The Role of Dispensing Device and Label Warnings on Dosing for Sunscreen Application: A Randomized Trial

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Abstract

Drug manufacturers are expected to provide labeling information needed to yield safe and effective product use. However, it is not clear that consumers dose sunscreen, an over-the-counter drug, appropriately; in fact, existing evidence suggests underdosing as a common phenomenon. The objective of this study was to evaluate the effect of dispensing device and labeling on self-administered doses of sunscreen in young adults. To investigate those effects, a $2 \times 2$ factorial laboratory experiment crossing dispensing device (two levels) with labeling treatment (two levels) was conducted. Participants applied sunscreen from each of the four treatments; dosing concentration, measured in mg/cm$^2$, served as the response variable. Participants ($n = 94$) were recruited on the campuses of Michigan State University (East Lansing, MI) and California Polytechnic State University (San Luis Obispo, CA). Each participant applied sunscreen from each unique treatment to sites on their arms and legs (four applications). Postapplication, a survey was completed to characterize demographics, risk perception, and sunscreen use patterns. Results indicate participants applied approximately 30% less sunscreen from the pump bottles than the squeeze bottles (difference estimate of 0.3059 mg/cm$^2$, standard error $= 0.0607$, $p < .0001$); there was no evidence of a difference based on label treatments. Post hoc recognition tests indicated only 55% of participants were able to recognize the two experimental labels they had viewed immediately following sunscreen application. Sunscreen application density was directly related to level of worry regarding skin cancer and frequency of sunscreen use ($\alpha = .05$). Our results suggest the dispensing device used to deliver sunscreen impacts the dosage amount consumers apply.

Keywords
dosing, labeling, mixed methods, nanoparticles, skin cancer, sunscreen

Modern sunscreen has been widely used since the 1920s when the connections between ultraviolet (UV) exposure and sunburn and skin cancer were first discovered (Provost, Landells, & Maddin, 2006). In 1978, the U.S. Food and Drug Administration (FDA) first regulated sunscreen as an over-the-counter (OTC) drug.

Sunscreen effectiveness is characterized by the ability of its particles to block UV radiation. Benefits of reduced exposure to UV through the use of sunscreen include: the prevention of sunburn, diminished aging of the skin, and a reduced possibility of developing skin cancers (Aldahan, Shah, Mlacker, & Nouri, 2006). In fact, studies of routine use of sunscreen starting in childhood found a reduction in the risk of developing nonmelanoma skin cancers by as much as 78% (Stern, Weinstein, & Baker, 1986). Despite the clear benefits of use, studies throughout history suggest that consumers consistently apply less than the recommended dose of sunscreen necessary to achieve maximum benefit (Autier, Boniol, Severi, & Dorè, 2001; Diffey & Grice, 1997; Lademann et al., 2004; Matveev & Maibach, 2002; Reich, Harupa, Bury, Chrzaszcz, & Starczewska, 2009; Szepietowski, Nowicka, Reich, & Melon, 2004; Wright, Wright, & Wagner, 2001). As such, strategies that encourage proper dosing are warranted to achieve the maximum health benefit.

As with any OTC, the benefits of use come with some risk. Limited studies suggest oxybenzone, one of the most common filter ingredients found in chemical sunscreens, can transdermally permeate the skin of animal models and has been found in measurable quantities in vital organs of the same (Fediuk, Wang, Raizman, Parkinson, & Gu, 2010). It has also been suggested that UV filters are potentially endocrine disrupters and...
may be associated with cancer (Krause et al., 2012; Waring & Harris, 2005). Additionally, scent-stabilizing phthalates commonly used in sunscreen have been found in pregnant women’s urine samples and are also considered possible endocrine disruptors (Buckley et al., 2012; Schettler, Skakkebæk, De Kretser, & Leffers, 2006). More broadly, the World Health Organization (WHO) has identified generalized risks associated with OTC products of all types. General risks associated with OTCs include: incorrect choice of therapy, rare but severe adverse effects, incorrect route or manner of administration, storage in incorrect conditions or beyond the recommended expiration dating, and inadequate or excessive dosage (Bown, Kisuule, Ogasawara, Siregar, & Williams, 2000).

Work presented here focuses on how two packaging factors (dispensing mechanism and labeling) potentially impact the application amount of sunscreen applied by young adults.

Sun protection factor (SPF) is calculated based on the assumption that consumers will apply a dose of 2 mg/cm² of sunscreen to the body’s surface exposed to UV rays (Faurschou & Wulf, 2007; Julian, Palestro, & Thomas, 2015). Studies suggest, on average, consumers apply only a quarter of the dose recommended to achieve adequate protection, 0.5 mg/cm² (Autier et al., 2001; Azurdia, Pagliaro, Diffey, & Rhodes, 1999; Azurdia, Pagliaro, & Rhodes, 2000; Bauer, O’Brien, & Kimlin, 2010; Bech-Thomsen & Wulf, 1993; Diffey & Grice, 1997; Isedeh, Osterwalder, & Lim, 2013; Neale, Williams, & Green, 2002; Reich et al., 2009; Srinivas, Lal, Thirumurthy, Sundaram, & Karthick, 2006; Stenberg & Larkö, 1985; Szepietowski et al., 2004). Underdosing makes sunscreen less effective and users are frequently unaware of the reduction in efficacy and are, thus, overconfident about their protection from UV damage (Faurschou & Wulf, 2007; Julian et al., 2015). In order to achieve adequate protection, in addition to appropriate initial dosing, reapplication of sunscreen is recommended every 2 hours, or after sweating or swimming (U.S. Department of Health and Human Services Food and Drug Administration [USFDA], 2011a; Wulf, Stender, & Lock-Indersen, 1997).

The structural design of packaging, as well as the design of the labeling, have the potential to influence both perceptions and physical interactions of consumers using regulated products like sunscreen (Jungman & Maibach, 2010). The FDA has mandated clear labeling for OTC drugs for many years; sunscreen labeling must include a drug facts label, SPF within a range of SPF 15 to SPF 50+, water resistance claims with specific time limits, and a warning alerting consumers the product does not protect against skin cancer or aging if it has an SPF between 2 and 14 (USFDA, 2011b). The directions for use for sunscreen products are often ambiguously worded, despite added labeling requirements published in 2012, which prohibit the use of specific phrases, including the following: “sunblock,” “sweat proof,” or “waterproof” due to the possibility of overstating efficacy and misleading consumers (USFDA, 2011a). To benchmark the labeling of existing sunscreen products, we conducted an analysis of commercially available sunscreens in North America using the Mintel Global New Products Database in March 2018. Of the 250 results, 184 were sunscreen products intended for human use (73.6%). There were 42 different application directions, only one of which specified an amount of sunscreen to be used; “Squeeze a quarter sized amount onto fingertips and blend evenly over face and neck before sun exposure.” The most common application directions included the terms: “generously” on 59 (32%) of the products and “liberally” on 116 (63%) of the products, in lieu of more directive wording.

But it is not only the labeling of an OTC that has the potential to influence consumer behavior. The USFDA is recognizing the potential packaging has to impact behaviors and, in turn, health outcomes, and with increasing frequency is asking for objective evaluation of how packaging influences consumer behavior with multiple products (USFDA, 2011b, 2017).

While the physical structure of the package has been examined on a very limited basis, previous studies left gaps in understanding specific to the impact of labeling in conjunction with structure using varied audiences (Diaz, Neale, Kimlin, Jones, & Janda, 2012; Lynfield & Schechter, 1984). Diaz et al. examined how packaging affected the amount of sunscreen children applied, finding that package type (i.e., pump bottle, squeeze bottle, or roll on) significantly affected application dose (Diaz et al., 2012). No specific inquiry regarding how labeling affected the same was noted. Lynfield and Schechter used adults and focused their investigation on how the effect of product formulation, with package type as a secondary factor of interest, impacted application dose. The authors report a difference in application amount when a wide mouth jar and a small tube were the points of comparison, with more product applied from the wide mouth jar (Lynfield & Schechter, 1984).

Hypotheses

**Hypothesis 1:** Packaging dispensing device affects application density.

We hypothesized that based on the work of Diaz et al. (2012) the use of a pump would significantly increase the amount of sunscreen applied as compared with a squeeze bottle when young adults applied sunscreen to themselves.

**Hypothesis 2:** Labeling warning message affects application density.

We hypothesize that label information that warns “Dermatologists recommend applying 9 tsps. (45 mL) to the entire body to lower risk of developing skin cancer” would result in a greater application density than doses delivered from treatments with labels that state “This product contains nanoparticles. The long-term effects of nanoparticles on the human body are unknown” (Figure 1).
Our messages were selected so that both the encouraging and discouraging messages were plausible to consumers with varying levels of familiarity with sunscreen. Both the messages could be true about the same sunscreen, despite the tone of the messages, as the dosage recommendations from dermatologists for sunscreen lotions are consistent no matter the active ingredient, and zinc oxide and titanium dioxide are nanoparticles commonly used in sunscreens.

**Hypothesis 3:** Participant characteristics affect application density.

Participant characteristics (e.g., skin tone, familial history of skin cancer, history of severe burns, etc.) significantly influence the amount of sunscreen young adults apply when the application density is the dependent variable of measure. Specifically, we hypothesized those with familial skin cancer, prior experience with severe sunburns, and fair skin tones would tend to apply sunscreen more generously.

Given the complexity of interactions and the limited body of work in this area, no hypotheses about the interaction of labeling and package structure were generated in advance.

**Materials and Methods**

Methods were conducted in accordance with those approved by the Michigan State University Social Science Behavioral/Education Institutional Review Board (SIRB) #16-574, and at California Polytechnic State University under the submission title, “The Effect of Packaging and Labeling Interventions on Sunscreen Application” (approval June 29, 2016).

**Participant Eligibility and Recruitment**

Eligibility requirements for participants stipulated participants be aged 18 to 36 years, a sunscreen user, and have no history of a skin condition potentially irritated by sunscreen. Participants were recruited through the SONA recruitment platform, flyers, and presentations inviting participation in the study. The age range of 18 to 36 years was selected so that all the participants were from the same generational cohort (millennial as defined in a report by Pew Research Institute [Taylor & Keeter, 2010]). Because the regulatory status change (specification of sunscreen as an OTC in 1978) had the potential to influence consumer perceptions of safety, efficacy and importance, this age range was specifically chosen because it represented a defined cohort born in the era after the change in the product’s regulatory status.

**Participant Characterization**

Collected demographic information included participant age, gender, self-declared hand dominance, and laterality. Laterality, which is used to express the preferential use of limbs in voluntary motor acts (Sadeghi, Allard, Prince, & Labelle, 2000), was collected in accordance with the techniques used by Mohr, Thut, Landis, and Brugger (2003, 2006). Participants were instructed to clasp their hands together, and researchers recorded which thumb was placed on top. Participants were then asked to fold their arms. As with the previous task, the arm which was on top was noted. As such, there were four possible lateraltities that were coded LL, LR, RL or RR (hand clapping preference followed by arm folding preference).
Prior to beginning the sunscreen application, a measuring tape was used measure the circumference of the ankle, the leg (approximately one inch below the knee), the wrist, and the upper arm (approximately one inch below the shoulder). These measurements were used to calculate an estimated surface area by treating limbs mathematically as truncated cones. The estimated surface area was used to standardize the comparisons of sunscreen density application across participants, who differed in size.

After participants were asked to apply the sunscreen from each of the four treatments, they were also characterized using survey responses which collected a variety of information (see Supplemental Material).

In an effort to better consider participants who failed to access the warning information relevant to the study, the survey began with a recognition test which asked them to circle the four sunscreens that they had applied from six possible choices (four of which they had, two of which they had not). The survey also contained questions pertaining to their personal history of sun burns and skin cancer; two questions about the frequency of sunscreen use, three questions related to their perception of risk of developing cancer, including level of worry and perceived likelihood of developing skin cancer (Kiviniemi & Ellis, 2013), age, skin tone, and parental status. Skin tone was determined by asking participants to self-identify the option that best matched their skin tone from the Pantone Skin Tone Guide (Pantone LLC, Carlstadt, NJ) with corresponding values recorded.

### Sunscreen Stimulus and Assessment of Dose

A total of four treatments were compared by crossing two dispensing mechanisms (i.e., a pump bottle and a squeeze bottle with a flip top closure) with two levels of warning (i.e., discouraging and encouraging; see Table 1 and Figure 1). The bottle that was used as the base for the four treatments was an 8 oz. low-density polyethylene Boston round bottle. Bottles were fitted with either a polypropylene pump or flip top spout cap. The bottles and closures were sourced from SKS Bottle & Packaging International (Wattervliet, New York). Rocky Mountain Sunscreen (Arvada, Colorado), in a hypoallergenic, fragrance-free formulation, was purchased in bulk and used to fill the bottles.

Each subject applied all four treatments each treatment to one of the four limbs (i.e., left/right arm, left/right leg). The legs and arms were selected for two reasons: First, the rule of nines (a technique used for estimating body surface area in burn patients) purports that, on average, each arm is roughly 9% of the total body surface area, and that each leg is roughly 18% of the total body surface area; UW Health, n.d.). Drawing from this, the surface area of half of one leg should be roughly equivalent to the surface area of that same participant’s arm. Second, because data collection occurred during the summer months in North America, the prevalence of shorts and t-shirts meant that participants would be able to apply sunscreen without needing private changing areas to remove clothing.

The following trigger prompt was used, “The four products that you are applying are all different, please inspect them carefully prior to applying them as you would if you were to spend the entire day outside on a very clear, sunny day.”

Differential weight served as a proxy for the amount of sunscreen applied; results were obtained by weighing each treatment before and after the application using a Fisher Science Education™ Portable Balance with a capacity of 300 g and readability of 0.001 g. Bottles were filled to approximately 295 g, and were refilled with product once the weight dropped below 285 g.

The experiment was designed as a counterbalanced, randomized complete block within-subjects design. That is, all participants perform all levels of independent variable (i.e., test all treatments). Within-subjects designs assist in reducing the noise caused by natural variations that occurs between subjects (e.g., body size affecting the amount of sunscreen applied). Participants were randomly assigned to application order by treatment and the order of location for application. As with any within subject study design, great care was taken to counterbalance treatment to avoid confounds with other factors.

Twenty-four participants comprised a complete block. Participants for four complete blocks (n = 96) were recruited. Sample size was based on the work of Diaz et al. (2012) using children who applied sunscreen (n = 87). Power calculations were conducted to determine how many blocks to recruit using a package effect of 0.2 mg, informed by the 0.18 mg difference found by Diaz et al. as the estimated difference effect size of package type, with four blocks of 24 participants, power was estimated to be 92% for the package effect. As the literature on the effects of labeling on dispensing behaviors is extremely limited, a rough estimate of half the effect of packaging structure was used to evaluate the power to detect a difference due to the labeling intervention. With an effect size of 0.1 mg and four blocks of 24 participants, the estimated power was approximately 40% for the labeling effect. The order of application from the different treatments and the application locations (legs and arms left and right) considered treatment type such that all combinations appeared four times over the course of the experiment.
sis did not reveal a run order effect on the amount of sunscreen applied.

To analyze application dose in light of FDA requirements for meeting SPF protections (USFDA, 2011b) and eliminate any application differences resulting from variations in limb size, the applied dose was converted to density (mg/cm²) by using the body measurements taken with the tape measure to account for the variations in surface area of the limbs. The weight of the applied sunscreen, normalized by the surface area, is hereafter referred to as the “application density”; units of mg/cm² are units of density, rather than thickness as is reported by previous authors (Autier et al., 2001; Azurdia et al., 1999; Bauer et al., 2010; Diaz et al., 2012; Faurschou & Wulf, 2007; Stenberg & Larkö, 1985). Application density was calculated using Equation 1.

\[
AD = \frac{w_f - w_i}{\pi \left[ l \left( \frac{c_i}{2\pi} + \frac{c_2}{2\pi} \right) + \left( \frac{c_i}{2\pi} \right)^2 + \left( \frac{c_2}{2\pi} \right)^2 \right]}
\]  

(1)

where \( l \) = length of limb (cm), \( c_i \) = greater circumference (cm), \( c_2 \) = lesser circumference height (cm), \( w_i \) = initial weight (mg), and \( w_f \) = weight after sunscreen application (mg).

### Results

Ninety-six participants between the ages of 18 and 34 years were recruited to participate in the study. All participants were recruited from either Michigan State University in East Lansing, Michigan, or California Polytechnic State University in San Luis Obispo, California (see Table 2). Data from two participants were removed due to recording error, for a total of 94 participants included in the analysis.

Package’s dispensing device \( p < .0001 \), self-reported frequency of sunscreen usage \( p = .03 \), and frequency of worry about developing skin cancer \( p = .03 \) were all indicated to significantly affect the application density of the sunscreen participants applied. No other terms in the model or interactions suggested significance at \( \alpha = .05 \). Multiple comparisons of the significant factors were preformed using Tukey’s honestly significant difference. Regardless of the label treatment present on the bottle (i.e., discouraging or encouraging), contrary to our hypothesis based on the previous literature, participants applied 30% less sunscreen from the pump bottle than they did from the squeeze bottle, with an estimated difference

### Table 2. Age and Sex of Participants by Test Location.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total sample</th>
<th>MSU sample</th>
<th>Cal Poly sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>94 (96)</td>
<td>47 (48)</td>
<td>47 (48)</td>
</tr>
<tr>
<td>Mean age (years)</td>
<td>23 (3.56)</td>
<td>25 (3.75)</td>
<td>20 (1.72)</td>
</tr>
<tr>
<td>Male</td>
<td>41% (38)</td>
<td>29% (13)</td>
<td>52% (25)</td>
</tr>
<tr>
<td>Female</td>
<td>59% (56)</td>
<td>71% (34)</td>
<td>48% (22)</td>
</tr>
<tr>
<td>Most frequent skin tone saturation reported( ^c )</td>
<td>2, 3, and 8 (each with ( n = 12 ))</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. MSU = Michigan State University; Cal Poly = California Polytechnic State University.

\( ^a \) Ninety-four participants were included in the statistical analysis since two were excluded from the study due to error in data recording. \( ^b \) Standard deviation. \( ^c \) Skin tone saturation had 15 possible values, ranging from 1 to 15 (fairest to deepest).
between the package types of 0.3059 mg/cm² (standard error = 0.0607, p < .0001). Table 3 presents a synopsis of statistical results and Table 4 and Figure 2 present information about the analysis related to the application density applied by treatment type. Figure 2 also provides information regarding participant application by treatment as they relate to the amount recommended in the FDA guidelines for testing to achieve sufficient protection. Only 8 of the 94 participants (9%) applied sunscreen in the thickness denoted by the FDA (≥2 mg/cm²) as required to achieve sufficient SPF protection for all four of their applications. In other words, less than 10% of study participants consistently applied enough sunscreen in each application to truly achieve 30 SPF as the protection level from UV rays. Consistent with the literature which suggests that people tend to underapply sunscreen, not a single adjusted mean (Figure 2) obtained for any of the four treatments was above the level (≥2 mg/cm²) recommended by the FDA to obtain appropriate SPF protection.

Another main effect that significantly affected standardized dose was the self-reported frequency of sunscreen use when planning to spend 2 or more hours outside in the sun (α = .05). Pairwise comparisons of the standardized dose were compared using Tukey’s honestly significant difference. The adjusted mean application amounts and the statistically significant differences are reported in Table 4.

With regard to self-reported frequency of use, participants tended to center their answers on the scale; as such, no evidence of statistical significance resulted when comparisons of application were made comparing users that reported use of sunscreen as “sometimes” or “rarely” (Figure 3). By contrast, people who reported always using sunscreen when spending 2 hours or more outside on a sunny day applied significantly higher amounts of sunscreen than people who selected the intermediate levels of the scale applied significantly less.

Multiple comparisons of the effect of worry about the development of skin cancer on the amount of sunscreen applied did not return any significant results; this was likely due to an extremely limited sample of participants who reported a high level of worry.

Discussion

Overall, this study reinforced the findings that users of sunscreen do not apply the amount that recommended to achieve the SPF level, and, thus, do not receive the full benefits associated with sunscreen use (Autier et al., 2001; Azurdia et al., 1999; Azurdia et al., 2000; Bauer et al., 2010; Bech-Thomsen & Wulf, 1993; Diffey & Grice, 1997; Isedeh et al., 2013; Neale et al., 2002; Reich et al., 2009; Srinivas et al., 2006; Stenberg & Larkö, 1985; Szepietowski et al., 2004). That said, they did tend to apply more than previous studies (Azurdia et al., 1999; Bech-Thomsen & Wulf, 1993; Diaz et al., 2012; Petersen & Wulf, 2014). One reason postulated for this increase is the sample’s age. The demographic sampled has lived their entire life with sunscreen regulated as a drug, which has the potential to influence their perception of

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**Table 3.** Results From Analysis of Variance of the Full Random Effects Model.

<table>
<thead>
<tr>
<th>Factor</th>
<th>Num. DF</th>
<th>Den. DF</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispensing device (pump or squeeze)</td>
<td>1</td>
<td>280</td>
<td>23.50</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Warning message (encouraging or discouraging)</td>
<td>1</td>
<td>280</td>
<td>0.06</td>
<td>.80</td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>68</td>
<td>0.05</td>
<td>.83</td>
</tr>
<tr>
<td>Know someone with skin cancer</td>
<td>1</td>
<td>68</td>
<td>0.05</td>
<td>.82</td>
</tr>
<tr>
<td>Worry about developing skin cancer</td>
<td>3</td>
<td>68</td>
<td>3.29</td>
<td>.03</td>
</tr>
<tr>
<td>Recognize labels</td>
<td>1</td>
<td>68</td>
<td>1.57</td>
<td>.21</td>
</tr>
<tr>
<td>Self-reported frequency of sunscreen use when outside for 2 hours</td>
<td>4</td>
<td>68</td>
<td>2.96</td>
<td>.03</td>
</tr>
<tr>
<td>Skin tone saturation</td>
<td>13</td>
<td>68</td>
<td>1.40</td>
<td>.18</td>
</tr>
<tr>
<td>Age</td>
<td>1</td>
<td>68</td>
<td>0.61</td>
<td>.44</td>
</tr>
<tr>
<td>Location</td>
<td>1</td>
<td>68</td>
<td>0.19</td>
<td>.66</td>
</tr>
</tbody>
</table>

Note. Num. DF = numerator degrees of freedom; Den. DF = denominator degrees of freedom. Bolded text indicates significance at α = .05

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**Table 4.** Predicted Mean Application Amounts.

<table>
<thead>
<tr>
<th>Package label combination</th>
<th>Predicted mean application amount (mg/cm²)*</th>
<th>Group*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pump bottle with encouraging label</td>
<td>1.0864</td>
<td>a</td>
</tr>
<tr>
<td>Pump bottle with discouraging label</td>
<td>1.0704</td>
<td>a</td>
</tr>
<tr>
<td>Squeeze bottle with encouraging label</td>
<td>1.3762</td>
<td>b</td>
</tr>
<tr>
<td>Squeeze bottle with discouraging label</td>
<td>1.3923</td>
<td>b</td>
</tr>
</tbody>
</table>

*Means followed by the same letter are not significantly different from each other using Tukey’s honestly significant difference (HSD) at a significance level of .05.
Figure 2. Adjusted mean applications of sunscreen from different packages. Means labeled by the same letter are not significantly different from each other using Tukey’s honestly significant difference (HSD) at a significance level of .05.

Figure 3. Standardized dosing by frequency of sunscreen use. Means labeled by the same letter are not significantly different from each other using Tukey’s honestly significant difference (HSD) at a significance level of .05.
the appropriate dose. A key finding of this study is the magnitude of the effect the packaging can have on sunscreen application, despite it being a relatively ignored factor in the literature surrounding sunscreen use and skin cancer prevention. While the information provided on a label is important for consumers, the packaging of sunscreen has great potential as a tool for guiding the appropriate dose to achieve proper UV protection; as such, it should be considered by regulators and manufacturers of sunscreen products.

Based on the findings of Diaz et al. (2012), we postulated that the pump would inspire a greater application amount than the squeeze bottle. The hypothesis was not supported by the results, which suggested consumers tended to apply significantly more sunscreen from the squeeze bottle (see Table 4). It is possible that despite the fact that a single pump did not provide an adequate amount to yield full protection of a limb for most adults, that consumers interpreted the amount the pump metered out with each press as the “correct dose,” resulting in inadequate amounts to provide sufficient protection. A 95% confidence interval for the amount of sunscreen in one pump from the bottle is 491 mg to 523 mg; this suggests it would take approximately three pumps to adequately cover an arm or lower leg with the average surface areas represented in this sample, 808.41 cm² and 691.04 cm², respectively. The pump could be considered a misleading or false perceived affordance (affordance refers to the actionable possibilities the package possesses; de la Fuente, Gustafson, Twomey, & Bix, 2015). If this were the case, there is a potential for underdosing when compared with the squeeze bottle in this experiment. While the pump affords dispensing a standard amount of product, this is not personalized based on the surface area of the consumer, and that signal potentially leads to consumers stopping the dispensing process before complying with application recommendations (de la Fuente et al., 2015). That said, the possibility also exists that, with careful modification which includes both instructions for use and physical package a pump bottle could be used enhance compliance; for instance, if specific recommendations for dosing (as measured in pumps) was created in tandem with labeling strategies that included height and/or weight which were actually read and understood by the consumer this approach could enhance application accuracy.

By contrast, results from Diaz et al. (2012) indicate the use of a pump bottle results in significantly greater amounts of product application as compared with a squeeze tube and roll-on dispenser. One reason we postulate our findings differ from Diaz et al. is that our study utilized adults applying sunscreen to themselves while Diaz et al. investigated how packaging influences the sunscreen application behaviors of children. Children and adults have differences in grip strength and hand size, which could explain differences in their ability to squeeze a sunscreen bottle (de La Fuente, 2004).

Additionally, when considering possible reasons for no apparent difference of dosing based on label treatment, it is important to realize that only 55% of participants were able to recognize the labels in the post-hoc test of recognition. Created label messaging utilized in this study was based on previous risk communication research (Siegrist & Keller, 2011), but perhaps different warning messages emphasizing the benefits of proper sunscreen usage to mitigate the damage UV rays can cause, rather than an ingredient warning could have performed differently.

Finally, familiarity with the product can come from repeated use, and a self-report of “Always” using sunscreen when spending 2 hours or more outside on a sunny day suggests repeated use. Additionally, it would follow that consumers who are more likely to burn when out in the sun for two hours or more are more likely to be repeat users of sunscreen products, potentially leading to these consumers being more cognizant of the amount they personally use to prevent burning.

The findings of this study indicate despite packaging’s influence on the amount of sunscreen people use, not enough research has been done to compare the different product package systems for their influence on compliance with sunscreen use guidelines, and the work is not complete. These findings may be useful in understanding what factors are associated with increased sunscreen use and how packaging can better encourage healthy skin protection practices, but these findings are initial.

Limitations

Some limitations are as follows: The application density is estimated, participants applied the sunscreen in a laboratory setting rather than a naturalistic environment. Furthermore, the post hoc test of recognition, which was intended to serve as a proxy for early stage processing (attention to the label) could have been less than 100% accurate as it required short term memory. As a result, our confidence in the fact that there was no evidence of a significant label type on application amount is eroded; the failure to correctly recognize these labels could be a failure to notice them (i.e., early-stage processing) or a failure to remember them (i.e., short-term memory), or suggest that the message has no effect. Further study into the formatting and messaging of these warnings for sunscreen and their impact on dosing amount is strongly recommended.

Authors’ Note

All authors had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. A. Harben took primary responsibility of this role. A. Harben, L. Bix and J. de la Fuente participated in the study concept and design. A. Harben conducted acquisition, analysis, and interpretation of the data related to sunscreen application and S. Robison collected and analyzed data relating to the survey of commercial sunscreen product labeling. A. Harben and L. Bix took primary responsibility for drafting the manuscript, serving also to provide critical revision. J. de la Fuente and S. Robinson served to revise the
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Declaration of Conflicting Interests

The authors declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Dr. Bix has served as a consultant to Vertex Pharmaceuticals, Inc., a biotech firm focused on drugs to treat cystic fibrosis, providing expertise on the development of protocols to evaluate packaging ease of use. She has received an honorarium and travel reimbursement to speak at Baxter and Johnson & Johnson Companies and travel reimbursement to share work from her group at the International Quality and Productivity Center’s conference on Pharmaceutical Labeling. Travel reimbursement has also been provided by the US Food and Drug Administration (FDA) and the US Centers for Disease Control and Prevention (CDC) in support of her participation for ongoing efforts medication safety. None of these entities played any role in the design or conduct of the study; collection, management, analysis or interpretation of the date; preparation, review or approval of the manuscript or the decision to submit or publish the study.

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Supplemental Material

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