Sunscreen application at the beach

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Summary

Background The sun protection factor (SPF) of sunscreens is determined after application of a standard amount. The European Cosmetic Toiletry and Perfumery Association (COLIPA) standard amount is 2 mg/cm^2. Real-life application of sunscreen is probably less than this.
Aim To determine the amount of sunscreen present on the skin of people at the beach.
Methods Volunteers at the beach were selected randomly and were not aware of being tested for the adequacy of their sunscreen application. All volunteers had applied sunscreen. Application had been more than 30 min before testing (sometimes up to 4 h earlier). The amounts of sunscreen applied to different body sites were determined quantitatively by tape stripping. Actual amounts of sunscreen applied were compared with the COLIPA standard. Also, sunscreen containing a fluorescent dye was applied to the skin of volunteers in a laboratory setting. The distribution of sunscreen application was visualized by UVA photography in a darkened room.
Results Sixty volunteers, 33 males and 27 females, aged 17–68 years (median 32 years), were recruited at the beach. Sunscreen coverage was inadequate at all body sites. Coverage at various body sites differed greatly. Most volunteers had applied 10% or less of the COLIPA standard amount to all body sites assessed. The best protected areas were the upper arm and décolleté but, even in these areas, most volunteers had only applied 10% of the COLIPA standard amount. The worst protected areas were the ears and top of the feet. The back was typically badly protected if treated by the volunteers themselves. The back was better protected if another person had applied the sunscreen. In the laboratory, the fluorescent dye-containing sunscreen showed the same pattern of sunscreen application as at the beach.
Conclusions In real life, at the beach, very little sunscreen remains present on the skin.

Keywords: COLIPA standard, fluorescence measurements, SPF, sunscreen application, tape stripping, UV protection

Introduction

The leisure behaviour of the European population has changed over recent decades. Today, people spend more time on beaches and in the sun.[1] Sun radiation can cause different types of biological effects such as skin aging[2,3] immunosuppression[4,5] and skin cancer.[6–8] The rate of UV-induced damage has increased rapidly in recent years.[9–11] The melanoma rate in Germany increases by 6–7% every year.[12] In Europe, 6% of the population suffers from skin cancer.[13,14] Therefore, protection of the skin against UV radiation is becoming increasingly important.

In addition to textiles, sunscreens are an efficient means of protection. The protection efficiency of sunscreens is

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characterized by the sun protection factor (SPF). SPF is related to the protection given against solar dermatitis when a sunscreen concentration of 2 mg/cm^2 is applied homogeneously to the body.[15] Therefore, 40 g of sunscreen should be applied to the body in order to obtain optimum protection, assuming that the human skin has a surface of $\approx 2\ m^2$. This means that a person who stays in the sun should use one tube of sunscreen every 2–3 days. However, under real conditions on the beach, one family uses one tube of sunscreen over a period of a week.[16]

Different studies have been carried out to evaluate sunscreen application behaviour in the general population. These are based on interviews concerning sunscreen application and on fluorescence measurements, demonstrating the non-homogeneous distribution of fluorescent dye-containing sunscreens on the skin.[17–19] All these methods were qualitative and emphasized the well-known fact that the standard conditions used to determine SPF are not valid for practical sunscreen application.

The aim of this study was to give both a qualitative and quantitative estimation of sunscreen application behaviour in people on the beach, under real-life conditions.

In the first part of the investigation, the distribution of sunscreen on the skin was made visible by using fluorescence measurements, as described previously.[18,19] These analyses were carried out in the laboratories of the Centre of Experimental and Applied Cutaneous Physiology (CCP).

The sunscreen application behaviour of volunteers may be influenced if they are aware of the subsequent testing. Therefore, in the second part, investigations were carried out on the beach using people who were not aware of being tested. Vacationers were asked to undergo the tape-stripping procedure. For the first time, it was possible to determine, quantitatively, the amount of sunscreen on different body areas of people on the beach. This was carried out by tape-stripping in combination with spectroscopic measurements.

Materials and methods

Sunscreen distribution measurements in the laboratory

The aim of the investigation was to make the distribution of the applied sunscreen visible on the skin. Therefore, fluorescein was added to a sunscreen formulation. Six volunteers were asked to apply the sunscreens as usual. Thirty minutes after application, distribution of the sunscreen was checked by fluorescence measurements, for which the volunteers were irradiated with UVA radiation in a dark room. Pictures were taken using a camera (Canon, EOS 50E).

The volunteers, aged between 26 and 32 years, knew that the distribution of the sunscreen would be checked after application. There was no contact with textiles between sunscreen application and testing.

Sunscreen distribution measurements on the beach

Location

The investigations were carried out on hot summer days ($T \geq 30$ °C) in July 2002 on Müggelsee beach (Berlin) and Prerow beach (Baltic Sea).

Volunteers and body areas

The sunscreen concentration on different body areas of 60 people on the beach was investigated. Volunteers had applied the sunscreen more than 30 min (some times 2–4 h) before the investigation. After application of sunscreen, volunteers went swimming and came into contact with textiles (towels, beach blankets, etc.).

Both men and women were investigated. Volunteers were aged between 17 and 68 years, were randomly selected and were not aware that they would be tested when applying the sunscreen. The vacationers were asked to undergo the removal of one tape strip from different body areas. Tape strips were removed from the upper arm, back, neckline, forehead, top of the foot and the ear. A sample of the applied sunscreen was also taken for calibration measurements.

Volunteers were asked about their sunscreen application behaviour.

Tape stripping

Defined removal of the stratum corneum and determination of the horny layer profile using the tape-stripping procedure have been described in detail by Weigmann *et al.*[20] Adhesive film (TESA film no. 5529, Beiersdorf, Hamburg, Germany) 19 mm wide was applied, fixed to a slide frame. In this way, the tapes could be handled easily on the beach.

On the beach, the adhesive film was pressed onto the skin using a roller.[21] The reverse of the adhesive film was covered with a sheet of paper during the rolling process, to avoid transfer of the sunscreen from neighbouring regions onto the reverse of the tape strip. Subsequently, the adhesive film was removed from the skin with a quick movement.

Tapes were stored in a container and spectroscopically analysed in the laboratory.

Penetration studies

The tape-stripping procedure was also used to determine the penetration profiles of sunscreen into the skin. These experiments were carried out in the CCP laboratories.

A defined amount of sunscreen (2 mg/cm^2, COLIPA standard[15]) was applied to the forearm and back of 50 volunteers, aged between 24 and 45 years. A series of tape strips was removed from these skin areas. The amount of the sunscreen filter substance and the number of corneocytes on the removed tapes were analysed.

The penetration profile was calculated based on the horny layer profile and the amount of UV filter substances detected on the single tape strips.[20]

Investigations were carried out using different commercial products and on different volunteers.

In the penetration studies, the relation between the amount of UV filter substance removed by the first tape strip and the total amount that had penetrated into the stratum corneum was determined. With the knowledge of this relationship, the concentration of the UV filters on the first tape strip could be used to calculate the total amount of sunscreen applied onto the skin.

The amounts of sunscreen on the skin determined on different body areas of the volunteers were compared with the COLIPA standard concentration of 2 mg/cm^2 used to determine SPF.

Spectroscopic determination of the applied amount of UV filter substances

Small samples of the sunscreens used by the volunteers on the beach were taken. In the laboratory, the samples were solved in ethanol. The absorbance of the UV filter substances was determined using a modified spectrometer LAMBDA 20 (Perkin–Elmer) with a rectangular beam diameter of 10 × 10 mm.[20] These values represent the calibration standard for determining the amount of filter substances on the corresponding tape strips removed from the different body areas. These tape strips were extracted in ethanol and centrifuged. The UV filter concentration per cm^2 was determined spectroscopically using the calibration standard.

Results

Visualization of sunscreen application behaviour

In the laboratory, volunteers were asked to apply sunscreen as they would normally do on the beach. The sunscreen contained a fluorescent dye. Distribution of the dye was investigated according to its fluorescence during UVA irradiation, in a dark room. The distribution of the fluorescent dye-containing sunscreen on different body areas is demonstrated in Fig. 1. The area treated with sunscreen shows a yellow fluorescence.

Even though the volunteers knew that they were about to be checked concerning sunscreen application, they showed typical sunscreen application behaviour as often observed on beaches. Sunscreen distribution was not homogeneous, e.g. the forehead close to the hairline was not treated because volunteers were afraid of damaging their hairstyles. Furthermore, they mostly forgot to apply the sunscreen to the ears, and areas of skin close to textiles were never treated.

It is difficult to treat the back oneself. Therefore, only the regions of the lateral thorax and the lower part of the back were treated. The upper part of the back could be reached only with effort and remained without sunscreen. Even if a second person had applied cream to the back, areas close to textiles were not treated, as seen in the middle part of Fig. 1.

Determination of the penetration profiles of sunscreens

The penetration profiles of different commercial sunscreens investigated in the CCP were analysed concerning the relation between the amount of sunscreen removed by the first tape strip and the total amount that had penetrated into the stratum corneum. A typical penetration profile of the UV filter Parsol 1789 is shown in Fig. 2. The penetration profile shows a cut through the stratum corneum where the distribution of the UV filters in different depths of the horny layer is shown. The distance between the horizontal lines corresponds to the number of corneocytes removed with the single tape strips. With an increasing number of tape strips, the number of corneocytes on the tapes becomes less.

It can be seen from Fig. 2 that the filter substances are located in the upper 25% of the stratum corneum, a situation that is typical for all types of commercial sunscreen.

The penetration profile presented in Fig. 2 was determined 1 h after application of sunscreen. Similar penetration profiles were obtained 2 or 3 h after the application of sunscreen.

The part of the sunscreen removed by the first tape strip, in relation to the total amount of sunscreen that penetrated into the stratum corneum, was investigated in 50 penetration experiments. These experiments were carried out on different volunteers using different commercial sunscreens. The average value and the standard deviation of the amount of sunscreen removed by the first tape strip was 65 ± 10% of the total amount, which penetrated into the skin.

Amounts of sunscreen applied to different body areas under real-life conditions

The 60 volunteers investigated on the beach used 32 different types of sunscreen. The results of the sunscreen

Figure 1 (a–d) Sunscreen is usually inadequately applied. Fluorescent dye-containing sunscreen illustrates the problem.

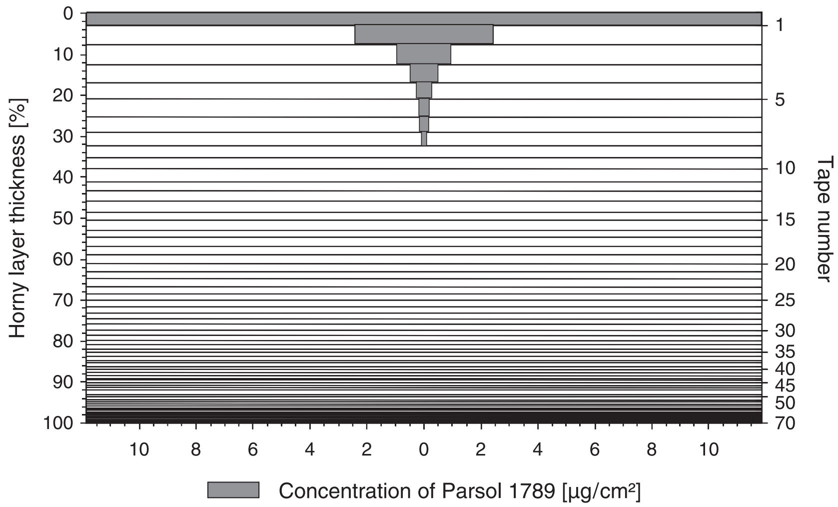

Figure 2 Typical penetration profile of the UV filter Parsol.

application behaviour of these 60 people are summarized in Fig. 3(a,b). The percentages of the total amount of sunscreens applied on different body areas in relation to the COLIPA standard of 2 mg/cm^2 are presented. The amounts of sunscreen on the skin were calculated from the concentrations detected on the first tape strips, which were taken as 65% of the total amount penetrated.

The amounts of sunscreen applied to the different body areas were divided into the following 11 groups for presentation (Table 1).

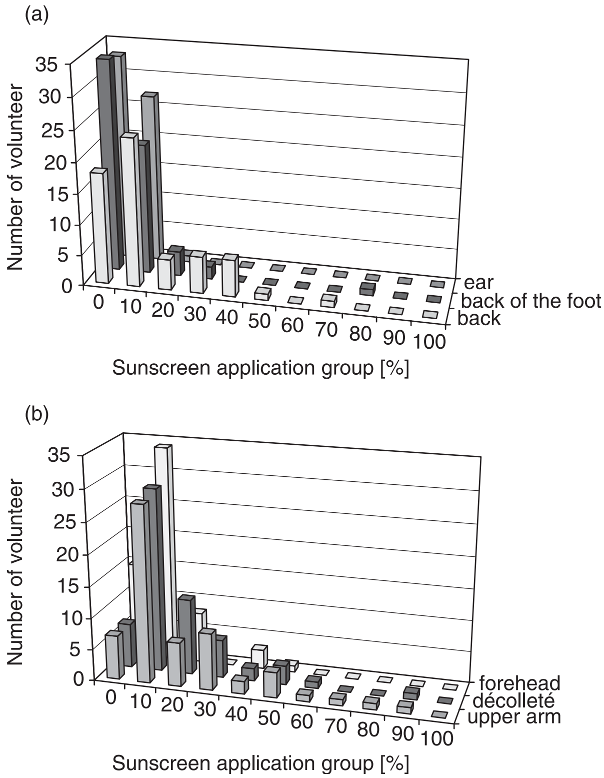

Figure 3 (a,b) At the beach, sunscreen is applied in inadequate amounts at all body areas. In these graphs, 100% represents the COLIPA standard for sunscreen application. However, most volunteers applied only 10% or less of the COLIPA standard.

The first bars (group 0%) in Fig. 3(a,b) correspond to the number of people who have not treated the corresponding skin areas. The following bars indicate the number of people who have applied the corresponding amount of sunscreen onto the investigated body site.

Group 100% corresponds to the COLIPA standard concentration that should be applied to obtain optimum sun protection related to the SPF.

Fifty percent of the volunteers explained that they had not applied sunscreen to the foot, because otherwise sand would stick to the sunscreen-treated skin. Seventy-eight percent of the volunteers did not like sunscreens, because they produce a non-physiological feeling on the skin. Nevertheless, they used sunscreens in order to protect their skin against sunburn.

Discussion

Photographs taken after the application of the fluorescent dye-containing emulsion demonstrate that sunscreen was applied non-homogeneously to different body areas (Fig. 1). This non-homogeneous distribution was found even in volunteers who had applied the sunscreen carefully because they knew that they would be checked after application. These results are in agreement with previous reports.[18,19]

Table 1 Classification of groups by amount of sunscreen applied.

Sunscreen application group	Actual amount of sunscreen/ COLIPA-recommended amount of sunscreen(%)
0%	0
10%	1–10
20%	11–20
30%	21–30
40%	31–40
50%	41–50
60%	51–60
70%	61–70
80%	71–80
90%	81–90
100%	91–100

The new aspect of this study was the quantification of the amounts of sunscreen applied by volunteers on the beach to different body areas. The results given in Fig. 3(a,b) show that the treatment of the various body areas differed greatly. The highest amounts of sunscreen were applied to the upper arm and neckline. Sunscreen was applied poorly to the back if the volunteers treated themselves. Application to the back was much better if someone else had applied the sunscreen. The forehead close to the hairline and the tops of the feet were always poorly treated.

The average sunscreen concentration applied was $< 10\%$ of the COLIPA standard of 2 mg/cm^2. This means that, in practice, the protection efficacy of the applied sunscreen is reduced significantly.

One reason for the small amounts of sunscreen detected could be that the people investigated on the beach had been in the water several times and, subsequently, had also come into contact with textiles. Most of the volunteers applied the sunscreen only once, and not regularly after swimming.

To solve this problem, a sunscreen should fulfil the following:

- have a high SPF, because the real-world sun protection on the skin is less than the SPF declared on the packaging, because of the low amount of sunscreen applied;
- be easily and homogeneously distributed to all body areas irradiated by the sun;
- feel pleasant on the skin, and not be greasy or oily in order to avoid sand sticking to the skin;

- because of the low sunscreen concentrations applied, sunscreens should provide additional protection against radical formation. The addition of antioxidant substances to sunscreen formulation is useful.[22–25]

Most of these demands are met in modern sunscreens. Today, sunscreens with high protection efficiency up to SPF 100 are available. Several modern sunscreens have antioxidant-containing formulations, protecting against UV-induced oxidative skin damage.

However, the prerequisite for optimal protection is a homogeneous distribution of the sunscreens on all body areas that will be irradiated by the sun. This needs to be significantly improved, as the results of this study show. The physiological feeling of the sunscreen could be improved by optimization of the formulation. It should also be possible to distribute the correct sunscreen concentration homogeneously to all irradiated body areas. In principle, this may be achieved by using a spray.

The optimization of sunscreens is the job of the cosmetics industry. Educating the population regarding correct behaviour in the sun is a task for the whole of society. Parents' responsibility for their children, education at school and information provided by public health agencies, newspapers, journals and television are important aspects in this context. Finally, we should be fully aware of the increasing rate of skin cancer.

Conclusions

In real life at the beach, sunscreen is applied inadequately to all sun-exposed areas. Most people, at all body sites, apply only 10% or less of the COLIPA-recommended amount of sunscreen.

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