Children's exposure to UV: results of a nationwide measurement campaign

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Contents

Summary

We measured exposure of children to ultraviolet radiation in a nationwide measurement campaign that ran from April to November 2019. For each child, measurements were taken during a period of 5 consecutive days using dosimeters that were placed on the child's chest. The dosimeter included an acceleration sensor, which allowed us to identify periods during which it was worn. During the measurement period, parents recorded children's activities in activity diaries. To investigate children's exposure by activity type, we grouped parent reported activities into broader categories.

The analysis included 4'058 hours of exposure measurements taken in 120 participating children. The highest measured intensities during single activities were between one and two standard erythemal doses per hour. The largest contribution to the total cumulative dose came from the types of activity "playing outdoors", followed by "walking" and "hiking". The highest mean exposures were found for "hiking", while the other types of outdoor activities showed similar rates of exposure. As anticipated, the mean exposures were higher during midday hours and at higher altitudes.

Based on measured daily mean exposure, we extrapolate the average annual exposure of children to be about 160 SED, if children are assumed to have been unexposed when the dosimeter was not worn (unmeasured periods), and 260 SED, if unmeasured periods are assigned the mean intensity of measured periods. However, these extrapolations are subject to large uncertainties related to dosimeter placement, the effects of posture and clothing, and sampling variability. Compared to average exposures measured in a large occupational study, for which the same dosimeters were placed on the upper arm of workers, the measured values are considerably smaller than those of exposed workers.

1 Background

Exposure to ultraviolet radiation (UVR) is associated with both positive and adverse health effects. Moderate exposure to UV radiation is necessary for the production of vitamin D. Higher doses of UVR can damage the tissues of the skin, eventually causing sunburns and increasing the risk for skin cancers and premature aging of the skin (photoaging) [7]. The childhood period is critical, first, because sun exposure at young age may increase life-time risk of cancer, and second, because safe sun exposure habits can be most effective if learnt and adopted in childhood [9]. Children are probably more sensitive to radiation exposures and exposures during childhood may have proportionally larger effect on the cancer risks later in life [4].

A number sun protection measures are widely recommended. These include avoiding the sun exposure during midday hours, to seek shade and to protect with suitable clothing or sun screen [3]. Sun protection is particularly recommended in situations with high ambient UVR levels as measured for instance by the UV Index. However, the relationship between actual exposure and ambient UVR is strongly modified by human activities. There is a need to document actual UV exposure in relation to concurrent activities and sun protection behaviour for children and adolescents [9]. A number of studies have measured UV exposure in children [9, 1, 6, 2], but there has been no such effort in Switzerland.

The measuring of UVR exposures in occupational contexts has received comparably more attention. In Germany, the GENESIS-UV study measures and monitors the occupational exposure to UVR [8]. This study is lead by the institute for occupational safety (IfA) of the Deutsche gesetzliche Unfallversicherung (DGUV). For the measurements presented in this study, we collaborated with the GENESIS-UV team in an effort to measure children's exposure to ultraviolet radiation.

2 Measurement campaign

This measurement campaign was conducted as part of a research project on low dose ionising radiation and childhood cancer risk funded by the Swiss National Science Foundation (Grant No. 320030_176218). In the course of this project, a questionnaire survey on radiation exposure (including UVR) was conducted targeting a random sample of about 8000 children aged 0-15 years old in Switzerland (response rate 34%). This survey addressed information on factors modifying exposure to gamma radiation (e.g. time spent indoors/outdoors, daily mobility patterns, building materials) and UVR (e.g. time spent outdoors at different times of the day, sun protection behaviour). Families were also asked whether they were willing to participate in a measurement campaign.

The measurement campaign was conducted in a nested sample of respondents to the survey and included children aged 4-15 years whose parents provided informed consent. The campaign involved dosimeter measurements of children's exposures to gamma radiation and UVR. Children were contacted by phone to confirm continued willingness to participate and to arrange a convenient time for the measurements. In total, 149 children and their parents participated in the measurement campaign and returned (at least partially) completed activity diaries.

We circulated 20 pairs of dosimeters (one UVR, one γ radiation) among participating children between April and November 2019. The two dosimeters were worn by the children on their chests for 5 consecutive days. During these 5 days, parents recorded the children's activities and whereabouts by filling out an activity diary. In this report, we summarize results of a preliminary analysis of measured UVR exposure in relation to reported activities.

2.1 Collected Data

The activity diary was completed by parents for their children. Parents were asked to report what the child did and where it was, including the exact addresses of the frequented locations. In addition, parents indicated whether the child was indoors or outdoors. We refer to the single reported activities as activity diary entries. Also, parents indicated whether the child was outdoors while it was sunny, and if so, whether they applied some sun protection measures.

The UV measurements were performed using Gigahertz-2012-X dosimeter. The dosimeters were provided by the GENESIS-UV team and have two sensors, one for UVA (320 nm to 400 nm) and one for UVB (250 nm to 320 nm) [5, 8]. Both sensors are calibrated to the solar spectrum for erythemal doses. Children wore the dosimeter using a strap specifically designed for the measurement campaign. The dosimeter were positioned on the chest of the children, shown in figure 1, and programmed to record a measurement every five seconds from 6:00 to 22:00.

Data on sex, age, communication language and residential address of children was obtained from the Federal Statistical Office (FSO) as part of a random sample requested for the questionnaire survey. Based on the residential address, area-based estimates of socio-economic position (SEP) could be linked to the database.

Figure 1: Image of a child wearing the strap containing the two dosimeters. The UV dosimeter is on the left, with the two sensors that measure UVA and UVB radiation.

3 Data preparation

3.1 Activity diary data

We geocoded all addresses of frequented locations reported by parents in the activity diary. The procedure of geocoding included: (1) initial geocoding using three services (Swisstopo, Google, OpenStreetMap), (2) comparison of retrieved geocodes, (3) manual comparison of original address with reverse geocoded addresses and (4) manual corrections.

We categorized the reported activity diary entries by type of activity and by type of place. This categorisation was done manually. The categories are not mutually exclusive and individual diary entries can be assigned to multiple types of activity. We defined following types of activities were: traveling, traveling in car/bus/train, cycling, waiting (e.g. at bus stop), walking, being in school, school break, playing outdoors, swimming (and any related activity, e.g. relaxing at a pool), being on a terrace (or balcony), other activities outdoors, hiking in the mountains, sleeping, reading, playing indoors, eating, other indoors, watching television, being on the phone and using a computer. Type of places were home, school, home of relatives (or friends), at or close to a water body, mountain, forest, playground and others.

3.2 Measurement data

Measurement records of UVR exposure were classified into "worn" and "not worn" based on the recorded signal an in-build acceleration sensor. By visually

inspecting the measurements of a whole day, periods during which the dosimeter was in motion were classified as "worn", while periods during which the dosimeter did not experience any acceleration were classified as "not worn". This classification was done and provided to us by the GENESIS-UV team [see 8, page 36].

In a first step, we aggregated the readings of the UV dosimeter from the 5 second intervals to one minute by calculating the mean of the measured UVR intensities. Further we transformed the unit of all measurements to standard erythemal doses (1 SED = 100 J/m^2). Radiation intensities are expressed in units of SED/h. The Standard Erythemal Dose (SED) is defined as radiant exposure of 100 Jm^{-2} and obtained by transforming the measurement records (100 $Jm^{-2}h^{-1}$) = $Wm^{-2} \times \frac{60 \times 60}{100}$).

In a second step, we linked the measurements (mean intensity for one minute intervals) to corresponding activity diary entries based on the time and duration of the activity as recorded by parents and the timestamps of the measurements. Based on this linkage, we calculated mean (mean intensity) and cumulative (measured intensity integrated over duration of activity) exposures for each activity diary entry.

The data recorded for a child during one day is illustrated in figure 2. In the shown example, the child was in school during the morning, and an increased exposure during the break is visible. The highest exposure on that day was received by the child when walking to a dancing lesson, during which the child laid aside the dosimeter. The dosimeter also appears to not have been worn during a party and water battle in the afternoon. During this time the dosimeter must have lain exposed to the sun for some time.

4 Conducted analysis

The analysis presented here is conducted mainly on the level of reported activity diary entries. We thus consider the mean UVR intensity over the period of activity diary entries disregarding the minute-by-minute variation of exposure during reported activities. Also, we only consider measurements that were classified as "worn". We restricted the analysis of UVR measurements to activity diary entries that have either (1) at least 15 minutes of UVR measurements classified as "worn" or (2) measurements classified as "worn" for at least 50% of their duration. Mean intensity during an activity was estimated as the mean of measurements classified as "worn".

First, we identified activity diary entries with the highest measured mean exposures. Then we calculated mean exposures by month during which the measurements were taken and by time of the day (means based only on measurements

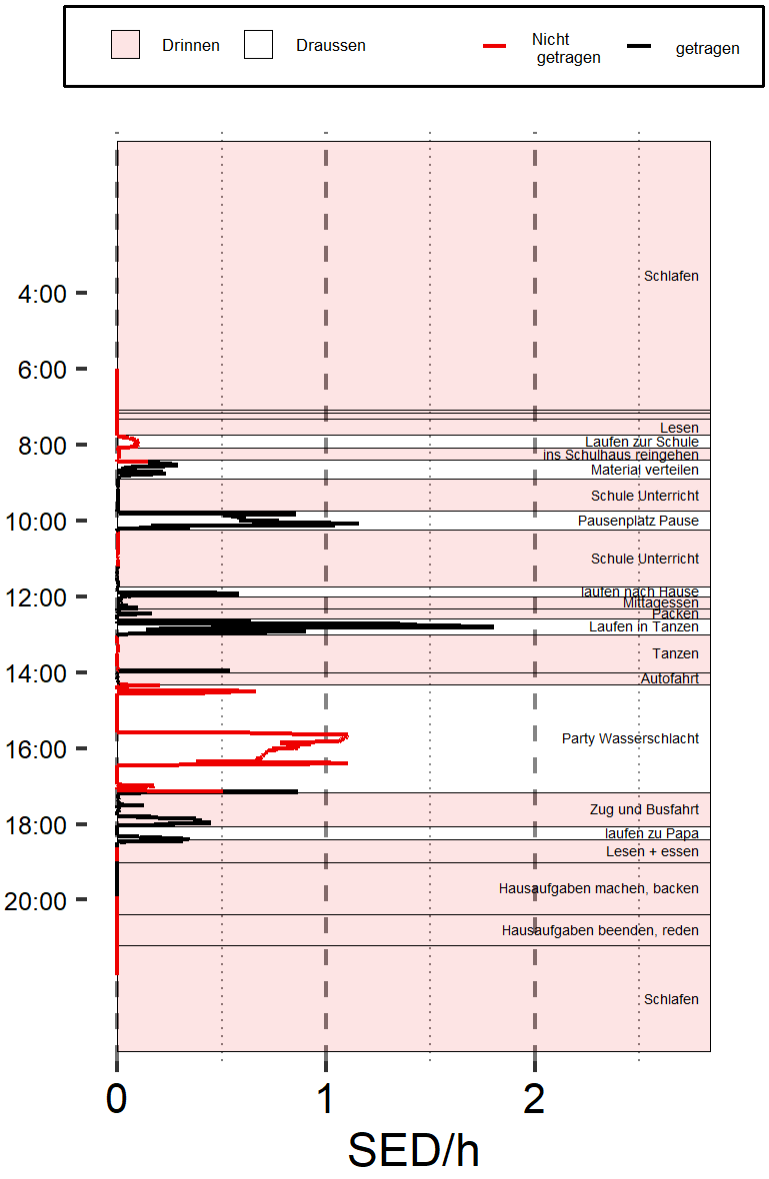

Figure 2: Illustration of the collected data for a randomly selected participant and day. The timeline goes from top to bottom. The background color indicates whether the child was indoors (red) or outdoors (white) based on parental reporting. Horizontal lines delineate different activities as reported by parents. The displayed signal shows the recorded UVR intensities (horizontal axis) by minute. The color of the line indicates whether the corresponding measurement was classified as "worn" (black) or "not worn" (red).

classified as "worn"). We also calculated mean intensities of UVR exposures and cumulative exposures by type of activity. Furthermore, we calculated daily cumulative doses and extrapolate to yearly doses in order to compare with measurements of occupational exposures collected in the GENESIS-UV project. We calculated daily exposure using two different ways of dealing with measurements classified as "not worn". First, we assumed zero exposure when the dosimeter were not worn, second, we assumed that mean intensities while the dosimeter was "worn" were the same as those while it it was "not worn".

For each day of measurements, parents indicated whether the child spent time outdoors during sunny weather and, if so, what sun protection measures were taken (sun screen, seeking shade, wearing a hat, wearing long sleeves and wearing long pants). We provide descriptive analyses of these responses and calculate measured UVR intensities by response category ("Yes", "Partly", "No").

5 Results

5.1 Participants and activities of children

The material (dosimeters and activity diaries with instructions) was sent to a total of 156 participants. We received fully or partially completed activity diaries from 149 participants. UVR measurements are available for **135 of these participants** (Table 1). Reasons for the lower number of participants with UVR measurements are: (1) some participants conducted measurements during a different week than initially agreed on, thus the dosimeter was not programmed accordingly. (2) In a few cases, we had issues with the dosimeter during the measurement period due to erroneous programming, battery charge or other defects and (3) issues with reading out the data of the dosimeter after the measurements.

A total of 13'120 different entries in the activity diary were reported by all participants combined. These were categorized into predefined types of activities. Most frequently reported types of activities were sleeping, playing indoors and eating, followed by school, other indoor activities and playing outdoors. The most frequent types of outdoor activities besides playing outdoors were the categories walking, cylcing, swimming and other activities outdoors. The category break (school break) can be regarded as mainly playing outside, but makes explicit that the activity took place in school.

The categories discriminated quite well between outdoor and indoor activities. Activities in the category waiting (in particular wait for bus, train etc. but also any reported "wait for...") were reported to be outside for about 65% of the time, while the other "outdoor" categories were reported to be outside for about 90% or more of their total duration. For activites in the "indoor" categories,

	n	**percent**	% Outdoors
overall	135	100	14.9
Sex			
male	74	54.8	15.5
female	61	45.2	14.0
agegroup			
4-7	58	43.9	15.2
8-11	54	40.0	15.5
12-15	23	17.0	12.4
language			
german	78	57.8	14.2
french	37	27.4	15.4
italian	20	14.8	13.7
Urbanisation			
(semi)urban	106	78.5	14.7
rural	29	21.5	15.5
sep_q			
1	36	26.7	13.6
2	29	19.3	13.9
3	26	18.5	14.0
4	27	20.0	16.9
5	17	12.6	16.8

Table 1: Characteristics of the 135 participating children with available UV measurements.

only those categorized as eating were reported to be outside for more than 10% of the time (15.8%).

Overall, children spent about 15% of their time outdoors. A detailed list of the frequency of reported indoor and outdoor activities is shown in table A.1 (Appendix).

5.2 Overview available measurements

Of the 13'120 activity diary entries, 11'066 could be linked to corresponding UV exposure measurements. A total of about 9'900 hours of recorded measurements could be linked to activity diary entries and, of these, about 4'147 hours of them were classified as "worn". An average of 73 hours of measurements are available per participant, of which (mean over participants) 41.6% were classified as worn, leading to about 30 hours of active measurements per participant.

After restriction of the UVR measurements to those flagged as "worn" as well as restriction of the activity diary data to entries with either (1) at least 50% of the duration or (2) at least 15 minutes covered with UVR measurements, remaining exposure measurements cover a total of **4'058 hours**. In total, 6'149 activity diary entries fulfilled above inclusion criteria, of which 2'053 entries were reported as being outdoors. For 15 participants, no measurements flagged as "worn" were available, limiting the dataset to **120 participants** for whom at least 2.9 hours of "worn" measurements are available (median duration: 35 hours, interquartile range: 25 h - 44 h, 10-90 percentiles: 17 h - 51 h). After further restricting to outdoor activities, the most frequently reported activity type was playing outdoors, followed by walking and eating (Table 2).

5.3 Measured exposures

The highest UVR intensity measured over one activity diary entry was at 1.92 SED/h during walking from Alp Sura to Bos Cha (Graubünden) (Table A.2). This entry also showed the highest cumulative exposure (duration times intensity) totalling 4.0 SED (Table A.3). A total of nine activities had measured UVR intensities above 1 SED/h. Of these, 4 were related to outdoor activities in the mountains, one was playing football and two were related to commuting between home and school. Activity diary entries with the highest cumulative exposures were predominantly (and naturally) activities of longer duration. The majority of these could be categorized into walking or hiking and into playing outdoors. Tables A.2 and A.3 list the 30 activity diary entries with highest measured intensities and cumulative exposures, respectively.

The highest average intensity by type of activity was found for entries categorized as hiking with a mean exposure of 0.31 SED/h (Table A.4). The total

Type of activity	n	Duration[h]
playing outdoors	501	580.38
walking	665	208.87
eating	157	158.77
other outdoor	166	138.00
hiking	36	77.83
cycling	163	74.63
school	61	60.42
swimming	68	59.10
schoolbreak	164	58.82
terrace	34	26.85
waiting	68	14.75

Table 2: Number and duration of outdoor activities with available measurements flagged as "worn". Only activities reported as outdoors with at least (1) 15 minutes of "worn" UV measurements or (2) at least 50% of the activity duration covered by "worn" measurements are included.

cumulative exposure over all participants for this type of activity was 25.7 SED. The UVR intensities of other types of outdoor exposures were similar to each other but at a considerably lower level: walking (mean intensity: 0.14 SED/h, cumulative 32.6 SED), swimming (0.14 SED/h, 7.3 SED), playing outdoors (0.14 SED/h, 83.4 SED) cycling (0.12 SED/h, 11.5 SED), waiting (0.12 SED/h, 2.0 SED), other outdoor activities (0.11 SED/h, 17.7 SED) and school breaks (0.11 SED/h, 7.1 SED). The largest single contribution to the cumulative doses received by children during typical outdoor activities came from playing outdoors (83.4 SED), followed by walking (32.6 SED) and by hiking (25.7 SED). Considerable contributions to the cumulative doses also came from activities that were mostly, but not always indoors. These include being in school (16.5 SED), eating (25.9 SED), playing indoors (19.7 SED), riding in a car, bus or train (14.1 SED) and other indoor activities (12.2 SED). More details are given in table A.4.

The distribution of measured UVR mean intensities per minute was skewed to the right, with distinct peaks for indoor and outdoor measurements (figure 3). The distributions shown in Figure 3 are bimodal suggesting some activities reported as indoors included some time outdoors and vice versa. As expected, measured outdoor intensities peaked during the lunchtime and early afternoon hours (figure 4). This trend is also reflected by indoor measurements, albeit less pronounced. The distribution of measured intensities by the month does not show any evident seasonal pattern during the main measurement period April to October (very few measurements done in November) (figure 5).

Over 529 person-days for which measurements are available, the measured mean cumulative daily exposure was 0.46 SED per participant. This estimate does not

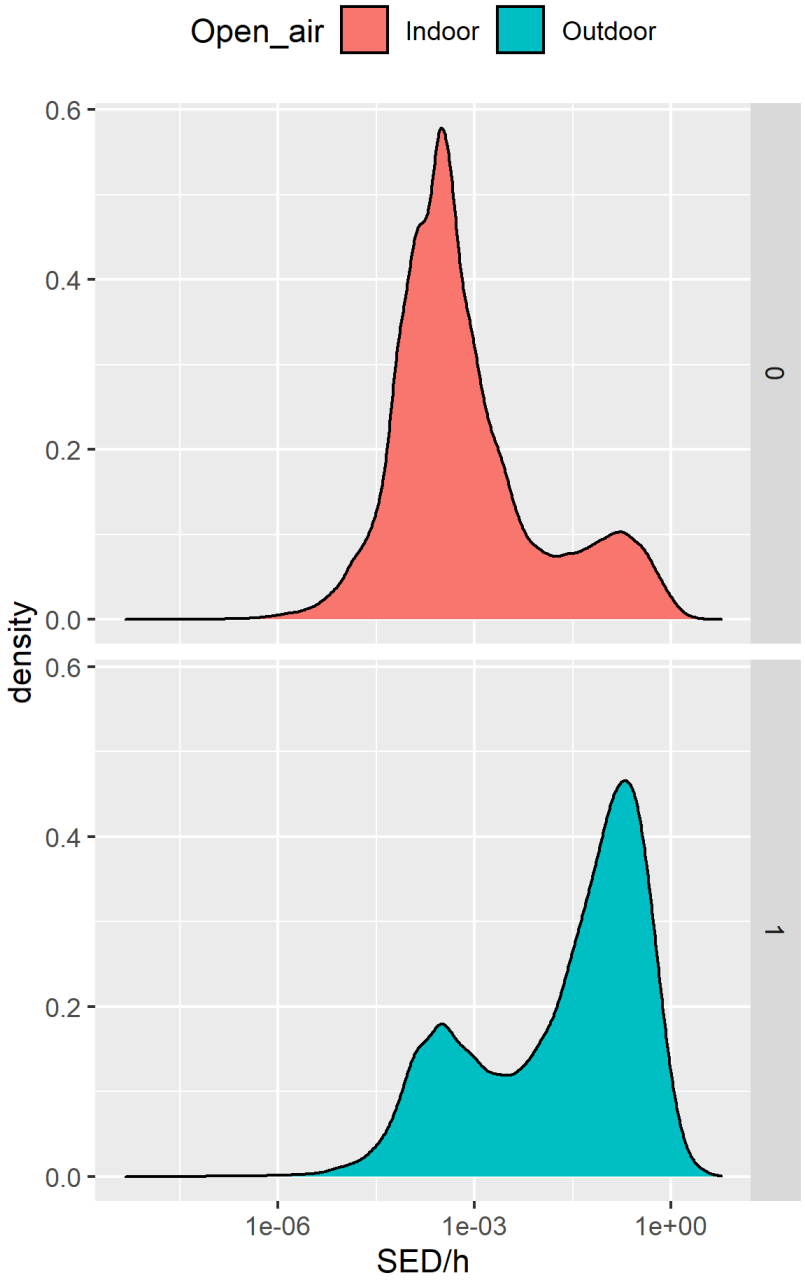

Figure 3: Distribution of measured UVR intensities (per minute) for measurements reported to be indoors (red) and outdoors (blue). The x-axis is on log-scaled.

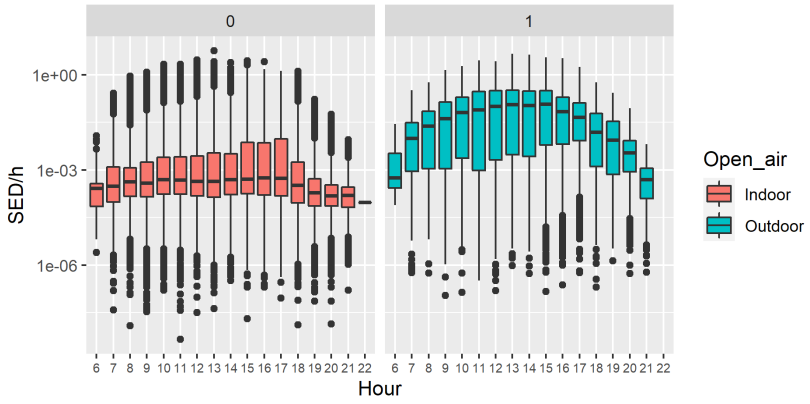

Figure 4: Boxplots of mean of measured UVR intensities (per minute) by hour of the day.

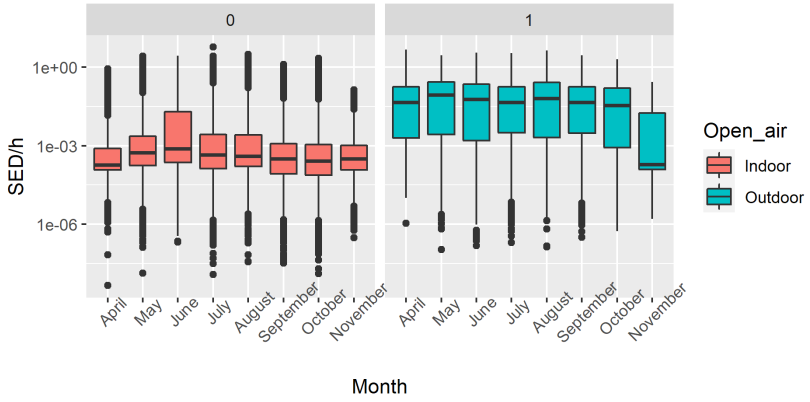

Figure 5: Boxplots of mean of measured UVR intensities (per minute) by month during which the measurements were conducted.

include periods during which the dosimeter was not worn. With a crude adjustment (assuming 12 hours of daily exposure at the average intensity measured when the dosimeter was worn), we get an estimate a mean daily exposure of 0.73 SED per person. Assuming that exposures during times when the dosimeters were not worn were on average lower than when these were worn, the true mean exposure likely lies between these two values.

The highest cumulative daily exposure measured by a participant was 8.8 SED. We recorded 8 participant-days with cumulative exposures between 2 SED and 3 SED. For about 10% of participant-days the measured daily cumulative dose was larger than 1 SED. The distribution of daily cumulative doses is right-skewed to higher values, the median daily cumulative dose was 0.30 SED. When we applied the same crude adjustement as above, the distribution shifted to higher values and the median was 0.48 SED.

5.4 Sun protection behavior

The question "Today, has your child been outside while it was sunny?" was answered by 90 participants on 448 participant-days. On 382 days of these days (85.3%) children were reported to have spent time outside while it was sunny. Table 3 shows frequency of response categories for different protective measures based on parents daily reports (entry of each day counted individually). The most frequently reported measures were protective clothing (on 37% (long trousers) and 21% (long sleeves) of the days when a child was reported to have been outside when it was sunny) , followed by sunscreen. However sunglasses were only rarely worn.
Mean measured daily exposures were higher when children spent time outside while it was sunny (0.53 SED vs. 0.13 SED). We observed a tendency for higher daily exposures when participants applied sun protection measures (Table 4). The largest difference is found for sunscreen, with mean daily exposures of 0.61 SED and 0.69 SED when applied or partly applied respectively, and 0.48 SED when not applied. These questions were not answered when children did not spent time outside when it was sunny. It is thus to be expected that the lowest daily exposures are measured when responses were missing.

Measure	No(%)	Partly(%)	Yes(%)	NA(%)
sunscreen	264(69)	30(8)	78(20)	10(3)
sunglasses	340(89)	21(5)	9(2)	12(3)
hat	209(55)	77(20)	90(24)	6(2)
long sleeves	198(52)	95(21)	82(21)	7(2)
long trousers	169(44)	66(17)	142(37)	5(1)

Table 3: Daily reports of sun-protective measures used by the children for the 382 days on which children spent time outside while it was sunny.

Measure	Yes	No	Partly	NA
hat	0.59	0.46	0.59	0.18
long_sleeves	0.57	0.49	0.53	0.17
long_trousers	0.59	0.50	0.42	0.16
sunglasses	0.38	0.52	0.57	0.22
sunscreen	0.61	0.48	0.69	0.21

Table 4: Crude mean of cumulative measured daily UVR exposure per person stratified by reported application of protective measures. The reported values are in the units of SED.

6 Discussion

Participants of the measurements campaign spent about 15% of the time outdoors. Measurements taken while the dosimeter was likely worn were available For 120 participants. The most frequent outdoor activities reported by participants were playing outdoors, walking and eating. A total of 4'056 hours of UVR measurements was included in the analysis. The highest measured UVR intensities were associated with hiking and activities at higher altitudes. Other types of outdoor activities showed similar average intensities that were collectively considerably lower than for hiking. UVR exposure was highest around noon and during the early afternoon hours and no seasonal trend was apparent. Playing outdoors contributed most to the cumulative doses. Though associated only with a moderate mean UVR intensity, it was, by a large margin, the most frequently reported type of outdoor activity.

It is difficult to extrapolate the measured exposures to full body doses. The measurements show a large variability caused by many effects we could neither control nor adjust for. Factors that have a considerable influence on measured exposure include the orientation of the dosimeter with respect to the sun and shading. This makes the interpretation of measured doses on an absolute scale difficult. Furthermore, clothing, posture and orientation of the child influence how the measured values relate to doses at different anatomical sites. The dosimeters were placed on the chest of children. Exposures on the shoulders,

neck or head most certainly were higher than exposures on the chest. Nevertheless, we assume that the effects of these factors are similar across activity types, and that a relative comparison of mean exposures between activity types is valid.

The measured intensities will typically be much lower than actual UV irradiance and a comparison with the UV Index is flawed. Lower readings of the dosimeter compared the the ambient level of UVR have multiple explanations: (1) To measure the ambient UV irradiance, the sensors of the detector need to be pointed directly towards the sun, which is rarely the case if the detector is placed on the chest. (2) The presented numbers are aggregates over the time interval of activity diary entries. Averages are lower than the highest measured exposures. Single measurements indeed included much higher readings. (3) Any shading or coverage of the detectors causes lower measured exposures. That includes shading from structures, but also shading from the child's body or clothing.

Based on the measured daily mean exposures, we can estimate an annual exposure (to the chest) for children of about 163 SED. Using a crude adjustment to account for the times during which the dosimeters were not worn, the estimate is about 266 SED. However, all measurements were done between April and November, the numbers do thus no take into account potentially smaller exposures during winter. The GENESIS-UV study estimates the highest yearly (occupational) exposures in fruit and vegetable gardeners (648 SED) and harvesters (617 SED). Occupations for which the GENESIS-UV study found similar (yearly, occupational) exposures to the ones measured in our study are for example foresters (201 SED), excavator drivers (168 SED) or sports teachers (154 SED) [8]. But, it is important to note that the positioning of the dosimeter was different in the GENESIS-UV study (upper arm) compared to our study (chest). Also, the GENESIS-UV study focuses solely on occupational exposures, while we were interested in the overall exposure of the children.

A limitation of the study is that the information collected on children's activities was self-reported by parents. The level of detail to which parents reported the activities and whereabouts of their children during the measurement period was heterogeneous. A less detailed reporting increases the chance of activity diary entries spanning outdoor and indoor phases. This probably explains the bimodal distribution of measured values displayed in figure 3 and the considerable contribution of activities reported as "indoor" to the cumulative doses. Additionally, and particularly for short activities, imprecise reporting of start and end time of an activity may have lead to some degree of misalignment of measurements with activities. Another limitation is that we did not measure exposures during winter months. Furthermore, we cannot rule out that parents and children might have altered their behaviour regarding sun exposure because they were aware of the fact that their exposure was being measured.

The high temporal resolution of exposure measurements combined with extensive information on whereabouts and activities of the children during the mea-

surements is the main strength of this study. The detail of the collected data allowed to investigate exposure patterns related to both whereabouts and type of activities of children and to compare different types of activities with regard to UVR exposures.

Overall, we found the highest exposures during midday and early afternoon hours and during activities that took place at higher altitudes. This is in agreement with what is expected. Apart from hiking, the different types of outdoor activities showed similar mean exposures. Our study shows, that a large fraction of UVR doses received by children comes from playing outdoors.

7 Outlook

A project at Unisanté Lausanne aims to use the collected UVR exposure measurements together with climatological models of ambient UVR to improve exposure models for epidemiological studies.

The collected information on children's whereabouts could be used to investigate the potential influence of the local environment on UVR exposure. In particular, it could be interesting to study potential effects of vegetation coverage as measured for instance by the normalized difference vegetation index (NDVI).

Participants of the measurement campaign all previously participated in a nationwide questionnaire survey and have thus provided detailed information sun protection behaviour and history of sunburns. It would be interesting to relate the information collected during the survey with that of the measurement campaign.

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A Supplementary Tables

Type of activity	**n**	**duration[h](%)**	**% Time Outdoors**
playing outdoors	747	1004.7(5.8)	96.8
other outdoors	277	308.0(1.8)	93.8
walking	1091	349.6(2.0)	94.4
swimming	180	276.3(1.6)	94.5
cycling	263	130.3(0.8)	99.1
hiking	33	81.7(0.5)	95.8
terrace	92	84.0(0.5)	89.7
waiting	119	31.2(0.2)	65.4
schoolbreak	244	92.1(0.5)	90.3
sleeping	1452	7403.8(42.8)	0.3
playing indoors	1527	2208.5(12.8)	5.2
eating	2115	1807.9(10.5)	15.8
school	844	1112.8(6.4)	7.3
other indoors	1100	1017.3(5.9)	8.6
television	561	810.3(4.7)	0.2
phone	252	348.4(2.0)	3.9
bathroom	1195	483.7(2.8)	0.3
reading	322	423.1(2.4)	2.8
computer	83	108.5(0.6)	3.0
none	126	273.1(1.6)	7.1
traveling	2720	1080.2(6.2)	51.1
traveling (car,bus,train)	1310	555.8(3.2)	14.7

Table A.1: Number of reported activities, total duration, and fraction of the time reported outdoors by type of activity for all participants. Note that the sum does not equal the total as some activities are included in more than one type of activity. For example an activity originally reported as "eating, playing" at "home-kitchen-kids room" would have been categorized to both eating and and playing indoors.

	Month	Hour	Activity	Place	UV duration	SED/h
1	August	13	Gelaufen	Alp Sura - Bos Cha	2.08	1.92
2	July	13	Schulweg laufen	Weg Zuhause - Schule	0.08	1.34
3	August	12	Joggen	ZH. r. Val Sinestra - oh. Sent	0.83	1.28
4	August	13	Wandern	Oberhalb Sent	0.70	1.22
5	May	12	Jouer au foot	Terrain de foot Begnins	0.45	1.22
6	July	16	Fahrradfahren nach Hause	Reise Schule - Zuhause	0.38	1.20
7	July	15	Bereitm. & in Reiten geh.	Reise Zuhause - Oerlingen	0.72	1.12
8	May	15	Se rendre a pied au metro	Voyage Grentte - metro	0.03	1.12
9	August	9	Gelaufen	Val Tuoi - Alp Sura	3.42	1.10
10	June	13	Zaehneputzen	Badezimmer - Zuhause	0.17	0.93
11	August	13	Laufen zur Bushaltestelle	Reise - Bushaltestelle	0.20	0.93
12	May	11	Revient de l'ecole a pied	Chemin de l'ecole	0.48	0.91
13	June	12	Pranzo	Sala	0.67	0.88
14	April	12	draussen vor schlossgut	platz spielplatz	0.50	0.88
15	August	15	Baden im See	Titisee	0.50	0.87
16	May	15	Ping-Pong trampoline	Jardin	0.37	0.86
17	July	12	Mittagessen	Kueche - Zuhause	0.50	0.85
18	May	12	Revient de l'ecole a pied	Chemin de l'ecole	0.10	0.83
19	May	12	Attente du bus	Place de jeu	0.28	0.80
20	May	11	Bus - jusqu'au domicile	Voyage - bus	0.57	0.80
21	August	14	Fahrradfahren	Reise Zuhause - Aurona	1.00	0.78
22	October	14	Fussweg Spielplatz		0.05	0.77
23	August	14	Biketour	Reise Titisee - Hotel	0.25	0.77
24	July	12	Spielen	Balisalp - Alphuette	1.40	0.76
25	August	13	Glace essen, spielen	am Titisee	0.50	0.76
26	May	11	Camminato fino a casa	Viaggio - scuola - casa	0.33	0.74
27	August	14	Spaziergang	Draussen	1.33	0.74
28	May	12	Se rendre a pied au metro	Voyage Grenette - Riponne	0.03	0.73
29	May	11	trasferte a piedi	casa - trasferte	0.17	0.73
30	May	10	Bateau	Lac Leman	0.57	0.73

Table A.2: List of the 30 activity diary entries with the highest measured UVR intensity. The column 'Hour' indicates the hour of the day during which the activity started, e.g. 14:34 would be displayed as 14. Activity and place labels are shown as reported by children's parents; a few labels were shortened for ease of display. UV duration indicates the duration of available measurements in hours. The mean intensity measured over this duration is shown in units SED/h. Only measurements reported as "worn" were included.

	Month	Hour	Activity	Place	UV_duration	SED
1	August	13	Gelaufen	Alp Sura - Bos Cha	2.08	4.00
2	August	9	Gelaufen	Val Tuoi - Alp Sura	3.42	3.75
3	October	8	Wandern, Kristallsuchen	Val Marghels, Gletscher	9.30	2.65
4	May	10	Spielen	Kinder- & Esszimmer - Zuhause	6.35	2.34
5	August	14	Gelaufen	Bos-Cha Val Tuoi	3.13	2.21
6	June	13	Giocato all'aperto	Giardino Camping Isola	2.67	1.88
7	July	13	Draussen spielen	Garten - Zuhause	4.12	1.74
8	May	13	Jouer dans le jardin	Jardin - domicile	3.67	1.69
9	May	15	Jeux exterieur	Rue de l'Horizon 34	3.58	1.62
10	June	7	Schulreise	Zug & Wandern Blumenst. Bad	6.62	1.60
11	July	10	Sisu Spielplatz	Hannigalp Sisu Spielplatz	3.42	1.55
12	September	12	Randonne	Rosenlaui- Grosse Scheidegg	5.33	1.54
13	September	10	Spielen draussen	Schulhof Kindergarten	3.82	1.53
14	May	8	Jouer dans le jardin	Jardin - domicile	4.25	1.44
15	October	11	Promenade en montagne	Region des Gastlosen	6.00	1.35
16	October	14	Fussball spielen	Roter Platz	4.02	1.29
17	September	9	Wanderung nach Jungen	Draussen	2.63	1.15
18	August	12	Joggen	Richt. Val Sinestra oh. Sent	0.83	1.06
19	August	13	Parascolaire	Preau Parascolaire	3.42	1.06
20	July	12	Spielen	Balisalp - Alphuette	1.40	1.06
21	May	14	Jouer dans le jardin	Jardin - domicile	3.50	1.03
22	June	9	Zuschauen Handball	Turnhalle Sporzentrum Gries	3.00	1.03
23	July	11	Mittagessen, spielen	Schulfreundin, Garten	3.25	0.99
24	May	12	Jouer a la place de jeux	Valle de la jeunesse	1.50	0.99
25	August	14	Spaziergang	Draussen	1.33	0.98
26	May	13	Regarder la tele + telephone	Salon + chambre - domicile	2.00	0.97
27	September	14	Viehschau	Roessliplatz Schwarzenberg	3.42	0.96
28	May	8	Jeux dehors	Dans la rue et le jardin	2.50	0.88
29	August	13	Wandern	Oberhalb Sent	0.70	0.85
30	June	15	Jeux d'interieur - tablette	Salon - domicile	2.62	0.85

Table A.3: List of the 30 activity diary entries with the highest measured cumulutavie UVR exposure (restricting to time during which the dosimeter was worn). The column 'Hour' indicates the hour of the day during which the activity started, e.g. 14:34 would be displayed as 14. Activity and place labels are shown as reported by children's parents; a few labels were shortened for ease of display.. UV_ duration indicates the duration of available measurements in hours. The cumulative exposure measured over this duration is shown in units SED. Only measurements reported as "worn" were included.

	Activity	Duration	SED/h	$\sum$SED
1	hiking	81.25	0.31	25.71
2	walking	214.87	0.14	32.63
3	swimming	61.58	0.14	7.34
4	playing outdoors	594.95	0.14	83.43
5	cycling	74.88	0.12	11.52
6	waiting	17.62	0.12	2.02
7	other outdoors	147.53	0.11	17.70
8	school break	60.93	0.11	7.07
10	terrace	31.27	0.09	3.32
11	none	71.83	0.06	3.17
12	phone	76.47	0.05	4.32
13	car/bus/train	327.13	0.04	14.06
14	eating	744.60	0.03	25.89
15	school	600.23	0.03	16.53
16	others indoors	357.00	0.03	12.23
18	playing indoors	934.65	0.02	19.71
19	reading	94.55	0.02	2.14
21	television	145.88	0.01	2.34

Table A.4: The mean UVR intensity and total cumulative exposure for a selection of activity types. Activity diary entries associated with two types of activities (e.g. "playing-eating" flagged as eating as well as playing indoors) are included for both categories without any weighting.

B Supplementary Figures

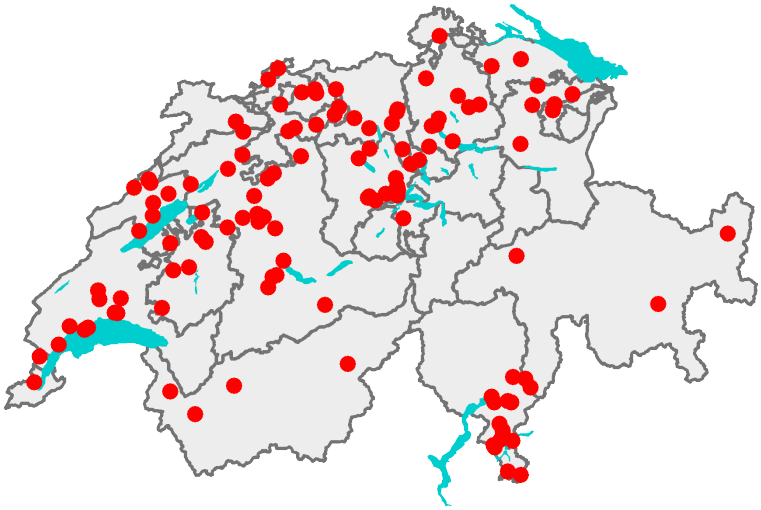

Figure B.1: The residential addresses of the 149 participants of the measurement campaign. To guarantee anonymization, the dots are randomly displaced for a few kilometers.

U.V.Index	Nbre de SED par heure	Estimation de l'intensité du soleil	Durée d'exposition de 3 SED
1	0,9	Faible	3 heures 20 minutes
2	1,8	Faible	1 heure 40 minutes
3	2,7	Modéré	1 heure 07 minutes
4	3,6	Modéré	50 minutes
5	4,5	Elevé	40 minutes
6	5,4	Elevé	33 minutes
7	6,3	Très élevé	29 minutes
8	7,2	Très élevé	25 minutes
9	8,1	Extrême	22 minutes
10	9,0	Extrême	20 minutes
11	9,9	Extrême	18 minutes

Figure B.2: UV Index and SED. Source: ElveaPharma

C Supplementary Material

The appended documents were sent to participants together with the strap, the dosimeters and some supplementary material. Appended are:

1. The general instructions.
2. The instruction on how to fill the activity diaries.
3. One copy of the activity diary template (five copies were sent to participants - one for each day).

Appended is the German translation of the documents. All documents were also translated to French and Italian.

Anweisungen für die Dosimetrie Messungen

Sehr geehrte Studienteilnehmer

Vielen Dank für Ihre Teilnahme an dieser Studie und Ihre Hilfe bei der Durchführung von Dosimetrie Messungen. Diese Messungen werden uns dabei helfen, die Exposition von Kindern gegenüber ionisierender Strahlung in der Schweiz zu bestimmen und die damit verbundenen Gesundheitsrisiken zu untersuchen.

In diesem Dokument finden Sie detaillierte Anweisungen für die Dosimetrie Messungen. Bei Fragen oder Problemen stehen wir Ihnen gerne unter 077 401 12 03 zur Verfügung.

Vorbereitung vor den Messungen

Sobald Sie die Messgeräte erhalten haben, machen Sie bitte folgende Schritte:

1) Lesen Sie diese Anweisungen
2) Entfernen Sie die Schutzabdeckung des UV-Dosimeters (siehe Bild unten, gelber Kreis). Behalten Sie die Schutzabdeckung, um Sie vor dem Zurücksenden wieder aufzusetzen.
3) Passen Sie den Haltegurt der Grösse Ihres Kindes an.
4) Lesen Sie die Anweisungen zum Aktivitäts-Tagebuch.

Messperiode

Der Messzeitraum beginnt am Mittwoch um 0:00 Uhr und endet am Sonntag um 24:00 Uhr. Während diesen 5 Tagen sollte der Gurt mit den Dosimetern tagsüber ständig getragen werden. In der Nacht kann der Gurt mit den Dosimetern neben das Bett gelegt werden, wenn möglich nicht direkt an eine Wand. Wir bitten Sie, während der gesamten Messperiode ein Aktivitätstagebuch Ihres Kindes zu führen.

Sie können die mitgelieferten Aufkleber und das Sammelheft verwenden, um Ihr Kind zu motivieren. Beispielsweise erhält Ihr Kind für jeden Tag, an dem Ihr Kind den Gurt mit den Dosimetern trug, einen Aufkleber zum Einkleben in das Heft.

Wie sind die Dosimeter zu tragen?

Haltegurt (links), D-Shuttle (oben) und UV (unten) Dosimeter. Wie man den Halter mit den Dosimetern trägt (rechts).

KLEIDUNG DARF DIE DOSIMETER NIEMALS BEDECKEN; TRAGEN SIE SIE IMMER ÜBER DER KLEIDUNG!

Das Aktivitäts-Tagebuch

Während der gesamten Messperiode bitten wir Sie, ein Aktivitätstagebuch Ihres Kindes zu führen. Bitte verwenden Sie die Formulare, die in der Box enthalten sind, welche wir Ihnen zugeschickt haben. Wenn Sie es vorziehen, das Aktivitäts-Tagebuch elektronisch auszufüllen, können Sie die Vorlage auf unserer Projekt-Website www.calir.ch herunterladen und die fertige Version per E-Mail an eine der untenstehenden Adressen senden.

Zusätzliche Anweisungen und ein Beispiel für das Aktivitäts-Tagebuch finden Sie auf einem separaten Blatt. Bitte lesen Sie auch die Anleitung zum Aktivitäts-Tagebuch vor Beginn der Messungen durch.

Nach den Messungen

Nach Abschluss der Messperiode müssen Sie uns die *Dosimeter* und den *Haltegurt* zusammen mit dem *Aktivitäts-Tagebuch* und dem unterschriebenen *Einwilligungsformular* zurücksenden.

Dies ist für Sie kostenlos. Bitte retournieren Sie die gleiche Box, die Sie erhalten haben, und verwenden Sie die beigelegte Adressklebeetikette. Bitte tun Sie dies so schnell wie möglich.

Wir können Ihre Messungen erst extrahieren, nachdem wir die Dosimeter zurückerhalten haben.

Einige wichtige Bemerkungen

- Die Dosimeter sind bereit für die Messungen. Sie müssen nichts an ihnen einstellen.
- Die Messwerte werden intern gespeichert. Wir können Ihre Messungen nur extrahieren, wenn Sie die Dosimeter zurückschicken.
- Wenn ein Gerät kaputt oder verloren geht, senden Sie bitte das verbleibende Gerät sowie den Gurt und das Aktivitätstagebuch trotzdem zurück. Selbst ab einem defekten Gerät können wir möglicherweise einige der Messungen abrufen.
- Die Dosimeter sind relativ robust. Bitte nehmen Sie diese jedoch nicht mit ins Wasser. Wenn Ihr Kind schwimmen geht oder intensiv Sport betreibt, können Sie den Haltegurt abnehmen, aber behalten Sie die Dosimeter in der Nähe, damit die Messungen die Exposition Ihres Kindes so genau wie möglich darstellen.
- Das Aktivitätstagebuch erfordert etwas Arbeit. Wir bitten Sie darum, weil es uns ermöglicht, die Expositionsmuster genauer zu untersuchen und somit wertvolle Erkenntnisse über die Strahlenbelastung von Kindern zu gewinnen. Bitte füllen Sie es möglichst gewissenhaft aus.
- Sobald wir die Dosimeter erhalten haben, werden wir die Daten extrahieren und analysieren. Den zusammenfassenden Bericht über Ihre Messungen erhalten Sie am Ende der Studie.
- Bei Bedarf finden Sie im Anhang einen "Brief an die Lehrperson", der diese über die Dosimetrie Messungen informiert. (Wir glauben, dass es gut ist, dies zu tun, insbesondere für Primarschul- und Kindergartenkinder. Wenn Sie weitere Kopien benötigen, kopieren Sie bitte den beigefügten Brief.)

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Anleitung zum Aktivitäts-Tagebuch

Bitte lesen Sie diese Anleitung vor der Messperiode sorgfältig durch. Je nach Alter des Kindes kann das Aktivitäts-Tagebuch entweder von einem Elternteil/Verantwortlichen oder vom Kind selbst geführt werden. Sie finden in den Unterlagen ein Formular für jeden Tag. Nachfolgend finden Sie ein Beispiel, wie das fertige Aktivitäts-Tagebuch für einen Tag aussehen könnte. Wir bitten Sie, folgende Anweisungen zu beachten, wenn Sie das Aktivitäts-Tagebuch ausfüllen:

- Zeit: Lassen Sie keine Lücken zwischen den Aktivitäten. Die Endzeit einer vorhergehenden Aktivität sollte immer gleich der Startzeit der nächsten Aktivität (grün markiert) sein. Der Tag sollte um 00:00 Uhr beginnen und um 24:00 Uhr enden.
- Reisen: Geben Sie an, wann das Kind unterwegs ist. Unterscheiden Sie zwischen Gehen/Radfahren und Bahn/Bus/Auto und geben Sie Start- und Endpunkt der Reise an. (gelb markiert)
- Outdoors: Bitte füllen Sie die Spalte Outdoors mit einem "X" aus, wenn die Aktivität im Freien stattgefunden hat. (rot markiert)
- Adresse: Sie brauchen die Adresse nicht zu wiederholen, wenn mehrere Aktivitäten am gleichen Ort stattfinden. Benutzen Sie einfach - " -, um anzugeben, dass es die gleiche ist wie vorher. Wenn Sie die genaue Adresse nicht kennen, können Sie diese Felder leer lassen. (blau markiert)
- Markieren Sie bitte (violett markiert) wenn die Dosimeter für Sport oder andere Aktivitäten weggelegt wurden.
- Wie typisch war der Tag: Bitte geben Sie an, wie gut dieser Tag den normalen Tagesablauf des Kindes an diesem Wochentag repräsentiert, d.h. wenn es Donnerstag ist, wie typisch er für die normalen Aktivitäten des Kindes an Donnerstagen war. (1 - typischer Tag, 5 - gar nicht typischer Tag)

Die mit dem Aktivitätstagebuch gesammelten Daten werden uns helfen, Messungen mit Aktivitäten und Standorten zu verknüpfen und dadurch die Strahlenbelastung von Kindern besser zu verstehen.

Vielen Dank für Ihre Teilnahme und Ihre Bemühungen!

Zeit		**Aktivität**		**Ort**	**Out-doors**	**Adresse des Ortes**			
Start-zeit	*End-zeit*	*Was hat das Kind gemacht?*		*Wo war das Kind?*		*Strasse*	*Nr.*	*PLZ*	*Ort*
00:00	*6:40*		*Schlafen*	*Zuhause - Schlafzimmer*		*Engelswmattstr.*	*31*	*1712*	*Tafers*
6:40	*6:55*		*Duschen*	*Zuhause - Badezimmer*		*“*	*“*	*“*	*“*
6:55	*7:20*		*Morgenessen*	*Zuhause - Küche*		*“*	*“*	*“*	*“*

7:20	7:30		Laufen zur Baushaltestelle	Reise - Daheim- Bushaltestelle	X	----------	----	1712	Tafers
7:30	8:14		Bus/Zug nach Bern	Reise- Tafers - Bern		----------	----	------	------
8:14	8:30		Laufen zum Büro	Reise- Bahnhof - Büro	x	----------	----	------	Bern
8:30	12:30		Arbeiten am Computer	Büro		Mittelstrasse	43	3012	Bern
12:30	13:15		Lunch	Cafeteria		"	"	"	"
13:15	15:00		Am Computer arbeiten	Büro		"	"	"	"
15:00	17:00		Vorlesung besuchen	Seminarraum		"	"	"	"
17:00	17:30		Teamsitzung	Büro		"	"	"	"
17:30	18:30		Am Computer arbeiten	Büro		"	"	"	"
18:30	18:45		Laufen und Einkaufen	Reise - Büro - Bahnhof	X	----------	----	-------	Bern
18:45	19:25		Zug/Bus fahren und Essen	Reise- Bern - Tafers		----------	----	-----	--------
19:25	19:35		Nachhause Laufen	Reise- Bushaltestelle - Daheim	X	----------	-----	------	------
19:35	19:45		Sporttasche bereit machen	Zuhause		----------	----	-----	------
19:45	19:55		Autofahren	Reise - Tafers - Fribourg		----------	----	-----	------
19:55	20:00		Umziehen für Training	Umkleidekabine		St.Leonard		1700	Fribourg
20:00	22:00	C	Fussball Training	Fussballplatz St.Leonard	X	"		"	"
22:00	22:10		Duschen	Umkleidekabine		"	"	"	"
22:10	22:20		Autofahren	Reise- Fribourg - Home		----------	---	-------	----------
22:20	22:50		Tasche ausräumen, Essen	Zuhause		Engelsmattstr	31	1712	Tafers
22:50	23:30		Fernsehen	Zuhause - Wohnzimmer		"	"	"	"
23:30	23:40		Bereit Machen für Schlafen	Zuhause		"	"	"	"
23:40	24:00		Schlafen	Zuhause - Schlafzimmer		"	"	"	"

Wenn Sie Fragen haben, können Sie sich an uns wenden unter:

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Aktivitäts-Tagebuch

Dosimeter D-Shuttle: ……
Dosimeter UV-GENESIS: ……
P_ID: ……

1. Hat Ihr Kind heute bei sonnigem Wetter Zeit draussen verbracht? O ja O nein
2. Falls ja, hat sich Ihr Kind dabei auf folgende Weise gegen die Sonne geschützt?

	Nein	Teilweise	Ja
Sonnencrème	O	O	O
Sonnenbrille	O	O	O
Kopfbedeckung	O	O	O
Langärmlige Kleider	O	O	O
lange Hosen/Jupe/langes Kleid	O	O	O

Aktivitäts-Tagebuch für: Name des Kindes: _____ Datum: ____.____._____

Wurde das Tagebuch am gleichen Tag ausgefüllt? O ja O nein

Wie typisch war der Tag (für diesen Wochentag)?

Bitte die entsprechende Box ankreuzen.

Sehr typisch				**Gar nicht typisch**
1	2	3	4	5

Lassen Sie keine Lücken im Tag! Vergessen Sie nicht die Reisezeiten!

Zeit		**Aktivität**		**Ort**	**Out-doors**	**Addresse des Ortes**			
Start-zeit	*End-zeit*	*Was hat das Kind gemacht?*		*Wo war das Kind?*		*Strasse*	*Nr.*	*PLZ*	*Ort*
00:00									

Notizen/Kommentare:
