Smartphone Mobile Application Delivering Personalized, Real-Time Sun Protection Advice
A Randomized Clinical Trial

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IMPORTANCE Mobile smartphones are rapidly emerging as an effective means of communicating with many Americans. Using mobile applications (apps), they can access remote databases, track time and location, and integrate user input to provide tailored health information.

OBJECTIVE A smartphone mobile app providing personalized, real-time sun protection advice was evaluated in a randomized clinical trial.

DESIGN, SETTING, AND PARTICIPANTS The trial was conducted in 2012 and had a randomized pretest-posttest controlled design with a 10-week follow-up. Data were collected from a nationwide population-based survey panel. A sample of 604 non-Hispanic and Hispanic adults from the Knowledge Panel 18 years or older who owned an Android smartphone were enrolled.

INTERVENTIONS The mobile app provided advice on sun protection (ie, protection practices and risk of sunburn) and alerts (to apply or reapply sunscreen and get out of the sun), hourly UV Index, and vitamin D production based on the forecast UV Index, the phone’s time and location, and user input.

MAIN OUTCOMES AND MEASURES Percentage of days using sun protection and time spent outdoors (days and minutes) in the midday sun and number of sunburns in the past 3 months were collected.

RESULTS Individuals in the treatment group reported more shade use (mean days staying in the shade, 41.0% vs 33.7%; \( P = .03 \)) but less sunscreen use (mean days, 28.6% vs 34.5%; \( P = .048 \)) than controls. There was no significant difference in number of sunburns in the past 3 months (mean, 0.60 in the treatment group vs 0.62 for controls; \( P = .87 \)). Those who used the mobile app reported spending less time in the sun (mean days keeping time in the sun to a minimum, 60.4% for app users vs 49.3% for nonusers; \( P = .04 \)) and using all protection behaviors combined more (mean days, 39.4% vs 33.8%; \( P = .04 \)).

CONCLUSIONS AND RELEVANCE The mobile app improved some sun protection. Use of the mobile app was lower than expected but associated with increased sun protection. Providing personalized advice when and where people are in the sun may help reduce sun exposure.

The rapid proliferation and enormous reach of mobile computing devices, including smartphones and tablet computers, are transforming the communication experience. An increasing number of adults are using them to run mobile applications (apps) and access the Internet from anywhere, including to obtain health information.

While there is no comprehensive theory explaining how mobile interventions improve health (ie, mHealth), they may be effective for several reasons. Mobile devices can enhance engagement with health information by proactively, unobtrusively, confidentially, and repeatedly reaching out to users, requesting their attention, creating an urgency to respond, and delivering advice in real time, on their schedules, 24 hours, 7 days a week, and anywhere. These properties should elevate the ecological validity of the health information by tailoring it to each user “in-the-moment” when and where it is most meaningful. They should create social support through their presence, relevancy, urgency, and interactivity and ability to increase adults’ accountability, deliver emotional support, and create a sense of volition, choice, and control. Moreover, mobile devices can manage time and location dependences, access remote databases, and deliver reminders for action. All of these attributes could be used to improve self-efficacy and response efficacy and provide cues to action to motivate risk-reduction behaviors.

In this project, we conducted the first evaluation of a mobile app that provided sun protection advice to reduce the risk of skin cancer. It is estimated that approximately 2 million non-melanoma skin cancers (ie, basal and squamous cell carcinoma) and 76,000 cutaneous malignant melanoma (43,890 males; 32,210 females) will be diagnosed in 2014, costing $1.4 billion annually for treatment. It was hypothesized that the mobile app would increase sun protection practices and decrease sunburn prevalence by improving sun protection norms, self-efficacy, outcome expectations, and intentions.

Methods

Sample
Participants were recruited from the Knowledge Panel, a survey panel representative of the US adult population administered by GfK Inc. GfK identified panel members who met eligibility requirements (ie, those who were non-Hispanic or Hispanic white, ≥18 years, and a US resident) and invited them to participate through their online system. Adults were screened on smartphone ownership (participation was limited to adults with Android handsets) and eligible individuals signed a consent form and completed the baseline survey online. Recruitment occurred from July 10 to 23, 2012. Participants received credit in the Knowledge Panel system.

Procedures
The trial involved a randomized pretest-posttest controlled design. Potential participants were randomized to receive invitations to join the study. Those who consented and completed the baseline survey in GfK’s online system were enrolled. Participants assigned to the treatment group received instructions through the online system to download, install, and use the Solar Cell mobile app. An online guide was provided, along with e-mail and telephone technical assistance. Seven weeks after randomization, treatment group participants were sent a reminder through the online system to use the mobile app. Ten weeks after the recruitment period began (September 18, 2012), all participants received the invitation for the posttest survey; posttesting concluded on October 3, 2012. A small group of participants failed to indicate they had completed their pretest in the online system, so they did not receive the posttest invitation. However, they were eligible and randomized, so they were recontacted for posttesting in December. Participants received credit in the Knowledge Panel system as an incentive. All procedures and forms were approved by the Western Institutional Review Board.

Solar Cell Mobile App
The Solar Cell mobile app was available for Android smartphones and has been described in detail elsewhere. In brief, it provided personalized sun protection advice based on (1) 5-day, hour-by-hour UV Index forecasts issued daily by the National Oceanic and Atmospheric Administration for each 0.5° latitude-longitude grid in North America (approximately 40 x 40 miles), (2) time and location from the phone, and (3) personal information from the user (ie, skin phenotype, height, weight, age, clothing coverage, use of sunscreen and its skin protection factor [SPF], and use of medications increasing sun sensitivity). Using algorithms based on published literature, Solar Cell provided the following advice: (1) risk of sunburn (time until sunburn and level of risk [low, moderate, extreme]), (2) time until reaplication of sunscreen, (3) recommended sun protection practices (use of sunglasses, sunscreen, hats, protective clothing, shade, and going indoors), (4) current forecasted UV Index, and (5) estimated amount of vitamin D produced by the skin. Pop-up screens provided educational information. Visual and audible alerts signaled when users needed to reapply sunscreen, achieved the recommended daily dose of vitamin D, and were at extreme risk of sunburn. Users could indicate when they were in the sun, in the shade, or indoors. Risk of sunburn was adjusted for skin phenotype, use of sunscreen and shade, and being indoors.

Measures
Outcome measures assessed exposure to the midday sun, sun protection practices, and sunburn prevalence in the past 3 months at baseline and posttest, the a priori primary outcomes. The surveys were pretested to ensure that the questions were understandable and easily answered, using cognitive interviewing procedures with non-Hispanic white adults (2 men and 3 women).

Sun Exposure and Sun Protection Practices
Sun exposure and protection practices were assessed with validated open-ended measures from the published literature. Sun exposure was measured by asking participants to report the number of days and number of hours spent in the sun between 10 AM and 4 PM (solar noon ± 3 hours) in the past 3 months. Participants next reported the number of those days...
that they practiced each of 7 sun protection behaviors, which were converted to percentage of days engaged in each practice (ie, wearing sunscreen with SPF 15 or higher, sunscreen lip balm with SPF 15 or higher, clothing that protected the skin from the sun, a hat with a wide brim, and sunglasses, keeping time in the sun to a minimum, and staying in the shade). The mean percentage of practicing all sun protection behaviors was also calculated. Sunburn prevalence was assessed with 2 questions: whether participants had ever been sunburned and how many times they were sunburned in the past 3 months (defined as being red and/or painful from exposure to the sun).20

Moderators and Mediators
Potential effect moderators and theoretical mediators were measured at baseline and posttest, again using measures from the literature. Moderators included demographics, skin phenotype (based on hair color, eye color, and skin tanability),21 2-item tanning image scale (“I think I look healthier when I tan”; “I think I look better when I tan”) [Cronbach α = 0.86 at base- tanning image scale (“I think I look healthier when I tan”; “I think I look better when I tan” [Cronbach α = 0.86 at base- tanning image scale (“I think I look healthier when I tan”; “I think I look better when I tan” [Cronbach α = 0.86 at base- tanning image scale (“I think I look healthier when I tan”; “I think I look better when I tan” [Cronbach α = 0.86 at base- tanning image scale (“I think I look healthier when I tan”; “I think I look better when I tan” [Cronbach α = 0.86 at base- tanning image scale (“I think I look healthier when I tan”; “I think I look better when I tan” [Cronbach α = 0.86 at base- tanning image scale (“I think I look healthier when I tan”; “I think I look better when I tan” [Cronbach α = 0.86 at base- tanning image scale (“I think I look healthier when I tan”; 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Statistical Analysis
The effect of Solar Cell was tested by comparing percentage of days practicing sun protection behaviors, time spent outdoors in the midday sun, and sunburn prevalence between the treatment and control groups. Comparisons were performed on posttest values, using analysis of covariance (ANCOVA) and controlling for baseline values and demographic covariates (identified by stepwise elimination at P < .10 [2-tailed]). Initially, comparisons were performed of participants who completed the posttest. Then, missing values were imputed and comparisons rerun to assess effects of loss to follow-up. Potential moderators of Solar Cell’s effect was probed by testing 2-way interactions between the moderator (with levels as appropriate) and treatment group in the ANCOVA models. All tests were performed using P < .05 (2-tailed).

Results
Profile of the Sample
Overall, 604 of 1286 individuals invited were enrolled in the trial (see the CONSORT diagram in the Figure). A total of 682 individuals (331 in the treatment group and 351 in the control group) did not consent or were deemed ineligible. Of those enrolled, 150 participants (24.8%; 83 in the treatment group [25.1%] and 67 in the control group [19.1%]) were lost to follow-up at posttest, leaving 454 participants with complete data (222 in the treatment group; 232 in the control group).

Participants had a diverse profile (Table 1). However, participants were younger, more educated, and more affluent and lived in large households, and fewer were Hispanic whites than in the US population. Specifically, they ranged in age from 18 to 80 years (68.5% were <45 years) and were well educated. The sample contained 9.6% Hispanic whites but was equally divided by sex. Also, 24.2% had high-risk skin phenotypes (4 or 5 on phenotypic index) and nearly a third had been diagnosed as having skin cancer. The average household size was 3.1 persons; 62.7% had incomes of $50,000 or greater; three-quarters were employed; most were married (nearly half had a child <18 years in their household, and three-quarters were heads of households); and about two-thirds owned their home. Participants were enrolled from 48 states (with exceptions of Idaho and Hawaii): 15.9% from the Northeast; 25.3%, the Midwest; 33.5%, the South; and 25.3%, the West, with 87.6% living in metropolitan areas. Randomization produced groups with no statistically significant differences in demographics, sun protection practices, time spent in the sun, or sunburn prevalence at baseline, except that the treatment group had fewer participants classified as head of household (73.4%) than the control group (80.3%; P = .04). There were very few differences associated with loss to follow-up. Those completing the posttest were older (mean age, 39.58 years; P = .02) and more owned their home (71.4%; P < .05) than those not completing it (mean age, 36.79 years; 62.0%).

Use of Solar Cell Mobile App
Of the 305 people in the treatment group, 232 (76.1%) downloaded Solar Cell, but only 125 (41.0%) used it (ie, ran the app and received the feedback screen) at least once after installing it (downloading and use was detected by web servers). Most of those who used Solar Cell (76.0%) did so 1 to 5 times (16.0%,...
6 to 10 times, and 8.0%, ≥11 times). These users created 166 profiles and ran existing profiles 532 times.

**Effect of Solar Cell Mobile App on Sun Protection Practices**
Solar Cell seemed to weakly affect sun protection practices at posttest (Table 2). Individuals assigned to Solar Cell and completing the posttest reported they used shade a higher proportion of time at posttest than controls. However, individuals assigned to Solar Cell also said they used sunscreen for a smaller proportion of time. No other significant differences were detected. When missing posttest values were imputed, none of the sun protection practices differed significantly by experimental group.

**Effect of Solar Cell Mobile App on Sunburn Prevalence and Time Outdoors in the Midday Sun**
There was no statistically significant difference between treatment groups on posttest sunburn prevalence (Table 1). The mobile app did not affect the amount of time users spent outdoors in the midday sun. They did not spend more days or hours in the sun than controls (Table 1).

**Moderators of Effect of Solar Cell on Sun Protection Practices**
The effect of Solar Cell on sun protection practices was moderated by preferences for a sun tan. Participants with stronger sun tan preferences assigned to Solar Cell reported using protective clothing while outdoors on a greater percentage of days than those in the control group ($F = 4.48; P = .03$) (see eTable 1 in the Supplement). With lower sun tan preferences, the Solar Cell group reported lower use of protective clothing than controls.

**Effect of Using Solar Cell on Sun Protection and Exposure Outcomes**
We probed whether the amount of Solar Cell usage was predictive of outcomes, defining use as whether participants ran the mobile app and received the feedback screen, which provided the sun safety advice. Analyses were conducted only within the treatment group on participants completing the posttest. Individuals who used Solar Cell reported a larger mean percentage of time practicing all sun protection behaviors combined than nonusers (Table 3). Use of Solar Cell was unrelated to sunburn prevalence, although means did suggest that participants who used it had fewer sunburns than those who did not (Table 3). Participants who used the app spent a larger percentage of days keeping their time in the sun to a minimum and fewer hours outdoors in the midday sun (but not fewer days) than those who did not use it (Table 3).

Solar Cell, when used, had favorable effects on sun protection in some subgroups, specifically those defined by employment, household size, and sex. Participants not employed reported more days wearing wide-brimmed hats when using Solar Cell than those not using it ($F = 8.57; P < .01$) (eTable 1 in the Supplement); individuals who worked displayed little difference. In large households, participants using Solar Cell reported staying in the shade when outdoors on more days than those not using it ($F = 5.81; P < .01$) (eTable 1 in the Supplement). Also, using Solar Cell was associated with reporting spending fewer hours outdoors in the midday sun (between 10 AM and 4 PM) by women; there was no difference in men ($F = 4.88; P = .03$) (eTable 1 in the Supplement).
Effect of Solar Cell on Theoretical Mediators

The main effect of Solar Cell on theoretical mediators— injunctive and descriptive norms, self-efficacy and outcome expectations, and intentions—was not statistically significant between treatment and control groups (eTable 2 in the Supplement). However, 2 demographic characteristics moderated the effect of Solar Cell on injunctive norms and self-efficacy expectations. Participants living in nonmetropolitan areas assigned to Solar Cell reported lower injunctive norms for sun protection by family and friends than controls ($F = 5.98; P = .01$) (Table 3). Individuals with lower income assigned to Solar Cell were more confident they could practice sun safety than controls ($F = 3.53; P = .01$; those with higher income assigned to Solar Cell were less confident) (Table 3).

Discussion

The Solar Cell mobile app seemed to promote sun protection practices, especially when it was used. Specifically, it increased use of shade. Shade can substantially reduce exposure to solar UV radiation (UV-R),25 but it needs to be available for it to be used. By contrast, Solar Cell reduced the use of sunscreen, which is not altogether unfavorable. Sunscreen, while a popular practice,23 is frequently not used properly to maximize its protective value.25 Many adults underapply it and/or fail to reapply it to receive its full protective value.26 Thus, health authorities recommend sunscreen be used as a secondary practice after staying indoors or in the shade and wearing protective clothing, hats and eyewear.27 Still, a recent SMS (Short Message Service) text messaging intervention did increase sunscreen use by middle school students.28

Solar Cell may be more effective with some groups than others. Women in the United States seem to practice more sun protection than men, and they may have been more responsive to Solar Cell's advice.29 The positive impact on individuals who preferred a suntan is a positive outcome, for tanning preferences may make them spend a large amount of time in the sun. When used, Solar Cell also benefited nonworking participants and those in larger households by increasing use of wide-brimmed hats, an uncommon precaution,23 and shade. Nonworking participants may have more time to use and learn Solar Cell's advice than working individuals. Participants in larger households probably had more children; they may have

Table 1. Participant Characteristics (continued)

<table>
<thead>
<tr>
<th>Demographics</th>
<th>(n = 604)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children &lt;18 y, %</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>55.0</td>
</tr>
<tr>
<td>Yes</td>
<td>45.0</td>
</tr>
<tr>
<td>Employment status, %</td>
<td></td>
</tr>
<tr>
<td>Not working</td>
<td>24.7</td>
</tr>
<tr>
<td>Working</td>
<td>75.3</td>
</tr>
</tbody>
</table>

*a Range, 1, lowest risk for skin cancer, to 5, highest risk.*

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**Table 1. Participant Characteristics**

<table>
<thead>
<tr>
<th>Demographics</th>
<th>(n = 604)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>38.89 (13.15)</td>
</tr>
<tr>
<td>Education, %</td>
<td></td>
</tr>
<tr>
<td>&lt;4-y college grad</td>
<td>58.9</td>
</tr>
<tr>
<td>4-y college degree</td>
<td>25.7</td>
</tr>
<tr>
<td>Post graduate degree</td>
<td>15.4</td>
</tr>
<tr>
<td>Race/ethnicity, %</td>
<td></td>
</tr>
<tr>
<td>White, non-Hispanic</td>
<td>90.4</td>
</tr>
<tr>
<td>Hispanic</td>
<td>9.6</td>
</tr>
<tr>
<td>Other, non-Hispanic</td>
<td>0.0</td>
</tr>
<tr>
<td>Sex, %</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>47.9</td>
</tr>
<tr>
<td>Male</td>
<td>52.1</td>
</tr>
<tr>
<td>Skin score (phenotypic index), %*</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>15.1</td>
</tr>
<tr>
<td>2</td>
<td>25.7</td>
</tr>
<tr>
<td>3</td>
<td>35.0</td>
</tr>
<tr>
<td>4</td>
<td>20.9</td>
</tr>
<tr>
<td>5</td>
<td>3.3</td>
</tr>
<tr>
<td>Skin cancer, %</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>69.5</td>
</tr>
<tr>
<td>Yes</td>
<td>30.5</td>
</tr>
<tr>
<td>Household head, %</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>23.2</td>
</tr>
<tr>
<td>Yes</td>
<td>76.8</td>
</tr>
<tr>
<td>Household size, mean (SD)</td>
<td>3.13 (1.51)</td>
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<tr>
<td>Housing type, %</td>
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</tr>
<tr>
<td>One-family house detached from any other house</td>
<td>71.4</td>
</tr>
<tr>
<td>One-family house attached to ≥1 houses</td>
<td>6.9</td>
</tr>
<tr>
<td>Building with ≥2 apartments</td>
<td>18.4</td>
</tr>
<tr>
<td>Mobile home</td>
<td>3.3</td>
</tr>
<tr>
<td>Income, $</td>
<td></td>
</tr>
<tr>
<td>&lt;25 000</td>
<td>16.4</td>
</tr>
<tr>
<td>25 000-49 999</td>
<td>20.9</td>
</tr>
<tr>
<td>50 000-99 999</td>
<td>36.2</td>
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<tr>
<td>≥100 000</td>
<td>26.5</td>
</tr>
<tr>
<td>Marital status, %</td>
<td></td>
</tr>
<tr>
<td>Married or living with partner</td>
<td>69.2</td>
</tr>
<tr>
<td>Widowed, divorced, separated</td>
<td>8.0</td>
</tr>
<tr>
<td>Never married</td>
<td>22.8</td>
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<tr>
<td>Metropolitan Statistical Area status, %</td>
<td></td>
</tr>
<tr>
<td>Nonmetropolitan</td>
<td>12.4</td>
</tr>
<tr>
<td>Metropolitan</td>
<td>87.6</td>
</tr>
<tr>
<td>Region, %</td>
<td></td>
</tr>
<tr>
<td>Northeast</td>
<td>15.9</td>
</tr>
<tr>
<td>Midwest</td>
<td>25.3</td>
</tr>
<tr>
<td>South</td>
<td>33.5</td>
</tr>
<tr>
<td>West</td>
<td>25.3</td>
</tr>
<tr>
<td>Ownership status of living quarters, %</td>
<td></td>
</tr>
<tr>
<td>Rented for cash or occupied without payment of cash rent</td>
<td>31.0</td>
</tr>
<tr>
<td>Owned or being bought by you or someone in your household</td>
<td>69.0</td>
</tr>
</tbody>
</table>

(continued)
followed Solar Cell’s advice either over concern for their children’s safety or to set a good example. It was somewhat unexpected that more affluent individuals who used Solar Cell had lower self-efficacy expectations than those who did not use it. Perhaps, more affluent adults were overconfident, and Solar Cell showed them that sun protection was more complicated than they believed, which could make them try harder to take proper precautions.

<table>
<thead>
<tr>
<th>Outcome Measures</th>
<th>Covariates</th>
<th>Control</th>
<th>Treatment</th>
<th>Test Statistic</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunburned (n = 450)</td>
<td>1, 2, 4, 6, 17</td>
<td>28.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>27.5</td>
<td>χ² = 1.58</td>
<td>.21</td>
</tr>
<tr>
<td>Sunburns, No. (n = 445)</td>
<td>1, 3</td>
<td>0.62&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.60</td>
<td>F = 0.03</td>
<td>.87</td>
</tr>
<tr>
<td>Days, No. (n = 451)</td>
<td>1, 5, 16</td>
<td>42.63&lt;sup&gt;c&lt;/sup&gt;</td>
<td>44.86</td>
<td>F = 0.98</td>
<td>.32</td>
</tr>
<tr>
<td>Hours, No. (n = 447)</td>
<td>1, 3, 5, 16</td>
<td>123.73&lt;sup&gt;c&lt;/sup&gt;</td>
<td>123.18</td>
<td>F = 0.00</td>
<td>.96</td>
</tr>
<tr>
<td>Days wearing sunscreen with SPF 15 or greater (n = 352), %</td>
<td>1, 3, 5, 6, 12, 14</td>
<td>34.5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>28.6</td>
<td>F = 3.95</td>
<td>.048</td>
</tr>
<tr>
<td>Days wearing sunscreen lip balm with SPF 15 or greater (n = 339), %</td>
<td>1, 5</td>
<td>18.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>18.7</td>
<td>F = 0.01</td>
<td>.94</td>
</tr>
<tr>
<td>Days wearing clothing that protected the skin from the sun (n = 357), %</td>
<td>1, 5, 9, 17</td>
<td>19.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>24.4</td>
<td>F = 1.93</td>
<td>.17</td>
</tr>
<tr>
<td>Days wearing a hat with a wide brim (n = 376), %</td>
<td>1, 5, 7, 12, 15, 16</td>
<td>17.3&lt;sup&gt;c&lt;/sup&gt;</td>
<td>15.8</td>
<td>F = 0.39</td>
<td>.53</td>
</tr>
<tr>
<td>Days wearing sunglasses (n = 394), %</td>
<td>1, 10, 15</td>
<td>69.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>64.8</td>
<td>F = 2.80</td>
<td>.09</td>
</tr>
<tr>
<td>Days staying in the shade (n = 329), %</td>
<td>1, 5, 9, 15, 17</td>
<td>33.7&lt;sup&gt;c&lt;/sup&gt;</td>
<td>41.0</td>
<td>F = 4.51</td>
<td>.03</td>
</tr>
<tr>
<td>Days using all sun protection practices (n = 413), mean, %</td>
<td>1, 5, 7, 17</td>
<td>37.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>37.3</td>
<td>F = 0.02</td>
<td>.90</td>
</tr>
</tbody>
</table>

Abbreviations: ANCOVA, analysis of variance; SPF, sun protection factor.

Table 3. Results of ANCOVA Models Comparing Outcomes by Whether Participant Used Solar Cell Mobile App

<table>
<thead>
<tr>
<th>Outcome Measures</th>
<th>Covariates&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Did Not Use</th>
<th>Used</th>
<th>Test Statistic</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunburned (n = 219)</td>
<td>1, 2, 4, 6, 17</td>
<td>32.3&lt;sup&gt;d&lt;/sup&gt;</td>
<td>20.7</td>
<td>χ² = 2.34</td>
<td>.13</td>
</tr>
<tr>
<td>Sunburns, No. (n = 218)</td>
<td>1, 3</td>
<td>0.78&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.43</td>
<td>F = 3.35</td>
<td>.07</td>
</tr>
<tr>
<td>Days, No. (n = 221)</td>
<td>1, 5, 16</td>
<td>45.77&lt;sup&gt;d&lt;/sup&gt;</td>
<td>41.67</td>
<td>F = 1.60</td>
<td>.21</td>
</tr>
<tr>
<td>Hours, No. (n = 218)</td>
<td>1, 3, 5, 16</td>
<td>135.30&lt;sup&gt;d&lt;/sup&gt;</td>
<td>98.66</td>
<td>F = 5.89</td>
<td>.02</td>
</tr>
<tr>
<td>Days wearing sunscreen with SPF 15 or greater (n = 171), %</td>
<td>1, 3, 5, 6, 12, 14</td>
<td>26.5&lt;sup&gt;d&lt;/sup&gt;</td>
<td>29.9</td>
<td>F = 0.63</td>
<td>.43</td>
</tr>
<tr>
<td>Days wearing sunscreen lip balm with SPF 15 or greater (n = 176), %</td>
<td>1, 5</td>
<td>17.7&lt;sup&gt;d&lt;/sup&gt;</td>
<td>17.5</td>
<td>F = 0.00</td>
<td>.96</td>
</tr>
<tr>
<td>Days wearing clothing that protected the skin from the sun (n = 172), %</td>
<td>1, 5, 9, 17</td>
<td>18.8&lt;sup&gt;d&lt;/sup&gt;</td>
<td>26.4</td>
<td>F = 2.54</td>
<td>.11</td>
</tr>
<tr>
<td>Days wearing a hat with a wide brim (n = 183), %</td>
<td>1, 5, 7, 12, 15, 16</td>
<td>12.0&lt;sup&gt;d&lt;/sup&gt;</td>
<td>13.0</td>
<td>F = 0.11</td>
<td>.74</td>
</tr>
<tr>
<td>Days wearing sunglasses (n = 192), %</td>
<td>1, 10, 15</td>
<td>62.5&lt;sup&gt;d&lt;/sup&gt;</td>
<td>65.4</td>
<td>F = 0.43</td>
<td>.51</td>
</tr>
<tr>
<td>Days keeping time in the sun to a minimum (n = 180), %</td>
<td>1, 5, 7, 17</td>
<td>49.3&lt;sup&gt;d&lt;/sup&gt;</td>
<td>60.4</td>
<td>F = 4.19</td>
<td>.04</td>
</tr>
<tr>
<td>Days staying in the shade (n = 170), %</td>
<td>1, 5, 9, 15, 17</td>
<td>40.2&lt;sup&gt;d&lt;/sup&gt;</td>
<td>40.2</td>
<td>F = 0.00</td>
<td>.99</td>
</tr>
<tr>
<td>Days using all sun protection practices (n = 202), mean, %</td>
<td>1, 5, 7, 17</td>
<td>33.8&lt;sup&gt;d&lt;/sup&gt;</td>
<td>39.4</td>
<td>F = 4.07</td>
<td>.04</td>
</tr>
</tbody>
</table>

ABBREVIATIONS: ANCOVA, analysis of variance; SPF, sun protection factor.

<sup>a</sup> Covariates controlled in the models: (1) Baseline value; (2) age; (3) education; (4) race/ethnicity; (5) sex; (6) skin score (Phenotypic Index); (7) skin cancer; (8) household head; (9) household size; (10) housing type; (11) income; (12) marital status; (13) Metropolitan Statistical Area status; (14) ownership status of living quarters; (15) children younger than 18 years; (16) employment status; (17) Do you agree or disagree with the statement “I look healthier and better when I tan?”

<sup>b</sup> Actual means.

<sup>c</sup> Least-square means.

<sup>d</sup> Least-square means.
It is disappointing that Solar Cell did not reduce sunburns, although neither did a recent text messaging intervention with adolescents. A recent meta-analysis showed variation in success of mobile interventions using text messaging, with those focused on smoking cessation and physical activity being most successful. The lack of impact on sunburn prevalence may have occurred because use of Solar Cell was lower than expected, despite extensive usability testing, clear expectation that enrollees use it, and advice that adults indicated they desired (eg, estimates of the risk of sunburn). Intervention attrition and declining and/or low use has been observed with other technology-based interventions (eg, web-based interventions) and with mobile interventions, despite the apparent enthusiasm for health-related mobile apps. Unfortunately, commercial data indicate that most people who download apps fail to use them regularly. In our formative research, some individuals predicted that they would use the mobile app to learn sun protection and then discontinue use, a trend observed with a diabetes mellitus self-management mobile app. Some participants also may have tried Solar Cell and felt they already knew its advice. Increased use of Solar Cell was associated with improvements in sun protection practices and time spent in the midday sun, so future research on implementation strategies for mobile interventions is an important consideration both in randomized clinical trials and when evidence-based interventions are translated more broadly.

Fortunately, there was no evidence that providing advice on sunburn risk on a mobile app adjusted in real time for UV level and sun protection actions caused adults to spend more time outdoors and increase their high-risk UV-R exposure. This unfavorable adverse effect has been observed with sunscreen and personal UV meters. However, Solar Cell, when used, seemed to motivate participants to try intentionally to reduce their time in the sun. The advice in Solar Cell was designed to help individuals make more informed decisions regarding sun exposure and sun protection by not only displaying the risk of sunburn but also advocating sun protection practices appropriate for the real-time UV-R level and showing how taking these precautions decreased risk of sunburn, also in real time. The combination of tailored sun protection and real-time personal exposure information provided by the mobile app may be one way to avoid this undesirable adverse effect of sun protection technologies. Consistent with this conclusion, feedback on UV-R exposure provided online to students and teachers in a primary school in Australia resulted in lower sun exposure of students.

There were several strengths in the trial. The sample was large and recruited nationwide; randomization created equivalent groups; and few differences were associated with loss to follow-up, all implying that the evaluation was unbiased. However, there were notable shortcomings. Generalizability may be limited by the racial and education composition of the sample. The trial enrolled only non-Hispanic and Hispanic whites; however, the incidence of skin cancer is far higher among non-Hispanic whites than in other racial/ethnic groups and is increasing in Hispanic whites. Likewise, the sample had high education, but smartphone ownership reflects this trend. Outcome measures were assessed by self-report but we used validated, reliable measures. The measures of sun protection practices and time spent outdoors were newly validated and used for one of the first times in a trial. As discussed herein, the inability to get most intervention group participants to use Solar Cell was a major weakness. GfK would not provide us direct contact with participants. It was difficult to assist them with technical problems and we were only able to remind participants to download and use the mobile app 1 time after randomization.

Conclusions

Smartphone mobile apps have potential to deliver disease prevention interventions to a large and growing segment of the US population, engage them proactively, confidentially, and repeatedly, and provide real-time personalized advice when and where they need it. Solar Cell, one of the first sun safety mobile apps evaluated in a randomized clinical trial, may help adults with high-risk skin types or who spend a lot of time outdoors make effective prevention decisions that reduce dangerous doses of UV-R.

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