



# Long-term Trend in Sunscreen Use among Beachgoers in Denmark

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**This observational study examined the trend from the 1990s to 2016 of sunscreen use, sun protection factor (SPF) and quantity of sunscreen applied amongst beachgoers in Denmark. In 1997, 1998, 1999 and 2016, a total of 1,306 beachgoers were asked if they had used sunscreen on that day and, if so, which SPF. In 1992 and 2016 another 143 beachgoers had their sunscreen bottles weighed before and after application. The frequency of sunscreen use among women increased from 45% in 1997 to 78% in 2016, while the frequency of use among men increased from 39% to 49%. For both sexes the median SPF increased, on average, by one unit per year, from SPF 5 in 1997 to SPF 20 in 2016. The quantity of sunscreen applied increased from 0.48 mg/cm<sup>2</sup> in 1992 to 0.57 mg/cm<sup>2</sup> in 2016. Thus, the frequency of sunscreen use, the SPF, and the quantity of sunscreen applied have increased in the recent decades.**

*Key words:* quantity of sunscreen; sun protection factor; sun-bather; sunscreen use.

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Sunscreens restrict the amount of ultraviolet radiation (UVR) transmitted into the skin (1). UVR is a risk factor for development of skin cancer, and application of sunscreen is therefore recommended (1). In 2006 the European Commission recommended that only sunscreens with a sun protection factor (SPF) of 6 or more should be labelled as sunscreens in the European Union (EU) (2). From 2007 sun protection campaigns were directed at the general Danish population, recommending use of clothing, seeking shade, especially around noon, and frequent application of sunscreen in adequate amounts (3, 4). The recommendation is to use a handful of sunscreen for a full-body application to obtain a quantity of 2 mg sunscreen per cm<sup>2</sup> body area, which provides a protection corresponding to the labelled SPF (2, 5).

Registrations of sunscreen use at Danish beaches were carried out in the 1990s when less attention was paid to sunscreen use. In a field study conducted in 1994, 65% of 808 Danish sunbathers reported having used sunscreen with a median SPF of 5 on the day of investigation (6). Weighing sunscreen bottles before and after application

of sunscreen at a Danish beach in 1992 showed that adults applied a mean of 0.48 mg/cm<sup>2</sup> (7).

Since the 1990s several retrospective studies of sunscreen use in Denmark have been conducted (3). Retrospective studies involve the risk of recall bias. This is the first study to report direct measurements of sunscreen use collected before and after launching of the sun protection campaigns and the recommendation of the European Commission. In an attempt to obtain a realistic picture we report direct measurements from volunteers who happened to be on the beach. The aim of this study was to determine the trend in frequency of sunscreen use, SPF and quantity of sunscreen applied among beachgoers in Denmark from the 1990s to 2016.

## METHODS

The study was conducted in beach areas close to Copenhagen, Denmark. The beaches were visited between 10 a.m. and 4 p.m. on sunny days in June, July and August. The temperature was above 22°C on study days in 1997, 1998, 1999 and 2016 according to The Danish Meteorological Institute. All participants were Caucasian, at least 15 years old, happened to be on the beach, and participated anonymously.

The present study comprised a frequency study and a quantity study, with no individual participating in both components. The frequency study was performed in 1997, 1998, 1999 and 2016, whereas the quantity study was performed in 1992 and 2016. All data from 1992 have previously been published (7).

### *Frequency of sunscreen use*

Sunbathers wearing no more than swimwear were approached on the beaches. We tried to include all Caucasian 15 years or older on the visited beaches. Subjects were asked in person if they had used sunscreen that day and, if so, which SPF. Participants' sex and age were noted. The experimental design of the frequency study was identical for all study years.

### *Quantity of sunscreen*

Other Caucasians arriving at the beach were asked if they had brought a sunscreen to be used at the beach and if they were willing to participate. If participation in the study was accepted, their sunscreen bottles were weighed before and just after application. The SPF on the bottle was noted to compare with the self-reported SPF in the frequency study.

In 1992 the quantity study was performed on a nudist beach. Thus, it was not necessary to take skin covered by swimwear into account and the skin area accessible for sunscreen application was calculated from the participants' weight and height (7).

In 2016 the study was performed on a beach on which people wore swimwear. Participants' type of swimwear was registered and self-reported weight and height were noted to make it possible to estimate the maximal possible sunscreen application area. The

total body surface area (BSA) was calculated from participants' weight and height using the Mosteller formula (8). The BSA accessible for sunscreen application was calculated by subtracting the soles of the feet plus the scalp hair area (fixed at 7%) and the swimwear-covered area from the total BSA. Swimsuits were estimated to cover 20% of BSA, large trunks 18%, small trunks 10%, and bikinis between 3% and 9% (Fig. 1). The mean quantity of sunscreen per cm<sup>2</sup> of skin was calculated by dividing the amount of sunscreen used by the BSA accessible for sunscreen application. Part of the 2016 data has previously been reported (9).

### Statistics

Statistical analysis was performed with IBM SPSS statistics version 22 (IBM, Armonk, NY, USA). Descriptive statistics for normally distributed data include mean and standard deviation (SD). For data not normally distributed this includes median and interquartile range (IQR). Correlations were assessed with Spearman's rank-order correlation. A binary logistic regression was used to investigate determinants of sunscreen use. The difference in quantity of sunscreen used between 1992 and 2016 was calculated by Welch's unpaired *t*-test. Other relations between unpaired data were assessed using the Mann-Whitney test. The significance level was  $p < 0.05$ .

## RESULTS

### Frequency of sunscreen use

A total of 1,306 subjects participated in the surveys in 1997, 1998, 1999 and 2016. Characteristics of study participants are presented in Table I. The frequency of sunscreen use varied from year to year and between sexes (Table I), but not with age ( $p = 0.7$ ). According to the conducted binary regression model the probability of using sunscreen was 2.24 times higher for women than for men controlled for study year ( $p < 0.0001$ ). The model was, however, not very strong (Cox and Snell  $R^2 = 0.06$ ). Women's probability of using sunscreen increased from 45% in 1997 to 78% in 2016. For men the increase in probability increased from 39% in 1997 to 49% in 2016.

### Sun protection factor

In the frequency study SPF was self-reported and found to be 5 in 1997, 6 in 1998, 8 in 1999 and 20 in 2016 (Ta-

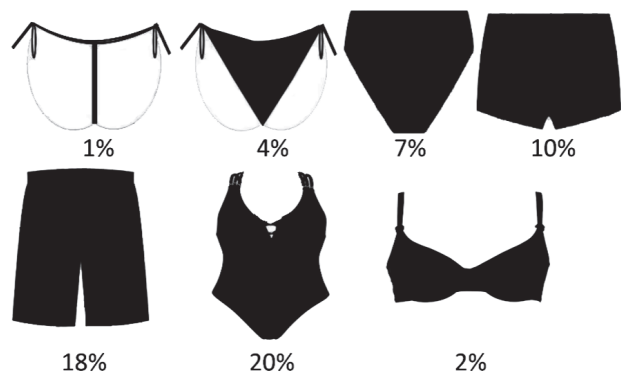


Fig. 1. Pictograms of swimwear and the estimated percentage of body surface covered.

Table I. Characteristics of participants, their frequency of sunscreen use, and used sun protection factor (SPF)

Year	Participants <i>n</i>	Women %	Age, years Mean (range)	SPF used Median (IQR)	Frequency of sunscreen use, %	
					Women	Men
1997	239	48	27 (15-75)	5 (4-8)	45	39
1998	473	57	28 (15-76)	6 (5-8)	58	33
1999	452	59	31 (15-82)	8 (5-10)	70	53
2016	142	75	29 (15-75)	20 (15-30)	78	49

IQR: interquartile range.

ble I). The SPF increased, on average, by one unit each year ( $r = 0.46$ ,  $p < 0.0001$ ). There was a weak correlation between increasing age and higher SPF in 2016 ( $r = 0.29$ ,  $p = 0.03$ ). For the other years, there was no correlation between age and SPF ( $p > 0.3$ ). In 1999 women used a median SPF of 7, while men used a median SPF of 8. This small difference was significant ( $p = 0.02$ ). In the other years, there was no relation between sex and SPF ( $p > 0.09$ ).

In the quantity study SPF was noted directly from the sunscreen bottles used. In 1992 the median observed SPF was 6, whereas in 2016 it was SPF 20.

The validity of self-reported SPF was confirmed, as it is in very good agreement with observed SPF.

### Quantity of sunscreen

A total of 111 volunteers (85 women and 26 men) were enrolled in the study in 2016. They exposed a mean of 83% (SD 5%) of BSA, corresponding to 1.46 m<sup>2</sup> (SD 0.11 m<sup>2</sup>) and used 8.4 g (SD 4.7 g) sunscreen. This corresponds to a mean quantity of sunscreen used of 0.57 mg/cm<sup>2</sup> (SD 0.31 mg/cm<sup>2</sup>). There was no difference in quantity of sunscreen applied between sexes ( $p = 0.2$ ) or with age ( $p = 0.1$ ).

In 1992 participants 15 years or older ( $n = 32$ ) used 0.48 mg/cm<sup>2</sup> (SD 0.18 mg/cm<sup>2</sup>) (7). Participants applied significantly larger sunscreen quantities in 2016 than in 1992 ( $p = 0.04$ ).

## DISCUSSION

There was an increase in frequency of sunscreen use, SPF chosen, and quantity of sunscreen applied from the 1990s to 2016. The launch of a Danish sun protection campaign in 2007 and the following years may explain the observed changes in sunscreen use (9). In particular, SPF has increased markedly, more than doubling over the last 16 years. From 2006 only sunscreens with SPF of 6 or more may be labelled as sunscreen in the EU. The present study suggests that this structural intervention has been effective. We found SPF of less than 6 to have been very common in 1997, 1998 and 1999, while only one beachgoer used an SPF below 6 in 2016.

The frequency of sunscreen use has increased among women, while the increase has been less for men. The

quantity of sunscreen applied by beachgoers on Danish beaches has increased by 19%, from 0.48 mg/cm<sup>2</sup> in 1992 (7) to 0.57 mg/cm<sup>2</sup> in 2016. The effective SPF corresponds to the labelled SPF only if a quantity of sunscreen of 2.00 mg/cm<sup>2</sup> is applied, and most probably the effective SPF decreases exponentially with decreasing quantities of sunscreen applied (10). Sunscreen labelled as SPF 20 applied in a quantity of 0.57 mg/cm<sup>2</sup>, as seen in the 2016 study, provides an effective SPF of 2.3. The most commonly used SPF (SPF=6) in 1992 applied in a quantity of 0.48 mg/cm<sup>2</sup> corresponds to an effective SPF of 1.5. Thus, even though the labelled SPF increased by 233% from 1992 to 2016, this corresponds only to an increase of 53% in effective SPF due to the small quantity applied. The study in 1992 was conducted on a nudist beach, whereas in 2016 it was conducted on a beach where people wore swimwear. It is not known if nudists used sunscreen differently from people in swimwear. The result of the quantity study may thus be affected by selection bias.

Previous studies performed outside Denmark have also measured the quantity of sunscreen by weighing sunscreen bottles before and after application, most of the measurements being performed in laboratory environments (11–13). The trend is, however, that participants use smaller quantities of sunscreen in real-life situations. A summary of studies from all over the world (7, 14–17) measuring quantities of sunscreen applied by weighing sunscreens bottles in real-life settings is presented in **Table II**. Quantities used were consistently less than 1 mg/cm<sup>2</sup>. The quantity applied is much smaller than 2 mg/cm<sup>2</sup>, which is the quantity required to obtain the labelled SPF (10).

When the quantity of sunscreen applied is calculated by weighing bottles before and after application, the result represents a mean quantity. Sunscreen is applied very unevenly and some accessible skin areas are probably left without sunscreen, while other areas receive a quantity above the mean.

There have been mass media campaigns similar to the Danish sun protection campaign in many other countries (18). Mass media campaigns are a validated tool to induce behavioural changes in the general population, and effects on sun protection behaviour have been documented (4, 19, 20). However, conclusions on sun protection may be biased since they are based on retrospectively self-reported sunscreen use. It may be difficult for participants to recall and estimate the overall frequency of sunscreen use. This is the case, for example, when answering questions like: “How often do you wear sunscreen? Never/rarely/sometimes/often/always” (18). It is a strength of our study that it investigated quantities and SPF of sunscreen used by direct measurements and observation of the sunscreen bottles. SPF was also examined together with frequency of sunscreen use by questions about behaviour on the same day. In 2016 SPF was examined both by looking at the labels on sunscreen bottles and by asking about use. Both methods of investigation used provided the same results: a median SPF of 20. It is, however, not certain that self-reported SPF is reliable in study designs in which participants are not asked about use on the day in question.

In conclusion, the frequency of sunscreen use, the SPF chosen, and the quantity of sunscreen applied have increased among beachgoers in Denmark over the past 25 years.

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**Table II. A summary of studies measuring applied quantity of sunscreen by weighing sunscreen bottles in real-life situations**

Study	Bech-Thomsen et al. (7)	Neale et al. (14)	Autier et al. (15)	Diaz et al. (16)	Petersen et al. (17)	Present study
Year	1992	1992–1996	1997–1998	Before 2012	2010	2016
Country	Denmark	Australia	Southern Europe	Australia	Egypt	Denmark
Participants	n = 42 Random beachgoers	n = 595 Subjects in a skin cancer prevention study	n = 124 Students 18–24 years	n = 87 Children 5–12 years	n = 20 Scandinavian sun-seekers	n = 111 Random beachgoers
Setting	Bottles weighed before and after application on the beach	Bottles weighed every 3–4 months	Bottles weighed before and after a summer holiday	Bottles weighed before and after 3 study weeks	Bottles weighed daily during a sun holiday	Bottles weighed before and after application on the beach
The sunscreen	Participant's own	Provided by investigator	Provided by investigator	Provided by investigator	Participant's own	Participant's own
Instructions given on sunscreen application	None	Participants instructed to use sunscreen daily	None	Participants instructed to use sunscreen daily	None	None
SPF	Mean of 6	15+	10 or 30	30+	Mean of 15	Median of 20
Quantity of sunscreen applied	Mean 0.49 mg/cm <sup>2</sup>	Median 0.79 mg/cm <sup>2</sup>	Median 0.39 mg/cm <sup>2</sup>	Median 0.48 mg/cm <sup>2</sup>	Mean 0.79 mg/cm <sup>2</sup>	Mean 0.57 mg/cm <sup>2</sup>

SPF: sun protection factor.

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