

Stress and relaxation based on heart rate variability: Associations with self-reported mental strain and differences between waking hours and sleep

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Abstract

This study investigated whether self-reported mental strain is related to physiological indicators of stress and relaxation produced by Firstbeat PRO Wellness Analysis Software[®] (WAS). WAS detects stress and relaxation states of autonomic nervous system from heart rate variability analysis of ambulatory recordings of R-to-R heartbeat intervals (RRI). Twenty-seven postal workers reported their mental strain while their RRIs were recorded during a working day, leisure time and sleep. Within subjects, self-reported mental strain correlated with stress analyzed by WAS. Furthermore, when stress and relaxation were analyzed by WAS, stress dominated the working day and relaxation most of the sleep.

Keywords: work, sleep, stress, mental strain, relaxation, Firstbeat PRO Wellness Analysis Software[®]

Introduction

There has been a steadily growing body of evidence suggesting that mental strain at work is associated with impaired health. Recently, the importance of recovery from work-related strain has been acknowledged (1). Therefore, when physiological responses to self-reported mental strain are measured, off-job time should also be taken into account. Ambulatory blood pressure or heartbeat monitoring are commonly used to measure physical responses of stress, but more sophisticated and handy methods are still needed. The method should monitor both the stress reactions and recovery from stress. Additionally, mental strain should be easily differentiated from physical activity.

A promising tool fulfilling these expectations is Firstbeat PRO Wellness Analysis Software[®] (WAS, Firstbeat Technologies Ltd;2). WAS detects stress and relaxation states of autonomic nerves system (ANS) by analyzing heart rate (HR) and heart rate variability (HRV) based indices from ambulatory recordings of R-to-R heartbeat intervals (RRI).

The aim of the present study was to investigate whether self-reported mental strain is related to the physiological indicators of stress and relaxation produced by WAS in Finnish postal workers. Furthermore, differences in stress and relaxation states between work, leisure time and sleep were studied.

Methods

Subjects comprised of 27 (17 males, 10 females) postal workers who worked at the postal sorting centre of medium-sized town of Jyväskylä, Finland. Mean age of the subjects was 41(range 26 - 59) years.

The study included one working day with the following leisure time and night. Heartbeat monitoring was scheduled to start at the beginning of working shift and to end twenty-four

hours later. Mean of the monitoring time was 18 h 01 min (SD 5:55). For within-subject analyses, the whole monitoring periods were used. In nine subjects (8 males, 1 female) the total monitoring period allowed to analyze three 4-hour periods representing work shift, leisure time, and sleep.

Physiological variables describing stress and relaxation were analyzed with Firstbeat PRO Wellness Analysis Software[®] version 1.4.1 (2). The analysis of stress and relaxation is based on the detection of sympathovagal reactivity that exceeds momentary metabolic requirements for the ANS. The program calculates HRV indices second-by-second using the short-time Fourier Transform method (STFT), and HR- and HRV-derived variables that describe respiration rate and oxygen consumption (VO_2) using neural network modeling of data (3-6). The program also calculates second-by-second indices of stress and relaxation, reflecting activity of the sympathetic (*absolute stress vector*, ASV) and parasympathetic (absolute relaxation vector, ARV) nervous system. ASV is calculated from HR, high frequency power (HFP), low frequency power (LFP) and HRV-derived respiratory variables. ASV is high when heart rate is elevated, HRV is reduced and respiration rate is low relative to HR and HRV. ARV is calculated from HR and HFP and it is high when HR is close to the basic resting level and HRV is great and regular. For more details, see Kettunen and Saalasti (4) and the Wellness Analysis Software User Manual (2). In the present study, the dynamic changes in physiological stress during the day were quantified by calculating mean value of ASV for every 5-min time period for which the information on self-reported mental strain was also available.

The WAS-program also draws conclusions on the duration of different physiological states of the body during the day or recording period by segmenting the data into stationary segments. The data segments, including movement, physical activity at different intensities and recovery from physical activity, are detected using HR, HRV-derived respiration rate, estimated VO_2 and movement-related ANS responses. For non-exercise data segments, the time when the body is in a stress state (*Stress Time*, ST), relaxation state (*Relaxation Time*, RT) or an unrecognized state are determined. The stress state is defined as an increased activation in the body, induced by external and internal stress factors (stressors), during which sympathetic nervous system activity is dominating and parasympathetic (vagal) activation is decreased. This definition does not take into account the nature of the stress response, that is, whether it is positive or negative. The relaxation state is defined as a decreased activation in the body during relaxation, rest and/or peaceful working, related to the lack of external and internal stress factors when parasympathetic (vagal) activation is dominating. In the present study, stress and relaxation times were calculated for the 4-h periods of the first working hours (work), the leisure time at home before going to bed (leisure time) and the first hours of sleep starting 30-min after falling asleep (sleep). In one case with evening-night work shift, leisure time was calculated for the first 4-h period after awakening.

Self-reported mental strain was measured with graph which the subjects were asked to draw on a form after the monitoring period. On the form, a X-axis referred to time and it was divided into 24 one-hour-segments (one segment per one hour). A Y-axis was scaled into from 0 to 10 referring to the subjects' experience of mental strain (0 = not at all, 10 = very much) for the total monitoring period. The graphs were scanned into a computer and saved. Every subject's second-by-second vectors derived from Wellness Analysis Software[®] and self-reported mental strain vector derived from graph were matched in time, and means of ASV and mental strain were calculated for every 5-min period from which reliable data for both variables were available. This was done separately for every subject.

For each subject, Pearson product-moment correlation coefficients were computed to examine the within-subject relationships between the self-reported mental strain and ASV. The 5-min periods of the variables were used for the correlations. Differences in stress (ST) and

relaxation (RT) times between the 4-h periods were studied using an analysis of variance (ANOVA).

Results

Distribution of the within-subject correlation coefficients between self-reported mental strain and ASV is shown in Figure 1. Of 27 subjects, 18 had positive, significant correlation, and 9 had either non-significant or negative correlation. When the 4-hour periods were in focus, sleep differed from work and leisure time in ST and RT (Table 1). ST was shorter and RT longer during the 4-h period of sleep than during work or leisure time periods.

Figure 1. Distribution of the within-subject correlation coefficients between mental strain and Absolute stress vector (ASV) (n=27).

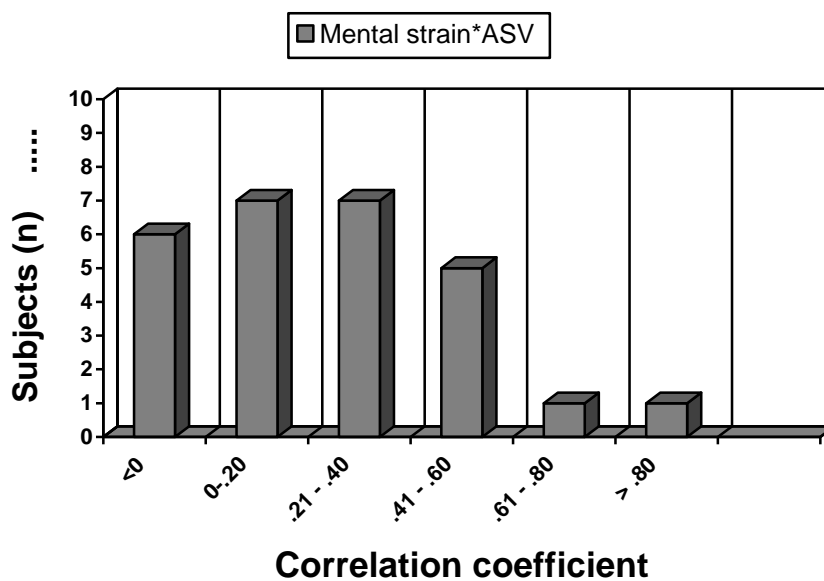


Table 1. Means (M) and standard deviations (SD) in stress (ST) and relaxation (RT) times during 4-hour periods of work, leisure time, and sleep; and group differences using an analyses of variance (ANOVA) (n = 9).

	<u>4-hour periods</u>			ANOVA	Differences between the 4-h periods
	Work	Leisure time	Sleep		
	M (SD)	M (SD)	M (SD)	F	
Stress time (min)	179 (64)	174 (41)	15 (24)	36.78***	1,2>3
Relaxation time (min)	0	16 (14)	192 (34)	232.24***	1,2<3

** p < .001

Discussion

The present study showed that it is possible to detect dynamic changes in stress and relaxation state during working day using combined information from HR and HRV as analyzed from ambulatory RRI data with Wellness Analysis Software[®]. Furthermore, Wellness Analysis Software[®] detected that stress state dominated most of the working and leisure time and relaxation state dominated during sleep, i.e. differentiated nicely waking hours from sleep. The current findings extend the previous knowledge where HR and HRV have separately been used in analysis of ANS function. Numerous studies have shown that HR is lower during the night than during the daytime period and HRV during daytime indicates relative sympathetic dominance, while the night is characterized by parasympathetic, or vagal dominance (e.g. 7-12). As far as we know, there are no studies using a more general scoring describing stress and relaxation state based on both HR and HRV during work, leisure time and sleep. Thus, WAS might be a promising tool in measuring an individual's work stress and relaxation in the context of occupational health care.

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