Paediatric Ocular Damage Related to Sunlight Exposure A Review of the Literature

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1 INTRODUCTION

It is well recognised that factors which individuals are exposed to during their childhood years can influence their lifelong health status. It is important that scientific literature be used to inform public health strategies to minimise this influence. The link to sunlight exposure and numerous health issues is well documented. The literature available on eye disease will now be presented, including the current understanding of the link between childhood sun exposure and lifelong damage to the eyes. Current prevention strategies and their success will also be discussed.

2 THE NATURE OF THE AUSTRALIAN POPULATION

The Australian population is increasing and also ageing. The Australian Bureau of Statistics (ABS) estimated Australian resident population (ERP) at June 2004 of 20.1 million people. It is projected that the ERP will increase to:

By 2051	24.9 – 33.4 million
By 2101	22.4 – 43.5 million

The ABS estimated by 2051 there will be a greater proportion of people aged 65 years and over than in 2004. There will also be a lower proportion of people aged under 15 years.

Health authorities are now questioning how to maintain healthy lifestyles into the later years and what factors impact on this. It is well known that older people suffer a relatively high incidence of eye disease such as cataract, glaucoma and age-related macular degeneration (ARMD). The issue of preventative strategies in childhood to reduce the incidence of eye problems later in life needs to be explored.

3 THE EYE AND ABSORPTION OF LIGHT

The Australian Radiation Protection and Nuclear Safety Agency (ARPNSA) released a fact sheet titled Sunglasses and Protection from Solar Ultraviolet Radiation (UVR). In describing the sun's radiation spectrum, sunlight is divided into ultraviolet – UVA (wavelength of 315-40 nanometre (nm)) which is the least damaging but has been linked to the development of skin cancers, UVB (wavelength of 280-315 nm) which has been implicated in causing damage to the eyes and skin & UVC (wavelength 100-280nm); visible light (wavelength of 400-700 nm): and infrared light (700 or greater nm).

According to ARPNSA seasonal fluctuations in UVR occur with summer midday having approximately three times higher UVR than winter midday; on some days it can increase to ten times the amount of harmful UVB. Daily fluctuations are also described with midday and 1pm in daylight saving periods often being the highest UVR periods. About 70% of UVB radiation occurs three hours either side of this time each day.

The source of UVR is divided almost evenly between the direct sunlight and the UVR scattered from the sky, “hence staying out of the direct sun does not eliminate the hazard and still means that both the skin and the eyes can suffer long term damage from scattered UVR” (ARPNSA).

Young and Sands(1998) provided an explanation of the absorption of ultraviolet radiation by the eye. They commented:

> “Much ultraviolet radiation reaching the eye is absorbed by its structures. In general, the cornea absorbs wavelengths below 300nm while the crystalline lens absorbs light below 400nm. Though the cornea’s absorption properties remain constant, the lens changes throughout our life. The lens of a young child transmits light at 300nm…while that of an older adult starts at 400nm. The retina and uvea absorb light between 400 and 1400nm” (p.477).

4 EYE DISEASE AND THE LINK TO SUNLIGHT

Young(1994) summarised the process by which sunlight damages the eye and the resulting common eye disease and commented:

> “The basic causes of all sunlight-related eye diseases are the same. In this sense, it is a single disease that may occur in different parts of the eye…all caused by the same factors: UV radiation in combination with oxygen and heat…In all of the sunlight-related eye diseases, damage to the native structure produced by radiation, oxidation and heat gradually accumulates, resulting in progressive deterioration. Ultimately a threshold is reached beyond which growth becomes abnormal or vision is impaired” (p. 126).

Young(1994) concluded that some eye diseases such as photokeratitis are acute and can occur after a few hours of sun exposure, but that the majority are chronic and occur after many years of sun exposure. These included pterygium, cataract, retinal ageing and degeneration such as age related macular degeneration and skin cancers such as basal cell carcinoma.

Young(1994) advocated prevention of sun related eye disease by “…simple, practical, safe and inexpensive means of using eyewear that absorbs the high-energy photons present in solar radiation” (p. 138).

Many eye conditions are known to be linked to sun exposure. The more common of these as indicated by Young(1994) will be outlined.

4.1 Pterygium

Wlodarczyk, Whyte, Cockrum and Taylor(2001) described pterygium as “a common problem in the Australian community. The wing-shaped, fibrovascular growths of conjunctiva extending onto the cornea have been found to affect 1.1% of the Australian population” (p. 370). The authors also listed the direct medical cost of pterygium in Australia in 2001 as AUD$8.3 million.

Moran and Hollows(1984) presented findings on the incidence of pterygium in 10 000 rural Australians, with a prevalence of 1.15% for non-Aboriginal and 3.45% for Aboriginal people. Threlfall and English(1999) listed "dust, wind, heat, infection, inflammation and sunlight" (p. 280) as possible causes. They concluded that "pterygium is strongly related to ocular sun exposure, with little evidence that exposure during any particular period of life is more important than in other periods" (p. 280). This statement was qualified by adding that this finding must be "…regarded with suspicion, as self-reported data concerning time spent outdoors in the first 5 years of life is likely to be unreliable in a historical study of adults" (p. 285). The authors concluded that "sun exposure at any time of life may be related to the development of pterygium" (p. 286) and thus "ocular protection is beneficial at all ages" (p.280).

4.2 Cataract

Cataract is described as opacification of the crystalline lens of the eye. It was a common finding in the Blue Mountains Eye Study, which was a study of an urban Australian population aged 49 years and older. Cataract was found to be "…the most frequent cause of mild bilateral visual impairment among persons aged 60+years" (Wang, Foran and Mitchell 2000, p. 268). Cataract was also noted to be the most common cause of unilateral vision impairment in the same group.

There is some dispute in the scientific literature regarding UVR exposure and the incidence of cataract. Lim, Mitchell and Cumming(1998) reported on the link between ultraviolet radiation and cataracts. The authors commented "our study findings…link ultraviolet radiation to cataract formation. However, the associations…were modest, which suggests that if exposure to ultraviolet light contributes to cataractogenesis, its role is probably small, and the overall process is likely to be multifactoral" (p.719).

Mukesh et al(2006) evaluated the risk factors for development of cataract in an Australian population, by recruitment of 3721 Victorian participants who were followed up within 5 years from the initial examination. The authors reported "…individuals with a laborer's occupation…were shown to have increased risk of developing cortical cataract" (p. 82), with the authors linking this to the outdoor nature of their work. The authors stated "sunlight exposure as a separate entity was not shown to be a significant risk factor for the development of any type of cataract in this study"
(p. 82), but further commented that this may have been influenced by "…the method used to calculate ocular sun exposure" (p. 84).

However, West, Duncan, Munoz and Rubin(1998) reported on a population based study in Salisbury, USA in which the amount of exposure and effects of UVB were studied. The authors concluded that "…a significant association between cortical opacities and annual UV-B exposure was found" (p. 717).

This occurred in a population who had suffered relatively lower UV-B exposure than other well known studies such as that by Taylor et al (1988) who examined watermen from the Chesapeake Bay area with high exposure to sunlight. Taylor et al(1998) also concluded there was an association between cataract formation and UV-B exposure in the Chesapeake waterman.

4.3 Age Related Macular Degeneration (ARMD)

Wang, Foran and Mitchell(2000) reported on the prevalence and cause of bilateral and unilateral visual impairment in the population examined in the Blue Mountains Eye Study. The authors found ARMD was the most common cause of bilateral blindness and moderate to severe vision impairment in people aged 70 years and over.

The possible link between UVR exposure and the incidence of ARMD was reported by Tomany et al(2004), as a component of the Beaver Dam Eye Study. The authors commented "…significant associations were found between exposure to the summer sun and the 10 year incidence of early ARM and increased retinal pigment" (p. 754). Tomany et al(2004) investigated the amount of sun exposure and the influence on the eyes, finding:

> "participants exposed to the summer sun for more than 5 hours a day during their teens, in their 30s, and at the baseline examination were at a higher risk of developing increased retinal pigment and early ARM by 10 years than those exposed less than 2 hours per day during the same period. In participants reporting the highest summer sun exposure levels in their teens and 30s, the use of hats and sunglasses at least half the time during the same periods was associated with a decreased risk of developing soft indistinct drusen and retinal pigment epithelial depigmentation" (p. 757).

4.4 Basal Cell Carcinoma (BCC)

Malhot, Huilgol, Huynh and Selva(2003) stated that BCC was the most common cancer in Australia and accounted for approximately 90% of all eyelid cancers, with "the incidence rates for BCC in parts of Australia among the highest rates of cancer ever reported in a defined population" (p. 624). The typical affected individual was elderly, having fair skin and a history of chronic sun exposure and skin damage.

Preston and Stern(1992) stated "exposure to sunlight is the principal cause of basal cell carcinoma" (p. 1649). The link between BCC and sun exposure was further discussed by Wong et al(2002). They found BCC was more likely to affect structures on the right side of the face due to increased sun exposure when driving in Australia.

4.5 Ultraviolet Fluorescent Photography to detect sun damage

Ooi et al(2006) reported on a study of 71 Australian children with an age range of 3 to 15 years who were examined using ultraviolet fluorescence photography (UVFP). The method was based on "…the established technique of UV fluorescence in the detection of dermatologic diseases resulting from UV exposure" (p. 295). The authors used the UVFP to demonstrate preclinical changes indicating UV related eye damage. The authors referred to work by Sandby-Moller, Thieden and Philipsen(2004) who reported UV radiation related skin changes which were found by skin fluorescence.

Of the 71 children studied 10% were found to have established pingueculae on standard photography; these children were all 13 years or older. 23% of the total studied showed increased fluorescence on UVFP, with 70% of these children only being detected using UVFP. Fluorescence was revealed by UVFP "…in children ages 9 years and above, with prevalence increasing with age" (p. 297).

Ooi et al (2006) commented that the cause of increased fluorescence may be attributable to other causes and "it is currently unknown how many children with detectable abnormalities on UV photography will progress to develop pingueculae or pterygium" (p. 297). However, they concluded "changes detected on UVFP may be the earliest indicator of UV changes in the body" (p. 298). The authors further advocated that UVFP could be used as a universal screening tool for children to indicate the "precursors of UV damage to the eyes" so that "parents will be able to clearly see a visual depiction of the damage that has already occurred to their child's eyes from sun exposure, and hence, with increased awareness and education, be more willing to take the steps required to prevent further damage from occurring" (p. 298).

5 STANDARDS FOR SUNGLASSES IN AUSTRALIA

ARPNSA stated that in 1971 Australia was the first country to introduce a national standard for sunglasses known as AS 1067.1:1990 titled "Sunglasses and Fashion Spectacles". In 2003 this standard was revised to classify sunglasses and fashion spectacles according to the amount of UVR they transmitted. Five categories of lenses were developed and it became mandatory for manufacturers to indicate to consumers through labeling which category the sunglasses belonged to. The categories included the following:

Lens category	Description
0	Fashion spectacles: not sunglasses -Very low sun-glare reduction -Some UV protection
1	Fashion spectacles: not sunglasses -Limited sun-glare reduction -Some UV protection
2	Sunglasses

Lens category	Description
	-Medium sun-glare reduction -Good UV protection
3	Sunglasses -High sun-glare reduction -Good UV protection
4	Sunglasses: special purpose -Very high sun-glare reduction -Good UV protection

(adapted from AS/NZS 1067:2003 by the Australian Cancer Council)
The Standards Australia amended requirements for sunglasses and fashion spectacles in 2004, were listed as Gazette No 170, dated 29/10/04. The following requirements must be met:

- Up to 30 March 2005 sunglasses and fashion spectacles must comply with either Australian Standard AS 1067.1 - 1990–*Sunglasses and fashion spectacles–Part 1: Safety requirements*, or AS/NZS 1067:2003 - *Sunglasses and fashion spectacles*.
- From 1 April 2005 sunglasses and fashion spectacles must comply with AS/NZS 1067:2003
- Toy sunglasses must also be clearly and legibly labeled as toys and meet all of the requirements of the mandatory standard.

6 PREVENTION OF SUN RELATED PAEDIATRIC EYE DISEASE BY WEARING SUNGLASSES

There is general agreement in the scientific literature of the link between UV exposure and damage to children's eyes. Midelfart(2005) discussed work by Dong et al(2003) and stated "…the sensitivity of the lens towards UVR varies over the course of a lifespan, and is most sensitive at a younger age. It is therefore very important to introduce an age factor to current safety standards" (p. 642).

Young and Sands(1998) stated "the intraocular lens of children transmits more light in the UV and low wavelength visible light range than that of adults. Additionally, people may receive up to 80% of their lifetime cumulative UVR before the age of 20" (p. 478). The authors concluded that all individuals including children should wear sunglasses whilst outside and commented "a pair of $20 sunglasses may protect the same as a $200 pair...price usually reflects lens optical quality and frame durability or popularity" (p. 478).

In 1999 The American Academy of Paediatrics described ultraviolet light as a hazard to children, including their eyes. It is stated that "infants and children <10 years may be at increased risk for retinal injury because the transmissibility of the lens to damaging visible blue and UV light is greatest during this period" (p. 330). The Academy concluded that "even infants should wear sunglasses. Larger lenses, well fitted and close to the surface of the eye, provide the best protection" (p. 331). They endorsed sunglasses which blocked 99 to 100% of the full UV spectrum, which may be labeled as "UV absorption up to 400nm, special purpose or meets American National Standards Institute UV requirements" (p. 331). Wearing a wide brim hat was also considered an effective way to reduce about 50% of UV-B exposure to the eyes. The Academy did not make any recommendations on the type of sunglasses which would be considered safe for children in design or materials. However the suggestion was made that children be allowed to choose their own sunglasses and that parents lead by example with sunglass usage whilst outside.

Dain(2003) stated "sunglasses should not introduce their own hazards by impeding vision or by causing injury due to their design or if the lenses or frames should break" (p. 83). Sunglasses need to be robust in material and design and should not impede visual acuity. Dain(2003) commented on the need for high quality lenses which are "…optically regular and afocal so they do not reduce visual acuity, introduce distortions or cause discomfort" (p. 83).

The coloration of sunglasses may also be an issue for colour blind individuals. Dain(2003) discussed the use of sunglasses with coloured lenses and concluded "congenital colour-deficient persons, particularly protans, have raised thresholds to red stimuli and significantly longer reaction times to red signals than colour normals. Colour sunglass lenses that absorb red light will place the colour deficient observer, especially the protan, at further disadvantage" (p. 84).

Compliance standards have been set globally for sunglasses and Dain(2003) commented "it is clear …that non-complying sunglasses still abound" (p.87). Dain, Hearne and Pepper(1985) reviewed sunglasses designed and marketed to be worn by children and reached the conclusion that no sunglasses examined met the Australian Standard 1067-1983.

Prevent Blindness America suggested sunglasses for children should be "impact resistant, lenses should not pop out of the frames, and the frames should be bendable, unbreakable and/or have snap on temples". It was also suggested that the lenses be made from polycarbonate "the most impact resistant material available" and never glass.

ARPNSA stressed the need to protect the eyes from UVR exposure in all conditions by use of sunglasses which the wearer finds reduce visible light to a comfortable level whilst blocking the harmful UVR and comply with Australian Standards AS/NZS 1067. ARPNSA recommended that both adults and children wear sunglasses.

In 2006 The Cancer Council Australia released a position statement titled "Eye Protection from Ultraviolet Radiation". The following recommendations were included in the key messages:

- Reducing UV radiation exposure as much as possible.
- Wearing a broad-rimmed, bucket or legionnaire style hat.
- Wearing close-fitting, wrap around style sunglasses that meet the Australian Standard AS/NZS 1067: 2003 for sunglasses (categories 2, 3 and 4).
- Glasses which transmit very little UV radiation, such as those labelled UV 400 or EPF (Eye Protection factor) 9 or 10.
- Sunglasses should not be worn at night as this reduces visibility.

The Australian Cancer Council recommended maximum protection for the eyes from sunlight by wearing close fitting sunglasses which have large lenses that wraparound the eyes to reduce the reflected UV radiation and prevent glare from entering the eyes around the edges of the sunglasses. The issue of children wearing sunglasses is also addressed with the suggestion during periods of moderate UV, i.e. UV ≥ 3 or above, children wear sun protective clothing including a hat which will provide some shade to the eyes. It is further commented that when children are old enough they should wear sunglasses which comply with Australian standards. It is made clear that this does not include sunglasses labelled by manufacturers as toys which will not provide sun protection.

The Cancer Council South Australia Primary Schools News Bulletin, February 2006 addressed the practicality of children wearing sunglasses at school. The following was comment was offered for schools to consider:

> "While it is certainly important to protect eyes from over exposure to ultraviolet radiation, there are other issues that schools need to think about when considering the use of sunglasses. One is the issue of safety – for example a ball hitting a child in the face while they are wearing sunglasses. Another factor is the cost – many parents cannot afford to buy sunglasses particularly when they may get lost or broken regularly. It is also important to note that wearing an appropriate sun protective hat, such as recommended bucket or broad rimmed hat, will reduce the UV radiation to the eyes by around 50%".

Despite the warning of possible eye injury from a child wearing sunglasses, no scientific literature could currently be located to describe the incidence or risk of this phenomenon.

Eye protection from the sun can therefore be achieved by the use of sunglasses which adequately reduce the UVR exposure. However, the public in general needs to develop an awareness of the need to consistently use such sunglasses. Livingstone, White, Hayman and Dobbinson(2003) presented a study which examined trends in sun exposure and protective behaviours in adolescents in all states and territories of Australia, from 1993 to 1999. Students from years 7 to 12 were surveyed, with 78 032 students participating. The outcome of the study showed an increased incidence of students sustaining sunburn through voluntary sun exposure, and a reduced incidence of students using maximum protective sunscreen. Sunglass usage was also examined and it was found that “the practice of wearing sunglasses decreased significantly over time…compared to 1993, students were less likely to wear sunglasses in 1996 and 1999…females were more than twice as likely as males to wear sunglasses in all survey years” (p. 580). Further “…only 11% of students reported that they routinely practiced all three protective behaviours of wearing a hat, using sunscreen, and wearing clothes covering the body” (p. 583).

Glavas, Patel, Donsoff and Stenson(2004) interviewed 100 spectacle wearers for their use of sunglasses and found most participants wore sunglasses in summer only and were generally unaware of the risks of UVR exposure and the importance of UVR eye protection.

Pakrou et al(2006) surveyed 40 South Australian school students aged 13-18 years to determine their knowledge of the effects of sunlight on the eyes and the need for protection. The results of the survey were then compared to a similar survey conducted in 1995 by Lee, Hirst and Sheehan. The 2006 study found a trend of increasing knowledge of the need for sun protective behaviours with increasing age. Participants “…aged 17-18 years had a significantly higher knowledge score compared to those aged 13 years through to 15 years of age” (p. 6). Participants who rated themselves as having dark skin had “…a significantly lower mean total knowledge score compared to people with fair, medium or olive skin. It may be that these students are aware that they are at less risk of sun-related diseases, and hence are less likely to educate themselves on the topic” (p. 6).

74% of participants owned a pair of sunglasses but only 44.5% reported wearing them regularly and 32% wore them occasionally. It was also found that “advertising of sunglasses in various forms of media appears to have a significant affect on the frequency of wearing sunglasses” (p. 4). Participants also indicated a willingness to “...spend at least the same amount or more on sunglasses if they consider the protective advantages of sunglasses” (p. 4). The study found an association with the participants’ willingness to wear sunglasses if other family members and peers also frequently wore sunglasses; a similar finding occurred in the Lee, Hirst and Sheehan(1999) study.

Concern was expressed by the authors over the finding that more than half the participants “…wrongly believed that wearing sun-screen offers ‘good’ or ‘fair’ protection to the eyes, an increase of 10% compared to the survey conducted in 1995” (p. 4). Also the total knowledge score of this cohort regarding sun protective behaviours was almost the same as the cohort previously studied in 1995. The study found only 2/3 of participants “…were aware that UV is harmful to the eyes” (p. 6); this was significantly lower than the finding in the 1995 survey. The authors commented “this is a little worrying as it appears that the increased efforts by various bodies over the past decade, aimed at increasing awareness in the youth, has not results in a significant increase in knowledge" (p. 4).

The authors commented:

> "There have been various media and educational campaigns aimed at informing and raising awareness of the sun's damage to the skin. There has however been much less emphasis on the damaging effects of sun exposure on the eyes. It is important that the young are made fully aware of the damaging effects of UV radiation on the eyes, as behaviours established early in life would be more likely to carry through into adult years. It is also thought that the eyes are more at risk from UV light damage in this group (p. 4).

Marks(1994) discussed the success of the implementations of sun protective programs beginning in the 1980s including the public education programs such as the "Slip! Slop! Slap!" and "SunSmart" campaigns, with "substantial shifts in knowledge, attitudes and beliefs about melanoma and sun protection in the Australian population"
(p. 105). Marks(1994) concluded that it was possible to change a population's sun behaviours by such campaigns.

Smith et al(2002) reported on the impact of media campaigns over three summers, designed to promote sun protective behaviours in Australia. The campaigns were run by the NSW Cancer Council in partnership with NSW Health Department. The authors evaluated the impact of the campaigns on the "awareness, knowledge, attitudes and sun protective behaviours" (p. 52) amongst parents and children. Analysis showed that the campaigns reached over half of the targeted population, however the authors commented:

> "The information exposure and campaign recall rose to approximately similar levels following each campaign, dropping down to baseline levels or slightly below these between campaigns, indicating that these interventions do not have a sustained or cumulative effect. This suggests the need for continued strategies to maintain sun protection on the population's agenda and possibly the development of alternative approaches that might have a more lasting impact" (p. 59).

In discussing education and screening programs for melanoma McCarthy(2004) commented that "programs have lead to a population highly aware of the deleterious effects of the excessive exposure to UVR in sunlight and knowledgeable about the clinical manifestations of skin cancer, particularly melanoma" (p. 244). Further, there was evidence that programs were being effective in reducing melanoma incidence and mortality as rates "…have leveled off in the last five years and are expected to fall in the next decade" (p. 244).

7 SUMMARY AND CONCLUSIONS

The Australian population is increasing and ageing and with this comes a greater incidence of eye disease. There is a proven link between the amount of sunlight a person is exposed to over their lifetime and the likelihood that they will suffer some form of eye damage. This could involve the external ocular structures with possible development of basal cell carcinoma, pingueculae and pterygium, or the internal structures with cataract and age related macular degeneration. The aetiologies of these eye diseases are known to be multifactoral, with sunlight exposure included.

There is an obvious and urgent need to minimize children's exposure to harmful ultraviolet radiation to protect their skin and eyes. This has to occur in an environment of accepted high levels of outdoor activity. Recent research has shown preclinical signs of sun damage in relatively young children, although the implication for developing eye disease later is not known (Ooi et al, 2006). Sunglasses are a possible option to reduce sun exposure to the eyes and surrounding skin. Australia has strict standards which help inform consumers on the level of sun protection they are receiving from the sunglasses they choose to wear. However, endorsement of sunglasses for children is not necessarily easily done. There are important considerations to be made regarding design, manufacture and cost. The question also arises of how effective could a well designed hat be to minimize the UV exposure without having to introduce sunglasses?

The adolescent population remains very much at risk of sun exposure and subsequent damage due to their lack of appropriate sun care for skin or eyes and their tendency to high levels of sun exposure through sport and recreational activities. However, modeling by family and peers has been found to have a positive impact on behaviours including wearing sunglasses (Pakrou et al, 2006).

Australia has been exposed to public sun protection campaigns since the 1960s when the link between sun cancer and sun exposure was made. There has been some measure of success in changing sun habits and it is projected that the incidence of melanoma will drop in the future. However, there appears to have been little focus on the need to protect the eyes as well as the skin. This is an issue that could be addressed in future planning for sun protection campaigns across all age groups.

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