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Danish sunbathers' application of sunscreen

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Content

Foreword

The project “Danish sunbathers’ application of sunscreen“ was initiated and funded by the Danish Environmental Protection Agency and was carried out from June through August 2016.

This report describes the project and its results. The aim of the project was to examine if Danish sunbathers use adequate amounts of sunscreen to obtain sufficient sun protection.

The project was carried out by Department of Dermatology, Bispebjerg Hospital, University of Copenhagen and was headed by professor Hans Christian Wulf, MD, DMSc, PharmD.

Summary and conclusion

Introduction
The sun protection factor (SPF) labelled on sunscreen bottles is a measure of the protective efficacy of the sunscreen against sunburn. To obtain the labelled SPF a sunscreen layer of 2 mg sunscreen per cm^2 sun exposed skin is required, as described by the European Commission in the Commission Recommendation of 2006. This corresponds to a sunscreen amount of 36 g per adult for whole body application (equal to a handful). A thinner layer of sunscreen lowers the protection significantly. A study from 1992 has shown that Danish sunbathers on the beach in Denmark used only 0.48 mg sunscreen per cm^2 skin.

Objectives
To examine if the recent focus on enjoying the sun with caution has been noticed by the sunbathers. More specifically, has the recommendation to use a handful of sunscreen (36 g per adult) been followed by sunbathers, resulting in the use of an increased amount of sunscreen and/or a higher SPF than described in the study from 1992. Based on these data it was investigated if the used amount of sunscreen was adequate to gain sufficient sun protection.

Methods
Ninety-nine Danish adults (76 women and 23 men) were enrolled at Danish beaches between 10:30 AM and 15:15 PM from June through August 2016. Their sunscreen bottles were weighed before and after sunscreen application. Participants' skin areas exposed to the sun were estimated from their height, weight and clothing. From the used amount of sunscreen, the labelled SPF on the bottle, and the exposed body surface area the true SPF was calculated for each participant.

Results
Most participants were between 18 and 40 years of age. Participants used 8.6 g sunscreen and exposed a skin area of 1.47 m^2 on average. This corresponds to an applied sunscreen thickness for women of 0.55 mg/cm^2 (range: 0.11 mg/cm^2 - 1.72 mg/cm^2) and 0.69 mg/cm^2 for men (range: 0.12 mg/cm^2 - 1.54 mg/cm^2). The mean labelled SPF of the women's sunscreen was 22 (range: 6-50) and the men's was 20 (range: 10-50). The mean true SPF for women was 2.6 (range: 1.2-13.1) and 3.0 (range: 1.2-8.0) for men. Men had a significantly higher true SPF than women (P = 0.046). For the whole population the mean true SPF was 2.7 (range: 1.2-13.1).

Conclusion
The mean skin area available for sunscreen application in the participants in this study was 1.47 m^2 skin. To gain a sunscreen layer of 2 mg per cm^2 a total amount of 29.4 grams should be used instead of a total amount of 36 grams as some of the skin was covered by clothes. We found that people used a considerable higher SPF and a larger amount of sunscreen than previously. Overall it provides an increase in average true SPF of almost 70% from 1.6 in 1992 to 2.7 in 2016. An average Dane can tolerate 3 to 4 SED (3.5 SED) before visible redness is induced by sun exposure. With a true SPF of 2.7 an average Dane can tolerate an exposure of about 9.5 SED (2.7×3.5). The mean true SPF we have found in the present study is adequate to protect average Danes against sunburn from sunbathing on a Danish beach for 3 hours assuming that the sunscreen is applied uniformly and back and front are equally exposed. Prolonged exposure, or skin lighter than average, requires a true SPF of more than 2.7.

Resume og konklusion

Baggrund
Solbeskyttelsesfaktor (SPF), der angives på solcremeemballage, er et mål for solcremens beskyttende effekt mod solskoldning. For at opnå den SPF, der angives på emballagen, skal solcremen påsmøres huden i en mængde på 2 mg per cm^2 solekponeret hud, som beskrevet i Den Europæiske Unions anbefalinger fra 2006. Dette svarer til 36 gram per voksen ved indsmøring af hele kroppen (svarende til en håndfuld). Et tyndere lag solcreme nedsætter beskyttelsen markant. Et studie fra 1992 viste, at danske solbadere på danske strande kun brugte 0,48 mg solcreme per cm^2.

Formål
At undersøge om de seneste års fokus på at nyde solen med forsigtighed er blevet bemærket af solbadere. Mere specifikt om anbefalingen om at bruge en håndfuld solcreme (36 g per voksen) følges af solbadere og dermed har resulteret i brugen af en øget mængde af solcreme og/eller en højere SPF end fundet i undersøgelsen fra 1992. På baggrund af disse data blev det undersøgt, om den anvendte mængde solcreme var tilstrækkelig til at opnå tilstrækkelig solbeskyttelse.

Metoder
99 danske voksne (76 kvinder og 23 mænd) blev inkluderet på danske strande mellem klokken 10:30 og 15:15, fra juni 2016 til og med august 2016. Deres medbragte solcreme blev vejet før og efter påsmøring af solcreme. Arealet af deltagernes solekponerede hudområder blev estimeret ud fra deltagernes højde, vægt og beklædning på stranden. Ud fra den brugte mængde solcreme, den på emballagerne mærkede SPF og det solekponerede hudareal blev den egentlige SPF udregnet for hver deltager.

Resultater
De fleste deltagere var mellem 18 og 40 år. Deltagerne brugte i gennemsnit 8,6 gram solcreme og eksponerede et hudområde på 1,47 m^2. Den gennemsnitlige mængde solcreme anvendt af kvinder var 0,55 mg/cm^2 (range: 0,11 mg/cm^2 - 1,72 mg/cm^2), mens mænd brugte 0,69 mg/cm^2 (range: 0,12 mg/cm^2 - 1,54 mg/cm^2). Den gennemsnitslige SPF mærket på emballagen brugt af kvinder var 22 (range: 6-50) og af mænd 20 (range: 10-50). Den gennemsnitlige egentlige SPF hos kvinder var 2,6 (range: 1,2-13,1) og 3,0 (range: 1,2-8,0) for mænd. Mænd havde en signifikant højere egentlig SPF end kvinder (P = 0,046). Samlet havde deltagerne en gennemsnitlig egentlig SPF på 2,7 (range: 1,2-13,1).

Konklusion
Deltagere eksponerede 1,47 m^2 hud i gennemsnit. For at opnå en solcremetykkelse på 2 mg/cm^2 skulle der bruges en samlet mængde solcreme på 29,4 g i stedet for en samlet mængde på 36 g, da deltagere havde noget af kroppen dækket af tøj. Vi finder at solbadende bruger en højere SPF og en øget mængde solcreme i forhold til tidligere. I alt opnår de en egentlig SPF, der er næsten 70 % højere i 2016 end i 1992 (2,7 versus 1,6). En gennemsnitsdansker kan tåle 3 til 4 SED (3,5 SED), før synlig rødme induceres ved solekponering. Med en egentlig SPF på 2,7 kan en gennemsnitsdansker tåle en eksponering på omkring 9,5 SED (2,7×3,5). Den gennemsnitlige egentlige SPF, vi har fundet i dette projekt, er tilstrækkelig til at beskytte mod solskoldning ved solbadning på en dansk strand i 3 timer, forudsat at solcremen er på-

smurt ensartet og solbadere eksponerer for- og bagsiden af kroppen ens. Hvis eksponeringstiden forlænges, eller personens hud er lysere end gennemsnittet, er det nødvendigt med en egentlig SPF på mere end 2,7.

1. Introduction

Sunscreens are recommended to protect the skin from ultraviolet radiation (UVR) from the sun, which is a risk factor for sunburn and skin cancer. The sun protection factor (SPF) labelled on sunscreen bottles is a measure of the protective efficacy of the sunscreen against sunburn. For instance, if the amount of 2 mg sunscreen per cm^2 is applied to the skin “SPF 15” means that approximately 93% of the burning UVR is blocked (reflected or absorbed) and about 7% (1/15) is transmitted. For "SPF 30" 96.5% is blocked and about 3.5% (1/30) is transmitted. For "SPF 50" approximately 98% is blocked. The method used to determine SPF of a sunscreen has been described by the European Committee for Standardization (EN ISO 24444). The method requires that the sunscreen is applied in a thickness of 2 mg sunscreen per cm^2 skin, corresponding to a total of 36 grams per adult for whole body exposure. This amount is recommended by the EU Commission (Commission recommendation). A thinner layer of sunscreen lowers the protection significantly, most probably in an exponential way (Faurschou et al. 2007).

Previous studies have shown that Danish sunbathers in average on the beach in Denmark used 0.48 mg sunscreen per cm^2 skin (Bech-Thomsen et al. 1992) and 0.79 mg/cm^2 on sun holidays in Tenerife (Petersen et al. 2013). This showed that the average applied amount of sunscreen was inadequate to obtain the labelled SPF, as 2 mg sunscreen per cm^2 is necessary to obtain the labelled SPF. The primary Danish study was conducted in the 1990s when little attention was paid to using appropriate amounts of sunscreen.

The general population are advised to use a handful of sunscreen for whole body application to obtain appropriate protection with a sunscreen layer thickness of 2 mg sunscreen per cm^2 body area (Danish EPA, factsheet). This information is also labelled on sunscreens available on the Danish market.

2. Aim

In this study it was examined if the recent focus on enjoying the sun with caution has been noticed by the sunbathers. More specifically if the recommendation to use a handful of sunscreen (36 g per adult) is followed by sunbathers, resulting in the use of an increased amount of sunscreen and/or a higher SPF than described in the study from 1992. Based on these data it should also be estimated if the used amount of sunscreen was adequate to gain sufficient sun protection.

3. Methods

Ninety-nine Danish adults (76 women and 23 men) were enrolled at 3 different beaches (Svanemøllen Strand, Bellevue Strand and Amager Strand) in the Copenhagen area. The data was collected by seven academics. The beaches were visited between 10:30 AM and 15:15 PM on 8 different sunny days between the 6th of June and 26th of August 2016. Everybody passing the investigators was asked if they had brought a sunscreen to be used at the beach and if they were willing to participate in the study. If participation was accepted their sunscreen bottle was weighed and the SPF noted. The volunteers were not observed during sunscreen application. After finishing sunscreen application the bottles were again weighed and the used amount of sunscreen was calculated by subtraction.

Participants' beachwear, height, weight and gender were registered to be able to calculate their possible maximal application area. The total body surface area (BSA) was calculated from the participants' weight and height by DuBois formula (Wang et al. 1992),
$BSA(m^2)=0.007184 \times height(cm)^{0.725} \times weight(kg)^{0.425}$.

The BSA available for sunscreen application was calculated subtracting the cloth covered areas (see percentages in Appendix 1), the soles of the feet and the scalp hair area (fixed 7%) from the total BSA. The registration form (in Danish) used at the beach is shown in Appendix 1.

The average sunscreen application layer was calculated by dividing the amount of sunscreen used by the body surface area available for sunscreen application. The true SPF depends on the amount of sunscreen applied to the skin, and is only equal to the labelled SPF if the sunscreen is applied with a thickness of 2 mg sunscreen per cm^2 skin. The true SPF is related to the thickness of the applied sunscreen in this exponential way:
$True\ SPF = label\ SPF^{sunscreen\ application\ thickness/2}$.

A minimum of 60 participants should be included but the number of men was low and to allow comparison between the genders more people were included.

All participants participated completely anonymously. No personal data were collected and for this reason the Danish Data Protection Agency has not been involved in the project.

Only non-parametric statistics tests were used as not all data were normally distributed. Descriptive statistics include mean, standard deviation, median, and minimal and maximal values.

4. Results

No statistical difference was found for the 3 beach locations, concerning gender, age, SPF, and sunscreen use. About 75% of the participants were enrolled at Svanemøllen Strand.

There was no relation between sunscreen use or SPF and time of sunscreen application (time of day and month).

The data from the individual participants are shown in Table 1.

Table 1: List of the individual participants and their sunscreen use.

ID number	M/F	SPF label	Used sunscreen (g)	Exposed BSA %	Sunscreen thickness (mg/cm^2)	True SPF
1	F	15	12.9	87	0.85	3.2
2	F	15	1.7	87	0.12	1.2
3	F	15	4.6	87	0.29	1.5
4	F	20	3.3	84	0.22	1.4
5	F	6	5.7	84	0.41	1.4
6	F	30	1.7	84	0.14	1.3
7	F	10	14.4	84	1.03	3.3
8	F	10	10.3	84	0.67	2.2
9	F	15	2.6	84	0.18	1.3
10	M	30	13.2	83	0.81	4.0
11	F	15	9.7	73	0.78	2.9
12	M	30	13.3	75	0.89	4.5
13	F	15	3.0	84	0.23	1.4
14	F	50	8.9	84	0.66	3.6
15	M	15	9.3	83	0.59	2.2
16	F	15	7.7	87	0.51	2.0
17	F	30	10.0	73	0.68	3.2
18	F	20	13.3	84	0.90	3.9
19	F	30	4.5	87	0.33	1.8
20	F	15	8.2	87	0.53	2.0
21	F	15	7.5	84	0.49	1.9
22	F	30	4.2	87	0.27	1.6
23	F	30	8.5	87	0.55	2.6
24	M	20	7.5	75	0.48	2.1

25	F	15	7.3	87	0.48	1.9
26	F	22	8.7	84	0.60	2.5
27	F	15	9.8	87	0.62	2.3
28	M	15	11.9	75	0.85	3.2
29	F	30	9.9	87	0.63	2.9
30	F	15	5.8	87	0.43	1.8
31	F	20	4.1	84	0.28	1.5
32	M	15	14.9	83	0.92	3.5
33	F	15	4.3	84	0.30	1.5
34	F	15	4.8	87	0.29	1.5
35	F	20	14.4	87	0.84	3.5
36	F	15	4.8	87	0.32	1.5
37	F	30	1.6	87	0.12	1.2
38	M	15	7.0	75	0.52	2.0
39	M	15	11.0	75	0.71	2.6
40	F	15	8.9	87	0.63	2.3
41	M	15	1.8	75	0.12	1.2
42	M	10	4.2	75	0.27	1.4
43	F	15	12.3	87	0.89	3.3
44	F	30	7.1	87	0.48	2.3
45	F	15	13.7	87	0.94	3.6
46	F	20	5.4	87	0.39	1.8
47	M	50	8.6	75	0.60	3.2
48	F	30	4.9	87	0.34	1.8
49	F	30	7.7	84	0.56	2.6
50	F	15	16.7	84	1.03	4.0
51	F	15	11.0	87	0.69	2.5
52	F	30	4.8	73	0.37	1.9
53	F		12.2	84	0.80	
54	M	15	11.7	75	0.82	3.0
55	M	30	7.0	83	0.44	2.1
56	F	15	4.3	84	0.33	1.6
57	M	15	18.0	75	1.24	5.3
58	F	30	7.1	84	0.52	2.4
59	F	30	5.6	87	0.40	2.0
60	F	30	6.0	84	0.37	1.9
61	M	30	10.6	75	0.66	3.1
62	F	30	9.9	84	0.68	3.2
63	M	15	8.6	75	0.56	2.1
64	F	15	5.5	84	0.41	1.7

65	M	20	9.1	75	0.61	2.5
66	F	30	5.4	84	0.45	2.2
67	F	30	7.1	73	0.57	2.6
68	F	30	4.5	87	0.35	1.8
69	M	15	8.6	75	0.53	2.0
70	F	30	8.2	87	0.55	2.5
71	F	30	9.9	87	0.64	3.0
72	F	50	5.9	87	0.39	2.1
73	F	30	6.8	87	0.45	2.1
74	F	30	10.5	87	0.59	2.7
75	F	15	11.5	87	0.68	2.5
76	F	30	11.3	87	0.81	4.0
77	M	15	20.9	75	1.54	8.0
78	M	15	16.6	75	0.99	3.8
79	F	30	20.0	87	1.33	9.6
80	F	15	7.8	87	0.55	2.1
81	M	15	7.7	83	0.47	1.9
82	F	15	4.3	84	0.32	1.5
83	F	20	26.9	87	1.72	13.1
84	F	15	7.0	87	0.46	1.9
85	F	15	12.9	87	0.89	3.4
86	F	30	2.8	81	0.21	1.4
87	F	20	12.7	87	0.89	3.8
88	F	30	6.0	84	0.43	2.1
89	F	30	7.1	84	0.46	2.2
90	F	30	3.4	84	0.24	1.5
91	F	15	7.7	84	0.53	2.1
92	F	30	14.7	84	1.03	5.8
93	F	15	16.4	87	1.07	4.3
94	F	15	5.3	81	0.40	1.7
95	M	15	9.4	75	0.66	2.4
96	F		8.7	84	0.58	
97	F	20	1.6	84	0.11	1.2
98	F	20	6.3	84	0.43	1.9
99	M		9.8	75	0.66	

Abbreviations: M=man; F=female.

The mean age of the participants was 29 years (range: 18-73) for women and 34 years (range: 19-69) for men. There was no statistical difference in age between genders. There was no relation between age and used amount of sunscreen. Most participants were between 18 and 40 years of age.
The mean applied sunscreen thickness was 0.55 mg/cm^2 (range: 0.11 mg/cm^2 – 1.72 mg/cm^2) for women and 0.69 mg/cm^2 (range: 0.12 mg/cm^2 – 1.54 mg/cm^2) for men. The difference was significant (P = 0.019).
The mean labelled SPF of the used sunscreen was 22 (range: 6-50) for women and 20 (range: 10-50) for men. There was no statistical difference in labelled SPF between genders. The mean true SPF was 2.6 (range: 1.1-13.1) for women and 3.0 (range: 1.2-8.0) for men. The difference was significant (P = 0.046). See Table 2.
For the whole population the mean thickness of sunscreen applied was 0.58 mg/cm^2 (range: 0.11 mg/cm^2 – 1.72 mg/cm^2) corresponding to a true SPF of 2.7. See details in Table 3.

Table 2: Descriptive statistics divided by gender.

Gender		Mean	Std. Deviation	Median	Minimum	Maximum
Women	Age (years)	29	11.1	26	18	73
	Height (cm)	170	6.3	170	157	187
	Weight (kg)	62	7.7	62	45	95
	Exposed skin area (m^2)	1.46	0.11	1.45	1.19	1.77
	Used sunscreen (g)	8.08	4.48	7.2	1.6	26.9
	Label SPF	22	8.7	20	6	50
	Sunscreen thickness (mg/cm^2)	0.549	0.29	0.499	0.112	1.715
	True SPF	2.6	1.7	2.1	1.2	13.1
Men	Age (years)	34	12.5	31	19	69
	Height (cm)	182	6.8	180	173	197
	Weight (kg)	77	7.3	76	65	90
	Exposed skin area (m^2)	1.52	0.10	1.53	1.34	1.68
	Used sunscreen (g)	10.47	4.33	9.4	1.8	20.9
	Label SPF	20	9.1	15	10	50
	Sunscreen thickness (mg/cm^2)	0.693	0.30	0.656	0.124	1.540
	True SPF	3.0	1.5	2.6	1.2	8.0

Table 3: Descriptive statistics for the whole population.

	Mean	Std. Deviation	Median	Minimum	Maximum
Age (years)	30	11.6	26	18	73
Height (cm)	173	8.2	173	157	197
Weight (kg)	66	9.9	64	45	95
Exposed skin area (m^2)	1.47	0.11	1.47	1.19	1.77
Used sunscreen (g)	8.63	4.54	7.8	1.6	26.9
Label SPF	22	8.8	17.5	6	50
Sunscreen thickness (mg/cm^2)	0.582	0.30	0.545	0.112	1.715
True SPF	2.7	1.7	2.2	1.2	13.1

5. Conclusion

In recent years a considerably higher SPF is used at the beach than previously. However, a suboptimal amount of sunscreen is still applied even though it is 20% higher in 2016 than observed in 1992. Overall it provides an increase in true SPF of almost 70% from 1.6 in 1992 to 2.7 in 2016 (Bech-Thomsen et al. 1992, present study). See Table 4. Men applied a thicker sunscreen layer than women. This was also observed in another study of Danes on holiday in Tenerife in 2013.

Table 4. Danish sunbathers' application of sunscreen 1992-2016.

Reference	Number of participants	Mean label SPF	Mean sunscreen application thickness (mg/cm^2)		Mean true SPF
			Women	Men	
(Bech-Thomsen et al. 1992) DK	42	6	0.46	0.49	1.6
(Petersen et al. 2013) Tenerife	20	15	0.66	0.93	3.0
Present (2016) DK	99	22	0.55	0.69	2.7

The mean BSA available for sunscreen application in this study was 1.47 m^2 skin. To obtain a sunscreen layer of 2 mg sunscreen per cm^2 a total amount of 29.4 grams of sunscreen must be used to cover 1.47 m^2 skin.

The question is if the achieved level of true SPF by Danish sunbathers is high enough to protect them from sunburn when exposed in the middle of the day. The answer depends on the person's skin pigmentation and on how long time the person stays in the sun. The longer time in the sun with exposed skin the higher the Standard Erythema Dose (SED). UV index is almost identical to SED per hour in the middle of a summer day (maximum about 6 SED per hour in Denmark). One SED is the UVR dose that elicits a just perceptible erythema in people with very light skin. An average Dane can tolerate 3 to 4 SED (3.5 SED) before visible redness is induced by sun exposure. The true SPF protects the skin so that the full UVR dose does not penetrate into the deeper layer of the skin. As described earlier for instance a "SPF 15" means that approximately 93 % of the burning UVR is blocked, if the amount of 2 mg of this sunscreen per cm^2 is applied to the skin. With a true SPF of 2.7 an average Dane can tolerate an exposure of about 9.5 SED (3.5×2.7) before turning red, which corresponds to the amount of sun exposure during 1.5 hours (1.5 hours of 6 SED). If we assume that the person is exposed equally on both sides of the body a total UVR dose of 19 SED can be tolerated (3 hours of 6 SED).

The average Danish sunbather stays approximately 3 hours on the beach on a summer day in Denmark (Stender et al. 1996). However, the latest Danish study is from 1996 and habits may have changed.

The mean true SPF we have found in the present study is adequate to protect average Danes against sunburn when sunbathing on a Danish beach for 3 hours, assuming that the sunscreen is applied uniformly and the people sunbathing expose the back and front of their bodies equally. Prolonged exposure or skin lighter than average requires a true SPF of more than 2.7. A

Dane with very light skin protected by a true SPF of 2.7 can sunbath for less than one hour (1×2.7×2/6) without getting sunburned.

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Appendix 1.

INDSMØRING PÅ STEDET - STRANDFORSØG	
Mand	Dato: _____/___ 2016
Kvinde	
Alder:	
Højde:	
Vægt:	
Solcreme (navn/mærke):	
SPF:	
Vægt før indsmøring:	gram
Vægt efter indsmøring:	gram
Navn på strand:	
Navn på park:	

Badetøjstype (sæt O om):

1 %

4 %

7 %

10 %

18 %

20 %

2 %

Bemærkninger:

Procentangivelser er estimater for hvor meget tøjet dækker af det samlede hudareal.

Danish sunbathers' application of sunscreen

This report describes Danish sunbathers' application of sunscreen in 2016. We have investigated if the used amount of sunscreen was adequate to gain sufficient sun protection.

The sun protection factor (SPF) labelled on sunscreen bottles is a measure of the protective efficacy of the sunscreen against sunburn. To gain the labelled SPF it requires that the sunscreen is applied in a thickness of 2 mg sunscreen per cm^2 skin. A thinner layer of sunscreen lowers the protection significantly.

Ninety-nine Danish adults were enrolled at Danish beaches between 10:30 AM and 15:15 PM from June through August 2016. Their sunscreen bottles were weighed before and after sunscreen application. Participants' skin areas exposed to the sun were estimated from their height, weight and clothing. From the used amount of sunscreen, the label SPF on the bottle and the exposed body surface area the true SPF was calculated for each participant.

The participants used sunscreen labelled as SPF 22 in average. They used an amount of sunscreen providing them an average true SPF of 2.7 (range: 1.2-13.1).

The mean true SPF we have found in the present project is adequate to protect an average Dane against sunburn while sunbathing 3 hours on a Danish beach at midday. Prolonged exposure or skin lighter than average, requires a true SPF of more than 2.7.

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