

# Ultraviolet exposures in different playground settings: A cohort study of measurements made in a school population

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## Abstract

**Background:** Solar erythemally effective ultraviolet measured on the face, neck, arms, hands and legs of a cohort of school children was investigated with respect to student movement about a school environment located in Southern Queensland.

**Methods:** A total of 147 erythemally effective solar UV exposures were measured using polysulphone film dosimeters. Measurements were made on exposed skin surfaces during school hours between 8:30am and 3:05pm for the period 5 February to 4 June 2008.

**Results:** Median seasonal erythemally effective UV exposures varied from between 0.4 to 2.7 Standard Erythema Doses (SED) for school students observing the normal school routine between winter and summer respectively. These exposures increased significantly for school activities scheduled primarily outdoors, reaching a maximum of 50 SED recorded to a vertex site measured during a school swimming carnival.

**Conclusion:** The excessive erythemal UV exposures measured in this research have the potential to significantly contribute to the later development of melanoma and non melanoma skin cancers caused by acute and chronic cumulative exposure to solar UV in Queensland school environments. The research provides data on personal UV exposures measured in a school population engaged in daily school activities.

**Keywords:** Solar Ultraviolet, School Children, Occupational Exposure, Dosimeters, Erythema

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## Introduction

Exposure to solar ultraviolet during the course of a human lifetime has the potential to significantly impact upon the health of individuals. Cumulative exposure to solar UV is known to play a causative role in the development of non melanoma skin cancers (1,2) while long term and acute exposures are likely to be responsible for the development of melanoma skin cancers that develop later in life as a result of intermittent exposure especially during childhood (3,4). In Australia, for the year 2003, a total of 390 deaths were attributed to non melanoma skin cancers while a further 1146 died from malignant melanoma in the same year (5). Apart from the human cost, the costs associated with the treatment of non melanoma and melanoma skin cancers is in the order of \$294 million in Australia (6). Skin cancer is however a potentially preventable disease and the exposure built up over the course of an individual's schooling or working years can be significantly reduced by application of appropriate sun protective strategies.

Measurements of ultraviolet exposure to outdoor workers indicated that in most cases workers did not employ adequate forms of sun protection (7). The effect of protecting workers from full sun during meal breaks to reduce occupational exposure to solar UV has been investigated (8). Studies have also been performed to investigate the effect of different meal break times in southern Queensland schools on the solar UV exposures received by school children (9). Additionally, UV exposures to schoolchildren have been measured in Queensland during normal school hours (10,11) and recently in New Zealand (12). In the context of this past research, the current study aims to investigate the effect of student movement about a school environment and determine what influence student behaviour has on daily cumulative erythemally effective ultraviolet exposure. The study provides data on the erythemally effective ultraviolet (UVE) exposure for students observing their normal school routine and makes comparisons between students primarily using indoor environments to those sporadically using outdoor environments during the school day.

## Materials and Methods

A total of 147 measurements of personal UVE exposures were measured using polysulphone dosimeters to high school children attending Hervey Bay State High School, Queensland, Australia (25°S, 153°E) between February and June 2008. Personal UVE exposures were recorded among a volunteer group of 48 students on 21 separate measurement days in the February to June period. Typically several students volunteered on successive measurement days over the February to June measurement period, however most of the 48 student volunteers provided only one daily exposure record. The polysulphone dosimeters used in this study were manufactured from frames of flexible card of approximate dimension 15 mm x 10 mm having a clear circular aperture of 6 mm over which 40 µm thick polysulphone film manufactured at the University of Southern Queensland was adhered. The polysulphone film was calibrated to the erythemally effective UV for the periods February to April, April to May and May to June. In the calibration, the change in pre- and post-exposure polysulphone absorbance was measured at 330 nm (model 1601, Shimadzu Co., Kyoto, Japan) and plotted with respect to the horizontal plane UVE measured by the USQ's scanning spectroradiometer (model DTM300, Bentham Instruments, Reading, UK). The spectroradiometer has a quoted uncertainty of ±10% (13), which includes uncertainty measurements of temporal stability, wavelength response, cosine response, noise estimates, and traceability of the instrument's quartz tungsten halogen lamp calibrated to the National Physical Laboratory, UK standard. The polysulphone dosimeters employed for this research have been used previously for the personal measurement of facial exposure recorded to school children during sporting activities and have a calibrated uncertainty of ±24% (11). The UVE exposures measured for this research are expressed in units of Standard Erythema Dose (SED), where 1 SED is taken to represent 100 Jm<sup>-2</sup> of UVE (14).

Children involved in this study were instructed in the proper handling of the polysulphone film badges and asked to apply them to the skin normally exposed to solar UV. This was done by attaching dosimeter badge frames using medical tape onto regions classified as the face, neck, arm, hand or leg. Badges placed by children on the skin were located in a variety of places within each of these classified face, neck, arm, hand and leg areas but were limited to the forehead, nose, cheek, and chin for the face, the thigh just above the knee, the shin and upper foot for the leg, the outer surfaces of the upper arm and lower forearm, the back of the hand and the side and center of the back of the neck. Badges were attached at 8:30am (AEST) on each trial day in the study period under a covered area in the school playground and retrieved at 3:05pm (AEST) at the same location. Participating students were asked to

complete a daily diary of the school playground locations they attended during each period and meal break of the school day. The school regions were divided into three broad categories, these included: indoor regions (in class); outdoors but near to school buildings (including under shade structures); and open outdoor areas (school oval, pool area and agricultural plot). Students were asked to list only those areas where they spent the majority of each period or break time. Data on the degree of cloud cover, estimated in eighths (oktas) was measured by an observer on each trial day in the February through June period and the type of hat (voluntary at this study school) used by each participant was also recorded in the daily diary.

The collected diaries detailing each student's movement about the school were divided into three categories, these included: students who spent the entire day indoors; students who spent at least one of six possible periods or breaks (between 9:00am and 3:05pm) outside near buildings; and students who spent at least one period or break (between 9:00am and 3:05pm) in an open, less protected outdoor area of the playground. Data was also collected during the school swimming carnival when students were required to spend the entire day in an open outdoor environment. This case was included as it represents a significant variation from the normal school routine.

## **Results**

### *Swimming Carnival Exposure*

The largest variation in personal UVE exposure recorded over the February to June measurement period occurred during the school's swimming carnival which was run between 9:00am and 2:30pm, 15 February 2008. These exposures were recorded in an open playground environment offering limited protection from surrounding school

buildings. For this day, UVE exposures were measured to four volunteers on forearm and vertex sites. UVE exposures to the arm were recorded at  $15.8 \pm 3.8$  SED,  $12.3 \pm 3.0$  SED,  $4.9 \pm 1.2$  SED and  $38.7 \pm 9.2$  SED. Vertex measurements were also taken on the day and measured  $39.7 \pm 9.5$  SED,  $39.6 \pm 9.5$  SED,  $32.0 \pm 7.7$  SED and  $49.8 \pm 12.0$  SED. The uncertainty quoted in the above measurements represents the calibrated dosimeter uncertainty. Vertex exposures were the most consistent approximating exposures received on a horizontal plane. Variations in the exposure received by the arm are likely due to varying individual orientations of the forearm for students standing, sitting and moving about shaded locations in the swimming pool playground environment.

#### *Incidental playground exposures*

A total of 107 measurements were recorded to students between 8:30am and 3:05pm for every period of the regular school day with the remainder of measurements not being held over the full school day, not being included due to incomplete movement diaries or being recorded during the school swimming carnival. Out of the 107 personal measurements of exposure measured over regular school days, 12 were measured on students that spent the entire school day between 9:00am and 3:05pm indoors. This represents approximately 11% of the study population. A total of 23 measurements were made on students that had spent only 1 period of the school day outdoors of which 9 were required to spend time outdoors to attend agriculture or sports classes in open playground environments. These two groups make up the infrequent sun exposed school population group and comprise of approximately 32% of the study population. The majority of the measured population spent two periods outdoors. This group consisted of 44 measurements, 41% of the study population. Of these, most had spent their two periods outdoors during school meal breaks. The children that spent both meal breaks in the playground were located either near buildings or in open playground environments. Of these children, 73% chose to spend their meal breaks out of open environments with approximately half of the remainder spending both meal breaks in open outdoor playground environments. A total of 28 measurements were made on students that had spent more than 2 school periods in an outdoor playground environment (26%). All of these students had spent both meal breaks outdoors and were required to attend at least one class in an outdoor environment. This group represents the student population at most risk of overexposure to solar UV.

The median incidental personal UVE playground exposure recorded over the February to June measurement period between 8:30am and 3:05pm was 1.6 (IQR 0.8 to 3.3) SED. Median personal exposures measured over the late summer (February to April), autumn (April to May) and early winter (May to June) measurement periods were 2.7 (IQR 1.3 to 4.2) SED, 1.2 (IQR 0.8 to 2.5) SED and 0.4 (IQR 0.2 to 1.4) SED respectively. Large deviations from the mean personal exposures quoted above were due to students spending various amounts of time in the sun during the school

day. Figure 1 shows the mean student activity index during each period of the school day for outdoor behavioural data collected between February and June. For the figure, students spending time in open unprotected regions of the school playground were assigned an outdoor activity index of 4, students located in sunlit areas but located near buildings were assigned an outdoor activity index of 3, students located under building and shading structures were assigned an outdoor activity index of 1, and students located indoors were assigned an outdoor activity index of 0. Here the outdoor activity index gives some indication of student exposure to the ambient UV and has been weighted to represent the proportional level of sunlight received in each playground region. The data presented in the Figure is not a specific measurement of student exposure but a representation of mean behavioural trends observed in the school relative to the outdoor environment. Error bars show the inter-quartile range (IQR) in outdoor activity index in the sample population for which the IQR was 0 for all periods after 9:00am except the school lunch breaks. Large variations in the tendency of students to use outdoor environments were observed and these are clearly evident in the Figure during lunch break periods.

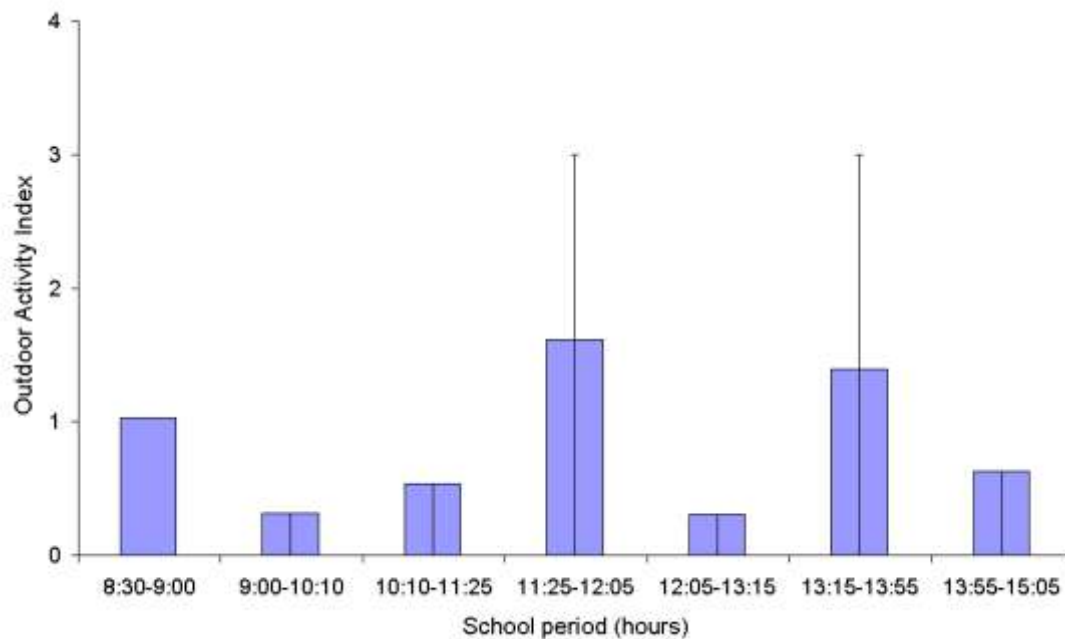


Figure 1: Mean activity index of student outdoor behaviour observed relative to time spent in sunlit areas of the school playground.

From Figure 1, the two most significant periods of outdoor activity occur between 11:25am and 12:05pm, and 1:15pm and 1:55pm. These times represent the two meal break times observed at the school. The highest mean activity index after these two time periods occurs in the period before school (8:30am to 9:00am). The likely reason for the high outdoor activity index observed at these times is due to limited access to indoor environments available at these times when school classrooms are locked.

There is also likely to be a tendency for students to seek outdoor playground regions for either sporting or leisure activity between indoor classes.

The frequency distribution of incidental school time UVE exposures measured between February and June is plotted in Figure 2. The figure shows that a greater number of exposures were observed in the lower daily exposure range, with the greatest number of students receiving incidental playground exposures of between 0.5 and 1.0 SED. The tendency for exposures to be skewed toward the lower end of the exposure range indicates that most students do not spend a significant proportion of the routine school day outdoors. Students that received exposures ranging from 0 to 0.5 SED were found to spend the majority of time in indoor environments. A total of 17 out of the 19 student UVE exposures that had a recorded daily UVE exposure of < 0.5 SED were recorded on students that had spent each of the four teaching periods at the school indoors and every one of the students in this sample range had spent both meal breaks either indoors, under cover or near the school buildings.

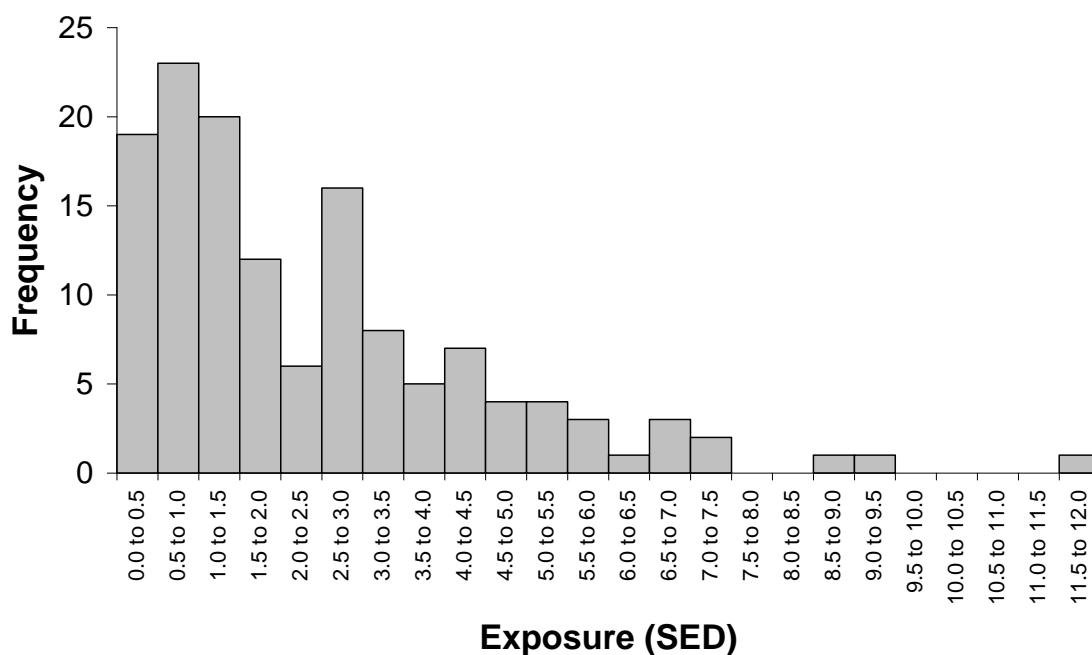


Figure 2: Frequency distribution of personal UVE exposure measured between February and June 2008.

In contrast to exposures measured on children spending most of their day indoors, significant incidental UVE exposures were observed for children that spent more than one school teaching or break period in the open outdoor playground environment. The median personal UVE exposure measured to students spending one period of the day in an open environment was 3.0 (IQR 1.7 to 4.9) SED which increased to a median exposure of 3.3 (IQR 2.6 to 5.1) SED for students spending more than one school class or break period in an open environment. The highest incidental daily exposure was measured at a forearm site ( $11.7 \pm 2.8$  SED). This exposure was measured to a

student that spent 2 class periods in open outdoor environments and had also spent both meal breaks near school buildings. The second highest daily personal UVE exposure ( $9.0 \pm 2.2$  SED) was measured on an arm site of a student that had spent 4 out of the 6 school class and break periods on the school oval or agricultural plot.

#### *Variation in UVE playground exposure with cloud cover*

UVE exposures measured with respect to variation in cloud cover are given in Figure 3. The mean daily UVE exposure measured over the study period and plotted in the figure for variation in cloud cover was averaged across all body sites. In the figure there is a clear association between UVE exposure and school environment. For all cloud cover cases, the UVE exposure increases for students spending more time in less protected playground environments.

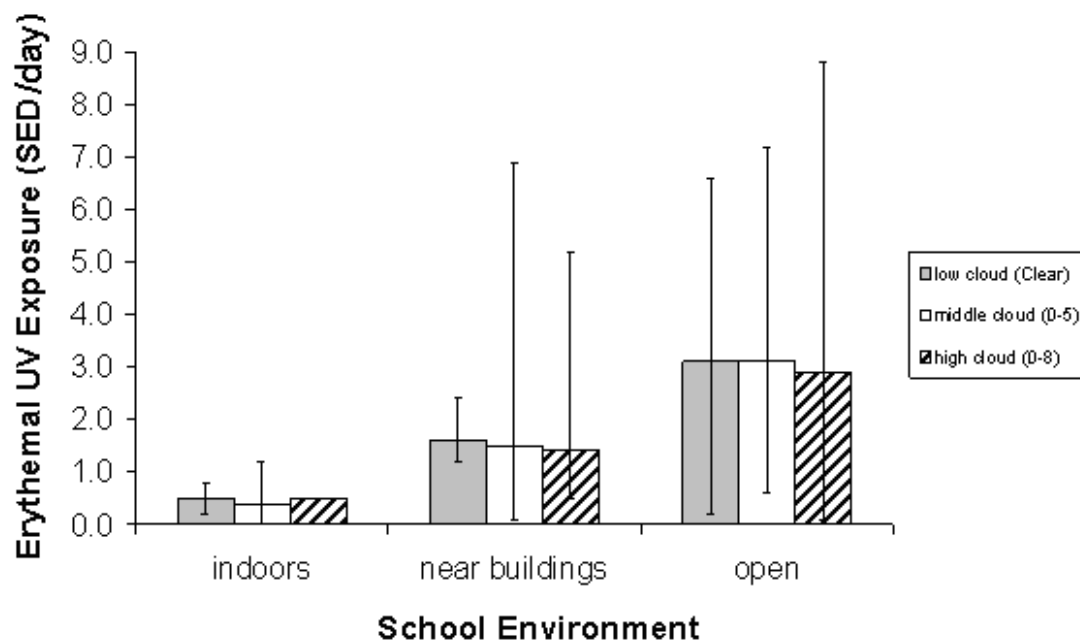


Figure 3: Mean daily UVE exposure plotted for students spending time indoors, near buildings in outdoor environments, and in open outdoor environments. Exposures are given for low (0-2 okta), middle (0-5 okta) and high (0-8 okta) cloud cover days. Error bars show the full range of daily UVE exposure for each respective environment and cloud cover range.

Low and middle cloud cover cases, averaged over all body sites show the greatest increases in UVE exposure with decreasing protection offered by the school environment. Increases in mean UVE exposure were slightly less for high cloud cover cases. This was due to increased cloud cover reducing the influence of protection offered by the school environment as the ambient UV was reduced by absorption due to high levels of cloud cover, particularly cloud cover blocking the direct UV when in front of the solar disk. Increases in the level of daily cloud cover resulted in



decreasing mean personal UVE exposure for students located near buildings and in open areas of the playground. The decrease in the mean UVE for students located both near buildings and in open playground environments with increasing cloud cover was 0.2 SED.

For some cases, daily UVE exposures exceeded 0.5 SED for students spending the day in protected indoor school environments. A likely explanation for this is due to student movement during the day, particularly at this high school when students were required to move from class to class. For this study, students were required to move between four 70 minute classes per day, meaning students would be required to be in outdoor environments at least 5 times daily, namely: before school; moving from the first class to the second; morning tea time; lunch time; and for a brief period after school. For the school studied in this research, 5 minutes of time is given to students to move from the first class ending at 10:10am to the second starting at 10:15am. Students moving to and from indoor environments at morning tea, lunch and before and after school would add to their personal time spent in an outdoor environment which may not have been necessarily recorded as the main school location noted in the daily student diary.

#### *Variation in UVE playground exposure with season*

Figure 4 shows the variation in grouped personal UVE exposures with season. Students that spent some of their school day outdoors (near playground buildings and in open environments) received the greatest exposures during the summer (5 February to 31 March) measurement period. Playground exposures received during the early winter and autumn are lower than summertime exposures. Mean winter exposures varied between 0.3 SED to 1.3 SED and showed the lowest variation in personal UVE exposure. Clearly, outdoor lessons and sporting events scheduled over the winter period of the year at the study latitude could result in large reductions in personal UVE exposure.

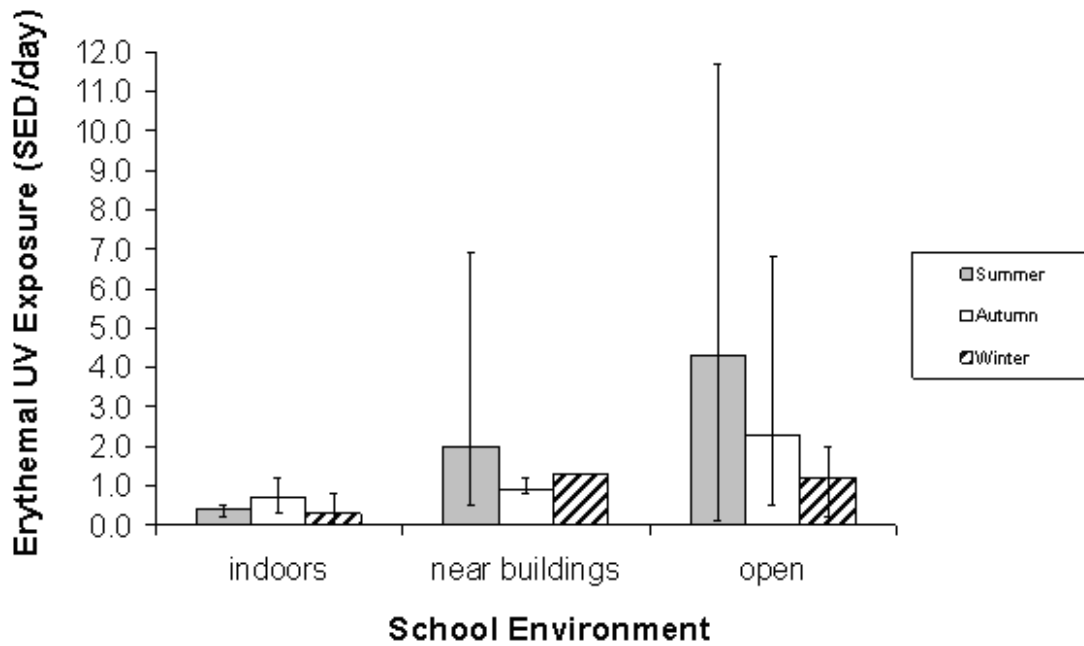


Figure 4: Mean daily UVE exposure plotted for students spending time indoors, near buildings in outdoor environments, and in open outdoor environments. Exposures are given for the late summer period (5 February to 31 March), autumn (1 April to 30 April) and early winter (1 May to 4 June) and were averaged across all body sites measured in the respective season. Error bars show the full range of daily UVE exposure for each respective environment and season.

#### *Variation in exposure with body measurement site*

Figure 5 illustrates the variation in UVE exposure with respect to body site for the different school playground environments. The mean daily UVE exposure plotted in the figure was averaged over all cloud cover conditions in the study period. Like Figure 3 and Figure 4, Figure 5 shows a clear association between UVE exposure and school environment for each of the face, neck, arm, hand and leg sites. The full range of recorded UVE exposure for each body site is also plotted in the figure.

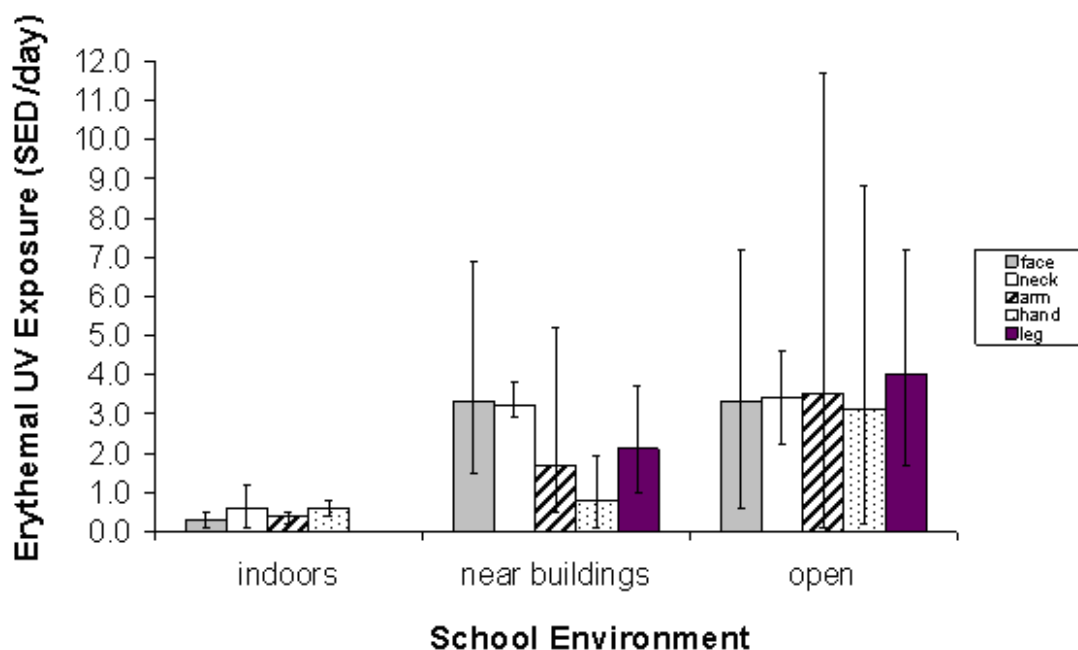


Figure 5: Mean daily playground environment UVE plotted with respect to body site. Exposures are given for facial, neck, arm, hand and leg sites and were averaged across all cloud cover conditions. No indoor or winter leg data was measured in the study period.

For all body sites except the hand, the mean daily UVE exposure more than doubled for students that spent some time of the day in open outdoor environments compared with students that spent their day indoors. These results clearly show that UVE exposures increase with time spent in outdoor environments for all measured body sites. The distribution of UVE exposure to body sites for this study however, gives no clear indication of sites that are at risk of greater exposures compared to another. A plausible explanation for this may be the random movement and orientation of each body site with respect to the playground environment and the various activities performed by students on a day to day basis.

#### *Hat use among the study group*

Of the 114 completed diaries on hat use noted during the February to June 2008 measurement period, 105 indicated that hats were not worn on the measurement day. Of the hats that were worn by students on the measurement days, 8 chose to wear a baseball style of cap and 1 student indicated that they wore a broad-brim style of hat. These results are comparable to the behavioural study of Milne et al. (15) which indicated that the use of quality hats in three Western Australian primary schools was observed to be often less than 30%. The data also supports the behavioural studies of Balanda et al. (16) and Lowe et al. (17) which highlight a decline in sun protection strategies used by high school aged children compared with primary school aged children and highlights the significant role school administrators can take to control

the behavioural patterns of children in their care to minimise lifetime cumulative exposure to potentially harmful solar UV, particularly during meal breaks which account for most of the cumulative UV exposure received throughout the day.

## **Discussion**

Measurements of personal UVE exposures to school children have been made and compared with behavioural patterns of movement about a school playground in a high school located in southern Queensland. Most of the incidental UVE exposure received over a normal school day was measured in the 0.5 to 1.0 SED range with the median daily exposure over the February to June period being 1.6 SED. These results are comparable to the measurements of Gies et al. (10) which measured median UVE exposures to the shoulder ranging from between 1.04 and 4.8 SED for school children using three Queensland school environments. In New Zealand primary schools, the mean lapel daily UVE exposure received at school was determined to be 0.9 SED (12). The results presented in this research are also similar to the measurements of Guy et al. (18) which determined the median daily lapel UVE exposure of South African school children to be 1.2 SED. The UVE exposures reported by Gies et al. (10) show that personal exposures are proportional to ambient measurements of UVE exposure incident in the playground environment. This research has determined personal exposure to be further dependent upon the local school environment.

The outdoor behaviour of students observed in this study suggests that cumulative daily UVE is affected most significantly by the tendency of students to be located in outdoor playground environments during meal break times. As meal breaks tend to be the periods of the school day closest to solar noon, reductions in cumulative daily UVE brought about by active sun protection strategies held during meal breaks are likely to have the greatest effect on reducing exposure risks in a school population. Each of the facial, neck, arm, hand, and leg sites showed a significant increase in UVE exposure for children moving into open unprotected school environments for variations in cloud cover and season. These findings reinforce the importance of applying adequate sun protective measures, in addition to avoidance of the sun during periods of peak UV intensity particularly during school meal breaks which were determined to be the times students most frequented open playground environments.

In contrast to incidental UVE exposures received by school children during a normal school day, exposures measured during the school swimming carnival were found to be as high as  $49.8 \pm 12.0$  SED. These results clearly indicate the extremes in variation

received by school children at this particular school. The measured swimming carnival exposure results, while not typical of a student's incidental playground exposure received during a normal school day, highlight the importance of planning and scheduling outdoor events including fun runs and sports carnivals during which there is a high probability of students receiving severe sunburns which is a well recognized risk factor for the later development of melanoma and non melanoma skin cancer. Furthermore, careful consideration and preparation of outdoor school activities, the active use of hats, protective clothing, sunscreen and exposure avoidance during periods of peak UV intensity need to be practiced if schools are to reduce UVE exposure limits.

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