Heart Rate Variability Analysis Based on Recordings Made by Soldiers in Field Conditions during a 19-Day Ranger Training Operation

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ABSTRACT

Maintaining soldiers' physical and mental capacities throughout an operation is essential for the success. Monitoring of these capacities is needed to avoid exhaustion and incapacitation that can compromise the success of the operation. Monitoring of physiological parameters is one way to follow-up the effects of physical and mental loading. The goal of this kind of monitoring should be to enable us to predict the remaining capacity in an individual soldier during the different phases of an operation. In the present study we evaluated the usefulness of heart rate variability (HRV) for monitoring the soldiers' physiological status during a 19-day ranger training operation. The electrocardiographic recordings were done by the soldiers themselves each morning immediately after wake-up. The HRV analysis was done after the operation. We did not observe any significant changes in the time and frequency domain parameters during the 19-day training. The quality of the ECG was so poor in about half of the recordings that the HRV analysis was not possible. Our conclusion is that in field conditions HRV analysis is suitable for physiological monitoring only if the data collection is done by professional personnel guaranteeing the quality of the data. Self performed data collection for HRV analysis can give acceptable data in tasks in which the soldier is sitting most of the time.

1.0 INTRODUCTION

In military operations soldiers are exposed to both physical and mental stressors. The physical stressors include prolonged physical exertion, insufficient energy and fluid intake, sleep deprivation and unfavourable weather conditions. Combinations of these stressors cause many kind of physiological changes, e.g. in body weight, blood volume, muscular function, endocrine function, physical work capacity, and cardiovascular function, which have been used to monitor changes in soldier's physical condition and to predict the remaining work capacity [1-3].

Heart rate variability (HRV) is measured because it is expected to give information about the cardiovascular autonomic nervous regulation. HRV can be measured from R-R interval samples ranging from tens of seconds to days. The longer is the R-R interval sample the more the HRV reflects different environmental or extrinsic influences, like diurnal rhythm, temperature changes as well as energy and fluid balance. Sample duration of 5 minutes is the most widely used in research. The usefulness of longer

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samples is limited by the occurrence of disturbances in ECG, extrasystoles as well as momentary heart rate changes. HRV analysis can be done in time domain or in frequency domain. Typical time domain parameters of HRV are standard deviation (SD) of R-R intervals and root mean square of successive differences in R-R intervals (RMSSD). In frequency domain analysis HRV is divided into components representing different frequencies in HRV. HRV occurring at frequencies below 0.04 Hz is called very low frequency variability (VLF) and the physiological mechanisms causing it are not well understood. HRV in the frequency range of 0.04 – 0.15 Hz is called low frequency variability (LF) and it is influenced by both the sympathetic and parasympathetic nervous regulation. HRV in the frequency range of 0.15 - 0.40 Hz is called high frequency variability (HF) and it is known to be influenced only by the parasympathetic nervous system [4].

HRV is known to be increased in subjects with good aerobic work capacity and on the other hand HRV is known to be decreased in stressful situations [5-9]. In the present study our aim was to evaluate the usefulness of HRV analysis during a 19-day ranger training operation when the data collection is done in the field by soldiers themselves.

2.0 METHODS

10 healthy males (age 29 ± 5 yr, height 179 ± SD 9 cm, weight 80 ± 12 kg; mean ± SD) participated in ranger training operation. During the first 7 days the subjects walked about 20 km per day in the forest carrying a rucksack of about 40 kg. The following five days they moved 10 km per day. They completed the operation during the last 7 days by walking 10 km per day with the rucksack weighing 20 kg. They slept in average about 4 hours per night. Polar S810 devices were used to record 5 minutes electrocardiogram (ECG) every morning immediately after waking up. During the recording the subjects were resting supine and were breathing spontaneously. In the analysis R-R intervals were measured from a two-minute period free from cardiac arrhythmias and disturbances. Mean R-R interval, standard deviation of R-R intervals (SDRR), root mean square of successive differences in R-R intervals (RMSSD), and percentage of adjacent R-R interval with greater than 50 msec difference (pNN50) were calculated. Spectral analysis of HRV was done using FFT method and high frequency (HF) and low frequency (LF) power of variability were calculated in normalized units. Data are given as mean ± SD.

3.0 RESULTS

Three subjects suffered from such injuries that they could not continue to the end of the study, and seven subjects completed the study. Data collection was performed on 17 days. The number of acceptable ECG samples varied between 1 and 8 on different days so that about half of the ECG recordings were not suitable for HRV analysis. In the beginning and at the end of the 19-day ranger training operation the R-R interval was 1138 ± 110 msec and 1094 ± 122 msec, respectively ($p > 0.05$), SDRR 82 ± 35 msec and 81 ± 31 msec respectively ($p > 0.05$), RMSSD 91 ± 41 msec and 92 ± 36 msec, respectively ($p > 0.05$), pNN50 55 ± 13 and 57 ± 11 %, respectively ($p > 0.05$), LF 51 ± 22 and 40 ± 15 %, respectively ($p > 0.05$), HF 48 ± 22 and 59 ± 15 %, respectively ($p > 0.05$). The standard deviations of these variables are high and suggest that the standardization of the conditions during ECG recordings has not been at acceptable level.

4.0 DISCUSSION

Ambulatory measurement of heart rate from the R-R intervals of electrocardiogram has become a readily available and inexpensive method allowing also calculation of heart rate variability (HRV). The technical simplicity of the R-R interval data collection has lead to the assumption that it would be equally simple to derive physiological information from the R-R interval data. However, HRV is affected physiologically by several factors such as respiratory frequency and tidal volume, age, gender, obesity, physical work capacity, level of physical activity during the measurement, use of medications as well as existence of pathological conditions. HRV also has a clear diurnal variation showing greatest values at night. These multiple influences on HRV have strong confounding effects when using ambulatory HRV information to estimate an individual soldier's level of physical exertion and remaining work capacity during an operation. Also the collection of R-R interval data needs to be done with good quality standards. Any sudden changes in the heart rate (or R-R interval) during the data collection tend to increase HRV. Typically these sudden changes are due to sudden noise or body movement, conversation, or sudden changes in physical activity. These momentary changes in HRV increase the variation and reduce the reproducibility of HRV measurements. This was probably also the case in our study when no significant changes in HRV could be observed over the 19-day ranger training operation.

The data from the present study suggest that HRV analysis based on data collection made in the field conditions by soldiers themselves is not a robust enough method to monitor the physiological status of soldiers. Both the time and frequency domain analysis of HRV require an ECG recording that is quite free from artefacts and technical disturbance, and has stabile baseline. These requirements are difficult to be met in the field because the soldier should be able to rest in calm conditions at least for 5 minutes to obtain acceptable HRV data. It seems to us that the studies of HRV analysis for monitoring the physiological condition of a soldier should be directed to more technical tasks, in which the optimal conditions for data collection can be achieved.

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