Many debilitating skin conditions begin with the same, seemingly innocuous symptom – erythema. As blood flow in capillaries close to the surface increases, the skin tissue becomes red, though it blanches to white with finger pressure. Erythema occurs with any kind of skin injury, infection or inflammation, and yet there is no objective measure for this symptom to aid in diagnosis and assessment of treatment efficacy. A research study at the University of Missouri sought to change this, looking specifically at the ability of visible reflectance spectroscopy to detect the effect of wearing copper socks on erythema[1].

Keywords
• Erythema index
• Copper-embedded socks
• Peak parameters

Techniques
• Reflectance spectroscopy
• Diffuse reflectance

Applications
• Noninvasive medical diagnostics
• Skin tissue analysis

Alleviating Erythema in Athletes’ Feet
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Background
Erythema of the feet is a pressing problem, as the friction between sock and foot can exacerbate foot pathologies like contact dermatitis, edema, blisters and sores. This issue has greater significance for a few specific groups, including athletes, amputees, the elderly and diabetics. In athletes, the presence of moisture increases the friction, leading to blisters that can impact performance. For amputees, skin trauma beneath the prosthetic sock has the potential to get infected, or at the very least compromise prosthetic comfort. In the elderly, thinning of the dermis as connective tissue loses strength and elasticity makes the tissue more prone to damage and slower to heal. This is
even more serious for diabetics, for whom lower immunity and nerve response allow ulcers to easily develop and go undetected.

Since sock materials are known to play a significant role on friction and blister formation, it has been proposed that wearing copper impregnated socks could reduce or eliminate erythema. Copper is known to have antibacterial, antifungal and antiviral properties, and is believed to speed wound healing. While studies have been performed to support the use of copper socks to treat athlete’s foot (tinea pedis)[2], they were based on visual assessments rather than measurement. Use of visible reflectance spectroscopy has the potential to assist clinicians in making objective measurements of erythema to assist diagnosis and treatment, and eliminate factors like melanin and skin tone in evaluation.

Visible reflectance spectroscopy is already widely used as a rapid, noninvasive diagnostic tool for skin characterization, being a relatively inexpensive research tool. By measuring the reflectance of skin at visible wavelengths (400-800 nm) and fitting the data to a model for the diffusion of light through skin for both healthy and pathological tissue, an erythema index was developed to quantify the impact of wearing copper socks.

### Experiment

An HR2000 spectrometer was configured for use in reflectance mode, using an integrating sphere with built-in tungsten halogen lamp as both light source and sampling optic (similar to the ISP-REF). The integrating sphere was placed in contact with the skin, sampling a 10 mm diameter area. A diffuse reflectance standard was used as a reference (WS-1). Measurements were taken with an integration time of 10 ms, averaging 128 scans.

Spectra were collected to cover the erythema range of interest from 500-820 nm, probing the chromophores and structures present within the dermis (top 50-100 µm) as well as the thicker epidermis beneath. Light incident upon the skin at these wavelengths is not only reflected from the surface, but also penetrates into the tissue, being scattered and absorbed by the various components. The behavior of light in skin tissue can be modeled via diffusion theory, which mathematically captures the process of light scattering multiple times before possibly being absorbed by a chromophore like hemoglobin, oxyhemoglobin or melanin. Many photons are lost to additional scattering within the tissue, while a fraction make their way back to the collection port of the integrating sphere for measurement.

The double-blind study looked at two groups of healthy, non-diabetic volunteers in turn. The first group of elderly subjects were assigned either copper socks to wear daily or identical, non-copper socks as a control, and were measured biweekly for 12 weeks. The second group of subjects, all between the ages of 18 and 35, wore one of each sock type; they were measured every three days for two weeks. The spectra collected were fitted to a diffusion model based on Svaaasand et al, 1995[3], a two layer model in which absorption is due primarily to a combination of melanin and oxygenated and deoxygenated hemoglobin. As these parameters were varied, the fit of the diffusion theory curve to the visible reflectance spectroscopy (VRS) curve could be optimized, as shown. An erythema index was then defined as the total volume fraction of blood, oxygenated and deoxygenated, determined from the curve fit (540 nm and 560 nm, respectively).

The erythema index was then used to plot a linear regression line for each subject over time (and for each foot in the case of the younger subjects wearing one each of control and copper socks). These plots are shown at the top of the next page. Some elderly subjects wearing the copper socks showed a reduction in erythema over time (upper plots), while others did not.
As a group, however, the slopes determined for the erythema index over time for the elderly subjects wearing copper socks did not differ significantly from those in the control group, as analyzed by one-way ANOVA and unpaired T-tests. The same was found for the younger group of subjects. This may have been due to the lack of significant erythema in the subjects at the beginning of the study, or to the relatively small sample size in both groups. Other factors such as compliance and access to the elderly subjects also may have contributed to the lack of significant differences, as well as specific health and age factors in the diffusion theory model used.

As is often the case in scientific research, each study performed serves to identify the important parameters that must be controlled in the work, in order to refine models and provide insight into next steps. These efforts to develop an erythema index based on diffuse reflectance spectroscopy lay a good foundation for further work into the objective clinical detection of erythema as a key symptom of many debilitating skin conditions. With more objective assessment of individual patients’ clinical status and progress, the treatment of skin pathologies for athletes, diabetics and the elderly can be improved to reduce the prevalence of complications and even amputations.

References


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