Keratinocyte skin cancer risks for working school teachers: scenarios and implications of the timing of scheduled duty periods in Queensland, Australia

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ABSTRACT

Relative keratinocyte skin cancer risks attributable to lifetime occupational and casual sunlight exposures of working school teachers are assessed across the state of Queensland for 1578 schools. Relative risk modeling utilizing annual ultraviolet exposure assessments of teachers working in different geographic locations and exposed during periods of measured daily playground duty times for each school were made for local administrative education districts by considering traditional school opening and closing hours, and playground lunchtime schedules. State-wide, basal cell carcinoma (BCC) and squamous cell carcinoma (SCC) relative risk estimates varied by 24% for BCC and 45% for SCC. The highest relative risk was calculated for the state's north (sunshine) coast education district which showed that risk could increase by as much as 32% for BCC and 64% for SCC due to differences in teacher duty schedules. These results highlight the importance of playground duty scheduling as a significant risk factor contributing to the overall burden of preventable keratinocyte skin cancers in Queensland.

Keywords: Keratinocyte skin cancer, occupation, teacher, UVR

1.0 INTRODUCTION

Keratinocyte cancers (KC) of the skin are the most commonly diagnosed of all human cancers, increasing in occurrence over the last four decades in Caucasian's globally with between 2 and 3 million cases treated annually (1). KC excludes cutaneous melanoma (CM) but includes the two most prevalent forms of human skin carcinoma, Basal cell carcinoma (BCC) and Squamous cell carcinoma (SCC). BCC is a common, localized form of skin cancer that rarely metastasizes but is frequently diagnosed in Queensland populations (2). SCC often occurs on sun-exposed surfaces of the body, typically developing from pre-existing lesions including actinic keratosis (3,4). It is estimated that before the age of 70 two out of three Australians will be diagnosed with some form of skin cancer, making it a major health issue (5). In 2019, approximately 714 Australians died from KC including BCC and SCC (6). While the annual mortality rate in Australia attributable to KC is lower than the annual number of deaths due to CM (1726 in 2019 (6)), the prevalence of KC is notably higher. The higher incidence of KC contributes to increased treatment costs with patients often developing more than one KC in their lifetime (7). Australian incidence estimates derived from population surveys in 2002 indicate that 884 per 100 000 develop a BCC with 387 per 100 000 developing an SCC annually (5).

The major cause of all forms of skin cancer is over-exposure to ultraviolet radiation (UVR), primarily from the sun, with the risk of skin cancer rising in relation to the level of exposure. However, there are several confounding phenotypical factors that can influence personal skin cancer risks, these include fair skin color/complexion, the number of pigmented moles and genetic predisposition (8,9). Of all these factors, the time spent outdoors is the primary contributor to lifetime UVR exposure (9). For most people, UVR exposure levels vary between 5% to 15% of available ambient UVR with this fraction increasing to 20% - 30% for outdoor workers (1). Subsequently, there is strong evidence linking outdoor occupational UVR exposure and skin cancer incidence (10,11,12).

For those residents living and working in areas of high ambient UVR, such as Queensland, intermittent exposures cannot be discounted in regards to contributing toward the lifetime risk of skin cancer (13,14,15,16). School teachers spend the majority of their working day indoors but are required to spend extended and intermittent periods of time outdoors including playground and bus supervision duties that often coincide with daily peak UVR irradiance. Downs et al. (17) recently determined that exposures exceeding 30 minutes between 11.00 am and 2.00 pm can account for approximately 30% of Queensland teachers exceeding daily occupational radiant exposure limits defined by the Australian Radiation and Nuclear Safety Authority (18,19). For more than 100 000 registered teachers in Queensland (20), this is concerning as there are high levels of UVR throughout the year.

Working populations are populations that exhibit exposure behaviors that can be controlled at a group level rather than by individual choice. Playground and supervision duties of school teachers are defined by employers and can, therefore, be scheduled to significantly influence lifetime exposure to UVR and consequently personal skin cancer risk. A state wide survey of school opening, closing and meal break times for Queensland, Australia has not yet been presented in the literature, nor has personal skin cancer risk caused by the contribution of school teacher duty schedule outdoors been considered across such a large sample. Teacher duty schedule contributes to personal skin cancer risk and is an important factor that can be controlled by government and independent school administrative authorities. This work is the first to consider the influence of school duty schedule state wide in a large population covering a wide geographical range. The objective of this research is to derive the relative KC risks of typical Queensland school teachers that can be attributed to measured variations in school opening, closing and meal break times.

1.1 Study Outline

The development of the solar UVR model used to derive local ambient UVR exposure for each day of the year and for each latitude and longitude of every school in Queensland is first described. This is followed by the derivation of personal annual UVR exposure estimates expected to be received by a typical school teacher placed on outdoor playground duty during each of the 40 school teaching weeks of the year.

Solar UVR exposure due to outdoor supervision duty and lifetime day-to-day casual outdoor exposure received on weekend or recreational days are applied to derive BCC and SCC risk assessments applicable to the Queensland teaching workforce. Comparisons of KC risk are made for teachers working within all 1578 schools across the state and within schools located within each of the state's seven administrative education regions. Derived skin cancer risks show the very high potential reduction in overall skin cancer burden that can be achieved per region and state wide by considering the variations that already exist in surveyed school opening, closing and meal break times.

2.0 MATERIALS AND METHODS

2.1. Basal & Squamous Cell Carcinoma Risk

Both BCC and SCC are prevalent forms of head and neck cancer associated with past exposure history to solar UVR (21). The risk of developing either SCC or BCC increases exponentially with total exposure to solar UVR and age. Schothorst et al. (22) established the risk of developing BCC or SCC according to the following equation,

$$Risk \propto kD^{\beta}(Age)^{\alpha} \qquad (1)$$

where, k is a factor used to represent genetic susceptibility, D represents total UVR exposure and the exponent β represents the biological amplification factors for either BCC or SCC, while $(Age)^{\alpha}$ explains the dependence of cumulative risk with increasing age. BCC has a higher incidence in worldwide populations compared to SCC, therefore β is higher when deriving BCC risk compared with SCC according to Equation 1. In this research, the Biological amplification factors for BCC and SCC were applied according to Schothorst et al. (22). These were 2.5 and 1.4 for BCC and SCC respectively and are based on skin cancer rates reported by the United Nations Environment Program (23).

Wong et al. (24) first applied Equation 1 to establish the relative risk of developing a facial KC. In their derivation, the relative risk was established by comparing the total UV exposure at a given facial site of interest for an individual wearing a hat, *D* compared to the total site exposure derived without protection, D_0. BCC and SCC risk can, therefore, be derived and is dependent on the relative total UV exposures for both the protected and unprotected exposure cases according to Equation 2:

$$Relative\ Risk = \frac{kD_0^{\beta}(Age)^{\alpha}}{kD^{\beta}(Age)^{\alpha}}, \qquad (2)$$

which becomes

$$Relative\ Risk = \left(\frac{D_0}{D}\right)^{\beta}, \qquad (3)$$

whereupon the factors *k* and $(Age)^{\alpha}$ are eliminated provided relative risk comparisons are made between groups of the same age and genetic susceptibility. Relative KC risk has been derived using this method by comparing relative exposure differences between population groups. This has included relative risk comparisons between sporting groups (25,26), and groups employed in different occupations (27). In this research, Equation 3 is used to derive the relative BCC and SCC risk of working teachers where D_0 represents the total annual UVR exposure of a teacher placed in one school compared with the annual UVR exposure of a teacher working in another, *D*.

2.2. Annual UVR exposure

Annual UVR exposures are chosen as the minimum interval of time over which an exposure, accumulated during a lifetime of work and recreation, may be repeated. Therefore the annual interval takes into account changes in exposure due to seasonal UVR between summer and winter, variation in playground duty schedule between teaching semesters and periods of expected vacation time occurring during the year. For the method employed here, annual UVR exposures were weighted to the erythema action spectrum (28). Erythemally weighted annual UVR exposures are biologically effective and are presented here in units of Standard Erythema Dose (SED), where 1 SED is the equivalent of 100 J m^{-2} erythemally effective UVR exposure (29). When comparing a typical teacher, who spends the same total amount of time and exposes themselves to sunlight during the same time of year while on vacation and during recreational weekend days, the relative risk of developing a BCC or SCC depends on the total time and duration of exposure to solar UVR while at work.

In Queensland, the school year is divided into four teaching terms. Annually, these terms run for 10 weeks, each separated by two week periods of vacation leave except for term 4. At the end of term 4 school teachers go on extended summer vacation for a period of six weeks, with the first two weeks of summer vacation being taken in December and the remaining four in January of the following year. Figure 1 illustrates the breakdown of the 2019 Queensland school teaching year.

FIGURE 1

The 2019 school year was used to model periods of annual teaching and vacation for Queensland schools. The time spent outdoors during the year depends on the number of vacation, weekend and workdays and may be expressed by Equation 4,

$$t_{TOTAL} = \sum_{i=1}^{63} t_{vac}(i) + \sum_{i=1}^{104} t_{wend}(i) + \sum_{i=1}^{198} t_{work}(i). \qquad (4)$$

In Equation 4, $tvac$ represents the time spent on each of the 63 days of the year on vacation, $twend$ the time spent during each of the 104 days outside during weekends (Saturdays and Sundays) and $twork$, the time spent outside on each of the 198 teaching days of the year. In determining the total time spent outside during the year, a total of one hour per weekend and vacation day was assumed. This time is based on the probability distribution of population exposure habits most likely to occur for indoor workers during winter weekend days defined by Diffey (30). Here, a winter weekend exposure of one-hour duration was chosen for every weekend and vacation day of 2019. This approach assumes Queenslanders who live in a tropical to sub-tropical climate experience less perceived variation in temperature compared with population groups located in higher latitudes, and therefore are more likely to maintain consistent exposure habits throughout the calendar year. The single hour spent outside during *twend* and *tvac* was set to occur between 11:30 am and 12:30 pm. This time corresponds typically with peak noon-time solar UV irradiance and was chosen as a conservative estimate of the weekend and vacation exposure range that may be experienced by any given individual. There is a clear limitation in making the assumption that a typical teacher spends one hour outdoors between 11:30 am 12:30 pm on each vacation and weekend day of the year, given not all individuals will spend this time outside in a single block. Weekend exposures are also likely to occur intermittently at different times of the day. If some weekend exposure is not included then the relative risk due to school exposure will be overestimated. One hour exposure near midday on weekends is chosen as including a potential over-estimation of weekend exposure leads to a more conservative estimate of the contribution of school time exposure to relative risk estimated by this model. Calculations of exposure risk due to sunlight exposure at work are therefore more likely to be conservative and would be higher for teachers who spend considerably less time outdoors while on weekend or vacation. For the developed risk assessment model, all teachers are assumed to behave in the same fashion when not at work in order to derive UVR exposure differences based only upon controlled variations in school supervision schedules.

The time a teacher spends outside while at work was calculated differently. Teachers in Queensland are expected to supervise children outside during meal breaks, sports and swimming carnivals and during student pick-up and drop-off times. All of these scheduled periods contribute to the total time a teacher will be exposed to solar radiation throughout the year. To model each outdoor contribution to a teacher's annual exposure time, four separate terms were used and applied consistently for each Queensland school. Total time spent outside assumed a teacher spent 10 minutes outdoors when arriving at work, *tbefore* (Monday to Friday), 10 minutes when leaving work, *tafter* (Monday to Thursday), 30 minutes supervising students during a scheduled weekly meal break, *tbreak1* (Tuesday mornings), another 30 minutes supervising students during a second weekly meal break, *tbreak2* (Thursday afternoons), and 30 minutes per week supervising after school bus pick-ups, *tbus*

(Friday afternoon). This corresponds to a total outdoor exposure of 90 minutes (1.5 hours) weekly due to direct supervision of students during meal breaks and bus duty (approximately equivalent to weekly supervision guidelines of the Queensland Teachers' Union (20)). Another 90 minutes (1.5 hours) incidental exposure is taken to occur due to school arrival (five days per week) and departure (four days per week, excluding scheduled bus duty Fridays). The total time spent outside while at work is expressed by Equation 5:

$$\sum_{i=1}^{198} t_{work}(i) = \sum_{i=1}^{198} t_{before}(i) + \sum_{i=1}^{40} t_{break1}(i) + \sum_{i=1}^{40} t_{break2}(i) + \sum_{i=1}^{40} t_{bus}(i) + \sum_{i=1}^{158} t_{after}(i). \qquad (5)$$

The exposure model assumes a total annual outdoor exposure of 286 hours, of which 63 hrs (22%) are spent outside during vacation, 104 hours (36%) are spent outside on weekend days and 119 hours (42%) are caused by exposure to UVR while at work, including playground supervision, bus duty and incidental before and after work exposure periods.

2.3. Occupational Exposure Schedule

Any exposure that occurs at work is dependent on scheduled school opening and closing time and the time of each scheduled school meal break. Most schools in Queensland begin teaching at 9:00 am and close at 3:00 pm for each working day of the four term annual school year. Most Queensland schools schedule two meal breaks per day totaling approximately 1.5 hours daily. In deriving the annual UVR exposure of a teacher scheduled to supervise two meal breaks and one bus duty per week, school opening, closing, and meal break times were surveyed for all 1578 Queensland schools that hold two breaks daily from each of the seven local education districts (Figure 2). A total of 196 of 1774 Queensland schools were excluded from this survey because these schools did not run regular weekly teaching or break schedules, or offered remote or flexible teaching programs.

Each typical school teacher's outdoor exposure was modeled according to a total exposure of 3 hours per week due to direct supervision and incidental exposure before and after school, however the timing of each of these exposure periods within the week was based on actual school start, finish and meal break times. Surveyed schools included government state primary schools (years prep to 6 (seven years in total)), state high schools (years 7 to 12), combined state schools (years prep to 12 (thirteen years in total)), and independently funded primary, high and combined schools. Weekly UVR exposures were then determined for each working, vacation and weekend day at the site of each Queensland school and summed over the entire year according to Equation 4. For the working days (Equation 5), *tbefore* represents the time outdoors beginning 10 minutes prior to each surveyed school's opening time for every working day in the week. The period, *tbreak1* represents the 30 minutes beginning every Tuesday for each school's first daily meal break. The period, *tbreak2* is the 30 minutes immediately before the scheduled end of each school's second meal break occurring on a Thursday. The weekly period, *tbus* represents the 30 minutes beginning every Friday at each school's surveyed closing time. Finally, *tafter* represents the 10 mins beginning on each working day of the week from the surveyed school closing time (except bus duty Fridays). The teacher exposure model is therefore based on daily intermittent before and after school UVR exposures, and a supervision schedule which requires playground/bus supervision on Tuesdays, Thursdays and Fridays for each of the 40 teaching weeks in the year.

FIGURE 2

2.4. Ambient UVR exposure

Teachers from different Queensland schools will experience variations in modelled annual UVR exposure due to differences in school playground duty schedule and differences in geographic latitude and longitude. To account for annual UVR exposure differences due to school location, the erythemally weighted solar UV irradiance incident on a horizontal plane was calculated for every minute of the year 2019 for the known latitude and longitude of each primary, high and combined school in the state of Queensland.

Erythemally weighted UV irradiance was modelled according to algorithms presented by Green et al. (31); Schippnick and Green (32) and the respective modifications recommended by Rundel (33). These calculations were performed for annual variations in local solar elevation and azimuth derived for each minute in the year (34) according to respective school latitude and longitude. The horizontal plane UV irradiance was derived at each one-minute step under a cloud-free atmosphere, total column ozone concentration of 320 Dobson Units, and Aerosol Optical Depth 0.4. The integral of the weighted ambient erythemally effective solar UV irradiance was evaluated in this study over every minute of the year during which a teacher's schedule would place them outdoors (28,35). The total annual erythemally effective UVR exposure, D calculated for periods of outdoor activity is derived according to Equation 6,

$$D(m)[SED] = 0.3\left(\int_{m=1}^{t_{vac}} E_{vac}(m) + \int_{m=1}^{t_{wend}} E_{wend}(m) + \int_{m=1}^{t_{work}} E_{work}(m)\right)/100, \quad (6)$$

where $Evac$, $Ewend$ and $Ework$ represent the erythemally effective UV irradiance [Wm^{-2}] to be evaluated as integrals over each minute long exposure interval, m a teacher is outdoors during respective vacation, weekend and work periods, $tvac$, $twend$ and $twork$. From Equation 6, teachers in every Queensland school are assumed to develop an annual facial exposure expressed in SED over 268 hours with differences in exposure being due to school duty schedule and school location. Given most BCCs and SCCs occur on the head and neck, the integrated annual exposure derived for a horizontal plane was also multiplied by a facial weighting factor of 0.3. This factor represents the approximate fraction of UVR that reaches an unprotected human face with respect to the UVR incident upon a horizontal plane at solar noon (36).

3.0 RESULTS

Each state education district is defined by the state education department according to local administrative boundaries (37). These include schools in Far North Queensland (FNQ), North Queensland (NQ), Central Queensland (CQ), North Coast (NC), Darling Downs and South West (DDSW), Metropolitan (MET) and South East Queensland (SE) (Figure 2). Table 1 shows the daily average available ambient UVR received under cloud-free conditions upon a horizontal plane modelled for regional centers located within each state education district. Most Queensland schools are located in Metropolitan Brisbane (22.3%). FNQ, NQ, CQ, NC, DDSW and SE districts consisted of 8.1%, 8.5%, 14.4%, 17.0%, 15.7% and 14.0% of surveyed schools respectively.

TABLE 1

The distribution of schools within education districts (Figure 2) provide a general representation of state population densities. The MET education district is the smallest by land area but includes all state education catchments within the capital city of Brisbane. Similarly, the SE education district encompasses a small area but includes schools that service the high population density of the state's south-eastern corner, including its most southerly population center of the Gold Coast. The NC region is situated around the Sunshine Coast and Wide Bay districts and includes several high population density centers located between 100 and 400 km north of Brisbane. These three state education regions do not cover a wide geographic latitude and longitude and contrast with the very large state education regions of CQ, DDSW, NQ and FNQ. The largest of these regions, CQ extends along the Tropic of Capricorn from Pacific coastal districts to the state's western border, a region covering greater than 13° in longitude. FNQ, the state's furtherest northern education district is smaller in area then CQ and NQ but includes schools at the lowest tropical latitudes included in the statewide survey. The FNQ region includes schools located on Cape York Peninsula and Thursday Island, Torres Strait (10.6°S, 142.2°E).

Irrespective of region, all surveyed schools were found to begin the teaching day between 8:00 am and 9:30 am and close between 2:20 pm and 3:30 pm daily. A much wider variation in the two school meal break times was observed, however the highest proportion of schools were found to be on break at 11:00 am and 1:30 pm daily. These times represent the time of day when most Queensland schools were on their first and second breaks respectively.

3.1 UVR exposures and relative risk comparisons

The variation in annual statewide erythemally effective facial UVR exposure is presented in Figure 3 by education region. Teachers working in schools and conducting supervision duties within the FNQ region received the highest statewide annual maximum of 748 SED. The figure shows a general downward trend in annual exposure with increasing regional latitude. The FNQ regional school minimum exposure of 630 SED was greater than the maximum annual exposure received in the SE Queensland region of 611 SED. The mean annual facial exposure for teachers working in FNQ, NQ, and CQ education regions were higher than the maximum annual exposure derived for the DDSW, MET, and SE regions. Teachers working at schools in SE Queensland received the lowest statewide annual minimum of 528 SED. This resulted in a statewide annual exposure range (when compared to the maximum in FNQ) of 220 SED based on school location and playground duty schedule.

FIGURE 3

Figure 3 shows that the further south the education region is the lower the levels of annual UVR facial exposure for a teacher working in that region. The median facial exposure level for teachers working in the DDSW, MET, and SE education districts are lower than the minimum for the FNQ, NQ, and CQ regions. The median and the mean for annual facial UVR exposure are similar for each of the education regions (Figure 3). The estimates of annual facial exposure for all regions appear to be normally distributed. There were outliers (90th percentile or above) for the maximum UVR exposure levels for FNQ, CQ, NC, MET and SE education regions. There were also outliers for the calculation of minimum facial exposure levels (10th percentile or below) for the NC, MET, and SE education regions. The outliers for the maximum UVR exposure levels are of concern as the exposure levels received by a teacher at those schools is much greater than those received at other schools in the same education district. Relative risk assessments of BCC and SCC between teachers at each school located within each of the seven state education districts based on maximum and minimum district annual UVR exposures are summarized in Table 2. The distribution of BCC and SCC risk, derived with respect to comparisons of each school within a region to the school with the lowest annual district UVR exposure in that region, are presented in Figure 4.

FIGURE 4

The range in relative BCC and SCC risk varies from between 1.63 and 2.39 respectively when comparing the maximum annual exposure of 748 SED in FNQ against the lowest statewide annual exposure of 528 SED for SE Queensland. Similar comparisons made between the state maximum exposure of 748 SED for FNQ with respect to the maximum exposure received of 611 SED in the SE region show that the relative risk of developing BCC falls to 1.33, and 1.66 for SCC. Similarly, when comparing the highest minimum exposure received of 630 SED in FNQ against the lowest minimum exposure received in the SE region of 528 SED, the relative risk falls further to 1.28 and 1.56 for BCC and SCC respectively. However, BCC and SCC risks compared to regional minimum exposures show a much more consistent trend. All state education regions displayed an elevated median risk approximately 10% higher for BCC and 20% higher for SCC than expected for teachers working in schools that received district minimum UVR exposures (Figure 4).

Intra-regional exposures in FNQ, NQ, CQ, DDSW, and MET Brisbane (27.5°S, 153.0°E) were more consistent compared to the NC and SE education districts, resulting in regional UVR exposure differences of approximately 100 SED. The risk of both BCC and SCC was highest within the NC district and lowest in SE Queensland (Figure 4), corresponding to the regions with the greatest and least variation in annual UVR exposure. For the NC district, the highest intra-regional relative risk for BCC was 1.32 and 1.64 for SCC. The relative risk of developing a facial site SCC was always higher than BCC across all regions. Table 2 shows that regardless of region there existed a 19% and 36% minimum range in relative risk of developing BCC and SCC respectively. These calculations, based upon differences in annual UVR exposure caused by school location, opening and closing time and playground duty supervision show there is some scope for minimizing KC risk across each education region.

TABLE 2

3.1.1 North Coast and Far North Queensland

Despite the wide range in local school latitudes possible across the state of Queensland resulting in a statewide range in annual facial exposure of up to 220 SED, each of the seven education districts experienced considerable spread in exposure between schools based upon scheduled opening, closing and meal break times. Of all state education districts, the regional range in annual exposure varied the most for the NC region between schools situated within 360 km of each other inside a comparatively narrow geographically defined range. This exposure range was followed closely by schools located in FNQ (range - 118 SED). For the NC region, the highest annual exposure was 669 SED (Agnes Water, 24.2°S, 151.9°E) with the lowest regional exposure being 549 SED (Redcliffe, 27.2°S, 153.0°E). Between these two schools, which both commenced at 8:30 am daily and started break 1 at 10:30 am, the school in Agnes Water ran an earlier second meal break commencing at 12:30 pm and finishing at 1:30 pm. This compares with the school at Redcliffe, which began the second meal break of the day at 1:00 pm which ended at 1:40 pm. Significantly, the school at Agnes Water closed at 2:30 pm daily. The early school closing time potentially influenced weekly teacher bus duty exposures at Agnes Water, resulting in a higher annual exposure compared with the school at Redcliffe which closed daily at 3:00 pm.

Differences in meal break schedule also affected the state's second highest regional school exposure variation occurring in FNQ between the maximum at Silkwood (17.7°S, 146.0°E) and the regional minimum occurring at Wangetti (16.7°S, 145.6°E). Here again the school at Wangetti (630 SED) commenced both meal breaks at a later local time and closed for the day after the school at Silkwood (748 SED) located approximately 100 km further south. The annual exposure difference of 118 SED was caused by the first meal break at Wangetti starting at 11:15 am, compared to 10:30 am at Silkwood, the second meal break commencing at 1:45 pm in Wangetti compared to

12:30 pm in Silkwood and the school day ending at 3:30 pm in Wangetti compared to 3:00 pm in Silkwood.

3.1.2 South East Queensland

The least variation in intra-regional education district exposure occurred for SE Queensland. The statewide minimum in the region of 528 SED occurred in a school located in Southport (28.0°S, 153.4°E). Regional UVR exposures to working teachers increased within this education district by as much as 83 SED, reaching a maximum of 611 SED for a school located 35 km north of Southport at Eagleby (27.7°S, 153.2°E). This difference in annual exposure is here again due to differences in playground duty schedule and school closing time. In this case, both schools commenced second breaks at 1:00 pm but ran different first break periods, with the school at Eagleby beginning break 2 at 10:45 am compared to Southport which commenced at 10:25 am. The school at Eagleby also finished school at 2:45 pm compared with the school at Southport which finished over an hour later at 3:30 pm daily.

3.1.3 Metropolitan Brisbane

For schools located in education districts spread over a wide geographical range the risk of developing either a BCC or SCC is dependent on both local latitude and school opening, closing and break schedule. For schools located in more densely populated education districts the influence of school opening, closing and break schedule becomes the more important factor. Given the small size of the region, the increase in risk of 23% of developing BCC and 44% for SCC across schools located in the MET Brisbane region is significant. Here, the range in annual UVR for teachers located in MET Brisbane varied from 530 SED (Woodridge, 27.6°S, 153.1°E) to 614 SED (Coorparoo, 27.5°S, 153.1°E). The MET schools which recorded these exposures are separated by only 13 km but experience differences in starting time, closing time and both meal breaks. The school which recorded the minimum annual UVR exposure in MET Brisbane located within the suburb of Woodridge started at 8:20 am, began their first break at 10:00 am, began their second break at 1:00 pm and concluded the school day at 3:05 pm. Teachers working at the school with the highest MET annual UVR exposure in the Brisbane suburb of Coorparoo start their day at 9:30 am, begin their first break at 11:00 am, commence their second break at 12:30 pm and conclude the school day at 2:00 pm.

3.1.4 North Queensland, Central Queensland and Darling Downs & South West

For NQ, the lowest annual UVR exposure of 612 SED occurred at a school located in Cloncurry (20.7°S, 140.5°E). This school opens at 8:25 am, runs its first break from 11:00 am to 11:40 am, its second break from 1:40 pm to 2:00 pm and closes at 2:50 pm. In CQ the lowest annual UVR exposure of 582 SED occurred in Gayndah (25.6°S, 151.6°E). This school commenced at 8:40 am, ran its first meal break between 10:40 am and 11:25 am, its second meal break between 1:25 pm and 1:45 pm and closed daily at 3:00 pm. For the DDSW region, the school with the lowest annual UVR exposure of 539 SED was located in Plainland (27.6°S, 152.4°E). This school commenced at 8:25 am, ran break 1 between 10:50 am and 11:10 am, ran break 2 between 1:10 pm and 1:50 pm and closed at 3:10 pm. For each of these three schools the separation between the start of the first break to the start of the second meal break was 2 hours 40 minutes (NQ), 2 hours 45 minutes (CQ), and 2 hours 20 minutes (DDSW). When the time between these breaks was shorter, teachers received higher annual UVR exposures. The schools that resulted in the highest annual teacher exposures in NQ (Townsville 19.3ºS 146.8ºE), CQ (Mackay 21.1ºS 149.2ºE) and DDSW (Kogan 27.0ºS 150.8ºE) had meal break separation times of 2 hours, 1 hour 55 minutes and 2 hours respectively.

4.0 DISCUSSION

Skin cancer risk reduction strategies applied throughout Australia and Queensland place significant focus on primary prevention. The Victoria Cancer council's 'Slip Slop Slap!' and later 'SunSmart' campaign of the 1980s, originally developed for the south-eastern Australian state of Victoria has been adopted and run successfully nation wide for over 30 years. It has been estimated that 28 000 Disability Adjusted

Life Years (DALYS) have been saved in Victoria alone as a result of this program (38). When introduced initially, the Sun Smart program focused on personal use of protective clothing, encouraging the use of hats and promoting regular use of sunscreens. The message seems to have only been revised recently in 2007 to also encourage active use of sunglasses for eye protection and consideration of personal behavior by seeking shade wherever possible (39). Yet sun exposure avoidance, particularly during peak UVR irradiance periods around solar noon remains as the most significant sun protective behavior because avoidance prevents unnecessary UVR exposure before any protective clothing, hats and sunscreens are applied (40,41,42). Unfortunately, sunscreen use in particular is often reported as the most frequent and only form of sun protection adopted by Australian populations (43).

In schools across Australia much focus continues to be placed upon the use of hats and protective clothing worn by school children (44,45,46). The outcome from this research on teacher duty schedule indicates that KC risk varies significantly throughout the state. School policies that include provision for amendment to timetables to avoid peak UV exposure periods can also reduce the statewide burden of skin cancer. It is accepted that multifaceted education programs, including policies that encourage a variety of approaches to UVR exposure prevention in schools and the workplace can make a difference in changing attitudes to sun-protection and have a major impact on long-term health outcomes (47,48,49,50). Sun protection strategies aimed at preventing skin cancer have been shown to be most effective when implemented in primary schools (41). As role models, teachers working in Queensland primary, secondary and combined schools may also be able to positively influence attitudes inside whole school populations to reduce nationally high rates of KC and CM which can vary widely within Australian populations (51). Parisi and Kimlin (52) showed previously that there is potential to reduce UVR exposures in a school setting by consideration of different meal break times for school children. In this research, a new approach, focusing on UVR exposure avoidance was examined across all seven contiguous education districts in the state of Queensland, Australia. Variations in BCC and SCC risk were shown to be dependent on school location and surveyed opening, closing and meal break schedules.

Sun exposure among working teachers can vary considerably throughout the day

(27,53). The analysis of BCC and SCC risk conducted within each state education region for a model teacher scheduled to supervise children during weekly bus and meal break duties has given some insight into the potential skin cancer risk reductions that can be achieved through thoughtful timetabling. Across the state, the maximum difference in annual UVR exposure between a teacher working a fixed schedule and experiencing regular periods of exposure during weekend and vacation days was 220 SED. This was observed as the difference in annual exposure between schools located in FNQ and SE Queensland. When looking at the difference in estimated UVR exposure levels for the state education regions and the similarities in when breaks are being held at around 11:00 am and 1:30 pm daily, having different break times for specific education regions would likely be of benefit in lowering annual levels of UVR exposure for teachers required to conduct playground supervision. It was observed across all regions that the SCC risk of Queensland teachers is much higher than that of developing BCC. This is expected because the risk of developing SCC shows greater dependence on the cumulative amount of time spent in the sun compared to BCC (54,55). Unsurprisingly, skin cancer risk, and in particular SCC is often higher in occupations of outdoor workers (56). Zink et al. (57) recently confirmed higher rates of incidence in gardeners, mountain guides and farmers compared with rates among indoor workers. However many workers still do not regularly consider the occupational risk of developing a skin cancer (58).

Importantly, the most significant risk factor for the development of KC is exposure to UVR. In this study, the range in exposure evaluated with respect to each education district in Queensland was about half the state's maximum range of 220 SED varying from 120 SED in the NC region to 83 SED across schools located within the SE district of the state. Teacher exposures modelled according to surveyed school schedule tended to be minimized when the school day ended late in the afternoon or the difference in meal break timing was high. This difference spread the likelihood of a working teacher not being on duty during peak solar noon periods. This was most notable for the highest school density region of the state with schools located in the Brisbane MET district. Here, the school with the lowest annual UVR exposure ran breaks from 10:00 am to 10:20 am and from 1:00 pm to 1:35 pm. The first break in this case starts 3 hours before the second. When examined over the full calendar year, the chance of a working teacher being outdoors during the midday peak will be less in a school with a greater difference in meal break times than for a school in which the difference in break times is less. Teachers working in schools that received minimum district exposures located in FNQ, CQ, NC, DDSW and SE also displayed this trend where the difference between first and second meal breaks was 2 hours 30 minutes, 2 hours 45 minutes, 2 hour 30 minutes, 2 hours 20 minutes, and 2 hours 40 minutes respectively. This compares with the same school districts that recorded the highest annual UVR exposures from FNQ, CQ, NC, DDSW and SE in which the recorded meal break separations were only 2 hours, 1 hour 55 minutes, 2 hours, 2 hours 15 minutes, and 2 hours 15 minutes respectively.

For schools located in the western regions of the state, starting later in the day and beginning meal breaks later in the day is likely to effect a reduction in total annual UVR exposure. For NQ, the lowest annual UVR exposure of 612 SED was recorded for a school located in western Queensland at Cloncurry (20.7°S, 140.5° E). This school started the day at 8:25 am, however the first meal break began at 11:00 am, with the second meal break beginning at 1:40 pm. The school closed at 2:50 pm, however the first break period beginning later in the day is likely to have resulted in avoidance of the peak solar noon UVR irradiance period for most of the year due to the school's western longitude. This seems reasonable as the NQ school with the maximum UVR exposure (693 SED) was located on the east coast in Townsville (19.3°S, 146.8°E) and had a school opening time of 8:45 am and the same starting time for break 1 at 11:00 am, followed by a break 2 time beginning at 1:00 pm before closing daily at 2:45 pm.

Gordon et al. (7) recently demonstrated the potential for a significant cost benefit in reducing KC incidence among Queenslanders. Gordon et al. (7) found that the median patient treatment cost for KC is $2126. Reductions in incidence due to school timetabling adjustments may therefore have significant long-term cost benefits. Occupational skin cancers are often underreported in Australia and elsewhere (59). Preventive measures play a significant role in reducing the potential cancer burden. It has been shown previously that well developed education campaigns can return cost savings at least greater than $2 per $1 spent on skin cancer prevention (38,60). Although this research has specifically examined the potential KC risk to working school teachers, students placed in an open environment during every scheduled break time will receive much higher annual UVR exposures that those listed for our typical teachers who were outside on duty for no more than 1.5 hours weekly. This is an avenue for future research.

5.0 ACKNOWLEDGEMENTS

The authors would like to acknowledge the collaborative support of the University of Southern Queensland and James Cook University.

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7.0 FIGURES

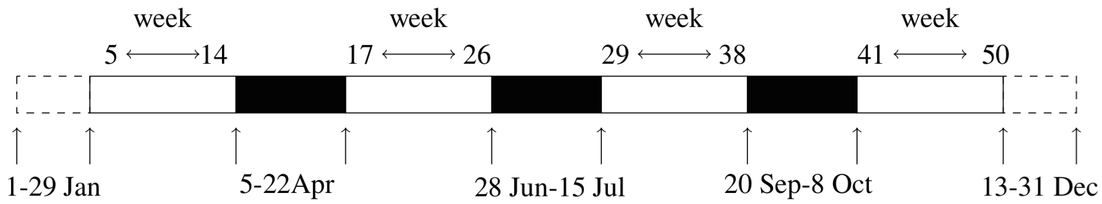

Figure 1: Periods of Queensland school summer vacation (dashed outline), mid-term vacation (black) and teaching terms (white) for the 2019 calendar year.

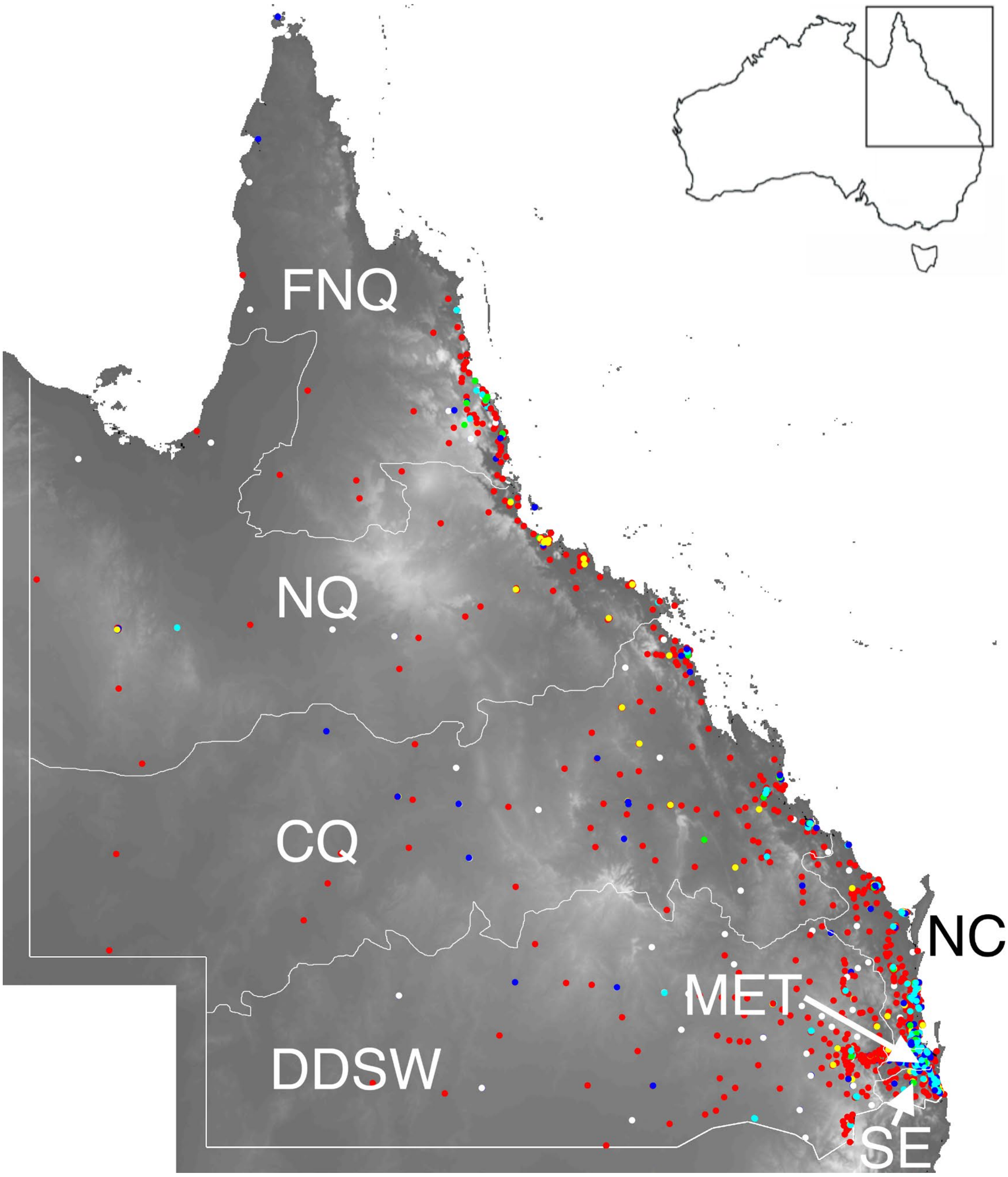

Figure 2: Location of 1578 schools surveyed with respect to Queensland education districts. (School classifications: Red - state primary, yellow - state high, white - combined state, blue - independent primary, green - independent high, cyan - independent combined). Map inset, the state of Queensland (29° to 10°S, 138° to 154° E) shown with respect the Australian continent, geographic North is at the top.

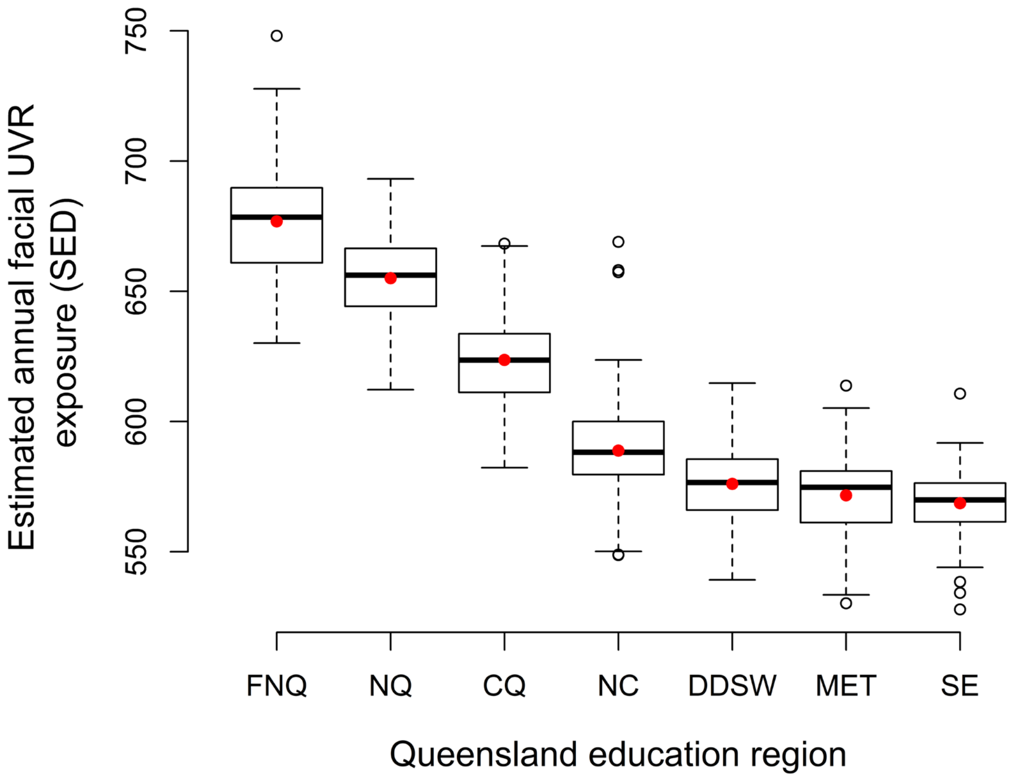

Figure 3: Variation in annual facial UVR exposure for Queensland schools in each state education region. Red circles - regional mean exposure, solid line - median, box - quartile 1 and quartile 3, lines - 10th percentile and 90th percentile, open circles - single school exposures outside 10th and 90th percentiles.

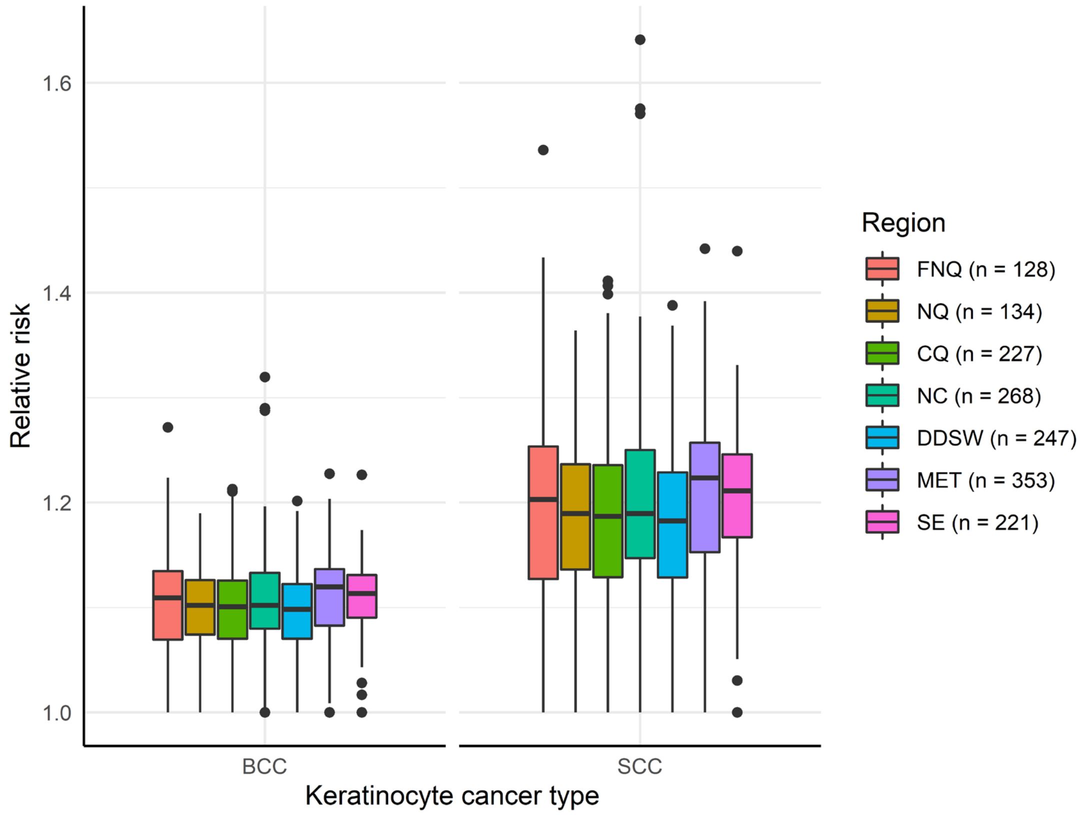

Figure 4: Distribution of relative basal cell carcinoma risk (BCC) and squamous cell carcinoma risk (SCC) by state education region. Solid line - median, box - quartile 1 and quartile 3, lines - 10th percentile and 90th percentile, circles - single school relative risk outside 10th and 90th percentiles.

8.0 TABLES

Table 1: Daily average ambient ultraviolet exposure modelled under cloud-free conditions for major regional centers located within each of the seven education districts of Queensland (Region abbreviations described in text).

		Average daily UVR exposure (SED)											
Region	City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
FNQ	Cairns (16.9°S,145.8°E)	64.9	63.1	55.2	42.5	31.0	25.6	27.8	37.1	49.8	60.1	64.5	65.2
NQ	Townsville (19.3S,146.8°E)	65.8	62.8	53.5	39.9	28.1	22.8	25.0	34.4	47.6	59.2	65.0	66.4
CQ	Mackay (21.1°S, 149.2°E)	66.3	62.4	52.0	37.7	25.9	20.6	22.8	32.1	45.8	58.3	65.2	67.2
NC	Caloundra (26.8°S, 153.1°E)	66.6	60.0	46.7	31.0	19.4	14.6	16.6	25.4	39.7	54.7	64.7	68.4
DDSW	Toowoomba (27.6°S,152.0°E)	66.5	59.5	45.9	30.0	18.5	13.8	15.8	24.5	38.8	54.1	64.5	68.5
MET	Brisbane (27.5°S, 153.0°E)	66.5	59.6	46.0	30.2	18.7	14.0	15.9	24.6	37.7	54.2	64.6	68.5
SE	Gold Coast (28.1°S,153.5°E)	66.4	59.2	45.3	29.4	18.0	13.3	15.2	23.9	38.2	53.6	64.4	68.5

Table 2: Maximum, minimum, and mean of estimated annual facial UVR exposure for schools in each of the seven Queensland education regions. Relative risk of BCC and SCC is calculated between the maximum and minimum annual exposure within each region (Region abbreviations described in text).

	Queensland Education region						
	FNQ n=128	NQ n = 34	CQ n = 227	NC n = 268	DDSW n = 247	MET n = 353	SE n = 221
Maximum annual exposure (SED)	748	693	668	669	615	614	611
Minimum annual exposure (SED)	630	612	583	549	539	539	528
Mean (± SD) annual exposure (SED)	677(19)	655 (15)	624 (18)	589 (17)	576 (14)	572 (13)	569 (12)
Relative Risk of BCC	1.27	1.19	1.21	1.32	1.20	1.23	1.23
Relative Risk of SCC	1.54	1.36	1.41	1.64	1.39	1.44	1.39