Original Research Paper

**Title:** A mobile technology intervention in skin cancer prevention with UVR dosimeters and smartphone applications in young adults: A randomised controlled trial

**Running title:** Do apps and dosimeters change young adults’ sun protection?

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Abstract
Background: Skin cancer is the most prevalent but also most preventable cancer in Australia. Despite Australia’s long running public health campaigns, young Australian adults continue to report high levels of ultraviolet radiation (UVR) exposure and frequent sunburns. Young people are now increasingly turning away from traditional media such as newspapers and TV favouring online streaming, which is challenging the healthcare sector to develop new ways to reach this group with targeted, personalised health promotion messages. Advances in technology have enabled delivery of time- and context-relevant health interventions.

Objectives: The primary aim of this randomised controlled trial (RCT) was to test the effect of ultraviolet radiation feedback from a smartphone application (app) APP or a UVR dosimeter feedback device on sun protection habits, sun exposure behaviours, sunburn, and physical activity levels in young adults.

Methods: Young adults aged 18–35 years (n=124) were recruited from Queensland, Australia between September 2015 to April 2016 via social or traditional media campaigns and outreach activities in the local community. Participants were randomised using into 3 groups for a four week intervention: 1) No intervention control group; 2) UVR monitor group, who were asked to wear a UVR dosimeter feedback device set to their skin type (Healthtronics SunSafe Pty Ltd, Australia); and 3) a SunSmart app group, who were asked to download and use the SunSmart phone app (SunSmart Victoria, Australia). Data were self-assessed through surveys online at baseline, and 1 week and 3 months post-intervention.

Results: Complete data was available for 107 (86%) of participants (control group n=36, UVR monitor group n=36, SunSmart app group n=35). Uptake of the intervention in the UVR monitor group was high with 94% of participants using the device all or some of the time when outdoors. All SunSmart app group participants downloaded the app on their smartphone. There was no significant difference in the change in the sun protection habit (SPH) index (main outcome measure) across the three groups. However, compared to the control group a significantly greater proportion of the UVR monitor group reduced their time unprotected and exposed to UVR on weekends during the intervention compared to baseline (OR 2.706; CI 1.047-6.992, P =.04). This significant effect was sustained with greater reductions observed up to 3-months post-intervention (OR 3.130; CI 1.196-8.190, P =.02). There were no significant differences between the groups in weekday sun exposure, sunscreen use, sunburn, suntan or physical activity.

Conclusions: Using technology such as apps and personal UVR monitoring devices may improve some sun exposure behaviours among young adults, but as the SPH index did not increase in this study further research is required to achieve consistent uptake of sun protection in young people.

Trial Registration: The Australian and New Zealand Clinical Trials register ACTRN12615001296527

Keywords: Skin Neoplasms, Melanoma, Health Promotion, Public Health, Preventive Medicine, Web Applications, Smartphones, Sunlight, Sunburn, Technologies
Introduction

Ultraviolet radiation (UVR) or sunlight exposure is the main environmental risk factor for melanoma and keratinocyte skin cancers (including basal cell carcinoma and squamous cell carcinoma). It is predicted that in the United States of America (USA) new cases of melanoma will rise from around 70,000 in 2007-2011 to 116,000 in 2026-2031 [1]. Melanoma is the most common cancer in those aged 15 to 39 years in Australia [2]. Consistently across the USA, several European countries and Australia, young adults are reporting higher levels of sunburn compared to older adults, despite having good knowledge and sun-protective intentions [3-5]. In Australia, people 18–24 years were seven times more likely to report sunburn on the previous weekend than those over 65 years [6]. Young people, men, those from a lower socio-economic class or education level are all less likely to engage in preventative activities [7].

Over the past thirty years, Australia has successfully implemented world-class skin cancer prevention campaigns such as Slip! Slop! Slap!; SunSmart; and ‘Protect yourself in five ways from skin cancer’ delivered mostly using traditional public health and media channels such as posters, brochures, television, radio, and newspaper advertising [8, 9]. These programmes have raised public awareness and improved preventative behaviours amongst Australians and have thought to have led to a slight reduction in melanoma incidence in young generations [10]. Despite this success, the achievable impact of traditional media is waning due to the increased use of personalised internet-delivered multimedia content, especially among young people [11-13].

While the increasing use of mobile technology offers many opportunities for providing and collecting information and delivering time-, person- or context-sensitive health interventions, very few studies to date have tested sun protection interventions with personalised messaging [14]. Buller et al. provided personalised time until sunburn information using a mobile phone app to over 600 USA residents, 18+ years, which led to a significant increase in sun protection behaviours [15]. A greater proportion of intervention group participants reported they kept time in the sun to a minimum (60% for app users vs 49% for non-users; p = 0.04) and used more sun protection (39% vs 34%; p = 0.04). Our previous study recruited 574 participants 18-42 years from Queensland, Australia sending 21 personalised motivational sun protection text messages [16]. At 12 months post randomisation, the sun protection group (mean change 0.12) had significantly greater improvement in their sun protection habits index compared to control (reference mean change 0.02; p=0.03) [16].

Personalised feedback information could also be received using UVR-detecting dosimeters. The personal UV dosimeter provides feedback by sounding an alarm at a defined UVR threshold, alerting the user the need for sun protection to reduce risk of sunburn. Commercial interest has seen a large number of UVR-detecting devices being marketed directly towards the public. The devices can be worn as watches (attached to a strap) or pinned to clothing such as hats or shirts. There is a lack of evidence whether they aid consumers’ sun protection behaviours. To build the evidence for their efficacy for sun protection behaviour change the objective of this intervention trial was to evaluate one mobile phone app (SunSmart App, Cancer Council Victoria) and one personal UVR dosimeter monitor (Healthtronics SunSafe Pty Ltd) which has been shown in pretesting to provide accurate readings, and assess the impact these have on young adults’ sun exposure and sun protection habits compared to a no-intervention control group.
Methods

Study design and participants

The Skntec trial, conducted in Queensland Australia, used a randomised controlled design with two intervention groups (SunSmart App or UVR monitor) and a measurement-only control group. Approval was obtained from the Queensland University of Technology’s (QUT) Human Research Ethics Committee and carried out in accordance with the Declaration of Helsinki with written informed consent from all participants (approval number QUT 1400000302). Eligibility criteria included young adults 18 to 35 years, never been diagnosed with a melanoma, own a smartphone, and not a regular user of the SunSmart app or a personal UVR dosimeter. Participants (n=124) were recruited online via email at the University or social media. Traditional media such as posters at sporting centres and in the local community were also used for recruitment (Figure 1). Prospective participants completed a screening telephone call or in-person visit at the University. The project was outlined, eligibility determined and written informed consent obtained.

Figure 1. Flow chart of study recruitment
The study was conducted during September 2015 to April 2016 (Spring, Summer and Autumn in Australia) when the UV Index in Queensland is consistently above six and can reach 14+, requiring sun protection every day. During the baseline two-week period participants completed an online questionnaire and recorded their daily sun exposure as well as physical activity using an online sun diary previously described [17]. After the baseline period participants were block randomised, stratified by gender, using a computer generated random number list created by the study software engineer independent from other study procedures. Participants were randomised at baseline when their allocation was created in the database. The research nurse and participants were blind to the allocation of the intervention arms during the baseline phase, which was only revealed by the research nurse to participants at the commencement of the intervention phase.

For the four-week intervention phase participants were separated into three groups: 1) No intervention measurement only control group; 2) UVR monitor group, who were asked to wear the UVR dosimeter feedback device whilst outdoors (Healthtronics SunSafe Pty Ltd, Australia) (Figure 2A); or 3) the SunSmart app group, who were asked to download and use the free SunSmart phone app on their personal mobile phone (Cancer Council Victoria, Australia) (Figure 2B). Participants were emailed by the research team if the daily sun diaries had not been completed for more than 3 days in a row. At completion of the intervention phase participants in the UVR monitor group returned their monitors via mail. Participants in the SunSmart app group were emailed instructions to remove the App from their phone and asked to confirm it was uninstalled via return email.

Follow-up post-test measurements were taken at one week, and three months post-intervention with participants completing an online questionnaire and recording their sun exposure daily for two weeks using the online sun diary. Participants were reimbursed for their time at the end of the study with a $70 (AUD) gift card.

Figure 2. Intervention devices: A) Personal UVR dosimeter monitor (Healthtronics SunSafe Pty Ltd, Australia). B) SunSmart app (Cancer Council Victoria, Australia).
Intervention devices

UVR monitor: The Healthtronsics SunSafe UV dosimeter device (Figure 2A) pins to an individual’s clothing, and can be personalised for skin type alarming when UVR thresholds are met. This device computes a daily maximum UV dose for each particular skin type using the Fitzpatrick skin type scale 1-5. Its UV detectors are housed on a sloping panel to adjust for the different positional orientation areas of the body exposed to the sun when standing up or lying down. The UV-B-SAFE 1 model is water resistant and solar powered. All participants assigned to the UVR monitor device confirmed receiving the device, which contained the manufacturer’s instructions on how to set the device to that skin type.

SunSmart app: The SunSmart app (Figure 2B) displays the daily UV Index, the weather for a range of Australian locations, and a daily time-period when sun protection is required based on the most sun sensitive skin type-1. During download the app notification function was enabled to send daily reminders of the time periods sun protection is required. The SunSmart app also gives recommendations for how people can best protect themselves from the sun, how the UV index works and a vitamin D tracker and sunscreen calculator tool [18].

Outcome measures

Outcomes were assessed at baseline, and 1 week and 3 months post intervention. Sociodemographic data was collected at baseline including, skin cancer risk factors (hair colour, eye colour, tendency to burn, ability to tan, personal or family history of skin excisions, or skin cancer), and sun protection attitudes and intentions using questionnaires previously developed [19]. An evaluation questionnaire was conducted at the end of the study and assessed satisfaction with the intervention devices and the intervention delivery.

Sun Protection Habits Index: The primary outcome measure was the sun protection habits (SPH) index developed by Glanz et al [20] measured at baseline and evaluation time points. It queries the frequency of six sun-protective methods that are used when outdoors using a 4-point Likert scale (1 = never/rarely to 4 = always) which are averaged to derive the score, including wearing a shirt with sleeves, wearing a hat, wearing sunglasses, using sunscreen, staying in the shade, and limiting time in the sun during midday hours. SPH index test-retest reliability has good internal consistency (0.76) and test-retest reliability (0.78) and estimates of its validity have been previously reported [21].

UVR Exposure, sunburn, physical activity: Data on frequency of sunburn and suntan (number of times), time spent in sun unprotected on weekdays and weekends (minutes and hours, body areas exposed unprotected), sunscreen use (yes/no) and physical activity (minutes and hours) were collected using the online sun diary.

Statistical Analysis

Generalised Estimating Equations (GEE) models were used for analysing changes in the mean SPH index over time. The model contained group, gender, skin type. We also fitted the interaction of time with: (i) gender and (ii) group. The sun diary variables (reduced sun exposure or
torso exposure, increased sunscreen use, decreased sun-tanning, physical activity,) were dichotomised into: i) yes (improvement by more than 5% from each individual's baseline), or ii) no (no improvement). Number of participants in each category and percentage are presented. Logistic binary regression analyses were used to detect the odds of improvement in each intervention group compared to the control group.

*Sample size calculations:* To detect an effect size of 0.4, an optimal sample size of 300 was determined. However, only 55% of the requested funding was received allowing us to recruit a maximum of 200 participants.

**Results**

*Participant characteristics*

The mean age of the participants was 25.8 years, 69% (85/124) were female, 74% (91/124) had a university degree, and 87.9% (109/124) of participants worked mainly indoors (Table 1). More than half of the participants (58% (72/124) had fair skin that was sun-sensitive including skin that moderately or severely burns after 30 minutes of sun exposure in summer without protection. Characteristics were quite evenly distributed among the groups.

<table>
<thead>
<tr>
<th>Total n=124</th>
<th>Control n=41</th>
<th>SunSmart App n=41</th>
<th>UVR Monitor n=42</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age mean</strong> (Range 18-35)</td>
<td>25.8</td>
<td>25.4</td>
<td>26.5</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>85 (68.5)</td>
<td>26 (63.4)</td>
<td>32 (78.0)</td>
</tr>
<tr>
<td>Male</td>
<td>39 (31.5)</td>
<td>15 (36.6)</td>
<td>9 (22.0)</td>
</tr>
<tr>
<td><strong>Highest completed education</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Completed high school</td>
<td>21 (16.9)</td>
<td>8 (19.5)</td>
<td>7 (17.1)</td>
</tr>
<tr>
<td>Trade or tech cert or diploma</td>
<td>12 (9.7)</td>
<td>6 (14.6)</td>
<td>3 (7.3)</td>
</tr>
<tr>
<td>University or college degree</td>
<td>91 (73.4)</td>
<td>27 (65.9)</td>
<td>31 (75.6)</td>
</tr>
<tr>
<td><strong>Current work situation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employed full-time</td>
<td>24 (19.4)</td>
<td>9 (22.0)</td>
<td>9 (22.0)</td>
</tr>
<tr>
<td>Part-time or casual</td>
<td>20 (16.1)</td>
<td>6 (14.6)</td>
<td>8 (19.5)</td>
</tr>
<tr>
<td>Student</td>
<td>80 (64.5)</td>
<td>26 (63.4)</td>
<td>24 (58.5)</td>
</tr>
<tr>
<td><strong>Is your main job now...</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mainly indoors</td>
<td>109 (87.9)</td>
<td>38 (92.7)</td>
<td>35 (85.4)</td>
</tr>
<tr>
<td>Mainly outdoors</td>
<td>2 (1.6)</td>
<td>-</td>
<td>1 (2.4)</td>
</tr>
<tr>
<td>About equal amounts indoors and outdoors</td>
<td>13 (10.5)</td>
<td>3 (7.3)</td>
<td>5 (12.2)</td>
</tr>
<tr>
<td><strong>Born in Australia</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>58 (46.8)</td>
<td>20 (48.4)</td>
<td>20 (48.8)</td>
</tr>
<tr>
<td>No</td>
<td>66 (53.2)</td>
<td>21 (51.2)</td>
<td>21 (51.2)</td>
</tr>
<tr>
<td><strong>Eye colour</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue or Grey</td>
<td>28 (22.5)</td>
<td>9 (22.0)</td>
<td>13 (31.7)</td>
</tr>
<tr>
<td>Green</td>
<td>16 (12.9)</td>
<td>5 (12.2)</td>
<td>4 (9.8)</td>
</tr>
<tr>
<td>Brown</td>
<td>65 (52.4)</td>
<td>24 (58.5)</td>
<td>19 (46.3)</td>
</tr>
<tr>
<td>Other*</td>
<td>15 (12.1)</td>
<td>3 (7.3)</td>
<td>5 (12.2)</td>
</tr>
<tr>
<td><strong>Natural hair colour at age 21 (or now if younger)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red (including auburn)</td>
<td>7 (5.6)</td>
<td>3 (7.3)</td>
<td>2 (4.9)</td>
</tr>
<tr>
<td>Fair or blonde (including white)</td>
<td>8 (6.5)</td>
<td>1 (2.4)</td>
<td>4 (9.8)</td>
</tr>
<tr>
<td>Light brown</td>
<td>25 (20.2)</td>
<td>8 (19.5)</td>
<td>10 (24.4)</td>
</tr>
</tbody>
</table>

7
<table>
<thead>
<tr>
<th>Skin colour</th>
<th>Dark Brown</th>
<th>Fair</th>
<th>Medium</th>
<th>Olive/Dark</th>
<th>Black</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>42 (33.9)</td>
<td>72 (58.1)</td>
<td>38 (30.6)</td>
<td>13 (10.5)</td>
<td>1 (0.8)</td>
</tr>
<tr>
<td></td>
<td>16 (39.0)</td>
<td>24 (58.5)</td>
<td>13 (31.7)</td>
<td>3 (7.3)</td>
<td>1 (2.4)</td>
</tr>
<tr>
<td></td>
<td>10 (24.4)</td>
<td>21 (51.2)</td>
<td>15 (36.6)</td>
<td>5 (12.2)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>16 (38.1)</td>
<td>27 (64.3)</td>
<td>10 (23.8)</td>
<td>5 (11.9)</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Skin reaction in strong summer sun for 30 minutes without protection?</th>
</tr>
</thead>
<tbody>
<tr>
<td>My skin would not burn at all</td>
</tr>
<tr>
<td>My skin would burn lightly</td>
</tr>
<tr>
<td>My skin would burn moderately</td>
</tr>
<tr>
<td>My skin would burn severely</td>
</tr>
<tr>
<td>My skin would not tan</td>
</tr>
<tr>
<td>My skin would tan lightly</td>
</tr>
<tr>
<td>My skin would tan moderately</td>
</tr>
<tr>
<td>My skin would tan deeply</td>
</tr>
<tr>
<td>My skin would tan deeply</td>
</tr>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Unsure/don’t know</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Previous skin cancer, mole, or other spot/s removed or treated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
</tr>
<tr>
<td>No</td>
</tr>
<tr>
<td>Unsure/don’t know</td>
</tr>
</tbody>
</table>

| aOther = eye colour mixed colour or undefined                    |

<table>
<thead>
<tr>
<th>Intervention fidelity and data collection completeness</th>
</tr>
</thead>
<tbody>
<tr>
<td>In the UVR monitor group, fidelity of the intervention was high</td>
</tr>
<tr>
<td>reporting using the UVR monitor all or some of the time when</td>
</tr>
<tr>
<td>outside. All SunSmart app group participants downloaded the</td>
</tr>
<tr>
<td>app on their smartphone and 97% of participants received the</td>
</tr>
<tr>
<td>daily UV index sun protection pop-up notifications. All</td>
</tr>
<tr>
<td>participants completed the baseline questionnaire (n=124),</td>
</tr>
<tr>
<td>87.9% completed the 1 week (n=109) and 86% completed the 3</td>
</tr>
<tr>
<td>months post-intervention questionnaire (n=107). The online sun</td>
</tr>
<tr>
<td>diary was completed by 95% participants at baseline (n=118),</td>
</tr>
<tr>
<td>110 (88.7%) participants during the intervention and 1 week</td>
</tr>
<tr>
<td>post-intervention, and 107 (86.3%) participants at 3 months</td>
</tr>
<tr>
<td>post-intervention.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sun protection habits (SPH index)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At baseline the mean SPH index was (2.36, SE 0.08) for the UV</td>
</tr>
<tr>
<td>monitor, (2.47, SE 0.07) for the SunSmart App and (2.42, SE</td>
</tr>
<tr>
<td>0.08) for the control group. At the three month time-point the</td>
</tr>
<tr>
<td>sun protection index had improved in all three groups by +0.13,</td>
</tr>
<tr>
<td>+0.14, +0.06 in the UV monitor, SunSmart app, and control</td>
</tr>
<tr>
<td>groups, respectively (P =.001). This increase did not differ</td>
</tr>
<tr>
<td>significantly by group, resulting in a non-significant group by</td>
</tr>
<tr>
<td>time interaction (P &gt; 0.35, GEE).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>UVR exposure, sunscreen use and physical activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compared to the control group a significantly greater proportion</td>
</tr>
<tr>
<td>of the UVR monitor group improved their sun protection on</td>
</tr>
<tr>
<td>weekends during the intervention phase (OR 2.706; CI 1.047-6.992,</td>
</tr>
<tr>
<td>P = .04, Table 2).</td>
</tr>
<tr>
<td>The UVR monitor group continued demonstrating an improvement in</td>
</tr>
<tr>
<td>sun protection on weekends 3 months post-intervention (OR 3.130;</td>
</tr>
<tr>
<td>CI 1.196-8.190, P = .02, Table 2). Weekend UVR exposure did not</td>
</tr>
<tr>
<td>differ significantly between the control group and the SunSmart</td>
</tr>
<tr>
<td>App group at any time point. Total</td>
</tr>
</tbody>
</table>
and weekday UVR exposure did not differ significantly between either intervention group at any time point and the control group.

Sunscreen use and physical activity levels remained largely unchanged across the study period in all three groups (Table S1 and S2).

Table 2 Proportion of participants who reduced their time in the sun unprotected

<table>
<thead>
<tr>
<th></th>
<th>Yes(^a)</th>
<th>No</th>
<th>OR (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% (n)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>During Intervention(^b)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekday and weekend UVR Unprotected Exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>38.9 (14)</td>
<td>61.1 (22)</td>
<td>1.00</td>
<td>ref</td>
</tr>
<tr>
<td>SunSmart App</td>
<td>44.4 (16)</td>
<td>55.6 (20)</td>
<td>1.379 (0.525, 3.627)</td>
<td>0.514</td>
</tr>
<tr>
<td>UVR monitor</td>
<td>47.4 (18)</td>
<td>52.6 (20)</td>
<td>1.407 (0.557, 3.549)</td>
<td>0.470</td>
</tr>
<tr>
<td>Weekday UVR Unprotected Exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>41.7 (15)</td>
<td>58.3 (21)</td>
<td>1.00</td>
<td>ref</td>
</tr>
<tr>
<td>SunSmart App</td>
<td>30.6 (11)</td>
<td>69.4 (25)</td>
<td>0.622 (0.231, 1.670)</td>
<td>0.346</td>
</tr>
<tr>
<td>UVR monitor</td>
<td>47.4 (18)</td>
<td>52.6 (20)</td>
<td>1.280 (0.508, 3.225)</td>
<td>0.600</td>
</tr>
<tr>
<td>Weekend UVR Unprotected Exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>36.1 (13)</td>
<td>63.9 (23)</td>
<td>1.00</td>
<td>ref</td>
</tr>
<tr>
<td>SunSmart App</td>
<td>41.7 (15)</td>
<td>58.3 (21)</td>
<td>1.533 (0.563, 4.176)</td>
<td>0.403</td>
</tr>
<tr>
<td>UVR monitor</td>
<td>60.5 (23)</td>
<td>39.5 (15)</td>
<td>2.706 (1.047, 6.992)</td>
<td>0.040</td>
</tr>
<tr>
<td><strong>1 week after the Intervention(^c)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekday and weekend UVR Unprotected Exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>48.6 (18)</td>
<td>51.4 (19)</td>
<td>1.00</td>
<td>ref</td>
</tr>
<tr>
<td>SunSmart App</td>
<td>58.3 (21)</td>
<td>41.7 (15)</td>
<td>1.582 (0.611, 4.095)</td>
<td>0.345</td>
</tr>
<tr>
<td>UVR monitor</td>
<td>54.1 (20)</td>
<td>45.9 (17)</td>
<td>1.242 (0.498, 3.095)</td>
<td>0.642</td>
</tr>
<tr>
<td>Weekday UVR Unprotected Exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>51.4 (19)</td>
<td>48.6 (18)</td>
<td>1.00</td>
<td>ref</td>
</tr>
<tr>
<td>SunSmart App</td>
<td>47.2 (17)</td>
<td>52.8 (19)</td>
<td>0.972 (0.375, 2.514)</td>
<td>0.952</td>
</tr>
<tr>
<td>UVR monitor</td>
<td>37.8 (14)</td>
<td>62.2 (23)</td>
<td>0.576 (0.228, 1.455)</td>
<td>0.244</td>
</tr>
<tr>
<td>Weekend UVR Unprotected Exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>37.8 (14)</td>
<td>62.2 (23)</td>
<td>1.00</td>
<td>ref</td>
</tr>
<tr>
<td>SunSmart App</td>
<td>52.8 (19)</td>
<td>47.2 (17)</td>
<td>2.238 (0.831, 6.023)</td>
<td>0.111</td>
</tr>
<tr>
<td>UVR monitor</td>
<td>56.8 (21)</td>
<td>43.2 (16)</td>
<td>2.173 (0.853, 5.535)</td>
<td>0.104</td>
</tr>
<tr>
<td><strong>3 months after the Intervention(^d)</strong></td>
<td></td>
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<tr>
<td>Weekday and weekend UVR Unprotected Exposure</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>44.4 (16)</td>
<td>55.6 (20)</td>
<td>1.00</td>
<td>ref</td>
</tr>
<tr>
<td>SunSmart App</td>
<td>57.1 (20)</td>
<td>42.9 (15)</td>
<td>1.748 (0.666, 4.587)</td>
<td>0.257</td>
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<td>UVR monitor</td>
<td>50.0 (18)</td>
<td>50.0 (18)</td>
<td>1.250 (0.495, 3.162)</td>
<td>0.637</td>
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<td>Weekday UVR Unprotected Exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>38.9 (14)</td>
<td>61.1 (22)</td>
<td>1.00</td>
<td>ref</td>
</tr>
<tr>
<td>SunSmart App</td>
<td>42.9 (15)</td>
<td>57.1 (20)</td>
<td>1.205 (0.456, 3.182)</td>
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<tr>
<td>UVR monitor</td>
<td>38.9 (14)</td>
<td>61.1 (22)</td>
<td>1.000 (0.385, 2.595)</td>
<td>0.999</td>
</tr>
<tr>
<td>Weekend UVR Unprotected Exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>36.1 (13)</td>
<td>63.9 (23)</td>
<td>1.00</td>
<td>ref</td>
</tr>
<tr>
<td>SunSmart App</td>
<td>51.4 (18)</td>
<td>48.6 (17)</td>
<td>1.898 (0.717, 5.026)</td>
<td>0.197</td>
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<tr>
<td>UVR monitor</td>
<td>63.9 (23)</td>
<td>36.1 (13)</td>
<td>3.130 (1.196, 8.190)</td>
<td>0.020</td>
</tr>
</tbody>
</table>

\(^a\) Yes= reduced average daily minutes of time unprotected in the sun compared to baseline based on self-reported diary entry

\(^b\) n=110 for the intervention measurement period

\(^c\) n=109 for the 1 week after intervention measurement period

\(^d\) n=107 for the 3 months after intervention measurement period
Unprotected UVR torso exposure incidence

We observed that 51% of participants who completed the study (56/107) reported unprotected UVR torso exposure at one or more time points during the study. Unprotected UVR torso exposure did not differ by gender with 55% of females in the study (41/75) and 47% of males in the study (15/32). Unprotected torso exposure incidence did not differ significantly between the control group and intervention groups at any time point (Table S3).

Sunburn and suntan incidence

Sunburn rates were high with 58% (62/107) of participants reporting one or more sunburns during the study (range 1-11). Sixty-three percent of females (46/75) in the study reported one or more sunburns and 50% of males (16/32). There was no difference between groups in incidence of sunburn as well as sun-tanning (Table S4 and S5). Deliberate sun-tanning behaviour during the study was reported by 30% of participants (32/107; range 1-7), which was observed in 37% of females (28/75) and 13% of males (4/32). Sunburn and suntan incidence did not differ significantly between the control group and intervention groups at any time point (Table S4 and S5).

Satisfaction with intervention devices

Two thirds of participants (UVR monitor group 64% (23/36); (SunSmart app group 66%, 23/35)) found their intervention helpful to guide their sun protective behaviour (Table S6). About half of the participants self-reported that they changed or modified their behaviour in response to the output from the device (UVR monitor 47%, (17/36); SunSmart App 54%, (19/35)). About half of participants in that group found the UVR monitor to be encouraging (47%, 17/36), however only 19% (7/36) would purchase one. In the SunSmart app group 63% (22/35) of participants found the app encouraging and 40% (14/35) would download it in the future. Thirty-six per cent (13/36) of participants in the UVR monitor group and 60% (21/35) in the SunSmart App group reported the device repeated what they already knew. UVR monitor participants mean response for intervention device satisfaction out of a scale from 1-10 was 5.19 (SE 0.47), SunSmart App mean response was 5.66 (SE 0.36). Qualitative feedback from the open ended responses were grouped by theme and showed that young adults found the SunSmart app likable and easy to navigate. However, feedback for the content was that “it never changes”, “it’s always 8am to 4pm use sun protection”, “gets boring”. Participants liked the personalised feedback by the UVR monitor however were unlikely to carry a separate device for UVR detection. Participants wanted more control over the feedback method that the UVR monitor provides, and would find it more appealing if they could tailor the alert or alarm for their specific preferences (for example, if it allowed the user to select their song as an alarm or a more subtle vibration alert).
Discussion

This RCT examined the impact of using digital or electronic technologies to improve young peoples’ sun protection or sun exposure behaviours. It found no consistent benefit of providing participants with either a mobile phone app or electronic dosimeter for their sun protection habits compared to a no intervention control group. Despite all three groups reporting a similar improvement in the main outcome measure – the SPH index, our young participants continued to experience high sunburn rates throughout the study period.

While we did not observe a significant effect on the SPH index, some differences in specific measures of sun exposure were noted between the groups. The reduction in weekend unprotected sun exposure for the UVR monitor group was encouraging as weekend sun exposure is common with 21% of adolescents reporting being sunburnt on an average summer weekend in Australia [3]. Previous studies have suggested a suboptimal understanding of the UV-index and peak UVR times among young adults as reasons for this [22, 23]. Our findings suggest using a personal UV-monitor that produces an auditory alarm when a UVR dose of 2 MEDs was reached may be helpful to educate young adults on what is a safe level of UVR exposure for their skin type. However, this was not enough to also change their sun protection habitual behaviour as measured by the SPH index over and above the change achieved by just being a participant in the study. The change was also not strong enough to reduce sunburn rates. Participants commented that they would have liked to further personalise the alarm sounds, which could be tested in future studies.

Previous studies testing UVR monitors have reported varying results. Carli et al (n=91) found longer sun-exposure (p=0.003) and more frequent sunburns (p=0.004) in the UV monitor group compared to control [24]. These unfavourable adverse outcomes may have been due to limitations of the UV-monitor’s detector (SunCast UV monitor), which when not ideally positioned towards the sun may have under-reported UVR exposure. The UVR monitor (UV-B-Safe model) tested in our study has a sloping panel of detectors to better accommodate positional body orientations and alerted users with an auditory alarm in contrast to the SunCast UV monitor, which displayed the UVR measurement on a UV-index scale and did not have an alarm function. A Swedish study tested a UVR intensity indicator (Teraco, Inc., USA), which changed colour if the UVR levels are moderate, high or extreme [25]. These authors reported no statistically significant differences in the frequency of sunbathing, sunburn or attitudes towards being in the sun between groups receiving either the UVR monitor or written information about sun protection in 18–37 year olds. However, participant’s use of the UVR intensity indicator device was low with only 42% using it compared to 94% of participants in this study.

In a randomized clinical trial evaluating the Solar Cell app, which provided personalised, real-time sun protection advice and alerts it was found that a greater proportion of app users reduced the use of sunscreen 29% vs 35% for control (p= 0.048) and a greater proportion of app users increased use of shade (41% vs 34% control; p=0.03) [15]. Findings from our study and Buller et al (2015) both observed no difference in the number of sunburns between app users and control group. Fifty-eight per cent of participants reported one or more sunburns during the present study, which is slightly higher than the 47% observed among young adults in the USA by Buller et al [26]. The prevalence of
sunburn among young men was not significantly different from the prevalence among young women consistent with previous reports from the USA (Buller et al., 2011). High risk sun exposure behaviours such as torso exposure were commonly reported and sun tanning behaviours were similar to previous reports with a higher proportion of females reporting sun tanning than males [27].

The qualitative feedback received from the present intervention demonstrated that personalised tailored engaging feedback is preferred by young adults. They recommended combining elements from both intervention devices which may be advantageous to reduce sunburn rates in this population. Buller et al. [15] also reported the beneficial impact of tailoring information to each user “in the moment,” promoting a sense of volition, choice, and control. Our previous work also provides evidence for the benefit of personalised approaches. The Healthy Text study recruited 574 participants 18-42 years who received 21 motivational messages on sun protection compared to physical activity attention control messages [19]. At 12 months post randomisation, the sun protection group had significantly greater improvement in their SPH index compared to control [16] and building behavioural capacity (e.g., obtaining information and receiving reminders) was the most valued aspect of the messages [28]. Heckman et al. 2016 recently reported significant decreases in UV exposure and increases in SPH index 3 and 12 weeks after baseline for participants who received a tailored interactive multimedia internet intervention program (UV4.me) [29]. These studies are illustrating that further improvements to the technology platforms are needed to reduce the sunburn prevalence in young adult populations.

The observation of improvement in the measurement only control group may be due to participants completing multiple surveys about sun protection, which may have increased attention to their own sun protective behaviour. Previous studies by Koster et al [30] reported that simply keeping a UV exposure diary increased attention towards the behaviour examined. Other reasons could be exposure to other sun protection programs implemented over the study period (not measured) or seasonal variation with baseline data collected in spring and follow-up collected at the end of summer. The change in the control group could also be explained by the Hawthorne effect, which is when a person’s behaviour changes because they are knowingly under observation. Future study design could incorporate an attention control group to reduce the Hawthorne effect.

The strengths of this study include the randomised controlled trial design which created equivalent groups, high participant retention and testing relatively low-cost and readily available intervention components. Limitations of this study included the outcome measures were self-reported which are subject to recall and social desirability biases. The proper use of sun protection methods (e.g., adequate thickness in application of sunscreen) was not objectively assessed. Our sample size was relatively small and may have led to low statistical power contributing to the non-significant findings. The study used convenience sampling in a university setting and this may limit generalizability. Participants were mainly highly educated (university or college degree) and working indoors and results may not be generalizable to other subgroups of the population.

**Conclusion**
This study aimed to provide evidence for the effectiveness of digital and mobile technologies to improve sun protection behaviours among young adults. Self-monitoring devices for maintaining wellness are becoming more widespread. Tracking one’s health may enable consumers to improve health outcomes, but this study found relatively limited impact on important sun protection behaviours in this young population. An even more personalised approached to public health efforts may be needed to facilitate UVR protection and avoid increases in skin cancer cases.

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Conflict of Interest
The authors state no conflict of interest.
References


