Daily Minutes of Unprotected Sun Exposure (MUSE) Inventory: Measure description and comparisons to UVR sensor and sun protection survey data

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ABSTRACT

One in five US adults will be diagnosed with skin cancer. As most skin cancers are attributable to sun exposure, this risk factor is an important target for research and intervention. Most sun exposure measures assess frequency of specific sun-protection behaviors, which does not account for the use of multiple, potentially overlapping sun-protection methods. In contrast, the Daily Minutes of Unprotected Sun Exposure (MUSE) Inventory assesses sun-protection behavior during self-reported activities, providing several useful metrics, including duration of un-protected sun exposure on 17 body sites, combined to yield an overall MUSE score weighted by percent of body exposed. The present study was conducted July–September 2017, in Chicago, IL USA. For 10 days, participants (39 melanoma survivors; M_{age} = 58.59, 64.5% female) wore an ultraviolet radiation (UVR) sensor and com-pleted the Daily MUSE Inventory each evening. The Sun Habits Survey was completed at the end of the study. Outdoor time reported in the MUSE Inventory significantly predicted outdoor time recorded by UVR sensors, $B = 0.53$, $p < .001$. For all sun-protection behaviors except shade, reports from the Daily MUSE Inventory (i.e., percentage of outdoor time a particular strategy was used) correlated with frequency ratings of the same strategy from the Sun Habits Survey ($rs = 0.66–0.75$, $p < .05$). In sum, the Daily MUSE Inventory corresponds with sensor and survey data, and provides a novel metric of unprotected sun exposure that will be useful for eval-uating overall extent of sun exposure, including exposure on several smaller body sites that are at high risk for skin cancer.

1. Introduction

One in five US adults will be diagnosed with skin cancer in their lifetime (Stern, 2010) and rates continue to rise (Rogers et al., 2015; Glazer et al., 2016). The primary method to prevent skin cancer is re-ducing sun exposure (Koh et al., 1996; Parkin et al., 2011; Armstrong and Kricker, 2001). Despite improved public knowledge about skin cancer in the last few decades (Baum and Cohen, 1998), unprotected sun exposure, and even sunburn, remain frequently reported (Bränström et al., 2010), with 37.1% of US adults reporting a sunburn in the past year (Holman et al., 2014). Thus, there is a need for addi-tional research and interventions on sun protection.

For this research, valid measures of unprotected sun exposure are necessary. The most objective measure of real-time personal ultraviolet radiation (UVR) exposure – electronic UVR dosimetry – assesses ex-posure duration and intensity, but it cannot account for sun protection without self-reports. Currently, the most widely used self-report mea-sure of personal sun protection and exposure in the US is the Sun Habits Survey, which assesses the frequency of sun-protection behaviors on warm summer days (Glanz et al., 2008). Diary measures have also been developed to capture daily-level sun behavior and have taken various forms, including asking about outdoor time during specific windows of time (Cust et al., 2018; O'Riordan et al., 2009; Cargill et al., 2013; Chodick et al., 2008) or asking the length of time participants were

engaged in specific sun-protection behaviors (Hillhouse et al., 2012).

An important limitation of these measures is that they do not provide a score representing overall sun protection. Because effective sun protection can be achieved by using any of several sun-protection methods, simply summing or averaging frequency-based measures may misrepresent extent of sun protection. For example, a person who "always" uses protective clothing, but "never" uses sunscreen could inappropriately receive a lower score than a person who "often" (but not "always") practices several methods and remains unprotected some of the time. Similarly, use of individual sun-protection methods is often inconsistent and there is great variability in sun-protection behaviors both within and between persons (Hay et al., 2017). This variability makes it difficult to assess change over time in overall UVR exposure because it is unclear whether changes to individual methods result in changes in overall protection – for instance, a person may reduce their sunscreen use but still retain the same level of protection if using protective clothing to cover exposed areas.

While diary measures provide more specific information about sun-protection behaviors, current versions do not yield sufficient data on the overall thoroughness of these behaviors (e.g., body sites to which sunscreen is applied). The Daily Minutes of Unprotected Sun Exposure (MUSE) Inventory uses an activity-based recall method (Hillhouse et al., 2012) to address these limitations and provide scores representing duration of unprotected sun exposure after accounting for whether any sun-protection method was used to protect specific body sites during outdoor activities. The present study assessed concurrent validity of the MUSE Inventory with both the Sun Habits Survey and UVR sensors among a sample of melanoma survivors in the US.

2. Method

2.1. Participants

Participants were adult melanoma survivors who had previously enrolled in a study that provided skin self-examination to adults following treatment for melanoma stage IIb or lower (Robinson et al., 2016). Participants were required to have daily access to a computer and wireless internet. They received a $100 gift card as compensation.

2.2. Procedures

All study visits were completed between July and September 2017 in Chicago, IL, USA. At baseline, participants provided informed consent and received instruction on using the UVR sensor and study smartphone. Participants were instructed to wear the sensor near their left collar during daylight hours and to use the smartphone to download the sensor data each evening. Each evening for 10 days, participants were emailed a link containing the MUSE Inventory, reminders and instructions for performing the device download, and an online form to record any download or device problems. Participants then returned to the laboratory and completed a single administration of the Sun Habits Survey referring to the last 10 days.

2.3. Measures

2.3.1. Sun Habits Survey

Using the Sun Habits Survey (Glanz et al., 2008), participants rated their frequency of using specific sun-protection methods (e.g., shirt with sleeves) on a warm, sunny day, using 5-point Likert scales ranging from 1 (Never) to 5 (Always). Participants indicated duration of outdoor time during peak hours (10 AM–4 PM) on weekdays and weekend days, using a rating scale ranging from 1 (30 min or less) to 8 (> 6 h).

2.3.2. Daily MUSE Inventory

The Daily MUSE Inventory is a computerized measure, currently administered via REDCap (Harris et al., 2009), which assesses sun exposure based on the outdoor activities that a participant completes during a particular reporting window (Appendix A). This measure was initially developed and pilot-tested among 128 individuals with a familial history of melanoma (Aspinwall et al., 2018). The daily version of the measure was administered in a 14-day study of 50 participants with elevated melanoma risk (Stump & Aspinwall, 2017). Following the study, participants were interviewed about their use of the measure, including any aspects of the measure they found confusing or burdensome, which resulted in additional refinements (e.g., instruction clarification). In the present study, participants were asked to report details of all outdoor activities performed for > 15 min between 6 AM and 6 PM. Participants first entered an activity description, added start and end times, and then reported the clothing they were wearing by selecting pictures of clothing options with varying coverage, represented by 5 pictures each, for four separate body regions (head, torso, legs, and feet). Additional items assessed shade, whether they sweated or got wet, and use of accessories (e.g., sunglasses, gloves). Participants then reported all instances of sunscreen use, including time of day applied (or reapplied), body sites covered, and the SPF of the sunscreen. The Daily MUSE Inventory yields several sun exposure metrics, summarized in Table 1.

2.3.3. Sun-protection behavior percentages

To enable analysis of the association between measures, percentages of outdoor time participants employed each of several main sun-protection strategies (wearing hat, sunglasses, sunscreen, shirt with sleeves, or seeking shade) were computed based on MUSE Inventory responses. Specifically, for each behavior assessed by the Sun Habits Survey, the durations of all activities during which the behavior was performed were summed and then divided by total duration of all activities reported during the 10-day period. For sunscreen use, duration of use was computed by determining how long an activity time overlapped the two-hour window beyond initial sunscreen application. The effective time of the sunscreen was shortened to 80 min if the participant reported sweating or getting wet "a lot" during an activity, consistent with US Food and Drug Administration regulations indicating that 80 min is the maximum effective time for water-resistant sunscreens following heavy sweating or submersion (US Food and Drug Administration, 2017).

2.3.4. MUSE scores

MUSE scores represent the duration of unprotected sun exposure an individual received in a single day. Scores were computed separately for individual body sites and as an overall MUSE score, which considers both the total percentage of the body's surface area that was unprotected and duration of exposure. Body site surface area was estimated by referencing charts used to characterize the extent of burns (see Fig. 1) (Wedro, 2012; Zinn, n.d.). All clothing was considered equally effective at blocking UVR to simplify scoring algorithms and prevent the respondent burden of answering additional questions about fabric characteristics for each clothing item. To illustrate these calculations, we provide an example of a woman doing yardwork for 4 h while wearing a brimmed hat, T-shirt, shorts, and tennis shoes (see Fig. 2). Assuming no additional sun-protection strategies are used, this clothing combination leaves parts of her arms and legs exposed, which comprise 38.5% of her body. The scoring algorithm adjusts time outdoors (240 min) for this percentage of unprotected body surface area by multiplying these values, yielding an overall MUSE score of 92.4. In variations 1, 2, and 3, the protection provided by sunscreen with reapplication after 2 h, protective clothing (long sleeves, long pants, gloves), and deep shade, respectively, reduces MUSE scores to 0, while sunscreen that is not reapplied during this lengthy exposure provides sun protection for only the first 2 h (variation 4).

2.3.5. UVR sensor

The Shade UVR sensor assessed minutes of outdoor exposure