From health issues associated with aging populations to the emergence of more virulent diseases, the demand for easily deployable diagnostic tools is great. Spectroscopy is a noninvasive measurement technique well suited to meet our evolving health monitoring needs.

In this overview, we take a look at some typical applications of spectroscopy for health monitoring and demonstrate how simple skin reflectance measurements reveal a surprising level of spectral data related to hemoglobin and skin tone.

Optical sensing technologies for health monitoring have undergone remarkable advances over the last decade, to a level where you can place your finger over a smartphone camera and measure your heart rate. This makes perfect sense – after all, light interacting with tissue, blood and other biological samples reveals an abundance of detailed information. And it does it all noninvasively, in real time, and often, at lower costs per measurement than other methods.
Modular spectroscopy allows users to take the measurement to the sample, making it attractive for all sorts of health applications. Generally, portability is highly desirable for health monitoring, for a number of reasons. Wearable devices let us monitor different fitness criteria wherever we go. Sophisticated diagnostic instrumentation using miniature spectrometers and optical sensors is now small enough to fit into a backpack or carrying case, allowing it to be transported to remote locations to diagnose disease, triage patients and save lives. Health monitoring is not just limited to the hospital, doctor’s office or diagnostic lab. It is happening all around us in locations we never imagined possible.

**Experiment Details**

The reflection probe (QR400-7-VIS-BX) was placed in the reflection probe holder (RPH-1) at a 90 degree sampling geometry. A setscrew was used to hold the probe in the holder with the tip of the probe flush with the surface of the sample holder. The probe was placed in the sample holder to maintain a constant angle during the measurement and to keep the probe from depressing the skin too deeply. A diffuse reflection standard (WS-1) was used as the reference for the measurements.

We measured skin reflectance at the palm, neck and forearm. The palm reflection measurements were made from the center of the palm after clenching and releasing a fist to change blood flow. OceanView software was programmed to acquire every spectrum for ~30 seconds to capture the change in reflection as the blood flow returned to normal in the palm.

Reflection was measured from the neck with the probe placed in the vicinity of the carotid artery (same area where the pulse is usually taken). Also, reflection was measured on the dorsal forearm, with the probe placed where the hand and forearm meet and the probe holder extended along the same axis as the forearm (see Figure 1). The top of the forearm gets a lot of sun exposure, so the reflection results may have been affected by how tan someone was. Future studies should be done on the ventral forearm (palm facing up) or any other area that gets less sun exposure.

As shown in Figure 2, the shape of the reflection spectrum changed dramatically after the fist unclenched. The
top spectrum was the first spectrum acquired just after releasing the fist. It is relatively flat compared with the spectra acquired in the 15 seconds after the fist was released. The spectral features observed in the later spectra show a consistent downward trend and strong features associated with hemoglobin. These spectral features arise from the interaction of light with the blood vessels beneath the skin. As the fist is released, there is an increase in blood flow to the palm. The presence of oxygenated blood gives rise to the hemoglobin peaks observed in the later measurements. These spectral features, acquired with a relatively simple modular setup, are the same features used for health monitoring including blood oxygen saturation, heart rate and pulse rate.

Figure 2. As the clenched fist is released, increased blood flow to the palm is observed in its hemoglobin peaks.

**Neck Reflectance Measurements**

Reflection spectra were measured in the vicinity of the carotid artery from the necks of individuals with different skin tones (Figure 3). Neck R had the lightest skin tone and Neck C had the darkest skin tone. As shown in the spectral data, the darker the subject’s skin tone the more difficult it was to discern the same level of hemoglobin peaks. With the darker skin tones, the absorbance of the skin pigment melanin and other skin components masked the hemoglobin peaks that were more easily observed in the reflection spectra acquired for subjects with light skin tones.

Figure 3. In darker skin tone subjects, the absorbance of melanin helped to mask hemoglobin peaks detected more readily in lighter skin tone subjects.

**Dorsal Forearm Reflectance**

Reflection spectra also were measured from the forearm of individuals with different skin tones (Figure 4). Forearm R had the lightest skin tone and Forearm C had the darkest skin tone. As shown in the spectral data, the darker the skin tone the lower the reflection from the forearm. The absence of the strong hemoglobin peaks in these spectra relative to the neck spectra likely results from smaller blood vessels in this region and the presence of tissue components that mask the hemoglobin spectral features.

Figure 4. Reflectance measurements of the dorsal forearm varied by skin tone and the presence of tissue components.
Our skin reflectance experiments were accomplished relatively easily, outside of a rigorously controlled lab setting, yet still produced results from which to draw some reasonable conclusions. Ocean Optics customers have performed very similar skin reflectance measurements for potentially life-changing advances in characterizing the ageing of bruises in abuse victims and in monitoring bilirubin concentration in neonates.

The implications for spectroscopy that is applied to biomedical challenges and medical diagnostics are significant. Even as new medical breakthroughs inspire applications we can’t yet imagine, flexible instrumentation such as miniature, modular spectrometers can be updated and improved to keep up. In addition, there are newer detection technologies – advanced filter-based techniques, for example – that may reshape how we think of spectroscopy. Although it’s become almost a cliché to mention the Star Trek tricorder as an example of science fiction edging closer to science fact, the reality is that what once seemed fantastical is now firmly in the realm of possibility.

Contact us today for more information on setting up your spectroscopy system from Ocean Optics.