Leading Edge

# Sun Exposure and Physical Activity: The Valuable Role of UV Wearables

**Alyssa Henning**
School for Engineering of Matter, Transport, and Energy and School for the Future of Innovation in Society, Arizona State University, Tempe, AZ 85281 USA

**Jennifer Vanos**
School of Sustainability, Arizona State University, Tempe, AZ 85281 USA

**Nathan Downs**
School of Sciences, University of Southern Queensland, Toowoomba, QLD 4350, Australia

**Skin cancers are** one of the most common types of cancer in the United States [1], and melanoma has steadily increased over the last 20 years. Solar ultraviolet radiation (UVR) is known as the main cause of damaging effects to the skin [1], [2], yet also the most preventable risk factor. Outdoor physical activity, an important health behavior, exposes the body to UVR and is thus ostensibly linked to increases the risk of sunburn, melanoma, and non-melanoma skin cancers [3], [4]. Simultaneously, new UVR sensors can play an essential role in ensuring users gain enough sunlight for Vitamin D synthesis for optimal health. However, accurately monitoring personal UVR exposure is historically complex and costly, and thus minimal research exists at the intersection of personal UVR exposure during physical activity.

Due to these above concerns, the wearable industry is responding to the needs of researchers and consumers with improved UV-wearable technologies. Recent years have seen an influx of new technologies with wide-ranging form factors, uses, and target audiences. Some of these wearables are part of the same consumer-based industry that has emerged for smartwatches, fitness trackers, and running watches that work in tandem with smartphones, tablets, and computers [5], [6] (e.g., Figure 1). Other advances involve color-changing (photochromic) adhesives or wristbands.

This leading-edge piece introduces current and past personal UVR sensing technologies, specifically the critical attributes, uses, and availability for successful use. This piece also aims to help future researchers involved in personal UVR exposure studies understand sensor attributes and specifications that are most appropriate for their given application and sampling needs.

Various novel aspects of currently available UVR-sensing wearables include practical and actionable data displays for behavioral change, Bluetooth connectivity, sensor programming, and user-specific applications often relying on a smartphone. These attributes may influence and motivate future sensor development and research studies, such as advanced personal applications for behavioral risk reductions balanced with physical activity in the outdoor environment for overall health and skin cancer prevention.

Here, we provide a list and brief overview of 13 wearable UV dosimeters identified as available for purchase using primary and grey literature. Of these, four electronic sensors provide UVR doses on the wearable itself, and six are photochromic. Three wearables must use secondary devices or laboratory analysis to obtain a dose value (film-based and Scienterra dosimeters), and they are

*Digital Object Identifier 10.1109/MTS.2021.3101927*
*Date of current version: 2 September 2021.*

**Figure 1. Novel wearable sensing technologies, often connected to a smartphone, allow users to monitor optimal exposures to sunlight for health.**

thus not "real-time" and would not be fit for behavioral research or public use. The various commercial UV sensors that are available span form factor, target audience, and cost and are divided into four main categories.

**1a) Electronic consumer-based, predominantly public use, or behavioral research[1]**

- Eclipse Rx measures % total exposure and provides real-time UV index (UVI) with additional alerts when reaching user-specific limits (~$299).
- My Skin Track UV measures % "max sunstock" as well as UVI; uses near-field communication (NFC) (~$60).
- QSun wearables provide a time to sunburn as well as real-time UVI, with additional alerts when reaching user-specific limits (~$149).

**1b) Electronic broad research and consumer-based applications**

- The shade UV sensor provides "UV Units," calculates a % daily limit, and outputs real-time UVI on a cell phone (~$500). Shade has three available cell phone apps depending on their use.

**2) Electronic physical or clinical research only**

- The Scienterra Dosimeter, version 2, is a high-end research-based sensor providing an erythemally weighted UV exposure at high accuracy and user-based intervals, yet post-collection data download in the given model (V2) (~$300).

[1] Note: All four above use proprietary formulas (e.g., for "UV Units," "max sunstock," and so on).

**3) Photochromic: consumer- and research-based**

- *Adhesives:* LogicInk Sun Signals ($4 each), SPOT-MYUV ($1), SmartSun UV, Sunburn Alert (<$1).
- *Wristbands:* Smartsun UV, Sunburn Alert (<$1).

**4) Film-based: physical or clinical research only**

- Polysulfone (PS) dosimeter clip-on, requires lab analysis, require calibration, most used in historical studies ($0.5).
- VioSpor dosimeters (wristband) require lab analysis ($48).

Most *electronic* wearables are waterproof or water-resistant, provide real-time information, and are Bluetooth-enabled or use NFC. They thus depend on a smart device and App (apart from Scienterra), which may be an additional cost. The four top electronic sensors also have value-added functions such as sunscreen reminders, monitoring step count (Eclipse Rx), adding in local weather information (MySkin Track UV, QSun), and estimating Vitamin D synthesis (Qsun). *Photochromic* (color-changing) sensors (adhesive or wristband) are one-time use and low-cost ($4 each), and they can be valuable for behavioral research. These sensors interact with sunscreen and notify the user of their cumulative UV dose, hence giving a visual indication of when they need to reapply sunscreen, cover up, or step out of the sun. The Scienterra electronic dosimeters, polysulfone dosimeters, and VioSpor *B. subtilis* spore-based sensors require specific software, calibration, and/or spectrophotometry equipment to interpret their UVR outputs and are valuable for human-based clinical research studies.

The personal health and sensor revolution is continually shifting with novel technologies allowing person-centric UVR measurements. Each has a specific and intended use, and such data can aid users and researchers alike in assessing, understanding, and/or taking action to receive appropriate amounts of UV light. Such information can be particularly valuable for users at higher risk.

Appropriate selection of a given sensor for research can allow investigation of subjects' sun-protective behavior practices and general interactions with wearable sensors, as well as the development of personal UV prediction models.

**While the pace** of change in wearable sensing devices is ever increasing, these wearable UVR sensors currently provide multiple options for measuring personal UVR exposure during activity and/or advanced research studies. ■

## References


[1] American Cancer Society, "Cancer Facts and Figures 2021," Atlanta, GA, USA, 2021, pp. 13–15.

[2] American Cancer Society. (2021). *Basal and Squamous Cell Skin Cancer Risk Factors*. [Online]. Available: https://www.cancer.org/cancer/basal-and-squamous-cell-skin-cancer/causes-risks-prevention/risk-factors.html

[3] *Physical Activity Guidelines Advisory Committee Report, 2008*, Phys. Activity Guidelines Advisory Committee, Washington, DC, USA, 2008. Accessed: Sep. 26, 2019. [Online]. Available: https://health.gov/paguidelines/2008/report/pdf/CommitteeReport.pdf

[4] I.-M. Lee et al., "Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy," *Lancet*, vol. 380, no. 9838, pp. 29–219, Jul. 2012, doi: 10.1016/S0140-6736(12)61031-9.

[5] R. Rawassizadeh, B. A. Price, and M. Petre, "Wearables: Has the age of smartwatches finally arrived?" *Commun. ACM*, vol. 58, no. 1, pp. 45–47, 2015, doi: 10.1145/2629633.

[6] A. Henriksen et al., "Using fitness trackers and smartwatches to measure physical activity in research: Analysis of consumer wrist-worn wearables," *J. Med. Internet Res.*, vol. 20, no. 3, p. e110, Mar. 2018, doi: 10.2196/jmir.9157.



**Alyssa Henning** is currently pursuing the Ph.D. degree with the School for the Engineering of Matter, Transport, and Energy and the School for the Future of Innovation in Society, Arizona State University.

**Jennifer Vanos** is an Assistant Professor with the School of Sustainability, Arizona State University.

**Nathan Downs** is a Senior Lecturer with the School of Sciences, University of Southern Queensland.

■ Direct questions and comments about this article to Jennifer Vanos, School of Sustainability, Arizona State University, AZ, USA; jvanos@asu.edu.