schedule: work with video displays; low intensity of physical work; overall job tenure at least 2 years (observed: mean 21.24, SD 8.86 years).

Exclusion criteria for all subjects were the following: Systolic Blood Pressure greater than 140 mmHg; Diastolic Blood Pressure greater than 90 mmHg; Body Mass Index greater than 25 kg/m^2; excessive use of alcohol, caffeine, nicotine; and history of cardiovascular diseases (hypertension; Ischaemic Heart Disease).

Telephone operators worked on the following schedules: non-shift schedule from 8 am–5 pm, and shift schedule: 5 day/night rotating cycle with 6-hour morning shift from 7 am–1 pm, 6-hour afternoon shift from 1 pm–7 pm, and 12-hour night shift from 7 pm–7 am with subsequent two days rest.

1.1. Diagnostic system for analysis of Heart Rate Variability

Heart Rate Variability (HRV) was measured and analyzed by application of specialized hardware and software (Danev 1989; Nikolova 1993) that enables the following tests for the assessment of cardiovascular functional state: cardiotachogram; histograms; scattergrams; power spectrum analysis of HRV. RR intervals were analyzed and time-domain based, frequency-domain based HRV measures, and HRV-derived indices were calculated.

HRV data were determined from ten minutes of Electrocardiogram (ECG) recordings between 9 am and 11 am in supine position after a one-hour rest period. HRV data were obtained on three consecutive days and mean individual values of the measurements were calculated. The hardware is a portable electronic device which transforms the ECG signal into RR intervals and transmits the RR intervals to a PC for on-line processing. The position of ECG electrodes was bipolar modified Ist lead. The attachment of electrodes corresponds to the V_3 pre-cordial lead on the left and right thoracic level. The ECG signal was transformed to RR intervals with an AC converter (QRS detector and timer, resolution time 2224 samples per second). This sampling rate gives a variation of 0.48 msec in locating the peak of R wave and results in a minimum accuracy of 99.55% in computing heart rate up to 140 beats/min.

- **Time-domain based HRV measures:**

X (mean RR interval) (msec), resp. mean heart rate (beats/min); Short-Term Variability (STV) (msec). STV is a measure of the respiratory oscillations in heart rate variations and reflects the cardiovascular parasympathetic activity.

$$STV=\sqrt{\frac{\sum(x_i-\bar{x})^2}{n-1}} \qquad (1)$$

- **Frequency-domain based HRV measures:**

P_T/P_{RSA} ratio (arb.un.). P_T/P_{RSA} is the ratio of spectral powers of RR intervals in the low frequency range (0.01–0.05 Hz) to Respiratory Sinus Arrhythmia (0.15–0.5 Hz). P_T/P_{RSA} reflects sympathetic/parasympathetic activity. Spectral powers of RR intervals in the respective frequency bands were calculated using Fast Fourier Transform.

- **HRV-derived index:**

Health Risk (HR) (%) (Algorithm derived from Physical Stress-, Mental Stress-coefficients and number of premature heart beats). (Physical Stress- and Mental Stress-coefficients are HRV-derived indices and represent differences between measured and age-related reference values). Values of HR above 65% are associated with increased risk for cardiovascular diseases (CVD).

1.1. Method for Detection of supraventricular and/or ventricular extrasystoles

The determination of extrasystole type was done by using a computer method (Danev 1989) for detecting supraventricular extrasystoles (SVE) and ventricular extrasystoles (VE) in HRV recordings. Danev (1989) based his algorithm on parallel registration of SVE and VE in Electrocardiogram and Cardiotachogram in patients with cardiological diagnoses. The method was validated in different occupational groups and parallel investigation of cardiovascular autonomic activity in individuals with SVE and VE.

The following time series are calculated for application of the algorithms: two standard pre-extrasystolic and post-extrasystolic RR intervals; pre-extrasystolic and post-extrasystolic RR intervals corresponding to the complete and non-complete compensatory pause; mean of two standard RR intervals which precede and follow the corresponding extrasystole; mean RR interval.

1.2. Job Stress Assessment

Job stress was assessed by the NIOSH Job Stress Questionnaire adapted for Bulgarian language and conditions (Tosheva, Nikolova 2004). The following scales derived from the constructs work stressors, individual factors, buffer factors, short-term psychological reactions were studied: overall and differential work load, skill utilization, cognitive skills, opportunity for control and decision latitude, self-esteem, social support, work satisfaction.

1.3. Data analysis

The indicators of heart rate variability and heart rate are presented as mean values ± SD. The differences between the mean values of HRV indices and heart rate of the studied groups were tested for significance applying Student's t-tests for independent groups. Linear regression analysis (method stepwise) was applied to determine the dependencies of work-related psychological and social factors on heart rate and HRV indices.

2. Results

2.1. The effect of shift work on autonomic cardiovascular control. Screening of supraventricular and ventricular extrasystoles

The time- and frequency-domain based HRV measures are sensitive indicators for studying the cardiovascular autonomic con-

Table 1. Mean values (± SD) and level of significance (p) of heart rate variability indices and heart rate in shift schedule (n=62) and non-shift schedule (n=37) operators.

Indices	Non-shift schedule (n=37)	Shift schedule (n=62)	p-value
Age (years)	43.04 ± 8.23	43.24 ± 8.81	0.92
X (msec)	746.79 ± 246.3	748.60 ± 197.71	0.97
STV (msec)	39.44 ± 17.14	38.83 ± 18.44	0.88
P_T/P_{RSA} (arb. un.)	21.28 ±15.28	18.96 ± 10.63	0.41
HR (%)	51.18 ± 26.89	52.98 ± 27.05	0.77
Heart Rate (b/min)	72.04 ± 23.35	72.00 ± 21.36	0.99

Abbreviations used in the table:

X (msec)	Mean RR interval
STV (msec)	Short-Term Variability
P_T/P_{RSA} (arb. un.)	Ratio of spectral powers of RR intervals in the Low Frequency to Respiratory Sinus Arrhythmia bands
HR (%)	Health Risk

trol and for determination of the disorders in the autonomic function. Table 1 presents the mean values of time- and frequency-domain based HRV measures, HRV-derived index and heart rate for the two groups working shift and non-shift schedules.

The comparison of the mean values of HRV indices and heart rate between non-shift and shift schedule operators did not show significant changes in the autonomic cardiovascular control pattern. No significant changes were found in myocardial activity, such as increased rate of supraventricular and ventricular extrasystoles.

2.2. Functional dependencies of work-related psychological and social factors on mean heart rate and STV

The study of the functional relationships between heart rhythm and autonomic cardiovascular control assessed by HRV indices, and psychological and social factors associated with the working environment and work process factors revealed the following dependencies: significant dependence of mean heart rate on skill utilization, significant dependence of short-term variability (STV) on cognitive skills and skill utilization. Regression equations describing dependencies of work related psychological and social factors on mean heart rate and STV are presented in table 2.

4. Discussion

The impact of a shift work schedule on cardiovascular health was determined by studying the autonomic cardiovascular control and myocardial rhythmogenic activity. The cardiovascular health risk assessment was performed by comparison of shift schedule and non-shift schedule operators. The effect of shift work with average 15 year's exposure to night shift work on the autonomic cardiovascular control and myocardial rhythmogenic activity was studied by HRV and detection of SVE and VE. The comparison of time- and frequency-domain based measures of heart rate variability, the heart rate variability-derived index and heart rate of shift and non-shift operators did not reveal significant differences (Tab. 1).

The analysis of heart rate variability and screening for SVE and/or VE did not find any changes in the pattern of the autonomic cardiovascular control and myocardial rhythmogenic activity in shift operators. Our results are similar to the results of Van Amelsvoort et al. (2001) and Ito et al. (2001) who did not establish significant differences in HRV indices in shift operators. However in their study Van Amelsvoort et al. (2001) observed that the increased cardiovascular risk is associated with changes in the myocardial rhythmogenesis and induction of VE.

Similar to our results are the results from studying work schedules with long weekly working hours: no significant relationship has been established between the working hours and cardiovascular risk factors: HRV, arterial pressure, serum cholesterol (Iwasaki et al. 1998; Sasaki et al. 1999).

The occupational group of shift work telephone operators is likely to be more healthy than the population as a whole and does not reveal disturbance in cardiovascular functional state and corresponding morbidity rate in comparison to the general population as the latter includes individuals unable to work due to illness or disability. This healthy worker effect has to be considered in interpreting results. Furthermore, it

Table 2. Regression equations of mean heart rate and Short Term Variability (STV) on work-related psychological and social factors. (stepwise method, coefficients significant at $p<0.05$ are shown)

Mean Heart Rate = 71.96 + 37.49 × Skill Utilization
STV = 64.27 + 12.74 × Skill Utilization + 9.32 × Cognitive Skills

is possible that operators that drop-out of shift work comprise of subjects more prone to cardiovascular events.

Because measurements were taken only for a short period of time in the morning, nothing can be said about diurnal variation in myocardial rhythmogenic activity which may be quite different in shift working as compared to day working operators.

Although non-significant, the results of our study revealed a pattern of decreased sympathetic activity corresponding to a reduced P_T/P_{RSA} ratio in operators working on a shift schedule. This result is similar to results of Sasaki et al. (1999) who observed that the accumulation of sleep deficits could cause decreased sympathetic activity especially during shifts with increased length. In our future studies accumulation of sleep deficit will be investigated with respect to the association between dysfunctional sympathetic and parasympathetic cardiovascular control as well as rhythmic myocardial activity and the risk of desynchronized sympathetic and parasympathetic cardiac function as a pathophysiological mechanism in induction of SVE and VE.

The screening of cardiovascular health risk in shift work operators necessitates further studying of the relationship between the autonomic cardiovascular control and psychological and social work-related factors as the results of our study revealed a pattern of functional strain. The process of functional strain is characterized by stress-induced effects on cardiovascular functional status mediated by neural control mechanisms. The process of cardiovascular functional strain might be accelerated under the influence of work-related stress factors and might lead to CVD. The indicated factors: skill utilization and cognitive skills might exert a stress generating effect and affect the autonomic parasympathetic cardiac function. These results are in agreement with other studies revealing an association between work-related psychological and social factors and cardiovascular functional status controlled by the autonomic and central neural mechanisms mediating CVD incidence (Belkic et al. 1996; Huikuri 1997; Pickering 1997; Vrijkotte et al. 2000) and support the suggestion of Kristal-Boneh et al. (1995) that HRV might be used for assessment and prediction of cardiovascular health risk and performance under the effect of cognitive load, stress and occupational risk factors.

The focus of studies on cardiovascular risk in night shift workers should be the longterm investigation of disturbances in autonomic cardiovascular control and myocardial activity. These studies will elucidate the functional role of disturbed autonomic cardiovascular control as one of the mechanisms inducing myocardial arrhythmogenic activity and increased rate of ventricular extrasystoles.

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