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Short communication

Promoting sunscreen use in adolescents playing outdoor sports using UV detection stickers

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ABSTRACT

Sunscreen is a popular form of sun protection and when applied sufficiently (2 mg/cm^2) has been shown to block the harmful molecular effects of ultraviolet radiation (UV). This field study tested the effectiveness of UV detection stickers to improve sunscreen use. During a rugby league two-day sporting event (28–29 February 2020) in Queensland, Australia interested players 14–18 years old were provided with access to free sunscreen on DAY-1 and during the subsequent day (DAY-2) were provided with a free UV detection sticker and access to sunscreen. On DAY-2, one UV detection sticker was handed out to 550 attendees. The sunscreen bottles were weighted periodically by research staff throughout both event days. Primary outcomes were sunscreen usage. Overall, 868 g of sunscreen was used across both DAY-1 and DAY-2, with 19% (167 g) of sunscreen used on DAY-1 and 81% (701 g) of sunscreen used on DAY-2. This resulted in a > 3-fold improvement in sunscreen use on DAY-2 when the UV detection stickers were provided. We found UV detection stickers may improve use of sunscreen in adolescents during sporting events in high UV environments.

1. Introduction

Australia has one of the highest incidence rates of melanoma worldwide, which are at least double the incidence rates in the UK and US (Ferlay et al., 2013; Australian Institute of Health and Welfare, 2013). Melanoma can occur at a younger age than other cancers and is the most common cancer in people 15 to 44 years old (Australian Institute of Health and Welfare, 2013). Studies have shown regular sunscreen application can reduce the incidence of squamous cell carcinoma (SCC) (van der Pols et al., 2006) and may reduce melanoma (Green et al., 2011). Effectiveness of sunscreen depends on its application at an appropriate thickness (2 mg/cm^2) and regular re-application (Olsen et al., 2017). Previous research has shown both adults and children apply far less sunscreen than is recommended, which results in providing less protection (Autier et al., 2007; Diaz et al., 2012). An estimated 7220 melanoma cases could be prevented in Australia with effective use of sunscreen, however current sunscreen use in Queensland has reduced skin cancer incidence by only 10–15%, illustrating there is substantial opportunity for improvement (Olsen et al., 2015). Sun protection is a multifaceted behaviour and during adolescence adherence to sun protection practices declines and the incidence of sunburn increases (Livingston et al., 2007; Buller et al., 2011).

Outdoor sports represent an appropriate setting for targeted skin cancer prevention with players experiencing high levels of UV radiation during lengthy practices, game days and multiple day-competitions. Young adult competitive sport players (n = 237) reported high sunburn rates in Australia with 69% of players reporting a sunburn during the previous sporting season and 48% of participants reported the sunburn intensity was red and tender (Lawler et al., 2007). This may be due to sporting events taking place during high UV without shade, and players are constrained by specific uniform requirements that may not allow for protective clothing, including not being allowed to wear a hat or sunglasses during competition. Factors such as sweating and physical movement during sports may also be contributing to the need for more frequent sunscreen application (Moehrle, 2008). Therefore, the use of sunscreen and re-application remains the most effective method for sun protection in this setting.

New technologies may assist outdoor sports players in determining how long they can safely stay in the sun after applying sunscreen. Wearable UV detection sticker technology incorporates UV sensitive dyes into a sticker that can be used as an indicator to signal the sunscreen filter is no longer blocking UVR illustrating to the user they are no longer protected. The patent (WO2018035514 A1) describes the photochromic molecule and our previous study has shown the

Abbreviations: UV, ultraviolet; UVR, ultraviolet radiation; UVI, UV Index; SED, standard erythemal dose

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improvement of sunscreen reapplication in adult spectators at an outdoor sporting event provided with the sticker and free sunscreen (Hacker et al., 2019). However, testing whether this technology may improve adolescents sun protection practices remains unknown. Here, we present the findings of a field study to assess the effectiveness of UV detection stickers to improve sunscreen usage in adolescents who play outdoor sport.

2. Materials & methods

2.1. Study design and setting

Participants were attending a rugby league two-day sporting event (28-29th February 2020; Summer in Australia) at the Telstra stadium in Charleville, which is a rural town in Queensland, Australia (latitude 26.4°S, 146°E). The players were required to attend game play on both days. The rugby league event hosted 28 rugby league teams with both male and female players aged between 14 and 18 years old. All attendees at the event were made aware free sunscreen was being provided with announcements during the opening ceremony and the team manager's meeting on DAY-1. Participants had access to three commercially available sunscreen pump bottles (500 ml, SPF 50+) each day which were weighted periodically throughout the day (every 2–3 h) and sunscreen use was observed by a staff member to ensure there was an adequate supply available. During the subsequent day, DAY-2, players, team staff and supporters were provided each with one UV detection sticker SPOTMYUV™ (Suncayr, Pty LTD, Australia, https://spotmyuv.com/) by the research team as well as advised there was free sunscreen available. Participants were advised to place the intervention device (UV detection sticker) which lasts for one day on a sun exposed location on their body, such as their hand, and to use at their discretion. An information notice was provided next to the sunscreen bottles that the use of sunscreen was being measured as part of a research project, and no further information was recorded about participants using the sunscreen. The Human Research Ethics Committee of the Queensland University of Technology acknowledged this project was exempt from ethics review.

2.2. Weather measurements

UVR data was recorded using a UV-Cosine_UVI model (sglux GmbH, Berlin, Germany) and data was converted to the UV index scale. The standard erythemal dose (SED) was also calculated with daily summaries and hourly observations recorded. The UVR data was captured by the Australian Radiation Protection and Nuclear Safety Agency detector (Emerald, latitude 24°S, 148°E). The proportion of cloud cover in the sky above the stadium was recorded during each measurement day from 9am until 4 pm. Images of the sky above the stadium were captured using a fixed position and a hand-held camera (Fig. S1). The proportion of cloud cover in each image was counted using ImageJ software (Rueden et al., 2017) as previously described (Hacker et al., 2019). All field trial image analysis and quantification procedures were performed blind to the image ID. Temperature data was recorded in degrees Celsius and data was reported for the daily minimum and maximum as well as observations at 9am and 3 pm each day. The temperature data was captured by the Bureau of Meteorology weather station (044021, Charleville Aero, latitude 26.4°S, 146°E). All weather data measurements were collected during the event and no weather data was displayed at the venue.

2.3. Statistical analysis

Percentage calculations were used to detect differences between the DAY-1 and the DAY-2 outcome measurements. Analyses were performed using Graphpad Prism statistical software package (GraphPad Software, San Diego, CA).

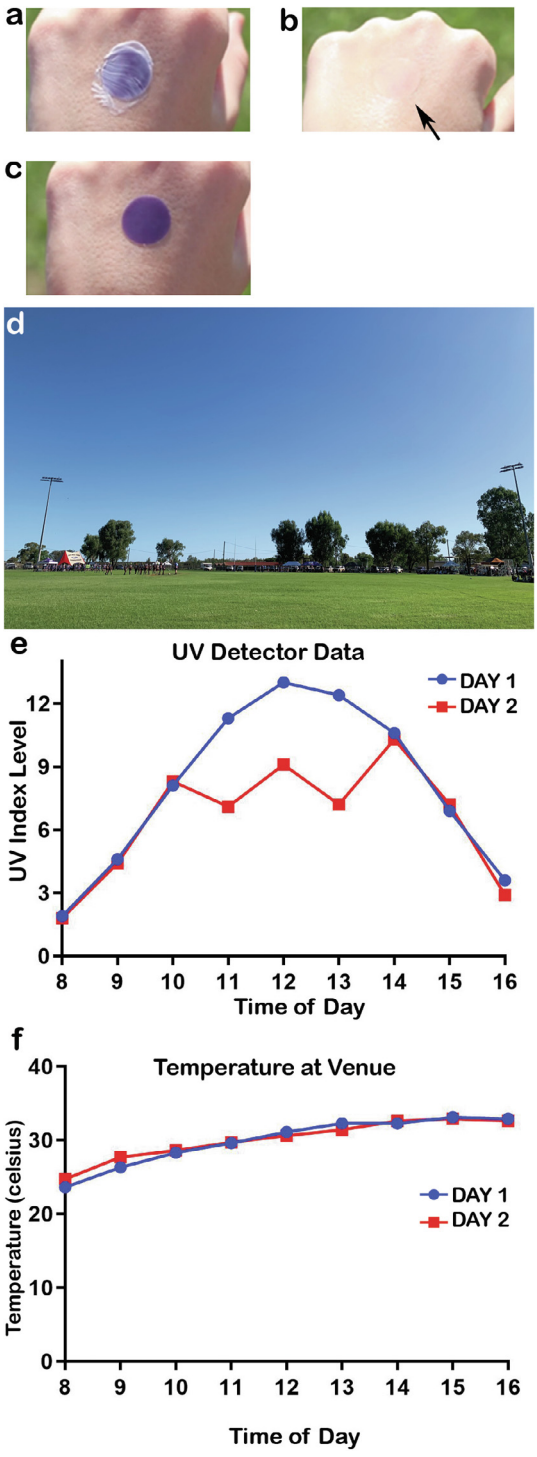

Fig. 1. Intervention device and testing venue. A) Sunscreen SPF50+ was applied to the SPOTMYUV™ sticker. B) The sticker was exposed to sunlight and the sunscreen applied on the sticker protected its UV sensitive dyes and remained clear. C) In the hours post-sunscreen application the sunscreen UV filters have degraded and are no longer blocking UV light changing the sticker color to purple. Overall, the sticker is clear when protected from UV light and changes to purple when not protected indicating sunscreen application or reapplication is required. D) The Telstra stadium in Charleville, Australia (latitude 26.4°S, 146°E) was the testing venue for this study during summer. E) The UVR levels were captured each measurement day and intensity graphed using the UV index scale. F) The temperature above the stadium were recorded hourly during each measurement day from 9 am until 4 pm. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 1
Weather Data.

Date	Treatment	Event Day	Temperature				UVI > 3	UVI > 3	UV	UV 12–1 pm[2] Dose	Cloud	Rain
			Min °C	Max °C	9 am °C	3 pm °C	Time	hrs	Daily Dose[1] SEDs*	SEDs*	Cover	
28-Feb-2020	Sunscreen only	DAY 1	18.9	33.8	26.3	33.1	9 am–4:00 pm	7.0	67	12	0%	0%
29-Feb-2020	UV sticker + sunscreen	DAY 2	17.4	33.3	27.7	32.9	9 am–3:30 pm	6.5	57	10	0%	0%

UVI = UV Index.
*SEDs = Standard Erythemal Dose.
[1] Daily dose calculated between 6:00–16:00.
[2] Midday dose calculated between 12:00–13:00.

3. Results

3.1. Participant characteristics

Over 532 registered players attended both days of the two-day rugby league event (Fig. S2). Over 80% of the players were 16 years or younger with 11 teams in the 16 boy's division, 12 teams in the 14 boy's division, 3 teams in the women's 17 years division and 2 teams in the 18 boy's division. Each team consists of 13 players on the field with a maximum squad of 20 players. The player registration process is approved by the Queensland Rugby League and includes parent or primary care provider's consent to play and evidence of the player's date of birth. During the morning between 8am-10am on DAY-2 one UV detection sticker per person (n = 550) were handed out (Fig. 1). The UV detection sticker changed color when in sunlight through-out the measurement period.

3.2. Weather conditions during event days

The length of each measurement day ranged from 6 h on DAY-1 to 7.5 h on DAY-2 (Table 1, Fig. 1D). The UVR exposure level was consistently high during the two measurement days with daily SEDs ranging from 57 SEDs to 67 SEDs (Table 1). The UV index level was above 3, requiring sun protection from 9am to after 3 pm each day. The UV dose in the hour noon-1 pm was 12 SEDs on DAY-1 and 10 SEDs on DAY-2 (Table 1, Fig. 1E). The cloud cover above the stadium venue was cloud free throughout both measurement days (Table 1, Fig. S1). The temperature between 9am and 3 pm ranged from 26.3 to 33.1 degrees Celsius during the measurement period (Table 1, Fig. 1F).

3.3. Sunscreen usage

The sunscreen usage increased from DAY-1 (control day) when 167 g was dispersed to 701 g on DAY-2 when a UV detection sticker was provided. On average 1.64 g (SE = 0.1551) is dispersed each time the sunscreen pump pack is pushed indicating on DAY-2 sunscreen was used over 427 times compared to DAY-1 with 102 uses recorded. On DAY-2 sunscreen was used continually throughout the day with 323 g (197 pumps) in the first two hours, 173 g (105 pumps) during the next 2-hours and 205 g (125 pumps) between 1 pm and 4 pm. While on DAY-1 most sunscreen 108 g out of the 167 g used was dispersed within the first 2-hours. Overall 868 g of sunscreen was used across the measurement period with 19% used during the control day and 81% used during the intervention day. We observed > 3-fold improvement (534 g increase) in sunscreen use on the intervention day.

4. Discussion

To investigate the impact of UV detection stickers we undertook a field trial in adolescent outdoor rugby league players participating in a two-day competition. We found providing adolescents with a UV detection sticker and access to free sunscreen increased usage, compared to provision of free sunscreen alone. To our knowledge, this is the first study to explore the potential benefits of UV detection stickers in adolescents. These findings are similar to our previous study providing UV detection stickers to adults which found higher rates of reapplication for participants in the UV detection sticker group 80% (295/369) compared to 68% (40/59) in the control group (p = 0.04) (Hacker et al., 2019).

Sunscreen is one of the most commonly used form of sun protection by adolescents (Volkov et al., 2013). A previous study of Australian outdoor sport players (n = 237) had found 47% of the participants used sunscreen inadequately and 30% reported not using sunscreen (Berndt et al., 2010). Heerfordt et al. (2018) has also shown using UV camera technology that two consecutive sunscreen applications improved sunscreen coverage reducing missed areas. Guidance on the application and re-application of sunscreen is warranted and wearable UV detection stickers can provide tailored and personalised information to the user in-the-moment where it is most useful (Heron and Smyth, 2010). Athlete playing uniforms included short sleeve shirts, shorts and long socks with sun exposed skin requiring between 10 and 15 ml of sunscreen for adequate protection. With the additional need for reapplication every 2 hours over 30 bottles of 500 ml sunscreen would have be required each day to apply adequate sunscreen to the 532 registered players. In this study, we did not measure the thickness of sunscreen applied by participants. The application technique of sunscreen is an important factor and applying consistently sufficient coverage across exposed skin. Sunscreen application could be a focus of future research and using objective measures such as UV camera technology or the sunscreen swabbing method the concentration of sunscreen applied could be explored (Bauer et al., 2010).

Strengths of our study include studying a large sample in a sporting setting, exposed to high UVR, and an adolescent population who report poorer sun protection practices and higher rates of sunburn compared to adults (Livingston et al., 2007). The consistent weather conditions across the two-day measurement period provided comparable data across both DAY-1 (control day) and DAY-2 (intervention day). The number of athletes was also consistent with participants required to play matches on both days. Limitations of the study include we did not capture self-reported sunburn or behavior change from participants. The ability to obtain consent from adolescents to complete questionnaires in a sport event setting is difficult with many player's guardians not present at the venue and most teams travelling via buses to the event. Future research could also expand on further enablers and barriers to sunscreen usage in adolescents who play outdoor sports and investigate if the UV detection stickers are helpful indicators in settings when high UVR levels are recorded in association with lower temperatures than those recorded in this study.

The alteration of behaviour by the subjects of a study due to their awareness of being observed has been described as the Hawthorne effect and a systematic review analysing nineteen purposively designed studies reported evidence of an effect (McCambridge et al., 2014). The Hawthorne effect may have been heightened on DAY-2 (intervention day) compared to the DAY-1 (control day) as participants were asked to

regularly observe the sticker's color. Participants may have also used their own sunscreen which was not recorded. Participants at the event were mainly male and the results may not be generalizable to other subgroups of the population. However men are commonly under-represented in prevention studies, and in adulthood have a higher mortality rate from melanoma (Australian Institute of Health and Welfare, 2016).

Adolescents who regularly engage in outdoor sports are at high risk of UVR exposure with many factors contributing including the time activities take place, sporting uniforms and limited shade provided at sport fields for junior competitions. This study explored the effectiveness of a wearable UV detection sticker to improve sunscreen usage in a high UV-environment and noted an increased use of sunscreen among adolescents provided with a UV detection sticker.

Conflict of interest

EH has previously received funding from Suncayr Ptd Ltd to undertake contract research projects. Authors CH and HF state no conflict of interest.

CRediT authorship contribution statement

Caitlin Horsham: Project administration, Investigation, Writing - review & editing. **Helen Ford:** Investigation, Writing - review & editing. **Elke Hacker:** Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Data curation, Formal analysis, Supervision, Visualization, Writing - review & editing.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pmedr.2020.101166.

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