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ORIGINAL ARTICLE

The perception of work stressors is related to reduced parasympathetic activity

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Abstract
Purpose The aim was to examine the perception of work stressors in relation to ambulatory measures of heart rate variability (HRV).
Methods Results are based on a sample of 653 healthy male workers aged 40–55 from the Belgian Physical Fitness Study conducted in 1976–1978. Data were collected by means of self-administered questionnaires and bio-clinical examinations. An index of physical and psychosocial work stressors containing five items was constructed based on the job stress questionnaire. Data on HRV were collected by means of 24-h ambulatory ECG recordings on a working day. Both time and frequency domain measures of HRV were calculated. Associations between work stressors and HRV measures were assessed by means of correlations, multiple linear regression analysis and analysis of (co)variance.
Results The work stressor index was significantly associated with lower pNN50 (the percentage of differences between adjacent normal RR intervals >50 ms), lower high frequency power and a higher ratio of low frequency over high frequency power. Very similar results were obtained after adjusting for age, language, occupation, smoking, body mass index, total cholesterol, systolic blood pressure and leisure time physical activity. No significant associations were found with SDNN (the standard deviation of all normal RR intervals) and low frequency power.
Conclusions The perception of work stressors was related to reduced parasympathetic activity in a sample of 653 healthy male workers. These findings support the idea that particularly the parasympathetic component of the autonomic nervous system is related to work stress.

Keywords Work · Stress · Coronary heart disease · Heart rate variability

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Introduction

There is ample evidence to consider psychosocial work factors as independent risk factors of coronary heart disease (CHD; Belkic et al. 2000, 2004). Numerous studies have examined the "job demand—control—support" model in relation to cardiovascular disease outcomes (Karasek and Theorell 2000; Kornitzer et al. 2006). According to a systematic review and meta-analysis of prospective cohort studies, work stress was associated with about a 50% excess risk of CHD (Kivimaki et al. 2006). On the other hand, our understanding of the operating mechanisms of this relation between work stressors and CHD is incomplete. Although clear associations have been found between occupational stress and variables derived from ambulatory blood pressure measurements, other conventional coronary risk factors such as elevated cholesterol, smoking and diabetes cannot fully account for the relation between job stress and CHD (Schnall et al. 1994; Hemingway and Marmot 1999; Belkic et al. 2000).

In general, two physiopathological pathways have been suggested in the connection between psychological stress and the cardiovascular system: the hypothalamic–pituitary–adrenal (HPA) axis and the autonomic nervous system (Brotman et al. 2007). In recent years, the cortisol awakening response has been more and more assessed as an indicator of HPA axis activation and has been related to a number of psychosocial factors including job stress (Chida and Steptoe 2009). Regarding the autonomic nervous system, heart rate variability (HRV) is increasingly recognized as a valuable quantitative marker of cardiac autonomic dysfunction (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology 1996). HRV describes variations in RR intervals and can be evaluated by both statistical time domain measures and spectral frequency domain measures. Low HRV points to excessive sympathetic or inadequate parasympathetic activity. A number of prospective cohort studies have demonstrated the prognostic value of reduced HRV in relation to CHD as well as cardiovascular and all-cause mortality in patients and general population samples (Kleiger et al. 1987; Tsuji et al. 1994; Liao et al. 1997; Dekker et al. 1997; Britton and Hemingway 2004). Reduced HRV as a short-term response to acute mental stress during standardized tasks has been shown in several studies using laboratory simulations (Steptoe et al. 2002; Hall et al. 2004; Isowa et al. 2006).

On the other hand, only a limited number of studies have examined the association between parameters of HRV and more chronic stress conditions such as work-related stress. In some studies with relatively small sample sizes, job stress was related to reduced HRV obtained from 24-h ECG monitoring (Vrijkotte et al. 2000; van Amelsvoort et al. 2000; Collins et al. 2005). A few large-scale studies reported associations between job stress and lower HRV assessed with short-term ECG recordings (Hemingway et al. 2005; Chandola et al. 2008; Hintsanen et al. 2007). However, several studies including homogeneous occupational samples reported negative findings regarding work stress and HRV (Kageyama et al. 1998; Kang et al. 2004; Riese et al. 2004).

The aim of this study was to examine the perception of work stressors in relation to 24-h recordings of HRV in a sample of healthy male workers. The Belgian Physical Fitness Study conducted in the late 70s was a prospective cohort study on the relation between physical fitness and ischemic heart disease (Sobolski et al. 1981). Ambulatory 24-h ECG recordings were taken in a subsample of the study including 770 male workers. These data have been re-examined in light of the new insights regarding the role of autonomic imbalance in the relation between stress and CHD. The availability of 24-h ECG recording data in a relatively large sample of working people provides an exceptional opportunity to assess the association between work stressors and HRV.

Methods

Study population

The association between work stressors and HRV was examined within the Belgian Physical Fitness Study, a prospective cohort study that identified physical fitness as an independent protective factor against ischemic heart disease (Sobolski et al. 1981, 1987). The study was conducted in 1976–1978 and included 2,363 male factory workers. All men aged 40–55 and regularly employed by the selected factories were invited to participate. The response rate was 75%. Ambulatory ECG recordings were obtained from a subsample of 814 participants. This inclusion was based on a selection of factories where it was feasible to fit all the workers with an ambulatory ECG monitor for a 24-h period. The ambulatory ECG recordings of a total of 770 participants were processed; 44 subjects were excluded due to technical reasons. For the analysis on work stressors and measures of HRV, we further excluded 117 persons with reported diabetes, previous hospitalization for CHD or electrocardiographic abnormalities suggestive of CHD. This resulted in a final study sample of 653 healthy male workers aged 40–55. All participants gave their informed consent before inclusion in the study. The study was approved by the ethics committees of Ghent University and the Free University of Brussels.

Data collection

Questionnaire

The participants completed several self-administered questionnaires. The perception of work stressors was assessed by means of a self-constructed *job stress questionnaire* (JSQ; Kittel et al. 1980, 1983). This instrument contained 27 questions dealing with general satisfaction at work, complaints about physical work conditions, responsibilities at work, changes in work department, changes in work conditions, imposed work pace, concerns about promotion, difficult professional relations, salary, periods of professional difficulties and worries, psychosomatic complaints, health preoccupation and nervousness. The 27 questions were reduced and treated as 18 separate items. A weighted sum score was a priori computed for each subject. This resulted in a total JSQ score with a normal distribution ranging from a theoretical minimum of −3.51 to a theoretical maximum of 10.57.

Besides the original JSQ scale as it was initially used in the Physical Fitness Study, we computed an adapted scale based on only five items: general satisfaction at work, responsibilities at work, imposed work pace, difficult professional relations (with superiors, colleagues or subordinates) and complaints about physical work conditions (noise, light, heat or tobacco smoke). These factors were chosen because they have been identified as major work stressors in the research field dealing with working conditions and health during the past decennia. Summing up these five dummy variables resulted in an index of physical and psychosocial work stressors ranging from 0 to 5. From this point, we will refer to this scale as the *work stressor index*.

The questionnaires also included information about age, smoking behavior, job title (white-collar or blue-collar) and language (Dutch or French). The Minnesota leisure time physical activity questionnaire was used to calculate each subject's mean energy expenditure during leisure time physical activity in the past 12 months; the score ranged from minimum 0 to maximum 408300 (Taylor et al. 1978).

Ambulatory ECG monitoring

Data on HRV were collected by means of 24-h ambulatory ECG recordings during regular everyday activities on a working day. Continuous ambulatory ECG recordings were obtained with a phase-locked loop speed control tape recorder at 2 mm/s (Oxford Medical, Medilog type I) with bipolar electrodes in the V5-V5R position. The ECG data were sampled digitally and analyzed with the Syne Tec software (version 2.00 ELA medical, F-Le Plessis-Robinson). Measures of HRV were calculated for the entire 24 h. Only recordings with >90% of qualified sinus beats for at least a 23-h period were included in the analysis of HRV. The average duration of the recordings was 23.3 h. Both time and frequency domain measures of HRV were calculated. The time domain parameters studied were SDNN (the standard deviation of all normal RR intervals, ms), pNN50 (the percentage of differences between adjacent normal RR intervals >50 ms, %) and HR (the mean heart rate over 24 h, beats per minute). The frequency domain parameters were low frequency (LF: 0.04–0.15 Hz, ms^2), high frequency (HF: 0.15–0.40 Hz, ms^2) and the ratio of LF over HF. Because of the skewed distributions of pNN50, LF, HF and LF/HF, natural logarithm (ln) transformations were performed.

Bio-clinical examination

Conventional coronary risk factors were measured during standardized bio-clinical examinations. Systolic blood pressure, body height and weight were assessed by trained observers. Body mass index (BMI) was calculated as body weight (kg) divided by the square of the height (m). Total cholesterol was centrally measured.

Statistical analysis

Bivariate associations between the JSQ scale and work stressor index on the one hand and HR, pNN50, SDNN, LF, HF and LF/HF on the other hand were assessed by means of Pearson correlation (r). In multiple linear regression analysis with the HRV parameters as outcome variables, the associations were adjusted for possible confounding factors. The following covariates were entered as continuous variables: age, body mass index, total cholesterol, systolic blood pressure and leisure time physical activity. Language, occupation and smoking were entered as dummy variables.

T-tests were performed to compare mean HRV values between JSQ scale groups and work stressor index groups. In analysis of covariance, possible confounding factors were entered as covariates. LSD (least significant difference) post hoc tests were conducted in order to make pairwise comparisons between the work stressor groups.

A level of $\alpha = 0.05$ was used to indicate statistical significance. All analyses were performed with SPSS 15.0 software (SPSS, Inc., Chicago, IL).

Results

Descriptive statistics for HRV parameters, work stressor scales and confounding variables in the sample of 653 healthy male workers are shown in Table 1.

Crude associations between the two continuous work stressor scales and HRV parameters were assessed by means of Pearson correlation (Table 2). Both the original JSQ scale and the adapted work stressor index were positively and significantly related to mean HR and LF/HF. In addition, a significant negative correlation was found between the work stressor index and pNN50 and HF. No significant associations were found with SDNN and LF. In multiple linear regression analysis, adjustments were made for age, language, occupation, smoking, BMI, total cholesterol, systolic blood pressure and leisure time physical activity. This yielded very similar results; only the association between the JSQ scale and mean HR became borderline significant.

In order to study the relation into more detail, several work stressor groups were considered. The study sample was divided into three equally large groups based on the tertile values of the JSQ. Furthermore, participants were categorized into low (scores 0–1), medium (scores 2–3) or

Table 1 Sample description of HRV parameters, work stressor scales and confounding variables ($N = 653$)

Characteristics	Mean (SD), median (IQR) or percent (*n*)
HR (beats per minute): median (IQR)	81.3 (75.8–86.7)
pNN50 (%): median (IQR)	3.83 (1.7–7.6)
SDNN (ms): median (IQR)	135.5 (109.5–160.6)
LF (ms²): median (IQR)	832.0 (548.0–1279.5)
HF (ms²): median (IQR)	150.0 (89.0–259.5)
LF (ms²)/HF(ms²): median (IQR)	5.39 (4.0–7.3)
JSQ scale: mean (SD)	0.37 (2.1)
Work stressor index: mean (SD)	1.95 (1.3)
Age (year): mean (SD)	47.0 (4.3)
Language: % (*n*)	
French	44.4 (290)
Dutch	55.6 (363)
Occupation: % (*n*)	
Blue-collar	24.7 (161)
White-collar	75.3 (492)
Smoking: % (*n*)	
No	54.2 (354)
Yes	45.8 (299)
Body mass index (kg/m²): mean (SD)	25.6 (3.0)
Total cholesterol (mg/dl): mean (SD)	236.7 (34.3)
Systolic blood pressure (mmHg): mean (SD)	135.1 (16.5)
Leisure time physical activity score: median (IQR)	70,050 (37,750–1,14000)

HRV heart rate variability, *SD* standard deviation, *IQR* interquartile range, *JSQ* job stress questionnaire

high (scores 4–5) work stressor index groups. *T*-tests were performed to compare mean HRV values between both JSQ scale groups and work stressor index groups (Table 3). Although the relation was not completely linear, the mean LF/HF value in the upper JSQ tertile group was significantly higher than in the first and middle tertile groups. Mean HR was significantly more elevated in the high work stressor index group compared to the low group, while the reverse was true for mean pNN50. A significant positive linear relation was found between the work stressor index groups and LF/HF. In analysis of covariance, possible confounding factors were entered as covariates. This turned the association between HR and work stressor index groups into borderline significant.

Discussion

In recent times, a lot of research effort has been put in unraveling the pathophysiological mechanisms of the relation between work stressors and CHD. One of the plausible assumptions in this regard is that disturbances of the autonomic nervous system with its sympathetic and parasympathetic mechanisms might mediate the stress—CHD relation (Brotman et al. 2007). The data of the Belgian Physical Fitness study conducted in the late 70s have been re-examined in light of these new insights. The aim of this study was to examine the perception of work stressors in relation to 24-h recordings of HRV in a sample of 653 healthy male workers aged 40–55.

The work stressor index, a self-constructed scale including five physical and psychosocial stress factors, was significantly associated with higher mean HR, higher LF/HF and lower pNN50 and HF. HRV measures are known to decline with age, while low HRV is associated with adverse conventional cardiovascular risk factors (Britton and Hemingway 2004). After adjusting the analysis for age, language, occupation, smoking, BMI, total cholesterol, systolic blood pressure and leisure time physical activity, very similar results were obtained. No significant associations were found with SDNN and LF. These findings support the idea that particularly the parasympathetic component of the autonomic nervous system is related to work stress. The time domain measure pNN50 estimates

Table 2 Associations between work stressor scales and HRV parameters; results from bivariate correlation and multiple linear regression analysis ($N = 653$)

	HR	pNN50	SDNN	LF	HF	LF/HF
Pearson *r* (*P*)						
JSQ scale	**0.09** (<0.05)	−0.05 (0.25)	−0.01 (0.89)	0.03 (0.44)	−0.03 (0.52)	**0.08** (<0.05)
Work stressor index	**0.10** (<0.05)	−**0.11** (<0.01)	−0.07 (0.09)	−0.02 (0.57)	−**0.09** (<0.05)	**0.10** (<0.01)
Standardized beta coefficient (*P*)[a]						
JSQ scale	0.08 (0.06)	−0.06 (0.15)	0.01 (0.76)	0.01 (0.79)	−0.04 (0.29)	**0.08** (<0.05)
Work stressor index	**0.09** (<0.05)	−**0.11** (<0.01)	−0.05 (0.24)	−0.02 (0.53)	−**0.08** (<0.05)	**0.10** (<0.05)

Significant associations at the 0.05 level are in bold

HRV heart rate variability, *JSQ* job stress questionnaire

[a] Adjusted for age, language, occupation, smoking, BMI, total cholesterol, systolic blood pressure and leisure time physical activity

Table 3 Mean HRV values (SD) in work stressor groups; results from *t*-test and analysis of covariance ($N = 653$)

	JSQ scale groups					Work stressor index groups				
	T1 ($N = 202$)	T2 ($N = 195$)	T3 ($N = 189$)	*P*	P^a	Low ($N = 261$)	Medium ($N = 288$)	High ($N = 74$)	*P*	P^a
HR	80.8 (8.6)	80.7 (8.9)	82.2 (8.8)	0.18	0.25	**80.4 (8.7)**	**81.3 (8.9)**	**83.2 (8.1)**[b]	<0.05	0.08
pNN50 (ln)	1.19 (1.2)	1.31 (1.1)	1.12 (1.1)	0.23	0.19	**1.33 (1.1)**	**1.15 (1.2)**	**0.99 (1.2)**[b]	<0.05	<0.05
SDNN	138.4 (39.3)	136.0 (36.3)	136.1 (34.3)	0.76	0.90	140.6 (37.0)	134.9 (36.9)	135.0 (36.9)	0.16	0.21
LF (ln)	6.65 (0.7)	6.69 (0.6)	6.72 (0.6)	0.50	0.77	6.71 (0.6)	6.66 (0.6)	6.70 (0.6)	0.57	0.39
HF (ln)	4.99 (0.78)	5.09 (0.74)	4.96 (0.79)	0.22	0.16	5.08 (0.8)	4.99 (0.8)	4.88 (0.9)	0.14	0.10
LF/HF (ln)	**1.65 (0.5)**	**1.60 (0.5)**	**1.76 (0.5)**[b,c]	<0.01	<0.001	**1.64 (0.5)**	**1.66 (0.5)**	**1.82 (0.5)**[b,c]	<0.05	<0.05

Significant associations at the 0.05 level are in bold

HRV heart rate variability, *SD* standard deviation, *JSQ* job stress questionnaire

[a] Adjusted for age, language, occupation, smoking, BMI, total cholesterol, systolic blood pressure and leisure time physical activity

[b] $p < 0.05$—results LSD post hoc test: significance of difference from first category

[c] $p < 0.05$—results LSD post hoc test: significance of difference from second category

the short-term component of HRV and specifically assesses the parasympathetic activity component of autonomic functioning (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology 1996). In case of 24-h ECG recordings, pNN50 corresponds to the frequency domain measure HF spectral power which is modulated by parasympathetic activity only. Conversely, SDNN provides an estimate of overall HRV; it is a global non-specific measure of both the sympathetic and parasympathetic components of the autonomic nervous system (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology 1996). Likewise, the frequency domain measure LF spectral power is modulated by both sympathetic and parasympathetic activities.

In the past decades, HRV has proven to be a useful tool in occupational health research: measures of HRV have been examined in relation to various work-related factors of physical, chemical and psychosocial nature (Togo and Takahashi 2009). Nonetheless, relatively few studies have examined chronic conditions of work stress in relation to HRV. While the association between work stress and higher mean HR has been confirmed in all of these studies, the findings regarding HRV are somewhat more diverse (Vrijkotte et al. 2000; van Amelsvoort et al. 2000; Collins et al. 2005; Hemingway et al. 2005). In the large-scale Whitehall II study, low job control as well as cumulative exposure to job strain was associated with lower SDNN, LF and HF assessed with 5-min ECG monitoring (Hemingway et al. 2005; Chandola et al. 2008). In a population-based sample of 863 workers from the Cardiovascular Risk in Young Finns study, effort–rewards imbalance was associated with lower pNN50 and higher LF/HF obtained from 3-min ECG recordings in women but not in men (Hintsanen et al. 2007). Work stress was not associated with 5-min recordings of HRV in a few small-scale studies with homogeneous occupational samples of healthy male workers (Kageyama et al. 1998; Kang et al. 2004). Study results obtained from short-term ECG recordings are difficult to compare with our findings based on 24-h monitoring. Particularly, SDNN is dependent on the length of the recording period, so it is inappropriate to compare SDNN measures obtained from recordings of different durations (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology 1996). The spectral analyses of short-term and long-term ECG's should be strictly distinguished as well because of the important differences in the interpretation of the results. A few studies have reported about the relation between job stress and HRV measures based on 24-h ECG monitoring. In a population of 109 male white-collar workers from a computer company, high effort–reward imbalance was found to be associated with lower RMSSD (the root mean square of successive differences between adjacent NN intervals) which measures the short-term component of HRV just like pNN50 (Vrijkotte et al. 2000). Collins et al. (2005) reported that job strain was associated with higher LF/HF, while low decision latitude was associated with lower SDNN in a sample of 36 men from a wide range of occupations. On the contrary, job strain was not associated with SDNN or LF/HF in 135 men and women from different job titles (van Amelsvoort et al. 2000). A study in 159 female nurses also reported a lack of association between job strain and HRV (Riese et al. 2004). On the whole, it is difficult to compare our findings with these studies because different measures of work stressors were used.

Our findings add support to the idea that disturbances of the autonomic nervous system play an intermediate role in the relation between work stress and CHD. There is growing evidence in literature that autonomic imbalance and decreased parasympathetic tone are involved in the pathway from negative affective states to a wide range of diseases (Thayer and Brosschot 2005). In this respect, low HRV is a plausible marker of the connection among stress-related cognitive deficits and negative health consequences. Recently, the 'stress-disequilibrium theory' dealing with the operating physiological mechanisms in chronic disease development was introduced by Karasek (2008). The major assumption of this theory is that lack of external social control decreases the internal capacity for self-regulation of the central nervous system. Environmental stress increases the risk of chronic disease development through an overloading of the internal control capabilities. While traditional stress models focus on the role of sympathetic arousal in the physiological pathway to disease, this 'stress-disequilibrium theory' highlights the significance of decreased parasympathetic activation for disease development. Reduced ordering capacity or biological variability of internal systems may lead to illness risk. Within this framework, HRV acts as a biological marker of the range of variation displayed by physiological systems. The results of our study are in accordance with these assumptions, since the perception of work stressors was associated with decreased parasympathetic tone.

The major strength of this study is that it allows assessing the association between the perception of work stressors and HRV obtained from 24-h ECG data in a large sample of working men. Only few similar studies on this issue are available. Moreover, these other studies are based on limited sample sizes, and results are to some extent conflicting. To our knowledge, this is the largest study with 24-h ECG monitoring data in relation to measures of work stressors. Long-term ambulatory ECG monitoring offers a precise and comprehensive characterization of HRV. Studies have also shown great stability and reproducibility of HRV measures derived from 24-h ambulatory monitoring (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology 1996).

On the other hand, this study has some important limitations. Concerning the measurement of work stressors, we were obviously restricted to the instruments available in the Belgian Physical Fitness study that was set up in the late 70s. The JSQ that was used in this study finds its origin in the 'Belgian Bank Study', which has been an important pioneer study in establishing the now widespread research tradition of work stress and CHD (Kittel et al. 1980). The original JSQ scale incorporates a wide range of different work factors including psychosocial and physical stressors but also items dealing for instance with psychosomatic complaints, health preoccupation and nervousness. Therefore, in order to obtain a more precise assessment of work stressors, an additional scale was computed based on a selection of five items. The results with this adapted scale were more convincing. The five specific items have been selected because they relate to factors whose role in chronic disease development has been shown in numerous studies in the pas decades. We incorporated three items that assessed psychosocial characteristics of the work environment (responsibilities at work, imposed work pace and difficult professional relations), one item that assessed subjective appraisal of the work environment (job satisfaction) and one item regarding physical working conditions. The results showed that an accumulation of these different kinds of work stressors was related to higher mean HR and lower HRV; no significant associations were found with any of the individual binary items.

Given the cross-sectional design of this study, the causality of the associations cannot be determined. It can not be ruled out that persons with an unhealthy profile of cardiac autonomic activity have selected themselves in jobs or work situations with more stressors.

Further research on the topic of work stress in relation to markers of autonomic imbalance and decreased parasympathetic tone is undoubtedly required. More in particular, there is need for studies that test standardized stress models such as the "job demand—control—support" model (Karasek and Theorell 1990) and the "effort—reward imbalance" model (Siegrist 2001) in relation to HRV parameters obtained from 24-h ECG monitoring in large samples of both men and women. It is recommended to conduct such a study in contemporary times, because of the major changes that have occurred in the labor market in Western societies during recent decades. In addition, there is need for prospective studies to assess the causal relation between work stress and HRV measures.

In conclusion, the findings of this study suggest that an accumulation of physical and psychosocial work stressors is related to reduced parasympathetic activity. The work stressor index was significantly associated with higher mean HR, higher LF/HF and lower pNN50. These results support the idea that disturbances of the autonomic nervous system and its parasympathetic component in particular may play a role in the link between work stress and CHD.

Conflict of interest The authors declare that they have no conflict of interest.

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