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ANALYSIS OF PHYSIOLOGICAL PARAMETERS DURING SOLDIER'S COMBAT TRAINING

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Abstract:
The paper presents a system used for monitoring physiological parameters of soldiers during combat training and analyzing the data for detecting the stress level. The proposed system includes two essential components: Soldier's Health Monitoring Device-SHMD and Combat Medical Support Station (CMSS). The SHMD recording some vital signs like as: electrocardiogram (ECG), heart rate (HR), respiratory rate (RR), plethysmografic waveform (PW), blood oxygenation (SpO2) and body temperature (T). The sensors for biosignals are fixed on a T-shirt that is wear by the soldier under military equipment, in contact with the skin. The CMSS receives all data through various communication channels (Internet, GSM, GPRS, WiFi, Bluetooth etc). This information from the soldier is processed and entered into a database. Also, the module includes a distribution platform based on a network protocol that facilitates the access of this data by the military doctor and also has an alarm function. A medical expert can analyze the data recorded for a specific subject and detect the level of stress during each training session. We analyzed the heart rate variability (HRV), extract from ECG signal and from plethysmografic waveform, during physical exercises and compare these results.

Key words: vital signs, wearable system, physiological monitoring, combat health monitoring

1.Introduction

The first care of any commander is the soldier's health. For this reason in combat operations is necessary to perform lifesaving interventions for personnel suffering combat trauma within minutes of wounding or injury, medical resources must be arrayed in close proximity to the forces supported [1].

Vital signs monitoring is an important issue in modern military medicine. A lot of systems for real time physiological monitoring are developed and this kind of device becomes an important new category of modern military wearable technologies. These devices fill a gap by providing individual Soldiers and their immediate leadership with actionable physiological status information needed to ensure individual and squad health and performance [2].

In 2007 the researchers from the U.S. Army Research Institute of Environmental Medicine tests the Warfighter Physiological Status Monitor that allow to the medical personnel to monitor the critical vital signs of Warfighters on the battlefield or in training, it also has other uses [3].

Another technology is the Warfighter Physiological Status Monitor (WPSM) that provides commanders and medics with the ability to actively monitor vital signs, core temperatures, and skin temperatures. Based upon acoustic measurements, ballistic impact detection will be monitored [4].

The possibility to monitor patient vital signs at all levels in order to assess patient status and guide treatment and evacuation decisions increase the chance to save injured and wounded military personnel. For example the US Army includes vital signs monitors for different medical environments, including air ambulance, patient holding, forward surgical team, operating room, pre-op, and post-op intensive care [5].

This paper presents a system used for monitoring physiological parameters of soldiers during combat training and analyzing the data for detecting the stress level.

2.Materials and methods

Wearable monitoring devices allow continuous or intermittent monitoring of physiological signals. Some papers describe the development of a wearable physiologic signals monitor device capable to register ECG, NIBP, day life events, and oxygen saturation (SpO2) to record in a flash memory and transmission-reception via wireless communications [6].

The proposed system for vital signs monitoring during combat operations includes two essential components: *Soldier's Health Monitoring Device-SHMD* and *Combat Medical Support Station (CMSS)*. The SHMD is build using OEM module and custom developed hardware and application software. Low power amplifiers and transducers are connected to the device, for vital signs monitoring. The biomedical parameters acquired are: electrocardiogram (ECG), heart rhythm (HR) plethysmografic waveform, oxygen saturation (SpO2) and body temperature (T) [7, 8]. The CMSS receives all data through various communication channels (Internet Protocol link, GSM, GPRS etc). This information from the patient is processed and entered into a database. Also, the module includes a distribution platform based on a network protocol that facilitates the access of this data by the doctor and also has an alarm function [9, 10]. Warning messages are sent to the combat doctor.

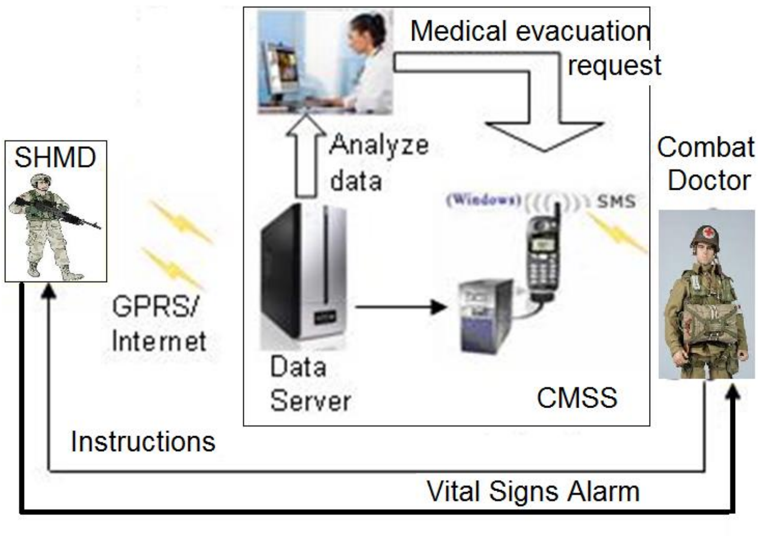

Fig.1 Diagram of monitoring system

The sensors for biosignals are fixed on a T-shirt that is wear by the soldiers under military equipment, in contact with the skin. All signals acquired are stored and processed by a medical device (named soldier's health monitoring device-SHMD) that compares these data with soldier's baseline sets of vital signs. If SHMD detects a significant statistical deviation from baseline is automatically activate the data transmission module that send to the combat medic the physiological status of the soldier and his localization.[11]

Fig.2 Subject wearing T-shirt with sensors

The combat medic can send all medical data using a secure transmission to a Combat Medical Support Station (CMSS) where will be establish a prioritization of medical needs and will be take the best decision for soldier's health.

The SHMD is able to acquire simultaneously the electrocardiogram (ECG), heart rate, plethysmografic waveform (PW), blood oxygenation (SpO2) and body temperature (T) and also to perform some digital signal processing on board. The signals are continuously recorded in separate files on flash memory for feature analysis. Once a significant statistical deviation from baseline is detected, the monitoring device requests a transmission to the CMSS. The communication between tasks allows a high level of parallelism between processes, each process may be individually enabled or disabled. This feature is very important in increasing the flexibility of the application because for real time monitoring SD Card Process may be disabled and Bluetooth Process is enabled. If no abnormality is detected then SD Card Process is enabled and Bluetooth Process may be disabled. This has a positive impact on power consumption because only the resources that are needed are enabled for use [8, 12].

3. Results

Cardiac rhythm analysis is more than just measuring heartbeats, being a complex method of interpreting multiple interactions that take place between the brain, the heart, and other systems of the human body.

It is important to understand that heart rate can be measured from two perspectives that provide different levels of information about the psychophysiological condition of the subject [13].

The most frequent interpretation of heart rate variability (HRV) involves the quantitative evaluation of this variability over a given time period. Although expressing this form of HRV is clearly an important element in this measurement, the rhythms and patterns contained in HRV are also largely influenced by the emotional component. Therefore, when analyzing HRV, it is necessary to evaluate how high this variability is (by the magnitude of the wave), but also the pattern of heart rate.

In addition, low levels of HRV are considered a psycho-physiological marker of emotional and psychological adjustment disorders. Thus, HRV is considered an important indicator that reflects the individual's ability to adapt effectively to stress and environmental requirements.

Another important observation is that HRV also varies with the time of day when measurements are made due to specific factors such as current emotional state, heart rate, and mental workload. It is precisely for these reasons that these measurements must be correlated with the other parameters purchased.

For this, we chose the HRV analysis both in time domain and in the frequency domain, followed by comparisons between the data obtained on different subjects.

For time domain analysis, the variation of the RR interval value during the recordings was represented, as shown in Figure 3.

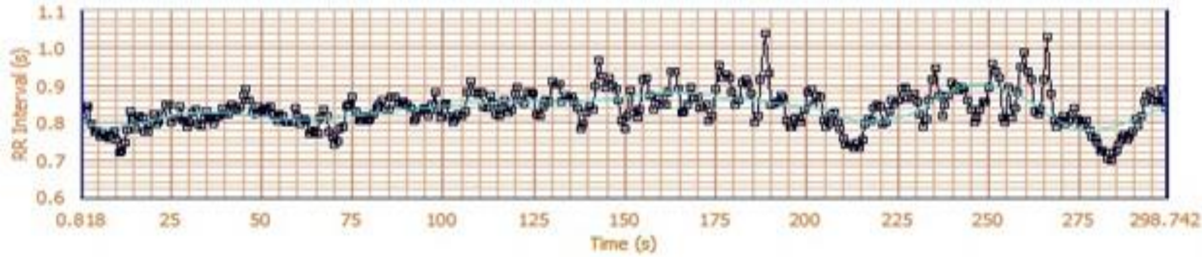

Fig.3. Variation of the RR interval

Histograms of RR interval values were also represented on each subject and each record.

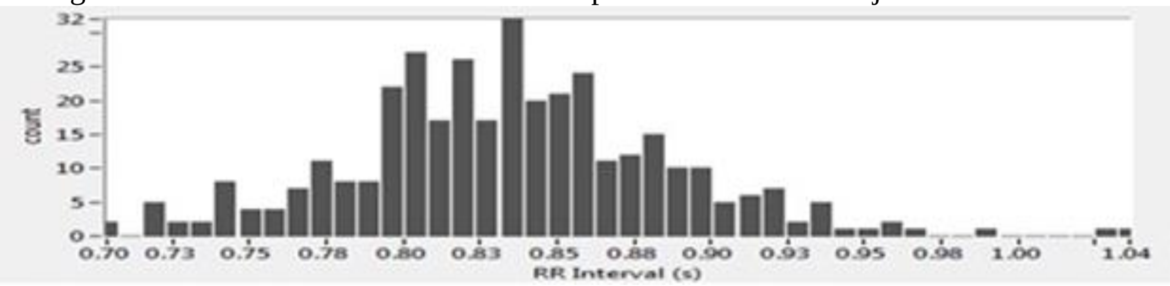

Fig.4 Sample of Histograms of RR interval

For the time domain analysis of the experimental data obtained, a series of statistical parameters such as RRmin, RRmax, RRmed, RRstd and RMSSD (Root Mean Square of the Successive Differences) were calculated.

The frequency array analysis of heart rate involves analyzing the spectrum of signal strength representing the R-R interval. From this signal, very low power spectra (VLF) (from 0.003-0.04 Hz), low frequencies (LF) (from 0.04-0.15 Hz) and high frequencies (HF) (range 0.15 -0.4 Hz) were extracted.

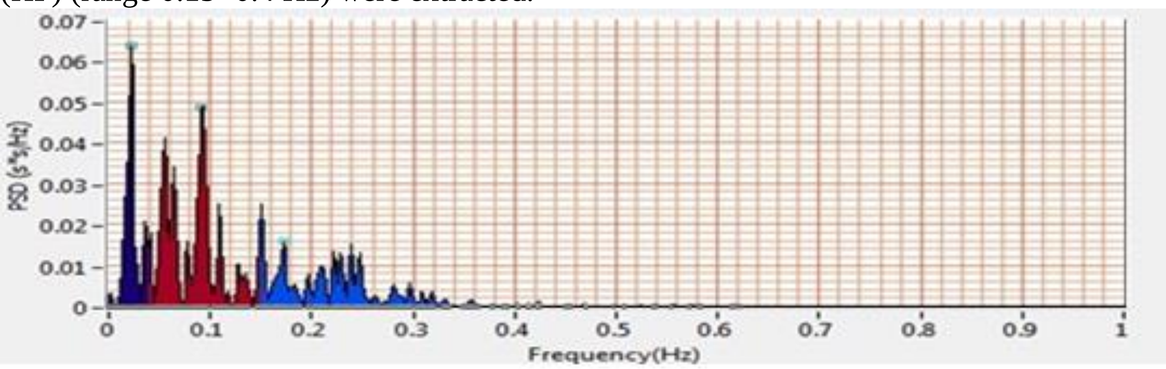

Fig.5 The frequency array analysis of heart rate

After extracting these parameters, the simpato-vagal index was calculated as the ratio between the LF component and the HF component. This index represents the influence of the nervous system on the body. A value greater then one of this ratio is a predominantly sympathetic influence, while a subunit report reveals a predominantly parasympathetic influence of the nervous system on the body.

4. Conclusion

In this paper we monitored some physiological parameters such as electrocardiogram (ECG) and heart rate (HR) of soldiers during combat training. We analyzed the HRV for detecting the stress level. We observed that HRV analysis could be a good instrument in evaluating the stress level of soldiers during training for combat actions.

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