Occupational determinants of heart rate variability

Abstract Objectives: Analysis of HRV has been suggested as a way to study the effects of work-related stresses on cardiovascular autonomic regulation. The aim of this study was to evaluate the use of HRV in the investigation of work-related stressors. Methods: Cross-sectional data from an ongoing cohort study were used to analyse the relationship of the potential workplace stressors of job-strain, noise and shift work, with HRV. Mean HRV values during sleep and work were calculated in 135 24-h EKG recordings. Results: Shift workers displayed significantly decreased SDNNi levels during sleep, compared with those of the daytime workers (adjusted least square mean values: 69.3 and 85.8 ms, respectively, \( P < 0.05 \)). Compared with the control group reporting low job demands and high work control (mean: 73.2), we found significantly elevated \%LF means during work adjusted for sleep in the low demands, low control group (77.9, \( P < 0.01 \)), high demands, high control group (77.7, \( P < 0.05 \)) and high demands, low control group (77.7, \( P < 0.05 \)). Workers reporting a high noise level compared with a low work noise level also displayed an elevated adjusted mean \%LF during work (78.0 and 75.3 respectively, \( P < 0.06 \)). Conclusions: The finding of a decreased SDNNi level during sleep in shift workers compared with day workers indicated a less favourable cardiovascular autonomic regulation, which may explain in part the excess cardiovascular disease risk in shift workers. The elevated \%LF during work in employees exposed to high job strain or high noise levels indicated a direct shift in the autonomic cardiac balance towards sympathetic dominance. We concluded that the analysis of HRV may provide a useful tool in the study of the physiological effects of work-related stresses.

Key words Heart rate variability · Shift work · Job strain · Workplace noise

Abbreviations HRV Heart rate variability · \%LF Low frequency power (0.04–0.15 Hz) in normalised units (Low frequency power/High frequency + low frequency power) · \( \log(\text{HF}) \) Power in the high frequency range (0.15–0.40 Hz) in logarithmic units · \( \log(\text{LF}) \) Power in the low frequency range (0.05–0.15 Hz) in logarithmic units · SDNNi Mean of the standard deviations of all NN intervals for all 5-min segments of the entire recording, in milliseconds · HF high frequency · LF low frequency

Introduction

Heart rate variability has become the accepted term to denote variations in both instantaneous heart rate and RR interval (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology 1996). Since the publication of studies establishing HRV as a strong and independent predictor of mortality after acute myocardial infarction (Kleiger et al. 1987; Malik et al. 1989; Bigger Jr. et al. 1992; Rovere et al. 1998), analysis of HRV has frequently been used in a clinical setting (Steenland et al. 1997). However, outside of the clinical setting, assessment of HRV can also be used as a non-invasive tool for predicting cardiovascular morbidity and mortality in healthy subjects (Dekker et al. 1997; Tsuji et al. 1994, 1996; Huikiri et al. 1998). Tsuji reported a hazard ratio of 1.47 for new cardiac events (95% confidence interval
Fluctuations in cardiac sympathetic and parasympathetic outflow cause a significant part of the beat-to-beat fluctuation in heart rate. Analysis of HRV could therefore be used as a tool to assess cardiac autonomic control. Variations in heart rate can be evaluated in time and frequency domain. Spectral analysis in the frequency domain enables a crude separation between vagal and sympathetic cardiac control to be made. Fluctuating efferent vagal activity is the major contributor to HF HRV (Malliani et al. 1991; Pomeranz et al. 1985). There is still some disagreement about interpretation of the LF HRV component. Some authors consider it as a marker of sympathetic modulations (Malliani et al. 1991; Pagani et al. 1997), while others adhere to the view that it reflects fluctuations in both sympathetic and vagal activity (Akselrod et al. 1981; Houle and Billman 1999).

During the past decade, HRV analysis has been proposed as a non-invasive technique for the assessment of job-related cardiovascular stressors (Kristal-Boneh et al. 1995). Up till now, there has been published only a very limited number of studies in which the relationship between working conditions and HRV is described. Work by Pagani et al. (1991) demonstrated a relationship between exposure to a psychological stressor (computer-controlled mental task, or a stressful interview) and the LF component of HRV. So far, no studies using a more general scoring of overall workplace stressors have been found. In this investigation we used the cross-sectional data of an ongoing cohort study designed to examine the effects of shift work on the cardiovascular risk profile. The influence of the workplace stressors noise, job strain, physical activity, and shift work on heart rate and HRV was investigated. We calculated 24-h mean heart rate and HRV values, and mean values during sleep and work, from all 5-min heart rate and HRV readings in the 24-h recording. Means during sleep and work were analysed, to differentiate between more acute and longer term effects. Means during work, corrected for values during sleep, were used as estimates of the direct effects of the indicated amount of workplace-related stressors on heart rate and HRV.

Methods

Population

All subjects participated in an ongoing cohort study of 396 shift workers and daytime controls. The participants worked in the integrated circuit manufacturing industry, waste incinerator plants, or in hospitals. The main objective of the cohort study was to determine the influence of shift work for 1 year, on cardiovascular risk factors. The ethical committee of Wageningen University approved the study, that implied that all respondents gave written informed consent before being included. Inclusion criteria were:

- Starting in a new job
- Working at least 32 h a week
- Expecting to work next year in the same job
- Not using medication, nor having had previous hospitalisation for cardiovascular disease
- Having no insurmountable objections to shift work (see Measurements)
- Being aged between 18 and 55 years

This study refers to the 155 members of the cohort who underwent an initial 24 h Holter recording covering a standard daytime working day. Of the recordings, 20 could not be used for this study (incomplete recordings due to non-compliance, skin irritation, technical failure, unexpected changes in the work schedule; two persons had an excessive number of premature beats). This left us with 135 complete and analysable recordings.

Data collection

Measurements were performed between 1 week and 2 months after the start of a new job.

24 h Holter recordings

The participants were submitted to a 24-h Holter recording, starting at the beginning of a morning shift (for the shift workers) or day shift (for the day workers). A trained research nurse prepared the Holter recorder. All subjects were instructed to note down the start and finish times of sleep, work, meals, leisure, physical activities and other possibly relevant events or activities. These diaries were later coded from a list of standard activities. The sleeping period was defined as the time 1 h after going to sleep until 1 h before getting up, as recorded in the diary.

Personal and work characteristics

All participants received a questionnaire which they were asked to complete, and return by mail. Unclear or missing answers were verified by telephone. Most questions were close-ended and came from standardised questionnaires.

Personal characteristics: In the questionnaire, education level was coded in seven levels, from primary to university education. In the final analysis these levels were reduced to categories: lower, intermediate and higher education. Physical activity indices for work, sport and leisure time were assessed as described by Baecke et al. (1982). Leisure time, physical activity and sports scores were combined into an overall leisure time physical activity score. Though current (type, quantity) and past (type, years, and quantity) smoking habits were queried, in the final analysis only the smoking status (non-smoker, current smoker, or ex-smoker) was used.

Current job title and job history: The questionnaire asked for details about the current job, including company, department, and shift work schedule. If in doubt concerning this schedule status on the employment form, we verified the data with the occupational health service or the human resources department of the employing firm. All jobs were coded for social status and job content. A total of nine different job titles were coded. In this study we defined shift work as “working in an alternating work pattern, including nights”. Shift timetables were coded as forward rotating (nights-afternoons-mornings, advancing schedule) or backward rotating (mornings-afternoons-nights, delaying schedule). We coded rotation as fast, when at most, three consecutive night shifts were worked. Five consecutive night shifts at most, in a row were coded as medium rotation. Irregular shift schedules, often made each month after consultation with all workers involved, were coded as irregular. Information on all previous jobs including title, employer, starting and ending dates and shift work status was requested.

Workplace noise: Workplace noise was assessed using a question developed by Ising (1997): “Please indicate the level of noise which matches best with the noise level at your workplace: (1) refrigerator; (2) typewriter; (3) electric lawnmower; (4) electric drill; (5) road drill”. Because of small numbers, especially in the higher