Children's sunburn exposed: Identification of sun exposure and parental sun protection patterns

K. Thoonen^a, V. Lima Passos^b, F. Schneider^a, H. de Vries^a, L. van Osch^a

^a Department of Health Promotion, School CAPHRI, Maastricht University, Maastricht, the Netherlands

^b Department of Methodology and Statistics, School CAPHRI, Maastricht University, Maastricht, the Netherlands

Additional information

Corresponding author

Karlijn Alexandria Henrieke Josephine Thoonen

P. Debyeplein 1, 6229 HA Maastricht, the Netherlands

karlijn.thoonen@maastrichtuniversity.nl

Abstract

Background: Preventing sunburn in childhood is imperative in the light of skin cancer prevention. To provide directions for targeted interventions, a better understanding of children's sunburn and associated parental behaviours is necessary.

Objective: To explore sun exposure and parent-for-child sun protection patterns and their relation with experienced sunburn in children.

Materials & Methods: An online survey study was conducted among parents (n=1299) of children (4 to 12 years). Latent Class Analysis (LCA) was performed to identify parental subgroups in children's sunburn, sun exposure and several sun protection behaviours (i.e. applying sunscreen, clothing, seeking shade) in two sun exposure settings (i.e. planned versus incidental). LCA results were validated by assessing predictions of class membership through several socio-demographic characteristics.

Results: Reported sunburn in the previous year was frequent (>40%). Four latent classes of sunburn-exposure-protection were identified. Overall, the majority of parents reported fair sun protection behaviours. While lower protection behaviours were not strongly reflected in lower sunburn rates among the classes, high amounts of planned exposure (e.g. going to the beach) seemed to correspond with higher sunburn risk. Parents of younger children and those with more sensitive skin, reported sun protection measures more frequently. Older children and those with more sensitive skin experienced more sunburn.

Conclusion: This study contributes to current insight in children's sunburn, based on parent-proxy reports. Although a clear differentiation in sunburn risk was not found, several groups relevant for future interventions were indicated. By revealing the complexity of children's sunburn, suggestions for further research are provided.

Key words: children's sun safety, parental behaviour, sun exposure, sun protection behaviours sunburn

Introduction

Melanoma and non-melanoma skin cancers (NMSC) are some of the most rapidly increasing malignancies worldwide, affecting especially fair-skinned populations (1). Since the late 1980s, skin cancer incidence has tripled in the United States (2, 3) and nearly quadrupled in the Netherlands (4, 5). Age-standardized incidence rates were estimated at 12.7 for the United States, compared to 25.7 for the Netherlands, 27.6 for Denmark, and 33.6 for Australia per 100,000 cases respectively in 2018 (6). Globally, melanoma represents the most fatal form of skin cancer and its incidence has risen more rapidly than any other malignancy in the last 50 years (3, 7).

Overexposure to Ultraviolet radiation (UVR) and sunburn are major risk factors for developing melanoma, particularly when acquired during childhood (8, 9). A meta-analysis revealed that having experienced sunburn at least once during childhood almost doubles the risk of developing melanoma (10). Additionally, although UVR-exposure throughout life increases melanoma risk, children's skin is more susceptible to damage, and the harmful effects can latently persist until adulthood (11-13). Children's skin has lower levels of protective melanin, resulting in a deeper penetration of UVR and greater damage to the skin (13). Limiting the amount of UVR and reducing sunburn incidence during childhood is therefore especially important. However, sunburn prevalence among children is still high, with reported percentages of children having experienced sunburn at least once during the previous year ranging between 29% to over 60% in the Netherlands, United States, Denmark and Switzerland (14-18). Factors associated with increased sunburn risk among children, such as older age, sun-sensitive skin (14, 19), and past sunburn of parents or children (18-20) were previously reported.

Preventing sunburn among children is of utmost importance. To protect the skin and prevent sunburn in children, several precautions can be taken, such as seeking shade, wearing UV- protective clothing and applying sunscreen (21). Performing these behaviours simultaneously is recommended, and should start in early life (22, 23). Sunscreen undoubtedly remains the measure applied most frequently (24-28) and is often used as sole prevention method among parents (29, 30). Seeking shade and wearing protective clothing are also considered highly important in order to enhance sun safety (12, 29, 31, 32), but sunscreen is still advised to be applied as an adjunct to other forms of sun protection (21, 34).

Parents and caregivers are crucial in establishing children's sun safety and subsequent prevention of sunburn experiences. They are primarily responsible for the application of sun protection measures for their children (28) and are most important in teaching children to perform their own sun protection behaviours (20). The large amount of influence of parents as

active agents and role models is well reflected in strong correlations between parents' own sun protection behaviour and their children's sun safety (18, 35, 36). Parents are therefore recommended to strictly adhere to sun protection guidelines and to teach their children adequate sun protection behaviours (37, 38), rendering them an essential target group for communications and interventions aimed at preventing children's sunburn.

Despite various studies reporting on parent-for-child sun protection behaviours, the association between the amount of children's UVR-exposure and performance of parent-for-child sun protection behaviours is underexplored. Equally unknown is how this exposure-protection connection affects children's sunburn experiences. Previous studies have focused on very young children (36, 39, 40), on nevus development rather than sunburn experiences (41, 42), or did not report sun exposure patterns (31, 43). The link between sun exposure, sun protection behaviours and sunburn is regarded as complex and needs further clarification. Hence, in order to gain insight in children's sunburn, identification of risk-patterns of UVR-exposure and parent-for-child sun protection behaviours in various situations is necessary.

The extent to which sun protection behaviours are necessary depends on the activities in which sun exposure is acquired. For example, when not actively focused on spending time outdoors, preparation efforts to protect ones' skin may be lower than when people intentionally expose themselves to the sun (44, 45). Consequently, the risk of sunburn increases in these unintentional sun exposure situations (e.g. playing outdoors) due to limited shade availability, prolonged duration of the exposure, or reliance on sunscreen use only, as shown by a recent study among adolescents and adults in New Zealand (46), and in Denmark (47). Two German studies among parents of very young children (3 to 6 years) revealed different parent-for-child sun protection behaviours: shade-seeking behaviour and wearing hats and sunglasses were applied more often in a beach setting than during everyday outdoor activities (48, 49). Moreover, parental sun protection behaviours among older children vary across sun exposure situations (25, 50, 51), and their relationship with sunburn is largely undocumented. There is evidence that the more intense and intermittently received UVR, e.g. during recreational activities, the greater the melanoma risk (8, 52). Therefore, shedding light on the association of different types of sun exposure, sun protection strategies and their relation to children's sunburn is expected to generate a better understanding of sunburn risk in different exposure settings. This knowledge would facilitate the development and implementation of targeted policy and interventions to counteract the increasing melanoma incidence rates.

This study aimed to explore the heterogeneity of inter-relations between: (1) children's sun exposure; (2) parental sun protection behaviours; and (3) children's sunburn frequency. To

achieve this goal, we applied latent class analysis (LCA), a model-based clustering technique (53), to empirically derive typologies capturing distinct patterns of inter-connections across the three domains. Further, links between the identified classes and parental and children's socio-demographic characteristics were investigated to explore possible subgroups that deserve specific attention in future interventions.

Materials and methods

Procedure and participants

This study was part of a longitudinal survey study whose data from the baseline measurement (June 2016 (T0)) was analysed. The study was exempt from medical ethical evaluation since participants were not exposed to medical procedures (54). The collected data was not traceable to specific participants in the dataset (55).

Eligible participants, caring for at least one child of primary school age (4 to 12 years), were retrieved from an existing research panel and received one invitational and one reminder email. A sample of 2449 parents, representative of the Dutch general population according to education level and income, were approached by research organisation TNS-KANTAR. Informed consent was acquired online (56). In total, 1299 Dutch parents filled in the online questionnaire. Parents obtained gift vouchers after completing the survey.

Measurement

The online questionnaire assessed, amongst others, 1) demographic characteristics; 2) children's sunburn experiences; 3) the amount of children's sun exposure; and 4) parental sun protection behaviours (i.e. sunscreen use, clothing, and seeking shade) in both planned and incidental sun exposure situations. Planned situations concerned sun exposure that is generally anticipated by the parent and/or the child (e.g. going to the beach or swimming pool), whereas incidental situations consisted of less intentional sun exposure situations (e.g. when walking, cycling or playing outdoors). Children's sunburn, sun exposure and sun protection behaviours during the previous summer season were assessed for the youngest child in the parents' household. The full questionnaire can be retrieved from Open Science Framework (OSF): <https://osf.io/zncwq/>. This study is reported in accordance with STROBE guidelines for observational research (57).

1) Socio-demographic characteristics

Parental and children's age, sex, skin type and parental educational level and province of residence were assessed. Parental age was categorized in three groups (18-34 years, 35-44 years, and ≥ 45 years), as was children's age (4 to 6 years, 7 to 9 years, and ≥ 10 years), the latter in agreement with the Dutch primary school system. Age categories were referred to as young, middle-aged and older. Parental and children's skin type was categorized in: I) burns very quickly, tans never or rarely; II) burns quickly, tans slowly; III) burns rarely, tans easily; and IV) burns almost never, tans very easily. Educational level was classified in lower (1), intermediate (2) and higher (3) education, cf. guidelines of Statistics Netherlands (58). The twelve Dutch provinces of residence were subdivided into North (1), East (2), West (3) and South (4), cf. classification of Dutch Ministry of the Interior and Kingdom Relations (59).

2) Children's sunburn

The frequency of children's sunburn was assessed using one item, in which parents were asked how often their child had experienced sunburn in the past 12 months. A 5-point Likert scale was used (never (1), 1-2 times (2), 3-4 times (3), 4-5 times (4) and > 5 times (5)).

3) Children's sun exposure

The amount of received sun exposure was assessed by asking parents the frequency with which their child was outside on sunny days during the previous 12 months, using a 5-point Likert scale (never (1), rarely (2), sometimes (3), often (4), as often as possible (5)). The questions regarding sun exposure were asked using two items; one regarding planned situations and one for incidental situations. Planned sun exposure involved intentional sun-seeking behaviour (e.g. going to the beach or swimming pool) and incidental sun exposure consisted of all other situations in which children were sun-exposed (e.g. playing outdoors, cycling). Parents received an explanatory text regarding how to distinguish between these sun exposure situations.

4) Parental sun protection behaviours

Three parent-for-child sun protection behaviours were assessed: 1) sunscreen use; 2) clothing; and 3) seeking shade. The execution of these behaviours was asked about regarding the two (planned and incidental) sun exposure situations, resulting in six items. A 5-point Likert scale was again used to assess the frequency of sun protection behaviours (never (1), rarely (2), sometimes (3), often (4) and always (5)). Sufficient sunscreen application encompassed using an SPF ≥ 30 , applying sunscreen 30 minutes prior to sun exposure, and reapplying sunscreen

every two hours. For clothing, wearing a shoulder-covering T-shirt, wearing a hat and wearing sunglasses was regarded as sufficient. Lastly, seeking shade between UV-peak hours, 12 and 3 PM, was considered adequate. Explanatory text regarding the sufficient performance of sun protection behaviours was provided in the questionnaire (<https://osf.io/zncwq/>).

Variables operationalisation

Data preparation for statistical analyses took place by recoding the categorical variables. An inspection of the answers' frequency distribution showed very low count in some response categories. For this reason, all categorical variables were collapsed to avoid sparsity problems. Children's sunburn frequency was recoded as never (1), 1-2 times (2), >3 times (3), while children's sun exposure in both planned and incidental situations was recoded as never (1), rarely and sometimes (2), often and as often as possible (3), and parental execution of sun protection behaviours in both sun exposure situations as never (1), rarely and sometimes (2), often and always (3). Based on this recoding, three answer categories were obtained across all items. First, the least protective answer category included the responses of >3 sunburn experiences, highest reported levels of sun exposure and lowest reported levels of sun protection behaviours. Second, the intermediate answer category contained responses of 1-2 sunburn experiences, being rarely and sometimes sun-exposed, and having rarely and sometimes performed sun protection behaviours. Lastly, the most optimal answer category consisted of the responses of having never experienced sunburn, lowest reported level of sun exposure and highest levels of reported sun protection behaviours.

Statistical methods

Descriptive statistics (means, standard deviations and percentages) were computed to examine the distribution of participants' characteristics, children's sunburn frequency, children's sun exposure and the frequency of parental sun protection behaviours. McNemar-Bowker and Chi-square tests were conducted to explore differences in sample protection behaviours in planned vs. incidental sun exposure situations and for sunburn frequency, respectively. Significance level was set at 5%. IBM SPSS Statistics for Windows, version 25.0, was used (60).

Analysis plan

1) Latent Class Analysis – model fitting

Latent Class Analysis (LCA), a model-based clustering technique, was conducted to explore the heterogeneity of children's sunburn and behavioural patterns (both children's sun exposure

and parental sun protection behaviours) (53, 61). The non-directly observable data-driven classes were revealed by grouping participants with similar responses to items related to sunburn, sun exposure, and sun protection behaviours, but different from other groups. Class-enumeration, i.e. determining the number of latent classes, was guided by the model fit Akaike Information Criterion (AIC) and adjusted Bayesian Information Criterion (BIC) (62), while visually assessing whether extracted classes were qualitatively distinct from each other. After settling for the final number of classes, post-hoc posterior probabilities of class membership is computed for each subject (53), who is then assigned to the class with the highest posterior probability. The index of entropy, though not used to guide class-enumeration, was also reported to indicate the quality of classification uncertainty (entropy values above 0.80 are considered of very good classification performance). LCA was executed using SAS software version 9.4 (63).

2) Classes' profiling

Chi-square tests were performed to explore unadjusted differences among extracted classes in socio-demographic characteristics (parental age, sex, skin type, province of residence and educational level, and children's age, sex and skin type). A multinomial linear regression model was fitted to establish which of these characteristics remained independently linked to class membership after mutual adjustment. Estimated odds ratio (OR) and 95% Confidence Intervals (CIs) are displayed in forest plots. To avoid multicollinearity in the multinomial logistic regression, age and skin type of the child rather than of the parents were included in the model.

Results

Socio-demographic characteristics

Of the included parents, 773 (59.5%) were mothers and the questionnaire was answered for 656 (50.5%) boys. Parents' age was normally distributed (range: 18 to 69 years) and most often between 40 and 44 years old (32.6%). Children's age was not evenly distributed, resulting in children most often being between 4 and 6 years old (n=595; 45.8%). Most children had skin type III (burns rarely) (49.7%), followed by skin type II (burns quickly) (35.9%). Most parents received higher education (n=625; 48.3%).

Table 1. Parent-for-child sun protection behaviours (N=1299)					
Comparisons between planned and incidental exposure				McNemar-Bowker test	p-value
<u>Sunscreen</u>		<u>Planned</u>	<u>Incidental</u>	$\chi^2 (3) = 330.91$	<.001
	<i>Never</i>	6 (.5)	16 (1.2)		
	<i>Rarely/Sometimes</i>	98 (7.5)	431 (33.2)		
	<i>Often/Always</i>	1195 (92.0)	852 (56.6)		
<u>Clothing</u>		<u>Planned</u>	<u>Incidental</u>	$\chi^2 (3) = 28.01$	<.001
	<i>Never</i>	23 (1.8)	24 (1.8)		
	<i>Rarely/Sometimes</i>	643 (49.5)	551 (42.4)		
	<i>Often/Always</i>	633 (48.7)	724 (55.7)		
<u>Seeking shade</u>		<u>Planned</u>	<u>Incidental</u>	$\chi^2 (3) = 18.32$	<.001
	<i>Never</i>	53 (4.1)	59 (4.5)		
	<i>Rarely/Sometimes</i>	731 (56.3)	782 (60.2)		
	<i>Often/Always</i>	515 (39.6)	458 (35.3)		
Parent-for-child sun protection behaviours stratified by child's age and skin type (Chi-square)					
		<u>Child's age</u>	<i>p-value</i>	<u>Child's skin type</u>	<i>p-value</i>
<u>Sunscreen</u>	<i>Planned</i>	$\chi^2 (4) = 6.57$	.16	$\chi^2 (6) = 16.55$	.01
	<i>Incidental</i>	$\chi^2 (4) = 15.32$	.004	$\chi^2 (6) = 28.56$	<.001
<u>Clothing</u>	<i>Planned</i>	$\chi^2 (4) = 13.21$	.01	$\chi^2 (6) = 36.35$	<.001
	<i>Incidental</i>	$\chi^2 (4) = 26.66$	<.001	$\chi^2 (6) = 24.20$	<.001
<u>Seeking shade</u>	<i>Planned</i>	$\chi^2 (4) = 17.72$	.001	$\chi^2 (6) = 11.18$	.08
	<i>Incidental</i>	$\chi^2 (4) = 23.63$	<.001	$\chi^2 (6) = 16.12$	.013

Sunburn, sun exposure and sun protection behaviours

Overall, during the previous year, 550 children (42.4%) had experienced at least one case of sunburn. Older children ($\chi^2 (4) = 12.80$, $p = .012$) and children with more sensitive skin ($\chi^2 (6) = 111.52$, $p < .001$) experienced more sunburn. Parents of younger children and children with more sensitive skin reported more frequent execution of almost all sun protection behaviours than parents of younger children and with less sensitive skin types. Sunscreen use and seeking shade were more often performed in planned situations, and clothing in incidental situations. Table 1 provides an overall summary of the whole sample, and as such, only a general overview of the marginal distributions. A more refined glimpse into the data is provided by the LCA findings.

Identifying subgroups (Latent Class Analyses)

Models with three to six latent classes were fitted. Table 2 shows model fit assessment criteria that were used to guide class-enumeration. They were not in full agreement, but visual inspection of the distinctiveness of the classes together with the BIC indicated that a solution with four classes was a good fit to the data (62).

Table 2. Model fit evaluation of Latent Classes			
Number of Latent Class	AIC	Adjusted BIC	Entropy
3	931.18	1042.78	.88
4	891.21	1040.67	.82
5	862.12	1049.45	.84
6	845.25	1070.44	.85

Figure 1 illustrates the distinct response patterns to the sunburn, exposure and protective behaviours questions of the four extracted classes. The plot shows the probability of class members of reporting high-risk, intermediate-risk and low-risk answers to sunburn, sun exposure and sun protection items. For instance, the y-axis of subplot 1A shows the probability for selecting the high-risk answer category, i.e. highest frequency of sunburn (≤ 3 sunburn), highest reported sun exposure (often and as often as possible) and lowest reported levels of sun protection behaviours (never performed), while the x-axis indicates whether the situation was planned or incidental. Similarly, figures 1B and 1C show the probabilities of intermediate- and low-risk answer patterns.

Figure 1. Profile plot with 4 latent classes depicting the probability (per class) of selecting the high, moderate and low risk answer category to the sunburn, sun exposure and sun protection questions. Classes' prevalence are presented as %.

Sunburn probability was relatively high (between ~40 and 45% for 1 or 2 cases of sunburn; ~50% of no sunburn) for three out of the four classes (1B), showing a low discriminatory power between these classes for this item. Class 1 demonstrated a lower sunburn risk (~30% of cases of 1 or 2 sunburn; ~70% of no sunburn). The probability of having children with ≤ 3 reported sunburns was very low among all classes (1A).

Sun exposure patterns showed a larger discriminatory power between classes. Class 1 and 2, which made up the majority of parents (>70%) reported highest levels of exposure in incidental situations and the remaining classes (3 and 4) reported lower incidental exposure than planned exposure (1A). Of note, class 1 shows almost complete withholding of planned sun exposure.

Sun protection patterns are again distinct between the classes. Class 1 and 2 reported relatively high levels of sun protection behaviours in both situations, whereas the remaining two classes (3 and 4) showed more variability, with protective behaviours being more frequent in planned rather than incidental situations. The latter classes had a clear preference for sunscreen use, followed by clothing and seeking shade, respectively. Of note, these classes differed in degree of sun protection behaviours, with class 3 showing the least sun protection behaviours (Figure 1C).

The four classes were named primarily reflecting parental sun protection behaviours:

1. *Class 1 with adequate sun protection behaviour* (n=288; 30.6% ≥ 1 sunburn) is considered the *best* performing class as reflected in: a) lowest sunburn probability; b) consistent reporting of high levels of sun protection behaviour; and c) no exposure in planned situations and high exposure in incidental situations.
2. *Class 2 with adequate sun protection behaviour* (n=726; 46.3% ≥ 1 sunburn), is defined as the *second-best* performing class as reflected in: a) moderate sunburn probability; b) consistent reporting of high levels of sun protection behaviour; and c) high levels of sun exposure in planned and incidental situations, indicating unfavourable exposure patterns.
3. *Class 3 with inadequate sun protection behaviour* (n=53; 51% ≥ 1 sunburn), is considered the *poorest* performing class as reflected in: a) moderate sunburn probability; b) low levels of sun protection behaviours in particular in incidental situations; and c) lower levels of sun exposure in planned and especially incidental situations, indicating a more favourable exposure pattern.

4. *Class 4 with inadequate sun protection behaviour* (n=232; 42.7% ≥ 1 sunburn) is defined as the *intermediate* performing class as reflected in: a) moderate sunburn probability; b) lower levels of sun protection behaviours; and c) lower levels of sun exposure in planned and especially incidental situations.

Socio-demographic class-profiling

Next, we compared whether parents' and children's characteristics differed across the four classes. In general, the majority of parents were middle-aged, had quickly burning (II) or rarely burning (III) skin complexions, were highly educated and lived in the Western part of the Netherlands. The majority of children also had skin type II or III. Differences in both parental and children's age and skin type (Table 3) distributions were observed across classes, with the best and second-best class including younger children with more sensitive skin types.

These differences were further confirmed after mutual adjustment (Figure 2). Results revealed that parents assigned to the best two classes had the youngest children with most sensitive skin complexions, while the best group (Class 1) included the youngest children. The two remaining classes included parents of older children, with less sensitive skin types. The total model was adjusted for parental age, sex, skin type, province of residence, educational level and children's age, sex and skin type. All model parameter estimates can be retrieved from Appendix I.

Figure 2. Forest plots with odds ratios (ORs) and associated CI's (95%) of statistically significant results of the multinominal (multivariable) logistic regression, demonstrating socio-demographic characteristics linked to class membership – OR are provided with respect to the best class (1). Reference group for skin type is 'Skin never burns (IV)'; Reference group for children's age is 'oldest child'.

Discussion

This study exposed differences in parental sun protection, children's sun exposure patterns and children's sunburn. Overall, sunburn frequency was high (>40%) among all children, and parents reported fair sun protection behaviours. Latent Class analysis revealed four sun (burn-exposure-protection) typologies, which, while differing in frequency and type of sun-protective strategies, could not be firmly distinguished in terms of sunburn frequency for three out of the four classes. Parents engaged in more protective measures during planned rather than incidental sun exposure. Avoiding sun exposure in these planned situations (e.g. going to the beach or swimming pool) seemed to be associated with a lower sunburn risk. These findings seem to confirm the complexity of the relationship between children's sunburn, sun exposure and parental sun protection behaviours: although the majority of parents were reporting relatively high levels of sun protection measures (Class 1 and 2), this resulted in a lower sunburn probability among only a small group of children (Class 1). This latter group included parents of young children and children with more sensitive skin types, who were inclined to limit sun exposure for their children in planned situations.

Substantial numbers of children in all four classes experienced at least one case of sunburn in the previous year, which is comparable to findings in other countries (14-16, 18). Parents in the best class with lowest yet notable sunburn prevalence (>30%) were engaging in all sun protection behaviours while limiting their children's sun exposure in planned situations. They seemed to have been highly aware of the importance of sun protection behaviours and sun avoidance, but their children's sun exposure in incidental situations was still high. This may indicate, in line with previous research, that parents underestimate the risk of UVR-exposure during everyday activities (49, 64, 65), or that they are not well prepared for sun protection in these settings (50). Parental awareness about sun exposure risk in multiple settings is therefore highly important to minimize sunburn risk, even among parents reporting high levels of sun protection behaviours.

High levels of sun protection behaviours were observed, with the majority of parents frequently reporting shade-seeking and clothing behaviours, in line with sun safety recommendations. This finding contrasts with earlier studies using comparable measures (16, 24, 25, 27, 28, 66). The observed discrepancy between high reported sun protection behaviours and substantial sunburn risk is noteworthy. This may indicate that, while parents may believe they are adhering to sun safety recommendations, the actual execution is suboptimal. Several studies reported on the incompleteness of sun protection measures for children. For example,

sunscreen efficacy depends mainly on correct application patterns (67). However, sufficient sunscreen application seems particularly difficult for parents (50), as indicated by their failure to apply sunscreen 30 minutes before going outdoors (66), by skipping sensitive body parts (29), applying insufficient amounts of sunscreen (68) or not reapplying every two hours (14). Parents' erroneous perception that they have sufficiently protected their child with sunscreen may lead them to prolong their time spent in the sun, resulting in sunburn (14, 69). Further, studies reported that children are less likely to be protected by sunglasses and a hat than with a T-shirt (70-72), while concurrent use is recommended (21, 73). Hence, it is possible that the parents in the current study overestimated their adherence to specific sun protection recommendations, despite the information provided regarding sufficient sun protection in the questionnaire.

Although research on sun exposure patterns in children is scarce, recent studies from Germany reveal that the amount of time that very young children (aged 3 to 6) spend outside during peak UV hours in various settings was high (48), and that older children receive high doses of UVR in playgrounds (74). Our findings also suggest high levels of exposure, in particular among young children, in both sun exposure situations. The parents of young children reported adequate sun protection behaviours when their children were highly exposed in planned situations, but this was not echoed in low sunburn risk. A lower sunburn risk was however found among young children whose parents limited their sun exposure in planned situations. These findings emphasize the difficulty of optimal sun protection in planned sun exposure situations and may lead to the question of whether sunburn prevention is entirely possible or realistic in such situations. Protecting children sufficiently on the beach or by the swimming pool is particularly challenging, since availability of shaded areas is often lacking, sunscreen has to be reapplied more frequent clothing is perceived as burdening (50, 75).

Parents assigned to the best-performing class had the youngest children with more sensitive skin complexions. The higher protection for younger children is in agreement with previous research (19, 25, 48). Since sun protection attitudes and behaviours decrease during adolescence and sunburn prevalence increases, establishing sun safety for older children is considered highly important (16, 28, 43, 76). Increased parental vigilance and sun protection behaviours among children with lighter skin types has also been described in earlier work (31, 40, 49, 50). Similarly, parents with darker skin complexions may assume that their skin phenotype protects them from UVR (39), resulting in them providing less sufficient sun protection for their children (66). The association of children's sun-sensitivity with better sun protection and thus lower sunburn rates might seem obvious, but is often not apparent (14, 16,

77). In the present study, a comparable relation between more sensitive skin types and high parental sun protection behaviours was found. Despite this, these children still seemed at high-risk for sunburn. The association between children's skin sensitivity, sun protection behaviours and their sunburn risk however deserves closer examination in order to compose future sun safety interventions.

Strengths and limitations

This study has several strengths that are worth mentioning. Firstly, the assessment of comprehensive sun protection behaviours in distinctive sun-exposing situations provides a novel and insightful approach compared to existing parental sun protection research. Secondly, by using a large sample size and including more than five indicators, the validity of the latent class fitting was optimized (78).

The task of exploring associations between sunburn, sun exposure and sun protection behaviours is not straightforward and is charged with some methodological challenges. Firstly, although sunburn rates in our study sample were comparable or even higher than reported sunburn in the literature, performance of parental sun protection behaviours was high. A social desirability bias could have been at play, urging parents to report more frequent protection behaviours (79). Further, since all questions were asked regarding the previous year, recall bias may have limited the accuracy of the self-reported behaviours (80). Despite our efforts to reduce these biases by stressing confidentiality and non-disclosure of the study purpose, these biases should be considered when interpreting the present findings. Secondly, sun exposure was broadly defined in this study, and details such as weather conditions, exact time of day and duration of activities were not taken into account. Self-reported sun protection has been shown to be a valid measure when contextual factors as time and activities are specifically assessed (81), or when the retrospective timeframe is as short as possible (82). Future assessment of sun exposure should ideally include tailored questions regarding specified sun-exposing situations. Lastly, the findings in this study may not readily be generalised to Dutch parents since the majority of parents received a high level of education and most children were aged between 4 and 6 years.

Implications

The majority of parents seemed to perform recommended sun protection strategies frequently, but a variability in sun protection behaviours and sun exposure patterns were also observed. Further, specific individual characteristics such as skin type and children's age explained such

variability in part. Despite the emergence of a positive picture of sun protection behaviours, a high sunburn risk was still prevalent among the majority of children. These exploratory findings hint at directions for further research in order to investigate children's sunburn in more detail.

First, all indicators were assessed subjectively. For future efforts, we recommend the application of more objective measurements of sunburn and received UVR-exposure as well as performance of sun protection behaviours. For example, some parents have difficulty recognising sunburn as such, e.g. being unaware that reddening of the skin already signifies sunburn, leading to an underestimation of sunburn prevalence (50, 83). Objectively assessing sunburn and its severity would be worthwhile to improve risk-profiling (e.g. through biometric measures of melanin and erythema on the skin (84)), since sunburn and particularly severe and painful sunburn are highly correlated with melanoma development in later life (85). Further, although validation studies show fair to strong correlations between self-reported and observed exposure (82, 86, 87), collecting objective data about children's UVR-exposure has been strongly advocated (88). Environmental effects such as shade coverage, altitude or humidity cannot be measured in self-reported questionnaires (89). Because detailed information on actual received UVR-dosage is lacking among children, the formulation of specific policy and guidelines, weighted for specific environmental characteristics (e.g. latitude, cloudiness, seasonality), cannot be formulated. As stated, parents may feel obliged to report desirable sun protection behaviours, or may overestimate their behaviours, which can both affect the validity of the findings. Investigating the execution of specific sun protection measures (e.g. using $\geq$ SPF 30, reapplication patterns (67) and wearing sunglasses as well as a hat) could provide further insight in the execution of parental sun protection behaviours.

Second, since the findings imply that particularly planned exposure (e.g. beach or swimming pool) may increase the risk of sunburn, implementing health-promoting environmental cues in these settings are advisable (75, 90). For instance, by providing shade, promotion of UV-protective clothing and freely available sunscreen, both parents and children can be encouraged to perform sun protection behaviours more effectively.

Third, similar to earlier studies (19, 25, 28, 35), the present study revealed that older children seem to receive less protective behaviours from their parents, and experience more sunburn than younger children. Future interventions should target older children, especially before entering the adolescent phase (26, 77).

Conclusions

This study emphasizes the complexity of the association between children's sunburn, their sun exposure and parental sun protection behaviours while indicating directions for further investigation. The findings indicate that despite fair to good reported sun protection behaviours, sunburn occurrence was still high among children. Furthermore, highest sun protection was reported for younger children with lighter skin types, which was reflected in lower sunburn risk among a small group of children. We were unable to fully unravel the underlying mechanisms of the associations between sun exposure, sun protection behaviours and sunburn. Therefore, recommendations for increasing sun safety in children are provided with a cautionary note. Further research is required to clarify these complex relations in order to improve or develop tailored interventions.

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Supplementary Tables

Table 3. Socio-demographic characteristics and class-profiling					
	Best class (n=288; 18.5%)	Second best class (n=726; 57.5%)	Poorest class (n=53; 4.6%)	Intermediate class (n=232; 19.4%)	
	n(%)	n(%)	n(%)	n(%)	p-value (Chi-Square)
<i>Parents' characteristics</i>					
Age					.003
- Young	53 (18.4)	102 (14.0)	6 (11.3)	21 (9.1)	
- Middle-aged	182 (63.2)	449 (61.8)	27 (50.9)	143 (61.6)	
- Older	53 (18.4)	175 (24.1)	20 (37.7)	68 (29.3)	
Sex					.220
- Male	110 (38.2)	286 (39.4)	26 (49.1)	104 (44.8)	
- Female	178 (61.8)	440 (60.6)	27 (50.9)	128 (55.2)	
Skin type					<.001
- I: burns very quickly	31 (10.8)	77 (10.6)	2 (3.8)	9 (3.9)	
- II: burns quickly	124 (43.1)	284 (39.1)	12 (22.6)	96 (41.4)	
- III: burns rarely	114 (39.6)	322 (44.4)	30 (56.6)	101 (43.5)	
- IV: burns almost never	19 (6.6)	43 (5.9)	9 (17.0)	26 (11.2)	
Education					.118
- Lower	36 (12.5)	102 (14.0)	11 (20.8)	43 (18.5)	
- Intermediate	111 (38.5)	278 (38.5)	20 (37.7)	69 (29.7)	
- Higher	141 (49.0)	343 (47.2)	21 (39.6)	120 (51.7)	
Province					.135
- North	19 (6.6)	68 (9.4)	2 (3.8)	19 (8.2)	

- East	74 (25.7)	162 (22.3)	8 (15.1)	61 (26.3)	
- South	132 (45.8)	308 (42.4)	33 (62.3)	100 (43.1)	
- West	63 (21.9)	187 (25.8)	10 (18.9)	52 (22.4)	
<i>Children's characteristics</i>					
Age					<.001
- Young	172 (59.7)	326 (44.9)	15 (28.3)	82 (35.3)	
- Middle-aged	71 (24.7)	221 (30.4)	22 (41.5)	71 (30.6)	
- Older	45 (15.6)	179 (24.7)	16 (30.2)	79 (34.1)	
Sex					.945
- Boy	145 (50.3)	366 (50.4)	25 (47.2)	120 (51.7)	
- Girl	143 (49.7)	360 (49.6)	28 (52.8)	112 (48.3)	
Skin type					.001
- I: burns very quickly	24 (8.3)	51 (7.0)	1 (1.9)	5 (2.2)	
- II: burns quickly	112 (38.9)	264 (36.4)	14 (26.4)	76 (32.8)	
- III: burns rarely	131 (45.5)	363 (50.0)	29 (54.7)	123 (53.0)	
- IV: burns almost never	21 (7.3)	48 (6.6)	9 (17.0)	28 (12.1)	

Table 4. All model parameter estimates of Multinomial Linear Regressions

	Effect	Estimate	SE	Exp(B)	Wald	p value
Class 2	Intercept	-1.02	.46		5.00	.025
	Province (North)	-.40	.39	.67	1.08	.30
	Province (East)	-.11	.26	.89	.18	.67
	Province (West)	-.05	.24	.95	.04	.84
	Education (Low)	-.18	.27	.84	.44	.51

	Education (Intermediate)	.41	.21	1.51	4.02	.052
	Parental age (Young)	.42	.36	1.52	1.39	.24
	Parental age (Middle-aged)	.05	.24	1.05	0.46	.83
	Parental sex (Male)	-.28	.19	.76	2.13	.14
	Parental skin type (I)	1.05	.55	2.87	3.71	.054
	Parental skin type (II)	.26	.40	1.30	.43	.51
	Parental skin type (III)	.24	.39	1.27	.37	.54
	Child's age (Young)	1.18	.26	3.24	20.47	.00
	Child's age (Middle-aged)	.44	.26	1.55	2.76	.10
	Child's sex (Boy)	-.11	.18	.90	.35	.55
	Children's skin type (I)	1.35	.63	3.86	4.67	.03
	Children's skin type (II)	.46	.39	1.58	1.41	.24
	Children's skin type (III)	.19	.37	1.21	.26	.61
Class 3	Intercept	.27	.37		.57	.45
	Province (North)	-.14	.31	.87	.19	.66
	Province (East)	-.42	.22	.66	3.46	.06

	Province (West)	-.24	.20	.79	1.47	.23
	Education (Low)	-.11	.22	.89	.26	.61
	Education (Intermediate)	.38	.18	1.46	4.62	.32
	Parental age (Young)	.28	.31	1.32	.78	.38
	Parental age (Middle-aged)	-.00	.19	1.00	.00	.99
	Parental sex (Male)	-.24	.16	.79	2.26	.13
	Parental skin type (I)	1.17	.47	3.23	6.18	.01
	Parental skin type (II)	.28	.32	1.32	.74	.39
	Parental skin type (III)	.44	.31	1.55	1.96	.16
	Child's age (Young)	.48	.21	1.6	5.20	.02
	Child's age (Middle-aged)	.24	.20	1.27	1.34	.25
	Child's sex (Boy)	-.10	.15	.91	.41	.52
	Children's skin type (I)	1.32	.56	3.74	5.47	.02
	Children's skin type (II)	.56	.32	1.75	3.10	.08
	Children's skin type (III)	.36	.30	1.44	1.47	.23
Class 4	Intercept	-1.51	.68		5.00	.03

	Province (North)	-.60	.83	.55	.53	.47
	Province (East)	-.36	.52	.70	.48	.49
	Province (West)	.59	.41	1.80	2.06	.15
	Education (Low)	.47	.43	1.60	1.20	.27
	Education (Intermediate)	.51	.36	1.67	2.10	.15
	Parental age (Young)	-.36	.62	.70	.33	.56
	Parental age (Middle-aged)	-.61	.36	.55	2.81	.09
	Parental sex (Male)	.07	.32	1.08	.05	.82
	Parental skin type (I)	-.40	.95	.67	.18	.67
	Parental skin type (II)	-.96	.60	.38	2.57	.11
	Parental skin type (III)	-.04	.53	.96	.01	.94
	Child's age (Young)	.21	.45	1.24	.23	.63
	Child's age (Middle-aged)	.69	.40	2.00	3.01	.08
	Child's sex (Boy)	-.18	.31	.84	.33	.57
	Children's skin type (I)	.02	1.23	1.02	.00	.99
	Children's skin type (II)	.05	.59	1.05	.01	.94

	Children's skin type (III)	-.03	.53	.97	.00	.95
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