Vital Parameter Sensing under Harsh Conditions

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A device for the recording of vital parameters required in the monitoring of exhaustion and adaptation at high altitude has been developed. The design and manufacturing has been achieved such as to provide reliable measurements under very harsh conditions by a mechanically robust and non obtrusive device. Tests achieved during a high altitude expedition in Tibet have confirmed reliability and robustness of the device.

Monitoring and analysis of adaptation and/or exhaustion during many sport activities, such as the ones conducted at high-altitude request the recording of several physiological parameters including heart rate (HR), activities of the autonomous nervous system and arterial oxygenation saturation (SpO2). Nevertheless commercially available multi-parameter devices with logging facilities are obtrusive, heavy and too fragile for the particularly harsh conditions as they appear in high altitude or on extreme expeditions in cold, humid or suffocating hot regions.

These requirements have motivated the development of a multi-parameter monitoring and recording device for extremely harsh conditions. The device consists of a central unit which contains data logging, recording, processing and displaying facilities and a red/infrared sensor. To comply with the requirements of harsh environments, two sensors have been developed. For normal conditions, a mechanically robust finger digit sensor has been designed as shown in figure 1. For extremely cold temperature where constrictive effects prohibit the accurate measurement of red and infrared blood properties at the finger digit, CSEM has developed a sensor for the forehead where blood perfusion is supported by a higher subcutaneous temperature due to a protective head band. Figure 2 highlights the forehead sensor manufactured such as to be maximally ergonomic due to its flexible structure.

Figure 1: Multi-parameter monitoring device with finger digit sensor

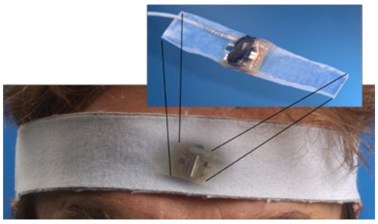

Figure 2: Flexible forehead sensor for cold temperature

The developed system has been tested during orthostatic tests (change from supine to upright posture) at low altitude and under extremely harsh conditions during a high altitude expedition in Tibet. A typical result of the orthostatic test, which is an important tool in exercise physiology for monitoring fatigue and exhaustion, is shown in Figure 3. As expected from the physiological point of view, one can note the changes in the activities of the autonomous nervous system in the time frequency analysis of the HR. Frequency components change from the parasympathetic or vagal band at about 0.25 Hz to sympathetic band at about 0.1 Hz as the posture changes from supine to upright. These changes are reflected in a quantitative manner by the sympatho-vagal balance which is the ratio of the power in the sympathetic and parasympathetic bands respectively.

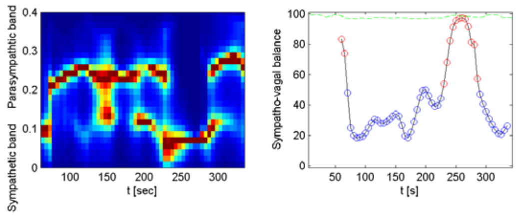

Figure 3: Time-frequency plot of the HR (right) and sympatho-vagal balance (left) during an orthostatic test (supine, upright and supine)

The tests at high altitude allow the monitoring of the subject's adaptation to altitude. During the acclimatization period of 36 days with temperature in the range from -25 to +30 degrees, the subject performed on a regular basis a 12 minute recording under supine baseline condition using the developed forehead sensor. Results shown in Figure 4 display the evolution of HR, sympathetic and vagal activity and SpO2 with respect to altitude. One can observe the acclimatization phenomena on the recorded vital parameters. An increase in altitude highlighted by dark-shaded segments is accompanied by an increase in HR and the sympatho-vagal balance and a decrease in SpO2. During adaptation phases highlighted by bright-shaded segments, vital parameters recover due to the physiological adaptation process even though altitude successively increases from 2000 m to 7200 m.

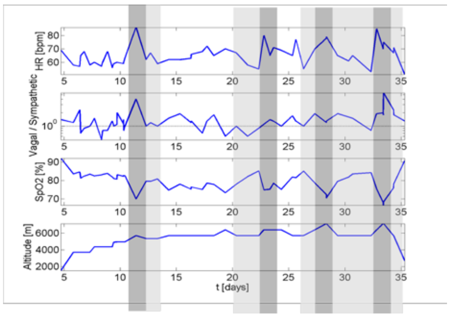

Figure 4: Analysis of vital parameter in supine resting condition during high altitude expedition (2700 m to 7200 m)

The presented tests under extremely harsh conditions have confirmed the robustness and reliability of the developed sensing unit. It is currently used in a joint collaboration with Dr C. Satori of the University Hospital of Lausanne (CHUV) in a monitoring application on a long lasting expedition through Mongolia, the mountains of Himalaya, the humidity of Burma and the suffocating heat of the desert of Australia.