Homeland Security
Science and Technology

TechNote

U.S. Department of Homeland Security
SAVER
System Assessment and Validation for Emergency Responders

The U.S. Department of Homeland Security (DHS) established the System Assessment and Validation for Emergency Responders (SAVER) Program to assist emergency responders making procurement decisions. Located within the Science and Technology Directorate (S&T) of DHS, the SAVER Program conducts objective assessments and validations on commercially available equipment and systems, and develops knowledge products that provide relevant equipment information to the emergency responder community.

SAVER Program knowledge products provide information on equipment that falls under the categories listed in the DHS Authorized Equipment List (AEL), focusing primarily on two main questions for the emergency responder community: "What equipment is available?" and "How does it perform?" These knowledge products are shared nationally with the responder community, providing a life- and cost-saving asset to DHS, as well as to Federal, state, and local responders.

The SAVER Program is managed by the National Urban Security Technology Laboratory (NUSTL), which also prepared this TechNote.

For more information on this and other technologies, contact the SAVER Program by e-mail or visit the SAVER website.

E-mail: NUSTL@hq.dhs.gov
Website: www.dhs.gov/science-and-technology/SAVER

Personal Physiological Monitoring Systems

Personal physiological monitoring systems (PPMS) allow for continuous, non-invasive monitoring of emergency responders' biometrics or vital signs including heart rate, blood pressure, respiratory rate, and body temperature. Some systems also include a GPS transponder to track the wearer's location. A basic system includes multiple sensors, a transmitter, a receiver, and a software application to display the measurements required for diagnosis. Sensors can be integrated into electrodes, wristbands, duty uniforms and personal protective equipment (PPE). PPMS for first responders should be compact so as not to hinder mobility but also robust to withstand environmental or other damage. Systems with sensors integrated into clothing should be machine washable for long term continued usage. Since PPMS can also be used for patient care, they may be subject to U.S. Food and Drug Administration (FDA) regulations such as Section 510(k) of the Food, Drug, and Cosmetic Act.

Applications

Figure 1. Sensor belt (left) and sensor electronics module (right)

Figure courtesy of Philips Respironics

Field usage of PPMS may prevent or reduce line-of-duty injuries and deaths, especially those caused by cardiovascular events. Due to a demanding physical workload and extreme environmental hazards, firefighters would benefit the most from PPMS; however, the technology is also applicable to disciplines such as law enforcement and medical services. Baseline data can be collected for individual responders by wearing sensors while performing everyday activities. An overall readiness index can be calculated with this data to help determine which personnel to dispatch to an emergency scene. During a response, an incident commander can remotely monitor the vital signs of active responders. Automated comparison of these measurements with previously recorded data can identify warning signs for overexertion and loss of consciousness, allowing for rotation of personnel by health status rather than by arbitrary shift changes. Physiological monitoring can also be applied in training environments to prevent overtraining, reduce injuries and assist in performance evaluation of individual personnel. Insights gained from monitoring responders during training exercises, and even during actual responses, can stimulate improvements in the training, fitness and rehabilitation programs of responder organizations.

Sensors and Platforms

Heart Rate

Heart rate, measured in beats per minute, is the most essential vital sign. Changes in heart rate can indicate changes in the level of physical activity. Heart rate can be derived from either electrocardiography (ECG) or photoplethysmography (PPG). ECG measures the electrical activity of the heart through electrodes attached to various parts of the body with an electrically conductive gel. ECG electrodes can be integrated into athletic wear such as compression shirts. PPG measures the light absorbed by the skin to determine changes in the volume of blood vessels. An LED illuminates an area in which blood vessels are visible through the skin and a photodiode measures reflected light. PPG devices are usually integrated into wristbands or clip-on monitors. Blood pressure can also be measured through PPG, though this method is not widely used. Errors in heart rate measurements are usually caused by improper placement of sensors. In commercially available systems, this occurs more frequently with PPG wristband systems.

Respiratory Rate

Respiratory rate, measured in breaths per minute, can indicate several medical conditions including respiratory dysfunction and anxiety. Respiratory rate is measured by respiratory inductance plethysmography (RIP). This is similar to PPG in that it measures changes in the volume of vital organs (in this case, the lungs). An electrical signal is sent through bands worn around the chest and abdomen. The expansion and contraction of the torso and diaphragm changes the inductance of the bands and the frequency of the signal. RIP bands are often integrated into athletic wear.

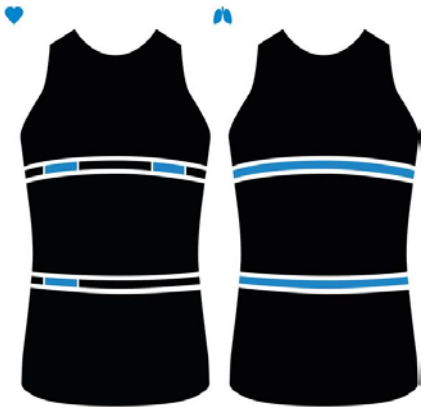

Figure 2. Heart rate (left) and respiratory rate (right) sensor locations

Figure courtesy of Hexoskin

Body Temperature

Abnormal body temperature can indicate the body's response to adverse environmental conditions, such as heat exhaustion. Although rectal, oral and axillary (under the arm) measurements produce the greatest accuracy, these methods severely limit mobility. Instead, body temperature can be measured in various ways including infrared (IR) thermometers in clip-on monitors and wristbands, sensors enclosed within ingestible capsules and electrodes containing thermistors or other heat-variant electrical components (similar to ECG) and integrated into athletic wear.

Software Integration

A key feature of many commercial PPMS is a software application which records biometrics and tracks performance progress. This feature presents situationally relevant data allowing responders to quickly diagnose any adverse conditions. Systems can transmit data over a wireless protocol, such as Bluetooth, for live monitoring or log data to internal or removable memory for future analysis. Some applications will also send alerts to other applications if adverse readings are detected. An already existing wireless capability in these devices also allows for easier integration into responder communications systems.

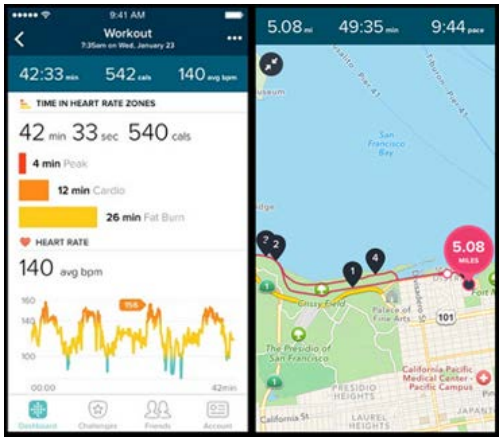

Figure 3. Screenshots of mobile application

Figure courtesy of Fitbit

References

- *U.S. Food and Drug Administration*: http://www.fda.gov/MedicalDevices/ProductsandMedicalProcedures/DeviceApprovalsandClearances/510kClearances/
- *Pacific Northwest National Laboratory*: http://nwrtc.pnnl.gov/PDFs/RemotePhysiologicalHealthandStatusMonitoringofFirstRespondersR13.pdf