The validated sun exposure questionnaire
association of objective and subjective measures of sun exposure in a Danish population-based sample
Køster, B; Søndergaard, J; Nielsen, J B; Allen, M; Olsen, A.; Bentzen, J

Published in:
British Journal of Dermatology

DOI:
10.1111/bjd.14861

Publication date:
2017

Document version:
Final published version

Document license:
CC BY-NC-ND

Citation for published version (APA):
Køster, B., Søndergaard, J., Nielsen, J. B., Allen, M., Olsen, A., & Bentzen, J. (2017). The validated sun exposure questionnaire: association of objective and subjective measures of sun exposure in a Danish population-based sample. British Journal of Dermatology, 176(2), 446-456. https://doi.org/10.1111/bjd.14861

Go to publication entry in University of Southern Denmark's Research Portal

Terms of use
This work is brought to you by the University of Southern Denmark. Unless otherwise specified it has been shared according to the terms for self-archiving. If no other license is stated, these terms apply:
• You may download this work for personal use only.
• You may not further distribute the material or use it for any profit-making activity or commercial gain.
• You may freely distribute the URL identifying this open access version.

If you believe that this document breaches copyright please contact us providing details and we will investigate your claim. Please direct all enquiries to puresupport@bib.sdu.dk
The validated sun exposure questionnaire: association of objective and subjective measures of sun exposure in a Danish population-based sample*

B. Køster,1,2 J. Søndergaard,2 J.B. Nielsen,2 M. Allen,3 A. Olsen4 and J. Bentzen1

1Department of Prevention and Information, Danish Cancer Society, Strandboulevarden 49 2100, Copenhagen Ø, Denmark
2Research Unit of General Practice, University of Southern Denmark, Odense, Denmark
3Electrical and Computer Engineering, University of Canterbury, Canterbury, U.K.
4Research Centre, Danish Cancer Society, Copenhagen Ø, Denmark

Linked Comment: King. Br J Dermatol 2017; 176:298–299.

Correspondence
Brian Køster.
E-mail: bk@cancer.dk

Accepted for publication
27 June 2016

Funding sources
B.K. received funding by TrygFonden and The Danish Board of Research and Innovation for this study.

Conflicts of interest
None declared.

*Plain language summary available online

DOI 10.1111/bjd.14861

Summary

Background Few questionnaires used in monitoring sun-related behaviour have been tested for validity.

Objectives We established the criteria validity of a questionnaire developed for monitoring population sun-related behaviour.

Methods During May–August 2013, 664 Danes wore a personal electronic ultraviolet radiation (UVR) dosimeter for 1 week that measured their outdoor time and dose of erythemal UVR exposure. In the following week, they answered a questionnaire on their sun-related behaviour in the measurement week.

Results Outdoor time measured by dosimetry correlated strongly with both outdoor time and the developed exposure scale measured in the questionnaire. Exposure measured in standard erythema dose (SED) by dosimetry correlated strongly with the exposure scale. In a linear regression model of UVR (SED) received, 41% of the variation was explained by skin type, age, week of participation and exposure scale, with exposure scale as the main contributor. The weekly sunburn fraction correlated strongly with the number of ambient sun hours ($r = 0.73$, $P < 0.001$).

Conclusions This criteria-validated questionnaire provides evidence of the exposure that the questionnaire aimed to measure. The evidence provided showed a strong link between the objectively measured behaviour and the behaviour measured by this survey construct. The questionnaire is the first validated tool to measure the UVR exposure in a national population-based sample.

What’s already known about this topic?

- Personal ultraviolet radiation (UVR) dosimeters and diaries have previously been applied in studies of UVR.
- Previous evaluation designs were weakly correlated or less well suited for evaluation.

What does this study add?

- Objective and subjective measures of outdoor exposure time are strongly correlated in a week-based evaluation design.
- The validated sun exposure questionnaire provides a design for reliable short-term evaluation of skin cancer prevention campaigns.
The incidence of both malignant and nonmalignant skin cancers has increased for decades in large parts of the world and especially in Caucasian populations. Exposure to ultraviolet radiation (UVR) is the main risk factor for skin cancer and it has been estimated that at least 80% of all skin cancers could be avoided by behavioural changes. The three main sources of UVR exposure among the Danes are spare time in the summer in Denmark, sunbeds and vacations to destinations with a high UV index (UVI).

Campaigns aimed at changing UVR behaviour in the general population have been launched in several countries. The effects of these initiatives are generally evaluated through the distribution of questionnaires. Bias (recall, selection, socially desirable answers) can potentially limit the reliability of conclusions drawn based on questionnaire data and it is thus essential that questionnaires be evaluated for validity and reliability.

Few questionnaires used in the evaluation of health interventions aimed at reducing skin cancer have been tested for validity and reliability, e.g. to validate self-reported measures of UVR exposure by testing behavioural questions against objective measurements or against other self-reported data sources. These studies show that it is possible to measure various aspects of people’s behaviour in the sun with validity; however, the published studies are limited in that only specific groups were included and, therefore, the results are not valid on a population level. Most studies used diaries to assess sun-related behaviour. Diaries are not feasible for campaign evaluation, as they are an intervention themselves. Recently, a small study validated a brief questionnaire against objective measures of UVR exposure, including UVR dosimeters.

The Danish Sun Safety Campaign’s questionnaires of the Danes’ sun behaviour are neither tested for criteria validity against objective measures of the personal UVR exposure nor tested for reliability, and people are asked in September to recall information about the summer, e.g. the length of time they spent in the sun. The problems with these questions are the recall over a long period and the generalization of typical behaviour during the summer. Previous annual evaluations of the Danish Sun Safety Campaign examined trends, e.g. the percentage of the population that experienced sunburn; however, summers in Denmark have large climatic variations.

The ideal evaluation objective is the number of skin cancer incidents; however, as a short-term evaluation objective this is not applicable, as skin cancer has a latency time of a minimum of 20 years. Therefore, it is necessary to measure the main cause of skin cancer, the UVR exposure, by objective measurements.

Sunburn has been used as an approximate measure for UVR exposure in epidemiological research, but it is important to keep in mind that it is the radiation causing the sunburn that also causes the cancer. Sunburn is associated with the cumulative and especially the intentional UVR exposure; however, it is not necessary to experience sunburn to develop skin cancer and therefore other measures of sun-related behaviour should complement the sunburn item in evaluation and research.

Previously we reported the feasibility of the study method and we examined sources of bias and possible optimizations. We showed criteria validity in a small sample and established that UVR exposure measurement periods of 1–3 weeks were applicable and yielded questionnaire results validly reflecting the measured UVR exposure.

The aims of this study were to establish the criteria validity of a questionnaire developed for monitoring and evaluating population sun-related behaviour. To our knowledge, this is the first study to validate a questionnaire on sun-related behaviour against objective UVR measurements in a national random population-based sample.

Methods

Study design and population

In March 2013, a random sample of Danes aged 15–65 years was drawn from the Danish civil registration system. They were mailed an invitation to participate in the study at the end of April. To be eligible to participate in the study they needed to be able to wear a personal dosimeter wristband for 1 week of their vacation in Denmark during weeks 19–35 (May–August) and complete an electronic questionnaire afterwards. The invitees signed up on the project page (http://www.mituv.dk) and indicated available weeks. Potential participants were then allocated to a participation week and contacted by phone at least 1 week in advance to receive instructions. Potential participants with more than one vacation week were allocated to a low season week, if available, to increase sample utilization. Participants who confirmed their participation by phone were sent a dosimeter including instructions. Potential participants with more than one vacation week were allocated to a low season week, if available, to increase sample utilization. Participants who confirmed their participation by phone were sent a dosimeter including instructions and a prepaid envelope by ordinary mail. After participation, they returned the dosimeter for data retrieval and received a questionnaire the following week. The project had 130 dosimeters available, which were deployed in a biweekly cycle of 65 participants, i.e. 1 week of data collection and 1-week postal management and data retrieval. Figure 1 shows the project flowchart. The 488 available persons who signed up but were not included were either not reached within 10 calls made between 9:00 and 21:00, were not needed because more than 65 participants were allocated (weeks 27–29 only), or declined because of personal reasons (change of vacation plans, wedding, giving birth, family-related deaths, change of work schedule, regret participation, etc.).

The study population was chosen to be representative of the Danish population within sex, age groups (15–24, 25–34, 35–44, 45–54, 55–65 years) and region. The recruitment of the 15- to 17-year-olds required parental consent, in which case the invitation letter was initially directed to one of the parents. Persons who requested not to be chosen for research projects were excluded from the sample.
Ultraviolet radiation dosimeter

The dosimeters were electronic and developed to digitally measure personal erythemal UVR exposure in behavioural studies.²⁹ They are based on a visible-blind AlGaN photodiode and their spectral response (240–320 nm) and cosine response were previously described by Allen and McKenzie.²⁹ The version used here was redesigned and manufactured by Scienterra Ltd, New Zealand, and used by Cargill et al.,²³ Wright et al.³⁰ and Køster et al.²⁷ The dosimeters were configured to take time-stamped measurements at 30-s intervals from 7:00 to 19:00. Wristbands were attached to the dosimeters. Measurements at the wrist have previously been shown to constitute approximately 50% of the ambient UVR (as received by the top of the head) in a small study.³¹ More importantly, the wrist was chosen to ensure that participants used the dosimeters in a uniform way. The different body sites receive varying amounts of UVR, for instance due to differences in the solar zenith angle,³² and even though solar zenith angles also differ depending on how the dosimeters are worn, the deviation is assumed to be diminished by the uniform site. Furthermore, because erythemal UVR exposures are always zero when indoors and usually non-zero outdoors during daytime hours, dosimeter values greater than zero are a good representation of time spent outdoors. The calibration instrument was a Robertson Berger type instrument with a spectral response according to the CIE action spectrum.³³

Sample size, bias and confounding

The sample size was given by the restricted availability of qualified dosimeters in combination with the summer study period as well as a measurement period of 1 week. A calculation showed that a 2/3 success rate of 1105 potential participants would provide sufficient power even for subgroup analysis assuming a 0.38 correlation coefficient.²⁷ The number of invitations was based on recruitment from our pilot study.²⁷ As one aim of the project was to develop a validated questionnaire which can be used in the future without further dosimetry measurements, the participants were blinded towards this purpose to avoid the use of homemade diaries or similar behaviour book-keeping. Thus, the participants were informed only of the overall aim: ‘to improve knowledge and evaluation of the Danes’ sun-related behaviour’. Possible
Statistics and quantitative variables

The dosimeters were calibrated against data from the Danish Meteorological Institute (DMI) (Robertson Berger type instrument), and second-degree polynomials were fitted for each dosimeter to convert logged data into the standard erythemal effective units for irradiance (1 UVI = 25 mWm$^{-2}$ of erythemally-weighted UVR) and integrated dose [1 standard erythema dose (SED) = 100 Jm$^{-2}$ of erythemally-weighted UVR]. The DMI also provided ambient UVR data.

Questionnaire assessment of time was converted from the possible answers of average daytime outside: ‘not outside’, ‘0–1 h’, ‘1–2 h’, ‘2–3 h’, ‘3–4 h’ to 0 h, ½ h, 1½ h, 2½ h and 3½ h, respectively, for each of the 4-h intervals 7:00–11:00, 11:00–15:00 and 15:00–19:00, and summed for a total daytime estimate. To examine the correlation between questionnaire reported time and registered time outdoors, we converted any 30-s UVR measurements to 30 s of outdoor time. We then summed measured time and dose for each participant and measurement week. Finally, the number of days the dosimeter was worn was accounted for and average exposure per day was calculated. For the questionnaire estimation of exposure, the total daytime questions were used as a 5-point Likert scale combined with questions regarding frequency of sunbathing and spending time in the sun sitting or lying to form an exposure score. Similarly, the estimation of sun-protection behaviour was summarized in a protection scale including questions about sunscreen [sun protection factor (SPF) 15+], hat, clothing and sun avoidance. Sun protection and outdoor exposure scales are shown in Table 1. These scales were developed using Rasch analysis.34 The entire questionnaire can be found in Data S1 (see Supporting Information). The self-evaluated weather was determined with a single question on average cloud cover (1–5). Skin type was assigned according to Fitzpatrick35 by self-evaluated skin tan/burn reaction to the first sun exposure of the season. Descriptive statistics for continuous variables are presented as medians (interquartile range, Q1–Q3) or means as appropriate. Confidence intervals for the Spearman correlation coefficients were calculated using Fisher’s transformation. Assumptions of linearity and homogeneity of variance were satisfied. The normal distribution of data was tested by q-q plots and Shapiro–Wilk tests. Square root transformation of data was distributed normally, and used when data deviated from the normal distribution. Linear regression models were used to assess associations between outdoor time measured by questionnaire and dosimeter, where dosimeter minutes were the independent variable and to assess associations between the exposure scale and the actual exposure measured by dosimeter. Residuals were normally distributed. The project was sent to the National Committee on Health Research Ethics who decided that their approval was not necessary. The Danish Data Protection Agency gave approval number 2012–41–0100.

Results

Participants

Figure 1 shows the study flowchart. Six thousand persons were invited and of those, 25% signed up for participation. We collected data from 749 successful dosimeter measurements and we received 736 completed questionnaires and for 664 persons we had complete data for both dosimetry and questionnaire with a response rate of 89%.

Descriptive data

Figure 2a shows the number of sun hours, the percentage of participants sunburned and ambient radiation during the study period [data from the DMI (dmi.dk) and personal communication]. The highest UVI measurement on a single day during this summer was 7.3. It is seen that the weekly sunburn percentage and number of sun hours are strongly correlated ($r = 0.73$, $P < 0.001$). Figure 2b shows ambient radiation and measured exposure in SEDs together with self-evaluated exposure scale

Table 1 Sun protection and outdoor exposure scales

| Sun protection scale | Mean 0–3 | Rest score correlation | Item–item correlation, range | Outdoor exposure scale | Mean 0–4 | Rest score correlation | Item–item correlation, range |
|----------------------|---------|-----------------------|-------------------------------|------------------------|---------|-----------------------|-------------------------------|
| Sunscreen SPF 15+    | 0.93    | 0.271                 | 0.12–0.34                     | Outdoor exposure, 7:00–11:00 | 1.619  | 0.395                 | 0.15–0.51                     |
| Long sleeves         | 0.97    | 0.495                 | 0.17–0.83                     | Outdoor exposure, 11:00–15:00 | 2.473  | 0.473                 | 0.26–0.57                     |
| Long trousers/skirt  | 1.01    | 0.446                 | 0.12–0.83                     | Outdoor exposure, 15:00–19:00 | 2.483  | 0.513                 | 0.24–0.57                     |
| Cap                  | 0.43    | 0.198                 | 0.08–0.73                     | Sunbathing              | 0.703  | 0.366                 | 0.15–0.47                     |
| Wide-brimmed hat     | 0.12    | 0.371                 | 0.14–0.73                     | Sitting or laying in the sun | 1.910  | 0.364                 | 0.20–0.47                     |
| Shade                | 1.18    | 0.331                 | 0.08–0.54                     |                        |         |                       |                               |
| Stayed inside 12:00–15:00 | 0.74   | 0.341                 | 0.10–0.54                     |                        |         |                       |                               |

SPF, sun protection factor.
and weather during the study period. The ambient radiation and measured exposure are significantly correlated, and the self-evaluated weather score and exposure scales are both strongly correlated with the measured exposure and each other (data not shown). Table 1 shows the composition of the sun protection and outdoor exposure scales used in this study and the single items’ correlation with the scale and with each other. Use of a wide-brimmed hat scored the lowest and shade the highest on the protection scale. Clothing had the strongest correlation with total scale score. The participants’ outdoor exposure time was shortest between 7:00 and 11:00 compared with the other 4-h intervals. Table 2 shows the distribution of demographic characteristics of the final sample, including sunburn and four questionnaire and dosimetry measures. The final sample included more women than men, and more persons in the age group 55–65 years than in the younger age groups. Twenty-nine per cent of the participants experienced sunburn. Sunburn decreased with age, was lower with darker skin type and increased with sunny weather. Men spent more time outdoors and were more exposed to UVR than women, which is in agreement with their own questionnaire reporting. The 15- to 24-year-olds spent the least time in the sun, while the 45- to 54-year-olds spent the most. For skin type, all four measures increased with darker skin type. Persons with vocational education registered and reported the largest exposure and outdoor time. The same was seen for persons on vacation in the mid-season, while those vacationing during pre-season spent the least time outdoors; both pre- and post-season registered the same amount of SED exposure. Persons with their own or family-related melanoma reported and registered similarly to persons without. All four exposure measures increased by the subjective weather score in accordance with the results shown in Figure 2b.

Table 3 shows the correlation between dosimetry-registered time and questionnaire-reported time, measured SED exposure and the exposure scale, and dosimetry-registered time and the exposure scale. Time outdoors registered on the dosimeter and that reported in the questionnaire were significantly correlated for all subgroups, except for measurements in weeks of high cloud cover. Measured SED exposure was significantly correlated with the exposure scale from the questionnaire for all subgroups. Time outdoors registered on the dosimeter was also highly correlated with the exposure scale for all subgroups. There were no differences in strength of correlation between subgroups except for the Zealand region, which was slightly stronger correlated.

Fig 2. (a) Variation in ambient exposure, sunburn and sun hours during study period. (b) Variation in ambient and measured exposure and self-evaluated exposure and weather during study period. The ambient exposure is shown per day and the self-evaluated weather score (0–4) was multiplied by 4 to be fitted into the diagram. Measured exposure are median values per person. (a, b) The y-axis units are according to descriptive legends. SED, standard erythema dose.

© 2016 The Authors. British Journal of Dermatology published by John Wiley & Sons Ltd on behalf of British Association of Dermatologists.
Table 2 Distribution of demographic characteristics, sunburn, measures of outdoor time and ultraviolet radiation exposure in a cross-sectional sample of 664 Danes

| Characteristic                        | Total (%) | % Sunburn | Outdoor time (minutes per day) registered on dosimeter, median (QIR) | SED/day registered on dosimeter, median (QIR) | Exposure scale score from questionnaire, mean (SD) | Outdoor time (minutes per day) reported in questionnaire, mean (SD) |
|---------------------------------------|-----------|-----------|---------------------------------------------------------------------|-----------------------------------------------|--------------------------------------------------|-------------------------------------------------------------------|
| Total                                 | 664       | 100       | 64.5 (34.7–113.3)                                                   | 1.2 (0.6–2.0)                                 | 9.2 (3.5)                                        | 308.2 (133.4)                                                   |
| Sex                                   |           |           |                                                                     |                                               |                                                  |                                                                   |
| Male                                  | 251       | 38        | 77.3 (36.7–127.0)                                                   | 1.4 (0.7–2.5)                                 | 9.5 (3.5)                                        | 326.8 (133.2)                                                   |
| Female                                | 413       | 62        | 58.9 (33.4–101.3)                                                   | 1.1 (0.6–1.8)                                 | 9.0 (3.5)                                        | 296.9 (132.4)                                                   |
| Age group (years)                     |           |           |                                                                     |                                               |                                                  |                                                                   |
| 15–24                                 | 100       | 15        | 40.4 (22.4–74.8)                                                   | 0.8 (0.4–1.6)                                 | 8.7 (3.1)                                        | 269.4 (124.7)                                                   |
| 25–34                                 | 104       | 16        | 52.1 (33.0–87.5)                                                   | 1.0 (0.5–1.6)                                 | 8.8 (3.1)                                        | 289.6 (125.4)                                                   |
| 35–44                                 | 118       | 18        | 75.1 (37.6–117.5)                                                  | 1.3 (0.6–1.9)                                 | 9.5 (3.4)                                        | 306.1 (118.4)                                                   |
| 45–54                                 | 132       | 20        | 75.6 (38.8–154.9)                                                  | 1.5 (0.7–2.6)                                 | 9.8 (3.9)                                        | 328.2 (151.4)                                                   |
| 55–65                                 | 210       | 31        | 71.1 (40.7–121.5)                                                  | 1.4 (0.8–2.3)                                 | 9.0 (3.3)                                        | 324.4 (133.1)                                                   |
| Skin type                             |           |           |                                                                     |                                               |                                                  |                                                                   |
| I                                     | 54        | 8         | 60.3 (30.5–88.9)                                                   | 0.9 (0.7–1.8)                                 | 8.3 (3.8)                                        | 288.3 (152.9)                                                   |
| II                                    | 383       | 58        | 64.4 (33.7–110.0)                                                  | 1.1 (0.6–1.9)                                 | 9.1 (3.3)                                        | 305.5 (126.2)                                                   |
| III/IV                                | 227       | 35        | 65.3 (37.9–128.3)                                                  | 1.3 (0.7–2.5)                                 | 9.6 (3.6)                                        | 317.4 (140.1)                                                   |
| Region                                |           |           |                                                                     |                                               |                                                  |                                                                   |
| Capital                               | 187       | 28        | 64.8 (33.4–116.0)                                                  | 1.1 (0.6–1.8)                                 | 9.3 (3.3)                                        | 308.7 (129.1)                                                   |
| Zealand                               | 103       | 16        | 71.7 (35.8–122.2)                                                  | 1.2 (0.6–2.2)                                 | 9.5 (3.6)                                        | 315.7 (138.0)                                                   |
| Northern Jutland                      | 68        | 10        | 52.1 (32.5–89.7)                                                   | 1.1 (0.6–1.9)                                 | 8.7 (3.5)                                        | 275.7 (135.6)                                                   |
| Central Jutland                       | 167       | 25        | 65.9 (36.0–104.1)                                                  | 1.3 (0.7–2.1)                                 | 9.3 (3.5)                                        | 313.5 (132.3)                                                   |
| Southern Denmark                      | 139       | 21        | 64.3 (36.3–130.4)                                                  | 1.2 (0.7–2.1)                                 | 9.0 (3.6)                                        | 311.4 (135.6)                                                   |
| Education (n = 658)*                  |           |           |                                                                     |                                               |                                                  |                                                                   |
| Primary school                        | 117       | 18        | 56.5 (27.7–101.4)                                                  | 1.1 (0.5–1.9)                                 | 9.0 (3.3)                                        | 319.0 (135.7)                                                   |
| Secondary school                      | 90        | 14        | 52.5 (31.9–88.9)                                                   | 1.0 (0.5–1.9)                                 | 8.4 (3.0)                                        | 265.3 (120.8)                                                   |
| Vocational                            | 91        | 14        | 88.9 (36.4–157.7)                                                  | 1.6 (0.8–2.7)                                 | 10.4 (3.5)                                       | 354.1 (141.3)                                                   |
| Higher education (<2 years)           | 67        | 10        | 65.4 (45.7–109.1)                                                  | 1.1 (0.7–2.1)                                 | 8.9 (2.7)                                        | 291.9 (100.9)                                                   |
| Higher education (2–4 1/2 years)      | 213       | 32        | 65.9 (35.6–109.8)                                                  | 1.2 (0.6–1.9)                                 | 9.1 (3.7)                                        | 299.2 (134.5)                                                   |
| Higher education (>4 1/2 years)       | 80        | 12        | 61.4 (35.0–114.8)                                                  | 1.1 (0.6–1.9)                                 | 9.6 (3.7)                                        | 328.1 (138.3)                                                   |
| Season                                |           |           |                                                                     |                                               |                                                  |                                                                   |
| Pre (weeks 19–24)                      | 238       | 36        | 48.9 (29.1–82.8)                                                   | 1.1 (0.6–1.7)                                 | 8.4 (3.2)                                        | 284.7 (129.6)                                                   |
| Mid (weeks 25–30)                      | 246       | 37        | 83.1 (39.3–146.1)                                                  | 1.5 (0.8–2.5)                                 | 9.9 (3.7)                                        | 332.6 (139.0)                                                   |
| Post (weeks 31–35)                     | 180       | 27        | 68.0 (37.8–116.3)                                                  | 1.1 (0.5–1.9)                                 | 9.3 (3.3)                                        | 305.8 (125.4)                                                   |
| Own or family-related melanoma         |           |           |                                                                     |                                               |                                                  |                                                                   |
| Yes                                   | 147       | 22        | 60.3 (30.5–88.9)                                                   | 1.4 (0.7–2.5)                                 | 9.0 (3.4)                                        | 303.3 (130.4)                                                   |
| No                                    | 517       | 78        | 60.3 (30.5–88.9)                                                   | 1.4 (0.7–2.5)                                 | 9.2 (3.5)                                        | 309.6 (134.3)                                                   |
| Weather (n = 663)*                    |           |           |                                                                     |                                               |                                                  |                                                                   |
| 1 Most of the time sunny               | 191       | 29        | 101.3 (58.6–157.4)                                                 | 1.7 (1.1–2.7)                                 | 11.3 (3.5)                                       | 373.7 (137.2)                                                   |
| 2                                     | 176       | 27        | 76.8 (44.3–117.7)                                                  | 1.3 (0.8–2.1)                                 | 9.3 (3.2)                                        | 309.9 (129.5)                                                   |
| 3                                     | 152       | 23        | 51.5 (31.5–86.5)                                                   | 1.0 (0.6–1.8)                                 | 8.6 (2.7)                                        | 287.6 (111.6)                                                   |
| 4                                     | 83        | 12        | 42.5 (25.1–70.9)                                                   | 0.9 (0.4–1.5)                                 | 7.7 (2.6)                                        | 269.3 (108.7)                                                   |
| 5 Most of the time cloudy             | 61        | 9         | 29.5 (16.7–38.6)                                                   | 0.6 (0.2–1.0)                                 | 5.6 (2.4)                                        | 201.1 (110.0)                                                   |

IQR, interquartile range; SED, standard erythema dose. *Missing data.

Regression analysis

In Table 4, we have examined the relationship between objective and subjective measures and factors influencing this relationship by linear regression. The ‘timescale’ and ‘outdoor exposure scale’ calculations determine the validity of the tool we have developed, while the ‘exposure measured by dosimeter’ calculations explain factors of radiation received by the dosimeter. Table 4 (timescale) shows factors explaining the questionnaire-assessed outdoor time. The model includes outdoor time registered by the dosimeter, the subjective perception of the weather and education and explains 35% of the
variation. The outdoor time registered on the dosimeter explains the largest part. Persons with primary, secondary school or higher education (> 4½ years) have higher self-reported outdoor times relative to their dosimeter measurement. The subjective perception of the weather influenced the model by higher questionnaire estimates relative to outdoor time registered on the dosimeter with increasing cloud cover, and especially the two extremes 'Sunny weather most of the time' and 'Cloud cover most of the time' differed from the mean weather. Table 4 (outdoor exposure scale) also shows a linear regression model of the exposure scale, which includes the UVR exposure and the outdoor time registered by the dosimeter, the subjective perception of the weather, the protection scale and education level. The model explains more than 42% of the variation. The radiation registered on the dosimeter explains the largest part and the influence from the covariates weather and education is similar to the model in Table 4 (timescale). The influence of protection is unclear;

| Characteristic | Total | Correlation between outdoor time registered on dosimeter and outdoor time reported in questionnaire | Correlation between SED/measurement day and exposure scale from questionnaire | Correlation between outdoor time registered on dosimeter and exposure scale from questionnaire |
|----------------|-------|-------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| Total           | 664   | 0.53 (0.47–0.58)***                                                                  | 0.54 (0.48–0.59)***                                                                  | 0.53 (0.48–0.59)***                                                                  |
| Sex            |       |                                                                                      |                                                                                      |                                                                                                |
| Male           | 251   | 0.60 (0.52–0.67)***                                                                  | 0.56 (0.47–0.64)***                                                                  | 0.57 (0.48–0.65)***                                                                  |
| Female         | 413   | 0.49 (0.41–0.56)***                                                                  | 0.52 (0.45–0.59)***                                                                  | 0.51 (0.43–0.58)***                                                                  |
| Age group (years) |       |                                                                                      |                                                                                      |                                                                                                |
| 15–24          | 100   | 0.49 (0.33–0.63)***                                                                  | 0.53 (0.38–0.66)***                                                                  | 0.50 (0.34–0.64)***                                                                  |
| 25–34          | 104   | 0.40 (0.23–0.55)***                                                                  | 0.48 (0.31–0.61)***                                                                  | 0.50 (0.34–0.63)***                                                                  |
| 35–44          | 118   | 0.52 (0.38–0.64)***                                                                  | 0.50 (0.35–0.63)***                                                                  | 0.49 (0.34–0.62)***                                                                  |
| 45–54          | 132   | 0.61 (0.49–0.71)***                                                                  | 0.64 (0.52–0.73)***                                                                  | 0.67 (0.56–0.75)***                                                                  |
| 55–65          | 210   | 0.48 (0.37–0.60)***                                                                  | 0.50 (0.39–0.60)***                                                                  | 0.48 (0.36–0.57)***                                                                  |
| Skin type      |       |                                                                                      |                                                                                      |                                                                                                |
| I              | 54    | 0.47 (0.23–0.66)***                                                                  | 0.54 (0.32–0.71)***                                                                  | 0.47 (0.23–0.65)***                                                                  |
| II             | 383   | 0.55 (0.47–0.61)***                                                                  | 0.52 (0.44–0.59)***                                                                  | 0.55 (0.47–0.61)***                                                                  |
| III/IV         | 227   | 0.51 (0.41–0.60)***                                                                  | 0.55 (0.46–0.64)***                                                                  | 0.52 (0.41–0.61)***                                                                  |
| Region         |       |                                                                                      |                                                                                      |                                                                                                |
| Capital        | 187   | 0.49 (0.38–0.60)***                                                                  | 0.55 (0.44–0.64)***                                                                  | 0.55 (0.44–0.64)***                                                                  |
| Zealand        | 103   | 0.72 (0.61–0.80)***                                                                  | 0.72 (0.62–0.81)***                                                                  | 0.70 (0.58–0.78)***                                                                  |
| Northern Jutland | 68  | 0.49 (0.28–0.65)***                                                                  | 0.53 (0.33–0.68)***                                                                  | 0.59 (0.41–0.73)***                                                                  |
| Central Jutland | 167  | 0.50 (0.37–0.60)***                                                                  | 0.47 (0.34–0.58)***                                                                  | 0.48 (0.35–0.59)***                                                                  |
| Southern Denmark | 139 | 0.47 (0.33–0.59)***                                                                  | 0.49 (0.35–0.61)***                                                                  | 0.43 (0.29–0.56)***                                                                  |
| Education      |       |                                                                                      |                                                                                      |                                                                                                |
| Primary school | 117   | 0.54 (0.40–0.66)***                                                                  | 0.61 (0.49–0.71)***                                                                  | 0.52 (0.37–0.64)***                                                                  |
| Secondary school | 90  | 0.48 (0.30–0.62)***                                                                  | 0.41 (0.22–0.52)***                                                                  | 0.39 (0.20–0.55)***                                                                  |
| Vocational     | 91    | 0.52 (0.36–0.66)***                                                                  | 0.63 (0.48–0.78)***                                                                  | 0.56 (0.40–0.69)***                                                                  |
| Higher education (< 2 years) | 67  | 0.32 (0.08–0.52)***                                                                  | 0.37 (0.14–0.56)**                                                                  | 0.37 (0.14–0.56)**                                                                  |
| Higher education (2–4½ years) | 213 | 0.52 (0.41–0.61)***                                                                  | 0.51 (0.41–0.61)***                                                                  | 0.54 (0.44–0.63)***                                                                  |
| Higher education (> 4½ years) | 80  | 0.65 (0.51–0.76)***                                                                  | 0.60 (0.43–0.72)***                                                                  | 0.63 (0.48–0.75)***                                                                  |
| Season         |       |                                                                                      |                                                                                      |                                                                                                |
| Pre (weeks 19–24) | 238 | 0.47 (0.36–0.56)***                                                                  | 0.50 (0.39–0.59)***                                                                  | 0.42 (0.30–0.52)**                                                                  |
| Mid (weeks 25–30) | 246 | 0.59 (0.50–0.66)***                                                                  | 0.59 (0.50–0.67)***                                                                  | 0.58 (0.49–0.65)**                                                                  |
| Post (weeks 31–35) | 180 | 0.45 (0.33–0.56)***                                                                  | 0.47 (0.35–0.57)***                                                                  | 0.49 (0.37–0.59)**                                                                  |
| Own or family-related melanoma |       |                                                                                      |                                                                                      |                                                                                                |
| Yes            | 147   | 0.46 (0.32–0.58)***                                                                  | 0.43 (0.29–0.56)***                                                                  | 0.41 (0.27–0.54)**                                                                  |
| No             | 517   | 0.55 (0.49–0.61)***                                                                  | 0.57 (0.50–0.62)***                                                                  | 0.56 (0.50–0.62)**                                                                  |
| Weather        |       |                                                                                      |                                                                                      |                                                                                                |
| 1 (Most of the time sunny) | 191 | 0.55 (0.44–0.64)***                                                                  | 0.53 (0.42–0.63)***                                                                  | 0.51 (0.40–0.61)***                                                                  |
| 2              | 176   | 0.41 (0.28–0.53)***                                                                  | 0.44 (0.31–0.55)***                                                                  | 0.35 (0.22–0.48)**                                                                  |
| 3              | 152   | 0.41 (0.27–0.53)***                                                                  | 0.38 (0.24–0.51)***                                                                  | 0.43 (0.29–0.55)**                                                                  |
| 4              | 83    | 0.46 (0.27–0.62)***                                                                  | 0.42 (0.23–0.59)***                                                                  | 0.37 (0.16–0.54)**                                                                  |
| 5 (Most of the time cloudy) | 61  | 0.22 (–0.04 to 0.44)                                                                  | 0.37 (0.14–0.57)**                                                                  | 0.27 (0.02–0.49)**                                                                  |

Spearman correlation coefficients are reported with 95% confidence intervals. Significance levels: *P < 0.05, **P < 0.01, ***P < 0.001.
We were able to establish the criteria validity of a developed questionnaire for monitoring and evaluating population sun-related behaviour and have shown the importance of a number of issues with regard to evaluation of exposure to UVR in a population-based sample. Firstly, sunburn and environmental factors, e.g. sun hours, correlates strongly and weather determinants need to be included in an evaluation because personal exposure depends strongly on the ambient UVR. Secondly, questions on UVR exposure in a week-based survey design showed strong correlation towards objective measurements of the UVR exposure in general and in all relevant subgroups. Exposure and protection scales provide knowledge tested for construct validity. Predictors of sunburn in our model were sex, age, skin type, number of ambient sun hours, outdoor time and use of sun protection.

The strengths of this study include a sample based on the Danish civil registration system, with relatively high participation and very high response rates and objective personal dosimetry measurements. In addition, we used both objective measurements for outdoor time and for radiation in our setup. Contrary to traditional studies, exposure to UVR based on questionnaires, this study reduced bias from recalling past sun exposure maximally by short measurement periods and short response periods. Limitations of the study are the wrist-worn dosimeters, which were shown to register about 50% of the ambient exposure (as received on top of the head); however, the bias introduced is assumed to be equally distributed and was described elsewhere. Lack of compliance with use of the dosimeters could introduce bias; however, compliance was also described and we did not register any directional bias. Persons wearing a dosimeter may be more aware of their behaviour and this could change their behaviour; however, we tested this in a smaller intervention study and did not find an effect on wearing a dosimeter.

This paper reports on the first project including a complete UVR exposure questionnaire validation. The week-based survey design that we used showed a strong correlation between questionnaire items and objective measurements and presumably a stronger correlation than data collections of longer periods not validated (e.g. summers, years). Correlations in this study are almost as strong as previously seen with the use of diaries; however, questionnaires are much easier to handle in population-based data collections. Our questionnaire gives valid estimates of the outdoor time as well as the amount of UVR exposure of the participants. Outdoor time and UVR registered alone does not take into account the sun protection and sun avoidance used. Sunburn is a proxy estimate of the skin damage and skin cancer risk of the participants, as this is a combined result of exposure and protection behaviour. Our model shows that women are a little less likely to be sunburned, contrary to many previous results. This could indicate that men underestimate or forget sunburn in long-duration data collections. The model also shows that there is a higher risk with younger age, paler skin type, increased duration of exposure and number of ambient sun hours. In the model that used the subjective measure to adjust for the exposure, the most pronounced difference was the
increase in the odds ratios of the 15- to 19-year-olds. The difference could be caused by an overestimation of own exposure or a lower compliance with the use of the dosimeter. In the crude analysis of sunburn, less sun protection equals less sunburn and the same is shown when the exposure (personal and ambient) is accounted for. This result most likely is an indication that people adapt to the behaviour they have planned to engage in and is not to be interpreted as sun protection does not work; however, it is an indication that people are aware that they need protection and that the amount of exposure is the strongest determinant together with skin type. The number of sun hours is a superior risk measure to ambient SED in our analyses (data not shown), most probably due to the sun-seeking behaviour of the Danes, and the large weather variation and long winters in Denmark. Other measures may be more applicable in other climates.\textsuperscript{41} The questionnaire developed and validated can be applied in short- or long-term studies that need to assess the UVR exposure in a study group or population, e.g. studies of skin cancer, sun protection, vitamin D\textsuperscript{25} or even outdoor behaviour. In addition, more precise estimates provided by the validated questionnaire will be of further value in determining the effectiveness and cost–benefit of skin cancer prevention campaigns.\textsuperscript{42}

Criteria-validated questionnaires are per se superior to questionnaires not validated as the validation provides evidence for the objective behaviour. The criteria-validated questionnaire presented is a tool to measure the UVR exposure in a population. The evidence provided showed a statistically significant and strong link between the objectively measured behaviour and the behaviour measured by this survey construct. The evidence provided showed a statistically significant and strong link between the objectively measured behaviour and the behaviour measured by this survey construct.

### Acknowledgments

We are very grateful to Zim Sherman of Scienterra Ltd for the design, manufacture and initial calibration of the dosimeters used in this work. We are also very grateful to Paul Eriksen at

| Characteristic                 | Unadjusted OR (95% CI) | Unadjusted P-value | Objective exposure variables aOR (95% CI) | Objective exposure variables P-value | Subjective (validated) exposure variables aOR (95% CI) | Subjective (validated) exposure variables P-value |
|-------------------------------|------------------------|--------------------|------------------------------------------|-------------------------------------|---------------------------------------------------|-------------------------------------------------|
| Sex                           | 0.7 (0.5–0.9)          | 0.02               | 0.6 (0.4–0.9)                            | 0.008                               | 0.6 (0.4–0.8)                                      | 0.004                                           |
| Age group (years)             | 15–24                  | 2.8 (1.6–4.7)      | 4.1 (2.3–7.4)                            | < 0.001                             | 3.7 (2.1–6.7)                                      | < 0.001                                          |
| Skin type                     | I                      | 4.5 (2.4–8.5)      | 4.0 (2.0–8.1)                            | < 0.001                             | 4.6 (2.2–9.4)                                      | < 0.001                                          |
| Education                     | Primary school         | 0.6 (0.3–1.1)      | 0.6 (0.2–0.8)                            | 0.03                                | 0.6 (0.2–0.7)                                      | 0.03                                             |
| Protection scale quartiles    | Q2                     | 1.0 (0.6–1.5)      | 0.9 (0.5–1.5)                            | 0.8                                 | 0.5 (0.3–1.3)                                      | 0.8                                              |
| Sun hours/week                | 1.03 (1.02–1.04)       | 0.001              | 1.03 (1.01–1.04)                         | < 0.001                             | 1.02 (1.01–1.03)                                   | < 0.001                                          |
| Hours per measurement day     | 1.4 (1.2–1.6)          | 0.001              | 1.4 (1.2–1.7)                            | < 0.001                             | NA                                                | NA                                              |

CI, confidence interval; NA, not applicable.

---

The validated sun exposure questionnaire, B. Køster et al. 2016 The Authors. British Journal of Dermatology published by John Wiley & Sons Ltd on behalf of British Association of Dermatologists.
the Danish Meteorological Institute for providing ambient ultraviolet radiation data for use in the calibration of dosimeters and in the analysis.

References
1 Bray F, Ren JS, Masuyer E, Ferlay J. Global estimates of cancer prevalence for 27 sites in the adult population in 2008. Int J Caner 2013; 132:1133–45.
2 Armstrong BK, Kricker A. How much melanoma is caused by sun exposure? Melanoma Res 1993; 3:395–401.
3 Lucas RM, McMichael AJ, Armstrong BK et al. Estimating the global disease burden due to ultraviolet radiation exposure. Int J Epidemiol 2008; 37:654.
4 Doll R, Peto R. The causes of cancer: quantitative estimates of avoidable risks of cancer in the United States today. J Natl Cancer Inst 1981; 66:1191–308.
5 Thieden E. Sun exposure behaviour among subgroups of the Danish population. Based on personal electronic UVR dosimetry and corresponding exposure diaries. Dan Med Bull 2008; 55:47–68.
6 Krarup AF, Thorgaard C, Behrens CL. Danskernes solvaner på solferier. 2010. 2010; 1–17. Report in Danish; available at: www.skrunedforsolen.dk.
7 Behrens CLD. Danskernes solvaner i den danske sommer, 2013. 2014. Report in Danish; available at: www.skrunedforsolen.dk.
8 Koster B, Thorgaard C, Philip A et al. Prevalence of sunburn and sun-related behaviour in the Danish population: a cross-sectional study. Nord J Public Health 2010; 38:548–52.
9 Koster B, Thorgaard C, Philip A et al. Sunbed use and campaign initiatives in the Danish population, 2007–2009: a cross-sectional study. J Eur Acad Dermatol Venereol 2011; 25:1351–5.
10 Dobinson S, Hill D, White V. Trends in sun protection: use of sunscreen, hats and clothing over the past decade in Melbourne, Australia. In: UV Radiation and its Effects. Workshop: an update 2002. Proceedings of a workshop held 26–28 March 2002, Christchurch, New Zealand. RSNZ miscellaneous series 60. Wellington, NZ: The Royal Society of New Zealand, 2002; 89–91.
11 Diffey BL, Norridge Z. Reported sun exposure, attitudes to sun protection and perceptions of skin cancer risk: a survey of visitors to Cancer Research UK’s SunSmart campaign website. Br J Dermatol 2009; 160:1292–8.
12 Forsea AM, del Marmol V. Impact, challenges and perspectives of Euromelanoma, a pan-European campaign of skin cancer prevention. J Eur Acad Dermatol 2013; 27:1317–9.
13 Saraiya M, Glanz K, Briss PA et al. Interventions to prevent skin cancer by reducing exposure to ultraviolet radiation: a systematic review. Am J Prev Med 2004; 27:422–66.
14 Edwards PJ, Roberts I, Clarke MJ et al. Methods to increase response to postal and electronic questionnaires. Cochrane Database Syst Rev 2009; 3:MR000008.
15 Parr CL, Hjartaker A, Laake P et al. Recall bias in melanoma risk factors and measurement error effects: a nested case–control study within the Norwegian Women and Cancer Study. Am J Epidemiol 2009; 169:257–66.
16 Gefeller O. Invited commentary: recall bias in melanoma – much ado about almost nothing? Am J Epidemiol 2009; 169:627–70.
17 Bland JM, Altman DG. Statistics Notes: validating scales and indexes. BMJ 2002; 324:606–7.
18 Dwyer T, Blizzard L, Gies PH et al. Assessment of habitual sun exposure in adolescents via questionnaire – a comparison with objective measurement using polysulphone badges. Melanoma Res 1996; 6:231–9.
19 Lower T, Girgis A, Sanson-Fisher R. How valid is adolescents’ self-report as a way of assessing sun protection practices? Prev Med 1998; 27:385–90.
20 van der Me I, Blizzard L, Ponsonby AL, Dwyer T. Validity and reliability of adult recall of past sun exposure in a case–control study of multiple sclerosis. Cancer Epidemiol Biomarkers Prev 2006; 15:1538–44.
21 English DR, Armstrong BK, Kricker A. Reproducibility of reported measurements of sun exposure in a case–control study. Cancer Epidemiol Biomarkers Prev 1998; 7:857–63.
22 Glanz K, Gies P, O’Riordan DL et al. Validity of self-reported solar UVR exposure compared with objectively measured UVR exposure. Cancer Epidemiol Biomarkers Prev 2010; 19:3005–12.
23 Cargill J, Lucas RM, Gies P et al. Validation of brief questionnaire measures of sun exposure and skin pigmentations against detailed and objective measures including vitamin D status. Photochem Photobiol 2012; 89:7.
24 Héry C, Tryggvadóttir L, Sigurdsson T et al. A melanoma epidemic in Iceland: possible influence of sunbed use. Am J Epidemiol 2010; 172:762–7.
25 Vogel RI, Ahmed RL, Nelson HH et al. Exposure to indoor tanning without burning and melanoma risk by sunburn history. J Natl Cancer Inst 2014; 106:pii-duj219.
26 Armstrong BK, Kricker A. The epidemiology of UV induced skin cancer. J Photochem Photobiol B 2001; 63:8–18.
27 Koster B, Sondergaard J, Nielsen J et al. Feasibility of smartphone diaries and personal dosimeters to quantitatively study exposure to ultraviolet radiation in a national sample. Photochem Photobiol Photomed 2015; 31:252–60.
28 Koster B, Sondergaard J, Nielsen JB et al. Effects of smartphone diaries and personal dosimeters on behavior in a randomized study of methods to document sunlight exposure. Prev Med Rep 2016; 4:367–72.
29 Allen M, McKenzie R. Enhanced UV exposure on a ski-field compared with exposures at sea level. Photochem Photobiol Sci 2005; 4:329–37.
30 Wright CY, Reeder AI, Bodeker GE et al. Solar UVR exposure, concurrent activities and sun-protective practices among primary schoolchildren. Photochem Photobiol 2007; 83:749–58.
31 Thieden E, Agren MS, Wulf HC. The wrist is a reliable body site for personal dosimetry of ultraviolet radiation. Photochem Photobiol Photomed 2000; 16:57–61.
32 Downs N, Parisi A. Mean exposure fractions of human body solar UV exposure patterns for application in different ambient climates. Photochem Photobiol 2012; 88:223–6.
33 McKinlay AF, Diffey BL. A reference action spectrum for ultraviolet induced erythema in human skin. Curr J 1987; 6:17–22.
34 Christensen KB. Fitting polynomous Rasch models in SAS. J Appl Mes 2006; 7:407–17.
35 Fitzpatrick TB. The validity and practicality of sun-reactive skin types I through VI. Arch Dermatol 1988; 124:869–71.
36 Veierod MB, Adami HO, Lund E et al. Sun and solarium exposure and melanoma risk: effects of age, pigmenatory characteristics, and nevi. Cancer Epidemiol Biomarkers Prev 2010; 19:111–20.
37 Hansen MR, Bentzen J. High-risk sun-tanning behaviour: a quantitative study in Denmark, 2008–2011. Public Health 2014; 128:777–83.
38 Brännström R, Chang YM, Kasparian N et al. Melanoma risk factors, perceived threat and intentional tanning: an international online survey. Eur J Cancer Prev 2010; 19:216–26.
39 Thieden E, Philipsen PA, Sandby-Moller J et al. Sunburn related to UV radiation exposure, age, sex, occupation, and sun bed use based on time-stamped personal dosimetry and sun behavior diaries. Arch Dermatol 2005; 141:482–8.
40 Krarup AF, Behrens CL, Thorgaard C et al. Sun exposure habits of the Danes in the Danish summer 2010. Solundersøgelsen 2010. En kortlægning af danskernes solvaner i den danske sommer. 2011; 1–59. Report in Danish; available at: www.skrunedforsolen.dk.

41 Sun J, Lucas RM, Harrison S et al. The relationship between ambient ultraviolet radiation (UVR) and objectively measured personal UVR exposure dose is modified by season and latitude. Photochem Photobiol Sci 2014; 13:1711–8.

42 Bentzen J, Kjellberg J, Thorgaard C et al. Costs of illness for melanoma and nonmelanoma skin cancer in Denmark. Eur J Cancer Prev 2013; 22:569–76.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher’s website:

Data S1. Questionnaire given in Danish, translated into English. Gross scales and applied values indicated. Only successfully validated scales were applied in the final analysis.