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Skin cancer interventions across the cancer control continuum: Review of technology, environment, and theory

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Abstract

The National Cancer Institute's Skin Cancer Intervention across the Cancer Control Continuum model was developed to summarize research and identify gaps concerning skin cancer interventions. We conducted a mapping review to characterize whether behavioral interventions addressing skin cancer prevention and control from 2000–2015 included (1) technology, (2) environmental manipulations (policy and/or built environment), and (3) a theoretical basis. We included 86 studies with a randomized controlled or quasi-experimental design that targeted behavioral intervention in skin cancer for children and/or adults; seven of these were dissemination or implementation studies. Of the interventions described in the remaining 79 articles, 57 promoted only prevention behaviors (e.g., ultraviolet radiation protection), five promoted only detection (e.g., skin examinations), 10 promoted both prevention and detection, and seven focused on survivorship. Of the 79 non-dissemination studies, two-thirds used some type of technology (n=52; 65.8%). Technology specific to skin cancer was infrequently used: UVR photography was used in 15.2% of studies (n=12), reflectance spectroscopy was used in 12.7% (n=10), and dermatoscopes (n=1) and dosimeters (n=2) were each used in less than 3%. Ten studies (12.7%) targeted the built environment. Fifty-two (65.8%) of the studies included theory-based interventions. The most common theories were Social Cognitive Theory (n=20; 25.3%), Health Belief Model (n=17; 21.5%), and the Theory of Planned Behavior/Reasoned Action (n=12; 15.2%). Results suggest that skin cancer specific technology and environmental manipulations are underutilized in skin cancer behavioral interventions. We discuss implications of these results for researchers developing skin cancer behavioral interventions.

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Keywords

skin cancer; intervention; cancer control; behavior; detection; screening; prevention; review; cancer control continuum; theory; environment; technology

Introduction

Melanoma incidence is increasing,[1] with 87,110 estimated new cases in 2017.[2] Non-melanoma skin cancer, although more easily treated, is associated with unmet patient support needs and substantial heath care costs.[3] Given the prevalence and health costs of melanoma and non-melanoma skin cancer, interventions promoting sun-safe behaviors, indoor and outdoor tanning cessation, and early detection of skin cancer are crucial.[1] The present paper is one of two[4] mapping reviews[5] undertaken simultaneously to examine the breadth of content and identify research gaps in the skin cancer behavioral intervention literature. Identifying research gaps can provide guidance for researchers developing interventions to reduce skin cancer incidence and mortality.

The reviews were conducted specifically to explore the nature of interventions at each stage of the cancer control continuum, which ranges from prevention through detection, diagnosis, treatment, and survivorship.[6] Interventions may target proximal behaviors along this continuum such as sun protection (prevention) or skin examinations (detection), as well as clinically-related outcomes such as sunburns or nevi, both of which should predict distal disease-related outcomes of disease incidence and mortality. The goal of the corresponding systematic mapping review was to characterize how existing skin cancer interventions map onto the cancer control continuum in terms of the types of interventions, nature of skin cancer relevant outcomes, effectiveness of interventions, and study population, among other characteristics.[4] The goal of the present review was narrower: to characterize the prevalence and nature of the use of (1) technology, (2) policy and built environment, and (3) use of theory in the behavioral skin cancer intervention literature at each phase of the cancer control continuum.

The specific components of technology, policy and built environment, and theory were selected because they mirror the components selected in a recent NIH grant portfolio review,[7] and represent themes identified in a recent meeting about skin cancer prevention.[8] Embedding and incorporating technology, environment, and theory into skin cancer behavioral interventions has the potential to increase both reach and potency and to facilitate intervention scaling to effect behavior change in large segments of the population.

First, technology can improve interventions in multiple ways, as it can serve multiple functions. Specifically, technology can be used to measure behavior or other outcomes (likely improving quality of measurement), to facilitate communication (e.g., emails between intervention staff and participants), to deliver the intervention (e.g., informational videos), or to serve as part of the intervention content (e.g., providing feedback about health harms through personalized UVR photography showing skin damage). Using technology to deliver interventions could allow for precise timing and greater tailoring of the content based on individual or environmental characteristics (e.g., UV index). Of note, we assessed

technology that is broadly applicable to multiple health behaviors—such as mobile applications— and technologies that are specific to skin cancer, such as dermatoscopes, reflectance spectroscopy, and dosimeters. Information regarding the types of technology and how technology functions within interventions is needed because the rapid growth of technological development may outpace intervention science.[9, 10] However, technology has not been leveraged in skin cancer prevention interventions as much as for other behaviors, such as physical activity.[8]

Second, we examined whether interventions included changes to the built environment and to relevant policies. The environment includes policies and procedures directing behavior and the physical structures where skin cancer-relevant behavior occurs. With respect to skin cancer interventions, examples of policy environment interventions include outdoor recreational sites providing worker training, worksites or schools mandating protective clothing use, schools implementing outdoor play policies, and laws limiting tanning bed use.[11, 12] Examples of built environment interventions include signs prompting sun safe behavior, shade structures, and sunscreen dispensers in public places. Built environment and policy interventions could alter the behavior of large segments of populations. Behavior change is difficult to maintain [13, 14], and environmental manipulations may invoke behavior change at an organizational or community level, which in turn may sustain individual behavior change.[15, 16] Although distinct, we grouped policy and the built environment because adopted policies could require changes to the built environment (e.g., school policy necessitating shade structures).[12, 17] Examining multiple types of environmental manipulations promotes understanding of these initiatives within the context of skin cancer behavioral change interventions.[18–20]

Third, some evidence suggests that interventions may be more effective if they are based on a theoretical framework.[21] Descriptions of common constructs from health behavior theories are available on the National Cancer Institute's (NCI) website.[22] Theoretical frameworks and constructs are often explicitly or implicitly proposed as the mechanism of behavior change,[21, 23, 24] and it is thus important to examine their presence in behavioral interventions.

Finally, we also included studies that examined dissemination and implementation of skin cancer interventions.[25] Disseminating—distributing information and intervention materials to a specific but wider audience—and implementing—using strategies to adopt and integrate evidence-based interventions into specific settings—effective interventions are necessary to improve population health.[26] Thus, we examined the nature of interventions that had reached the research stage of dissemination and implementation.

Methods

The complete process for identifying articles and additional exclusion criteria is reported elsewhere.[4] Included studies (1) were published between 2000 to June 2015 in peer-reviewed journals, (2) were written in the English language, (3) used a randomized controlled trial or quasi-experimental design, and (4) described interventions promoting skin cancer-relevant behaviors and outcomes. Consistent with the corresponding review,[4]

excluded studies (1) contained only intermediate outcomes of a behavior (e.g. knowledge or intentions) but not performance of a behavior, (2) focused on sunscreen efficacy outside of an intervention setting, or (3) reported on the same intervention for which a longer published follow-up was available. As human subjects were not involved in the study, no institutional review board approval was required.

Coding Procedure

A content expert (JT) trained an independent coder (BD) who had coded this same set of articles for a corresponding review.[4] BD subsequently trained an additional coder (JO). With the exception of five articles used for training purposes that were coded by two people, each study was fully coded by one person, with questions resolved by an arbiter (JT). JT also double-checked theory and theoretical construct codes, with any discrepancies resolved through discussion. JT coded the dissemination and implementation articles (hereafter referred to simply as dissemination articles).

The coding procedure and codebook were adapted from prior NCI grant portfolio analyses.[23, 27] We coded whether each intervention: 1) included technology, 2) introduced a policy or changes to the built environment, and 3) was designed based on theory and measured theoretical constructs as outcomes.

Technology was not defined in the codebook; rather, coders first marked the presence or absence of a comprehensive list of multiple types of technology (listed in Table 2 and including social media). Next, the purpose of the technology was coded; we included technology that was incorporated as part of the intervention (for example, delivering an intervention through video), that was used to objectively measure outcomes (i.e., “for measurement”), and that was used for participant communication with a medical professional or research staff. If technology was used as part of the intervention, we provided more detail on the specific type(s) of technology used (Table 2).

Environment was coded if interventions sought to change (1) policy or (2) a feature of the built environment. Policies were defined as being broad, local, or specific policies in “workplaces, schools, or health care settings, among others”. Policies could target sun protection, indoor/outdoor UVR exposure, or other outcomes. Policies were considered an environmental manipulation because they targeted large groups rather than intervening at an individual, dyadic, or familial level. The built environment was described as including architectural features, shade structures, and other environmental features such as signage. Coders further determined whether any policy or environment interventions sought to manipulate (1) access to indoor tanning, (2) use of sun protective behaviors (clothing, hats, eyewear), (3) sunscreen use, or (4) sun exposure; and whether the built environment altered or created (1) shade structure(s), (2) planting or shaded-trail use, (3) architectural features to minimize sun exposure, (4) signs to prompt behavior, or other.

Theory was coded to reflect whether the intervention was developed “based on any theory (i.e., does any theory drive the intervention?).” We also coded any theoretical constructs that were assessed as outcomes following the intervention; theoretical constructs were not coded

if they were only assessed at baseline or if they were described as being targeted by the intervention but were not assessed (Table 3).

We also coded geographic location, presence of funding from the National Institutes of Health (NIH), age group of participants, intervention approach and study phase along a translational science continuum from T0 to T4 (Appendix A, Table A.1).[27–29] Codes assigned to particular studies and reported here are included in Appendix B.

The seven dissemination studies represented three unique trials such that five papers reported on different outcomes of the same trial. Dissemination studies were coded only on a subset of characteristics, including: geographic location, study sample, NIH funding status, study phase, point along the cancer control continuum, type and purpose of technology, presence and purpose of built environment or policy interventions, and targeted outcomes. Theories were also recorded (the coding scheme was modified to include theories specifically relevant to dissemination and intervention research, such as Diffusion of Innovation).

Results

Eighty-six articles met inclusion criteria, including seven dissemination studies.[4] Of the 79 non-dissemination articles (Appendix B), 57 reported on interventions that exclusively targeted primary prevention behaviors, five exclusively targeted detection (e.g., skin examinations), and 10 targeted prevention and detection behaviors (Table 1). Seven studies focused on survivorship (cancer survivors or their families). No studies were identified in the diagnosis or treatment phases of the cancer control continuum. Thirty-eight of the 79 non-dissemination studies reported receiving NIH funding (48.1%).

Technology

We report the proportion of studies using technology in Tables 1 and 2 as a function of their location on the cancer control continuum. Overall, 52 of 79 (65.8%) studies incorporated technology, including 68.7% of prevention studies, 73.3% of detection studies, and 28.6% of survivorship studies (Tables 1 and 2). We characterized technology as general or skin cancer specific. Skin cancer specific refers to technology that is irrelevant to other behavioral domains, such as dermatoscopes or reflectance spectroscopy; general technology could be implemented regardless of behavioral domain, such as text messaging or videos. With respect to general technology, videos were used most frequently (n=18 of 79; 22.8%), followed by internet/email (n=11; 13.9%) and text messaging (n=6; 7.6%; Table 2). Videos were always used for educational purposes as part of the intervention, text messages were typically used to remind/prompt participants to perform a behavior, and internet/email served multiple purposes (Table 2). For example, one study involved an educational skin awareness video highlighting factors such as the severity of melanoma to promote clinical self-examinations.[30] With respect to skin cancer specific technology, infrared/UV photography was used most frequently (n=12; 15.2%), always as part of the intervention to provide personalized information regarding UVR effects. For example, Mahler and colleagues showed college students photographs of their face taken through a UV filter that highlighted dark spots from chronic sun exposure.[31] Reflectance spectroscopy was used in

12.7% (*n*=10) of studies, always to measure outcomes of the intervention. Other types of technology were used less frequently (Table 2). No instances of social media were identified. We also recorded the purpose—for example, as part of the intervention or for measurement—of each type of technology (Table 2).

We examined the proportion of prevention, detection, and survivorship studies that used technology as a function of multiple study characteristics: year of publication, geographic location, presence of NIH grant funding, developmental stage of participants, study phase, and intervention approach (Table A.1). Due to small sample size and numerous possible comparisons, inferential statistical analyses were not conducted. However, technology appeared to be used more frequently among more recent studies (2006–2015 vs. 2000–2005). Studies that targeted appearance motives or included personalized/tailored components appeared to have the highest rates of technology, with those targeting availability of and access to sun protection the lowest.

Environment

Only ten studies included an environmental change; eight targeted both the built environment and policy and two of these targeted the built environment only. Nine studies targeted prevention only, and one study targeted prevention and detection; none focused on survivorship (Table 1). Among those involving the built environment, all ten used signs to prompt behavior, four targeted sunscreen availability or affordability, and two involved shade structures. For example, a multi-site intervention included posters placed in prominent locations in ski and snowboard schools[32] and a zoo intervention posted signs at animal exhibits about how animals protect their skin from the sun.[33] Studies that incorporated built environment/policy had policies that intervened on sunscreen use and sun exposure (e.g., training for lifeguards and workers).

We also examined the proportion of prevention, detection, and survivorship studies that incorporated environmental manipulations as a function of multiple study characteristics (Table A.1). The majority of studies with an environmental manipulation were conducted before 2010 (9 of 10) and in the US (9 of 10).

Theory

Fifty-two (65.8%) studies mentioned that the intervention was based on at least one theory. For example, one intervention involved an educational video based on the Health Belief Model which targeted perceived susceptibility by discussing increased risk of melanoma for older men and self-efficacy by modeling a whole body skin self-examination, among other theoretical constructs.[30] Theory was mentioned in 67.2% of prevention studies, 60% of detection studies, and 71.4% of survivorship studies (Table 1). Across all 79 studies, the most common theories were Social Cognitive Theory (SCT; *n*=20; 25.3%), the Health Belief Model (HBM; *n*=17; 21.5%), and Theory of Planned Behavior/Reasoned Action (TPB; *n*=12; 15.2%).

Among the 67 prevention studies, the most frequently mentioned theories were SCT (*n*=15, 22.4%), the HBM (*n*=12, 17.9%), TBP (*n*=10, 14.9%), and the Transtheoretical Model (*n*=5, 7.5%). Other theories mentioned in more than one study were Protection Motivation

Theory (*n*=3), Diffusion of Innovation (*n*=3), Extended Parallel Process Model (*n*=3), Jaccard's Theory of Alternative Behavior (*n*=2), Prototype Willingness Model (*n*=2), Self-Perception Theory (*n*=2), Agenda-Setting Theory (*n*=2) and Precaution Adoption Process Model (*n*=2). Mentioned in one study each were Cognitive Model of Learning, Health Action Process Approach, Health Behavior Framework, Social Influence Theory, Attitude Change Theory, Psychosocial Model of Sun Protection, Social Norms Theory, Social Comparison Theory, "theories of persuasive message design" such as fear appeals, "Weinstein's Theory of Unrealistic Optimism," "informational, expert, and legitimate power of health care providers," and Implementation Intentions.

Among the 15 detection studies, the most frequently mentioned theories were SCT (*n*=5, 33.3%) and HBM (*n*=6, 40.0%). Mentioned in one study each were TPB, Transtheoretical Model, and the Extended Parallel Process Model.

Among the seven survivorship studies, the most frequently mentioned theories were SCT (*n*=4, 57.1%), HBM (*n*=3, 42.9%), TPB (*n*=2, 28.6%), and the Transtheoretical Model (*n*=2, 28.6%). Mentioned in one study each were Precaution Adoption Process Model, Preventive Health Model, PRECEDE-PROCEED Model, and Self-Efficacy Theory.

Overall, approximately three-quarters (*n*=59, 74.7%) of studies assessed at least one theoretical construct. Among studies that mentioned a theory (*n*=52), 86.5% assessed at least one theoretical construct. Among studies that *did not* mention a theory (*n*=27), 51.9% assessed at least one theoretical construct. Table 3 presents the occurrence of specific theoretical constructs. The most commonly assessed constructs were knowledge (38.0%), intentions/willingness (30.4%), self-efficacy/confidence (29.1%), attitudes (29.1%), perceived risk/susceptibility (27.8%), norms (13.9%), and perceived benefits (12.7%). Constructs assessed in fewer than 10 studies are shown in Table 3.

We next examined constructs assessed in studies that reported the four most common theories: SCT, HBM, TPB, and the Transtheoretical Model (see Table 4). Among studies mentioning SCT, the primary construct of self-efficacy was assessed in only 55.0% of studies. For HBM, perceived risk was assessed in only 52.9% of HBM studies, with all other HBM constructs assessed in less than 30% of studies. For the TPB, 75% of studies assessed intentions, but the other TPB constructs were assessed in no more than 25% of TPB studies. For the Transtheoretical Model, only 50% of studies assessed stages of change.

Finally, we examined the proportion of prevention, detection, and survivorship studies that mentioned at least one theory as a function of multiple study characteristics (Table A.1). More than 80% of prevention, detection, and survivorship studies reporting NIH funding mentioned theory versus 0–53% of studies that did not report NIH funding. The proportion of studies mentioning theory differed according to the intervention approach, ranging from 100% for prevention and detection studies using personalized intervention components to 41% of prevention studies that used education approaches in schools.

Dissemination and Implementation Studies

There were seven dissemination and implementation studies[34–40] representing three unique trials; five articles reported on different outcomes of one trial (Appendix B). Dissemination and implementation studies were studies that distributed information and intervention materials to a specific audience or used strategies to adopt and integrate evidence-based interventions into specific settings.[26] Two of the three trials (representing 6 of 7 articles) received NIH funding. Two of the trials were T3 (implementation and wider dissemination) and one was T4 (evaluating outcomes in real world settings) study phase. All were prevention studies. With respect to technology, all trials used email, two used websites, and one also provided a CD-ROM of intervention materials. No trials used skin cancer specific technology. Two trials targeted policy (e.g., worker training) to promote sun protection and a third provided intervention sites with a script for an employee sun safety in-service presentation. All three trials had intervention components targeting the built environment through signs, and one trial also included shade structures, but these aspects were not necessarily strategies for dissemination. With respect to theory, all three trials were based on Diffusion of Innovation Theory; one trial was also based on tailoring and one was also based on SCT and theories of organizational change. Outcomes included program uptake, employee and guest exposure to the program materials and perceptions of the materials, employee and guest sun behavior, and program sustainability over time.

Discussion

The goal of this review was to characterize the prevalence and nature of the use of technology, policy and built environment manipulations, and theory in existing behavioral skin cancer interventions and to identify research gaps. We discuss findings for technology, environment, and theory in turn.

Technology

Approximately two-thirds of studies used technology, with non-skin cancer specific technology such as videos and internet/email most frequently used. Newer technology, such as text messaging or social media, was less frequently used, perhaps because interventions were designed before this technology became popular. Social media interventions have shown promise for smoking cessation, dieting, and alcohol consumption and should be explored in the skin cancer domain,[41] although effect sizes are small and retention often low.[42] To counter these limitations, researchers using social media as part of skin cancer behavioral interventions should apply lessons from these other domains. Skin cancer interventions delivered via text messages or mobile applications could control message timing, frequency, and intensity and allow participants to personalize program features. Interventions could also include phone-delivered messages[43] with visual educational components that highlight appropriate sun protective clothing or sunscreen application or how to conduct skin self-examinations. A recent review of skin cancer prevention studies that delivered an intervention through mobile devices found that all interventions resulted in some degree of self-reported behavior change.[44]

Interventions infrequently used skin-cancer specific technology such as dosimetry or reflectance spectroscopy to obtain objective data on UVR exposure, and these may be less practical in real-world recreational settings. Nevertheless, incorporating technology could improve measurement of relevant outcomes such as outdoor UVR exposure or characterization of sunburn. Using these techniques may reduce error from self-reported data, and using photography to objectively assess outcomes might reduce inter-individual variation in self-reported outcomes. Technological advances also allow researchers to more efficiently refine and develop theories of behavior change, as technology can capture more data with greater precision.[45] However, technology also has limitations and would not solve all measurement issues; for example, reflectance spectroscopy cannot account for sunless tanning products or body hair and photography is qualitative data requiring expert coding. Further, current health behavior theories might not sufficiently account for the dynamic nature of behavior change,[24] suggesting that theories must evolve along with technology.

No studies used technologies such as platform integrations (i.e., computer software in a mobile device that integrates data from different sources such as sensors, user-feedback systems, or social network platforms) or passive capture of UV-relevant behavior (e.g., time spent outdoors on real-time basis). Platforms devised for other health behaviors could incorporate sun safety-relevant information. For example, real-time UV-index platforms exist as do GPS-enabled platforms to track and prompt physical activity,[46, 47] which could conceivably integrate sun safety and physical activity information and social networking features.[48] In one trial that delivered sun protection advice based on the UV index, only 41% of participants assigned to use the application that delivered the advice subsequently accessed and used it, but among those who used the app, sun protection increased.[49] We are unaware of platform and feature integration in the domain of sun safety, but platform integration can accommodate multiple sensor input[50] and is routinely used to prompt behavior.[10] Of course, sensor technologies have limitations in terms of participant compliance and data cleaning.

Environment

Few interventions targeted policy or the built environment. These types of interventions often take place in school settings and can involve constructing shade structures.[18, 51] Because schools often do not have policies that facilitate sun safety, built environment and policy interventions in school settings could have a major impact on skin cancer outcomes.[52] Policies at workplaces—particularly those involving outdoor work such as ski slopes or zoos—were targeted in relatively few interventions. Although these interventions are likely complicated and expensive to implement, they have the potential to impact many people. UV-relevant behavior might be assessed passively by video cameras in public parks and playgrounds with proper consent. This approach, in conjunction with computer learning methods, is used for physical activity research[53] and has relevance for sun safety. Of note, because changes to the environment are an infrequent intervention component, researchers might disagree on which specific interventions components can be categorized as changes to the built environment; for example, we considered posted signs as a built environment change but others may not.

Local, state, and potentially federal policies are changing and may affect youth access to commercial tanning facilities. To date, limited correlational research has gauged the effect of these policies[11] and further research is needed. Similarly, universities may examine policies on and near campus that influence tanning and sun exposure for students and staff.[54] As has been done with diet, physical activity, and tobacco control,[55, 56] natural experiments could be employed in sun safety research.

Theory

Approximately two-thirds of the studies were theory-based. However, although 27 of 79 studies did *not* report that the intervention design was informed by a theoretical basis, that does not mean one was not employed. Theories and theoretical constructs may have been measured but not reported if the study was published in a medical journal with stricter page limits that emphasizes clinically relevant outcomes such as sunburns or nevi. Thus, the use of theory in intervention development might be higher than what we reported. However, if a theory is not mentioned in the publication, the utility is lost for researchers who do not learn whether a particular theory should be used to design subsequent interventions.

The four most frequently used theories were Social Cognitive Theory,[57] the Health Belief Model,[58] Theory of Planned Behavior/Reasoned Action,[59] and the Transtheoretical Model.[60] Although these theories are widely used to design health behavior interventions, they were developed before modern technology and may not fully account for theoretical constructs that influence sun protection behavior. Moving forward, researchers might consider incorporating novel theories such as message framing[61, 62] or terror management theory[63] and theoretical constructs such as positive and negative mood and affect[64, 65] or implicit attitudes and prototypes[66] that have been used in some studies of sun protection. Because interventions were excluded from this review if they only assessed intermediate outcomes such as knowledge or intentions, but not behavior,[4] studies testing the application of novel theoretical frameworks to skin cancer research may be underrepresented if they are in the piloting stage. Researchers might also look to interventions in other behavioral domains such as smoking or addiction for insight and inspiration.[67, 68]

Most theories identified in this review were individual level theories. Although the use of a theoretical basis was relatively low for interventions conducted in school settings (41%), individual level theories should be relevant for all types of interventions, including those in school and organizational settings[69] and implementation research.[70] However, many theories that are relevant to school environments[69] and implementation research[70] were not identified in this review. One underutilized model is the Social Ecological Model, which accounts for multiple levels of influence including community and policy.[71] Thus, the breadth of interventions informing skin cancer behavioral interventions could be expanded.

The key constructs in the studies reporting the four most frequent theories were typically assessed in fewer than half of the studies, which is consistent with another review of the use of theory.[23] There are several explanations for this. First, researchers might choose the most applicable theoretical constructs from multiple theories; in fact, combining multiple theories may lead to stronger interventions.[71] Second, a theory could have informed the intervention but behavioral outcomes were assessed rather than theoretical constructs, or theoretical

constructs were assessed but reported elsewhere. Third, different names may be used for similar constructs. Last, it is likely that few studies assessed all constructs from a given theory given the low rates of endorsement of any particular construct, suggesting limits in the extent to which researchers can test whether theories predict behavior. We recommend that authors consider whether excluding constructs from a theory is justifiable when planning interventions and then explicitly state why certain constructs from the named theory were not included or assessed.

Limitations

There are several limitations. We excluded publications before 2000 and non-experimental research. Using publication date, rather than the year a study was conducted, would impact trend interpretation if the lag between trial initiation and publication varied substantially. Although some double-coding occurred during training and for the theoretical coding, articles were not fully double-coded which may impact reliability. We also did not code or account for study quality.

Conclusion

The present review of 16 years of skin cancer behavioral interventions found that among studies published between 2000 and June of 2015, approximately two-thirds used some type of technology, less than 15% used changes to the environment, and two-thirds reported using a specific theory to design the intervention, although the majority were traditional health behavior theories. Technology was used more frequently in recent years, and we expect that mHealth and eHealth interventions will continue to grow in popularity. Although we did not assess the simultaneous use of technology, environmental manipulations, and theory in particular studies, we believe that interventions should seek to jointly incorporate these constructs. Improving messaging tailoring and targeting was recently identified as a sun safety theme among a panel of experts,[8] and tailored messages could be theoretically-based, facilitated by technology, and target large groups of individuals. Overall, the results suggest room for advances in incorporating technology, environment, and novel theories and theoretical constructs into sun safety interventions.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Percentage and number of studies among the 79 skin cancer behavioral intervention studies conducted from 2000–2015 incorporating technology, environment, and theory according to the cancer control continuum

	% (n)				
Behavioral Intervention Component	**Prevention[a] *n*=67**	**Detection[a] *n*=15**	**Diagnosis, *n*=0**	**Treatment, *n*=0**	**Survivorship, *n*=7**
Technology (*n*=52)	68.7 (46)	73.3 (11)	0	0	28.6 (2)
Environment (*n*=10)	14.9 (10)	6.7 (1)	0	0	0
Theoretical basis (*n*=52)	67.2 (45)	60.0 (9)	0	0	71.4 (5)

[a]There are 72 unique prevention and detection studies. Ten of these 72 studies included both prevention and detection targets and are represented in both of these columns.

Percentages are based on the column *n*s.

Note: Studies included in review are listed in Appendix B.

Table 2

Type and purpose of technology used in skin cancer behavioral intervention studies conducted from 2000–2015 as a function of the cancer control continuum

Technology used	% (n) All studies *n*=79	Prevention, *n*=67[a]	Detection, *n*=15[a]	Survivorship, *n*=7	Purpose of technology
All types of technology	65.8 (52)	68.7 (46)	73.3 (11)	28.6 (2)	
General technology (i.e., not specific to skin cancer)					
Videos	22.8 (18)	20.9 (14)	26.7 (4)	14.3 (1)	• Part of intervention: Education (*n*=18)
Internet/email	13.9 (11)	13.4 (9)	13.3 (2)	14.3 (1)	• Part of intervention: Education (*n*=8) • Part of intervention: Create action plan (*n*=2) • Part of intervention: Email reminder to perform behavior or visit study website (*n*=2) • Measurement (*n*=2)
Text messaging	7.6 (6)	7.5 (5)	13.3 (2)	0	• Part of intervention: Reminder/prompt to perform behavior (*n*=6) • Part of intervention: Education (*n*=1)
Ecological momentary assessment/daily dairies	6.3 (5)	7.5 (5)	13.3 (2)	0	• Measurement (*n*=5)
Computer program	2.5 (2)	3.0 (2)	0	0	• Part of intervention: Education (*n*=2)
Mobile applications	1.3 (1)	1.5 (1)	0	0	• Part of intervention: Personalized feedback on level of risk for UV exposure (*n*=1)
Multi-media message services that allow transfer of image, video, audio and text on phone	1.3 (1)	1.5 (1)	0	0	• Part of intervention: Education (*n*=1)
Skin cancer specific technology					
Infrared/UV photography	15.2 (12)	17.9 (12)	6.7 (1)	0	• Part of intervention: appearance-based, personalized information on damaging effects of UVR (*n*=12)
Reflectance spectroscopy	12.7 (10)	14.9 (10)	0	0	• Measurement (*n*=10)
Light dosimeter	2.5 (2)	3.0 (2)	0	0	• Part of intervention: Increase awareness of UV exposure (*n*=2) • Measurement (*n*=1)

Technology used	% (n) All studies *n*=79	Prevention, *n*=67[a]	Detection, *n*=15[a]	Survivorship, *n*=7	Purpose of technology
Dermatoscope	1.3 (1)	1.5 (1)	0	0	• Measurement (*n*=1)

[a]Seven studies that used technology were categorized as both prevention and detection and thus may be represented in both of these columns.

Note: Some studies were coded as using more than one type of technology.

Table 3

Theoretical constructs assessed in skin cancer behavioral intervention studies conducted from 2000–2015 as outcomes of the intervention

	% (n)			
Theoretical construct	**All studies, *n*=79**	**Prevention, *n*=67[a]**	**Detection, *n*=15[a]**	**Survivorship, *n*=7**
Knowledge	38.0 (30)	38.8 (26)	33.3 (5)	42.9 (3)
Intention or willingness (to engage in a behavior) or implementation intentions	30.4 (24)	28.4 (19)	13.3 (2)	57.1 (4)
Perceived vulnerability / risk / susceptibility	27.8 (22)	28.4 (19)	33.3 (5)	14.3 (1)
Self-efficacy/confidence	29.1 (23)	22.4 (15)	26.7 (4)	71.4 (5)
Attitudes	29.1 (23)	28.4 (19)	20.0 (3)	28.6 (2)
Norms/normative beliefs	13.9 (11)	16.4 (11)	6.7 (1)	0
Perceived benefits	12.7 (10)	11.9 (8)	6.7 (1)	28.6 (2)
Perceived barriers	12.7 (10)	11.9 (8)	6.7 (1)	28.6 (2)
Environment	8.9 (7)	10.4 (7)	6.7 (1)	0
Perceived costs	7.6 (6)	9.0 (6)	6.7 (1)	0
Stages / processes of change	6.3 (5)	7.5 (5)	0	0
Outcome expectations	5.1 (4)	4.5 (3)	0	14.3 (1)
Response efficacy	5.1 (4)	6.0 (4)	6.7 (1)	0
Worry	3.8 (3)	3.0 (2)	13.3 (2)	0
Prototypes	3.8 (3)	4.5 (3)	0	0
Perceived severity	3.8 (3)	4.5 (3)	0	0
Perceived control	2.5 (2)	3.0 (2)	6.7 (1)	0

[a]There are 72 unique prevention and detection studies. Ten of these 72 studies included both prevention and detection targets and are represented in both of these columns.

Note: Studies included in this table were *not* restricted to only those studies that were coded as basing the intervention on a theory.

Several other responses were mentioned in one study each and not coded for: “see myself as the kind of person who lies out in the sun”, “action planning”, “coping planning,” “innovation attributes,” and “awareness concerns interest.”

Table 4

Theoretical constructs assessed in skin cancer behavioral intervention studies conducted from 2000–2015 using the four most commonly used theories.

	% (n)			
All theoretical constructs included in coding scheme	**Social Cognitive, Theory, *n*=20**	**Health Belief Model, *n*=17**	**Theory of Planned Behavior/ Reasoned Action, *n*=12**	**Transtheoretical Model, *n*=8**
Knowledge[a]	**45.0 (9)**	41.2 (7)	50 (6)	25 (2)
Intention or willingness (to engage in a behavior) or implementation intentions	20.0 (4)	35.3 (6)	**75 (9)**	12.5 (1)
Perceived vulnerability / risk / susceptibility	20.0 (4)	**52.9 (9)**	58.3 (7)	25 (2)
Self-efficacy/confidence	**55.0 (11)**	**29.4 (5)**	50.0 (6)	25 (2)
Attitudes	25.0 (5)	11.8 (2)	**25 (3)**	25 (2)
Norms / normative beliefs	25.0 (5)	**11.8 (2)**	**25.0 (3)**	0
Perceived benefits	15.0 (3)	**29.4 (5)**	41.7 (5)	0
Perceived barriers	30.0 (6)	**17.6 (3)**	33.3 (4)	12.5 (1)
Environment	15.0 (3)	0	8.3 (1)	**0**
Perceived costs	0	17.6 (3)	16.7 (2)	0
Stages / processes of change	0	0	0	**50 (4)**
Outcome expectations	**20.0 (4)**	5.9 (1)	0	0
Response efficacy	5.0 (1)	11.8 (2)	16.7 (2)	0
Worry	0	0	16.7 (2)	0
Prototypes	0	5.9 (1)	0	0
Perceived severity	0	**11.8 (2)**	16.7 (2)	0
Perceived control	0	0	**8.3 (1)**	0

[a]Behavioral capability (i.e., knowledge and skill to perform a given behavior) is the construct in Theory at a Glance.[72]

Note: Bold values indicate theoretical constructs that are included in a theory according to Theory at a Glance.[72]

Notes. Some constructs listed in Theory at a Glance were not coded and therefore not included in the table because they were not outcomes, although they have been used as part of the intervention. These constructs include “cue to action” (Health Belief Model), and “reciprocal determinism”, “observational learning”, and “reinforcements” (Social Cognitive Theory). For example, use of texting or prompting could be considered a “cue to action” and a video with a model might be “observational learning.”