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Commentary

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Commentary: Solar Ultraviolet Exposure in Individuals Who Perform Outdoor Sport Activities

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Ultraviolet radiation (UVR, 100-400nm) represents a portion of the electromagnetic spectrum between the wavelengths of visible light (400nm-700nm) and x-radiation (400 nm - 100pm). UV energy is further divided into UVA (315nm-400nm), UVB (280nm-315nm), and UVC (100nm-280nm) based on wavelength and energy. Certain molecules, or chromophores, within the skin are known to absorb energy within the UVR range and are responsible for biologic responses to UVR. These molecules include DNA and other nucleic acids, urocanic acid, aromatic amino acids, and melanins.[1]

As synthesized by Snyder, et. al., UV is measured by the minimal erythema dose (MED), which is the amount of UV exposure that causes erythema within 8 –24 hours, i.e., sunburn. While this is dependent on many individual factors, including Fitzpatrick skin type, during the summer in the U.S. it only takes 12 –15 minutes to achieve erythema ranges.[2] There are exogenous chromophores known to absorb UVR, such as those included in sunscreens, that can be used to attenuate the biologic effects of UVR on the skin.[1] Sun protective clothing, including long sleeves and hats, may be used to block UVR absorption altogether. Many smart phone applications (apps) for tracking UV exposure have also been developed in recent years.[3]

Terrestrial ambient sunlight consists primarily of UVA (90-95%) and UVB (5-10%).[4] In 2016, nearly half of all Americans participated in outdoor leisure activities such as jogging and running. This includes children, who spend substantial amounts of time outdoors until adolescence or early adulthood. Time spent outdoors for sporting activities increases again in the late 20s for females, and early 30s for males, before gradually declining throughout life.[5]

The amount of UVR a person is exposed to outdoors varies depending on their geographic location, the solar zenith relative to orientation of the exposed anatomical site,[6] the season, and the level of UVR reflectance from surrounding terrains such as snow or water.[7] The spectrum and intensity of UVR may also be affected by absorption and scattering by molecules in the atmosphere, such as ozone, and cloud cover.[8] Naturally, UVR exposure also differs by sport among athletes due to the unique combination of these factors.

UVR's ability to damage DNA in the skin leads to mutations that contribute substantially to skin cancer development.[9] About 90% of keratinocyte cancers (KCs), the most common form of cancer in the United States (US), arise in part due to exposure to UVR;[10] an estimated 5.4 million Americans are diagnosed with KC each year.[11,12] While it is clear cumulative UVR exposure increases risk for developing KC, it has been suggested that the number and severity of sun burns across the lifetime increases risk for melanoma, as well.[13-15] It has been suggested that increased UVR is associated with an increased number of atypical nevi, which may in turn be associated with cutaneous melanoma. Snyder, et. al., found the number of nevi, atypical nevi, and solar lentigines to be significantly increased in outdoor sports participants.[2]

However, UVR does have some important benefits, including the cutaneous synthesis of vitamin D_3, which occurs along the absorption spectra of UVB.[16] Deficient vitamin D levels have been implicated in a wide range of diseases from cancer to diabetes.[17] A 2014 meta-analysis concluded that 12.8% of all deaths in the US could be attributed to low serum vitamin D levels.[18] Recently we have learned that there other beneficial cutaneous mediators released upon exposure to UVR. It is a complex interplay of these molecules that enact the benefits of UVR, rather than the actions of vitamin D alone.[18] While sun exposure can certainly be beneficial, great care must be taken to balance the UVR risk-benefit ratio.

The UV Index (UVI) was developed by the WHO and is a globally recognized measure of UVR intensity. Factors influencing UV intensity include the time of day/year, geographic location, altitude, cloud coverage, and surface reflection.[13] Skin cancer incidence rates in the U.S. increase along the latitudinal gradient.[2] UVI is a readily accessible and free method to predict UV exposure and risk for sunburn,[13] therefore it could be utilized to decrease skin cancer risk. UVI can be measured using chemical films, biologic films, and electronic methods such as dosimeters, sun journals, and UV exposure apps that provide a geo-specific UVI to approximate UV exposure risk, though cost of measuring UV may vary by the specific measurement method employed.[2] However, there is generally poor public understanding and awareness of UVI.[2,13]

The 2020 review article by Snyder, et. al., highlights the opportunity for modern technology, such as the utilization of smart phone apps, to enhance sun hygiene among outdoor leisure-goers and athletes.[2] Such apps have the potential to be used for primary skin cancer prevention by enhancing sun safe behaviors[19]; thus, it is important to consider educating outdoor leisure-goers on relevant mobile technology as an adjunct to education by providers. In January 2022, we searched the Apple (Cupertino, CA) and Android (Google, Menlo Park, CA) app stores for applications that provide UV tracking.[3] Search terms included "ultraviolet," "ultraviolet radiation," UV," "UVI," and "UVR." In this commentary, we highlight the various categories of apps that may be useful to athletes and outdoor leisure-goers interested in tracking their UVR.

UVI Tracking

The most simplistic of apps available for download on smart phones solely provide the current UVI (Table 1). These types of apps allow users to either adjust settings to view the UVI on their phone's home screen, or simply display the current UVI based on GPS location when opened. Several display a UVI scale along with the current UVI. UVI scales are typically paired with broad sun safety recommendations based on the UVI categories of low, moderate to high, and very high to extreme. Some apps will also provide daily updates and alert users when the UVI is 3 or greater, which is the threshold for moderate to high UVI.[20]

UVI + UV Forecast

This category of apps expands upon simple UVI tracking by offering users UV forecasting (Table 1). These apps display the UVI scale with generalized sun safety recommendations based on current UVI. Again, these apps provide push notifications during times of very high and extreme UVI, reminding users to re-apply sunscreen and setting timers to avoid UVR over-exposure.

Personalized UVI Apps

A number of apps are available that combine UVI with user phototype to provide personalized recommendations to promote sun smart behaviors (Table 2). The most basic of these apps provide recommendations based solely on phototype and current UVI. Similar, but slightly more advanced, apps allow users to set custom UV alerts or utilize phototype and level of SPF applied to determine maximum sun exposure durations. Other apps determine burn risk, provide sunscreen calculators, and send users sunscreen reminders.

UVI + Vitamin D

While minimizing UV exposure offers protection from the potential development of skin cancers, it comes with the risk of lowering vitamin D levels, as the synthesis of active vitamin D is catalyzed by exposure to UVR.[13] To maximize the risk-benefit ratio of UVR exposure, this category of apps focuses on providing a balance between sun exposure and vitamin D levels (Table 3). These apps set objectives for users on their daily intake of Vitamin D, as well as sun safety measures based on Fitzpatrick skin phototype and UVI. Some include the use of facial recognition to further individualize recommendations based on "skin age" and health, while other alert users of how long they should stay outdoors and provide warnings when time limits are exceeded.

Table 1. Basic UVI Apps

App Category	App Name	Developer	Platform	Cost	Features
UVI Tracking					
	Fizz Weather	Fizz Software Ltd.	iOS	$0.99	Displays UVI
	Simple UV Index	Momotech	Android	Free	Displays UVI
	UV-INDEKS	Kraeftens Bekaemelse	Android	Free	UVI Scale Generalized sun safety recommendations Impact of cloud cover on UVI Alerts when UVI is ≥ 3
	UV Index – UV	Patrick Giudicelli	Android	Free	UVI Scale Generalized sun safety recommendations
	UV Meter	Kyu Tae Park	iOS	$0.99	UVI Scale Generalized sun safety recommendations
	Weather Clock Widget	Elecont LLC	iOS	Free	Displays UVI
UVI + UV Forecast					
	EPA's SunWise UV Index	U.S. Environmental Protection Agency	iOS and Android	Free	UVI Scale Generalized sun safety recommendations UV Forecast
	TANtastic UV	Paper Street Productions, LLC	iOS	Free	UVI Scale UV Forecast Push notifications for very high, extreme UVI Alerts to reapply sunscreen, reposition if sunbathing Timers to avoid over-exposure to UVR
	UV index – Tracker and Forecast	Bjorn Jenssen	iOS and Android	Free	UVI Scale Generalized sun safety recommendations UV Forecast

Table 2. Personalized UVI Apps

App Name	Developer	Platform	Cost	Features
SunSmart Global UV	Cancer Council Vic.	iOS and Android	Free	Personalized sun protection based on UVI, skin type Sunscreen calculator Estimate of how long users can remain in the sun safely
UV Index	Monirapps	Android	Free	Personalized sun protection based on UVI, skin type Personalized maximum exposure time
UV Index – Easy. Powerful	Zach Farley	iOS	Free	Personalized sun protection based on UVI, skin type Personalized maximum exposure time Set custom UV alerts
UV Index global	SulApp	Android	Free	Personalized sun protection based on UVI, skin type Determines burn risk, time to burn without protection Provides sunscreen reminders
UV Lens – UV Index	Spark64	iOS and Android	Free	Personalized sun protection based on UVI, skin type Determines burn risk, time to burn without protection Provides sunscreen reminders
Uvlower	Mopius Mobile GmbH	Android	Free	Personalized sun protection based on UVI, skin type Personalized maximum exposure time based on skin type and SPF applied
Wolfram Sun Exposure Reference App	Wolfram Group LLC	iOS and Android	$0.99	Personalized sun protection based on UVI, skin type Sunscreen calculator Estimate of how long users can remain in the sun safely

Table 3. UVI Apps that track Vitamin D

App Name	Developer	Platform	Cost	Features
D Minder	ontometrics	iOS and Android	Free	Personalized sun protection based on UVI, skin type UV Forecast Reminder to reapply sunscreen Alerts users how long they can remain outdoors Vitamin D intake tracker Smartwatch integration
QSun	Comfable Inc.	iOS and Android	Free	Personalized sun protection based on UVI, skin type, and facial recognition UV Forecast Reminder to reapply sunscreen Vitamin D intake tracker
UVI Mate	Full Stack Cafe	iOS and Android	Free	Personalized sun protection based on UVI, skin type UV Forecast Reminder to reapply sunscreen Vitamin D intake tracker Smart watch integration

Multi-Modal Apps

The most advanced apps integrate UVI technology between smart phone and other devices. "My Skin Track UV (iOS and android)" combines a battery-free wearable electronic sensor that links to an accompanying smart phone app. Within the smart phone app, real-time UV exposure is tracked, and users are provided with personalized "healthy skin" tips. "Sunbeam (iOS + apple watch)" integrate to display the UV index on user watch faces and monitor cumulative UV exposure. This data is integrated with user phototype, allowing the combo app to estimate vitamin D levels and provide sunburn exposure timers. "D minder" (Table 3) can also be integrated with smart watch devices.

Discussion

As synthesized by the 2020 systematic review by Snyder, et. al., to effectively prompt modification of sun protective behaviors, it is important to provide effective, modern instruction and educational support. Apps that monitor UVR have the potential to be incorporated into the clinician's educational repertoire in such a manner. As the younger population continues to turn away from traditional media methods, and more of the general population depends on technology in their daily routines, it is useful to provide technology-based delivery of health interventions that can be incorporated into daily hygiene routines.[21] A large number of smart phone apps for tracking UV exposure have been developed in recent years. However, not all UV smart phone apps are created equal; most apps simply provide UVI and forecast information. Much of the public does not understand what UVI means and are prone to underpredict their erythemal risk.[22-24] As such, there is a need for smart phone apps that utilize UVI and user characteristics to provide personalized recommendations that the public are able to understand without the need to interpret the UVI. Several systematic reviews suggest that personalized apps may have the potential to be effective in reinforcing appropriate sun safe behaviors, where apps without this feature have failed during prior investigations.[2,25,26]

The success of the SunSmart app, which has greater than 300,000 downloads, is attributed to Australia's massive public health effort aimed at raising skin cancer awareness rather than from user understanding of the UV forecast.[2] A handful of randomized controlled trials (RCTs) have demonstrated potential for success when app design follows the "Personalized" and "Multi-Modal" categories of UV apps described above, and when governmental public health campaign support is sought.[27-30] However, systematic reviews have shown mixed results regarding the use of messaging to increase comprehension of UVI and sun protective behaviors such as sunscreen use; wearing protective clothing like tightly woven long clothing, hats, and sunglasses; and seeking shade during hours of peak UV intensity, especially among young adults.[2,21,22]

Prior investigations that have not demonstrated an ability to change behaviors are lacking the incorporation of personalized messaging.[21,22,31] As discussed by Snyder et. al., although the 2015 "Solar Cell" study by Buller was able to increase sun protective behaviors in the short term, use of sun protective clothing was not maintained after 12 weeks. Similarly, Buller's 2016 "Go Smart Sun" study showed no difference in sun safe behaviors between resort-goers who were provided information on UVI and sun safety prior to vacation and those who were not. On the other hand, the 2016 study by Sachse, et. al., was able to increase SPF usage and self-reported change in sun protective behaviors in over half of participants by delivering personalized text messages to participants.[27]

These mixed results regarding the use of mobile apps holds true across many other chronic health conditions. In 2019, Apinaniz et. al., found no difference in weight loss or adherence to dietary and exercise recommendations among obese and overweight app users versus non-app users. However, all study participants received the same, non-personalized advice on physical activity and diet, regardless of intervention.[32] A 2020 study on cancer patients prescribed oral therapies found that, while a personalized app did not improve outcomes for all patients using the app, it was successful in promoting medication adherence for a subset of patients with self-reported adherence difficulty.[33] Though the evidence in the literature that apps can improve health outcomes is weak, the majority of studies have follow-up periods of 6 months or less and use a "one-size-fits-all" model of personalization.[34] Despite this, meta-analysis demonstrated that the use of apps to modify behavior offers a slight advantage over traditional health care interventions.[34]

Still, there are many potential areas for investigation regarding the efficacy of UV tracking apps in user adoption of good sun hygiene. These areas may include the utilization of push notifications, i.e. those that alert users directly, to provide personalized recommendations based on user skin sensitivity for sun safety, and the use of such notifications to alert users when it is time to reapply sunscreen or when they have been outside for extended periods of time.[13,35] Future research is also warranted regarding the use of smart watches that can detect UVI. Perhaps these devices could also prompt smart phone notifications when cumulative UV exposure is reaching recommended daily limits and advise users to seek shade.[35] Developers could also consider integrating location services to push notifications in real time when smart devices recognize that users are outdoors, or provide interactive features to make apps more engaging.

While the use of smart phone apps has significant potential for public health impact, the technology used by such apps to measure UV must also be investigated. As app technology is relatively new, there are limitations to our knowledge, including accuracy in estimations of UVI and when to make recommendations regarding UV exposure and sun safe behaviors. Apps utilize the MED to warn users of sunburn risk. Standardized erythema dose (SED), on the other hand, is more objective for measuring personal UV exposure and is the method for UV measurement employed by dosimetry.[36] Very few detectors of UVR have a sensitivity spectrum similar to that of the human erythema action spectrum and smart phone apps have not been tested in this manner.[35] Apps that include vitamin D tracking have yet another hurdle to overcome as research has recently revealed that the threshold dose for the cutaneous synthesis of vitamin D is not valid.[16]

Though these apps may be helpful in helping outdoor sports participants track their cumulative UVR exposure and provide reminders on how to avoid sunburns, perhaps exposure ratio to ambient (ERTA), would be more useful in quantifying the UV exposure of athletes. This measure compares personal exposure (PE) to ambient UV exposure as a ratio to provide accurate dosimetry measurements that account for personal orientation, solar elevation, and other confounders, all of which vary for outdoor athletes between competitions. ERTA can be used to quantify UV exposure across time and in a variety of settings, which is important for determining PE at specific sporting events. If apps could devise a way to include ERTA in their recommendations, limitations of MED and SED could be avoided. In regard to SED in particular, these limitations include that dosimeters lack ubiquity, require complex calibration, and lack inter-reliability. Multiple studies have shown the need for specific environmental conditions and calibration by scientific-grade fixed instruments for dosimeters to work, which is not practical for tracking personal exposure.[8,37,38]

In conclusion, apps that provide recommendations for sun safety will be challenged with effectively changing behaviors while maximizing the sensitivity of UVI data. Perhaps utilizing real-time satellite data would be of utility, though environmental factors such as cloud cover may be limiting. This must be balanced with the cost of apps to consumers and attempts to avoid overexposure to UVR if users believe apps will completely protect them from the harmful sequelae of UVR. It will likely be many years before we can truly evaluate the efficacy of apps as public health tools at reducing skin cancer incidence and mortality.

Conflict of Interest

The authors have no conflicts of interest to disclose.

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