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Assessment of daily light and ultraviolet exposure in young adults.

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ABSTRACT

**Purpose:** There are some limited reports, based on questionnaire data, which suggest that outdoor activity decreases the risk of myopia in children and may offset the myopia risk associated with prolonged near work. The aim of this study was to explore the relationship between near work, indoor illumination, daily sunlight and ultraviolet (UV) exposure in emmetropic and myopic University students, given that University students perform significant amounts of near work and as a group have a high prevalence of myopia.

**Methods:** Participants were 35 students, aged 17 to 25 years who were classified as being emmetropic (n=13), or having stable (n=12) or progressing myopia (n=10). During waking hours on three separate days participants wore a light sensor data logger (HOBO) and a polysulphone UV dosimeter; these devices measured daily illuminance and accumulative UV exposure respectively; participants also completed a daily activity log.

**Results:** No significant between group differences were observed for average daily illuminance (p=0.732), number of hours per day spent in sunlight (p=0.266), outdoor shade (p=0.726), bright indoor/dim outdoor light (p=0.574) or dim room illumination (p=0.484). Daily UV exposure was significantly different across the groups (p=0.003); with stable myopes experiencing the greatest UV exposure (versus emmetropes p=0.002; versus progressing myopes p=0.004).

**Conclusions:** The current literature suggests there is a link between myopia protection and spending time outdoors in children. Our data provides some evidence of this relationship in young adults and highlights the need for larger studies to further investigate this relationship longitudinally.

**Key Words:** outdoor activity, myopia, refractive error, sunlight.
INTRODUCTION

The prevalence of myopia in children and young adults varies greatly around the world. The Refractive Error Study in Children Survey Group report five sites where myopia prevalence is less than 15% at 17 years of age (Eastern Nepal, rural and urban Southern India, South Africa and Chile) and three sites with much higher myopia prevalence (urban Malaysia and urban and semi-rural China) (reviewed in Morgan, Rose and Ellwein). The prevalence of myopia is extremely high in East Asia. For example, 85% of Taiwanese 17 year olds, at the end of schooling and about to commence University, require an optical correction for myopia. There is a related high prevalence of severe myopia (>6D), and associated ocular pathologies including chorio-retinal degeneration and retinal detachment. A vastly different scenario is evident in Australia, where only 12-14% of 12 year olds have a myopic refractive error. The possible cause(s) of this large geographical variation in myopia prevalence is the focus of much current discussion.

Whilst it is well known that there is a strong genetic predisposition underlying myopia susceptibility, new findings suggest environmental factors, such as leading an outdoor lifestyle, may also have a strong impact on refractive error development. The Sydney Myopia Study found that the group of children who self-reported spending more than 2.8 hours per day performing outdoor activities had a more hyperopic mean spherical equivalent refraction (SER) than children who reported that they participated in lower amounts of outdoor activity. Further to this, a comparative study found Chinese children living in Australia had a lower myopia prevalence compared to children of the same age and ethnicity residing in Singapore. Although this difference could result from the earlier and more intense education requirements of children in Asia, the authors observed that Australian children spent more time reading and writing and less time watching television than their Singaporean counterparts. Another major difference was that the children living in Australia spent greater amounts of time outdoors.

There are a number of possible mechanisms by which outdoor activity could protect against the development myopia. One possibility is that distance viewing when outdoors encourages relaxation of the accommodation system which negates accommodative adaptations associated with performing prolonged near tasks. Another hypothesis is that pupil constriction caused by the high outdoor illumination results in a reduction in retinal image blur and this mitigates the error signal driving the emmetropization process. Physical activity has also been suggested as a means for myopia prevention rather than...
simply being outdoors per se; however performing large amounts of sport indoors does not seem to impact on myopia risk. Animal models of myopia, however, point to the greater intensity of illumination that is experienced outdoors being the likely critical factor.

Bright light inhibits the development of both deprivation and lens induced myopia in the chick model. Bright light, such as natural daylight, is known to stimulate the release of retinal dopamine which is an important neurotransmitter in the control of axial eye growth.

Dopamine agonists inhibit the development of myopia in animal models and dopamine antagonists block the ability of brief periods of normal vision to prevent form-deprivation myopia. Related to these findings, Fulks reported that the rate of myopia progression in children wearing single vision and bifocal spectacles was three times greater in winter than in summer. Higher myopia prevalence has also been found in Eskimos and Finnish army conscripts living near the Arctic Circle, where sunrise is non-existent during the winter months.

The broad spectrum of wavelengths in sunlight, including the emission of rays in the ultraviolet range (10-400nm), has also been suggested to be of significance in myopia prevention. Here it is suggested that the important factors are that sunlight contains UV light while indoor lighting consists of a more limited spectrum of wavelengths. However, no conclusive evidence is currently available to confirm that UV light exposure is required to prevent myopia development.

The aim of this study was to measure the daily light levels and UV exposure that University students experience and determine whether this had an impact on their refractive status recorded retrospectively over the previous two-three years. We hypothesised that emmetropic students and those with stable myopia would spend more time outdoors and be exposed to higher ambient levels of illumination and UV than students with progressing myopia. We also sought to ascertain whether young adults in Brisbane were exposed to safe or unsafe levels of UV.

METHODS

Participants

Participants were third and fourth year University students, aged 17 to 25 years, studying Optometry at the Queensland University of Technology. This sample was recruited to ensure that participants had similar levels of education, were completing the same course and individual variation in the amount of near work performed would be restricted.
Participants were classified as being emmetropic (n=13), or having stable (n=12) or progressing myopia (n=10). Myopia was defined as ≥ 0.50 D of myopia and emmetropia from -0.25 D to +1.00 D. This classification was based on the spherical equivalent refraction determined from a non-cycloplegic subjective refraction. Progression status was determined retrospectively by analysis of past optometry clinic record data; all participants had subjective refraction conducted in the first semester of University two-three years prior, but usually not since. The emmetropic group were emmetropic both at commencement of University and at the time of the study. The stable myopic group were initially myopic and myopia progressed by 0.25 D or less over the 2-3 year period. Progressing myopes were initially myopic and progressed by 0.50 D or more over the same period. All experiments were conducted with ethics approval in accordance with the declaration of Helsinki, and the requirements of the Queensland University of Technology Human Research Ethics Committee. Written consent was obtained from participants prior to commencing experimental work.

**Eye Examination**

Subjective refraction was performed using the maximum plus for best visual acuity methodology and blur back techniques to minimise accommodative demand influencing the refractive error results.²⁴ Students with hyperopia (≥+1.50D), anisometropia (≥1.50D), astigmatism (≥1.50D), amblyopia or keratoconus were excluded. Visual acuity was measured using a Bailey-Lovie distance chart at 6 metres; inclusion criteria included best corrected distance acuities of 6/6 or better in each eye. A cover test at distance and near was performed to exclude participants with a strabismus. All participants reported good general and ocular health; ophthalmoscopy and slit-lamp biomicroscopy were conducted to screen for ocular abnormalities. Individuals who had received past treatment for myopia progression in the form of therapeutic agents, bifocal or progressive addition lenses, orthokeratology or lasik eye surgery were excluded. Axial length and corneal power were measured using an optical biometer (IOL Master; Carl Zeis Meditec Inc, Jena, Germany).

**Questionnaire**

Participants completed a 57-item questionnaire pertaining to age, ethnicity, near work, family ocular history, outdoor activities (sport and recreation) as well as country of birth and upbringing. Questions regarding sun protection and lifestyle over the past 3 years were also asked. The questionnaire was derived from surveys used in published research projects on factors influencing myopia in children.¹¹
Light Intensity Measurements

HOBO light sensor data loggers (Onset Computer Corporation, model UA-002-08) were used to measure daily illuminance levels for each participant individually. All devices were programmed to record light intensity at five minute intervals. A clip was attached to the back surface of the HOBO to allow participants to secure the light logger to their clothing (either on a shirt pocket, collar or midline) in a stable upright position. A chain was threaded through the 3 mm eyelet at the top of the device and was worn around the neck to ensure the light logger was not lost if the clip became detached. The HOBO was worn for three days (Wednesday, Friday and Saturday) and then returned to the experimenters. The device was then plugged into an optical USB base station and data points were downloaded and transferred to the HOBO software program for analyses. The HOBO light loggers have been used previously to monitor seasonal light exposure in plants,26 and circadian light rhythms in elderly patients.27

Ultraviolet Radiation Measurements

Daily UV exposure was measured using polysulphone film (PSF) dosimeters; one dosimeter was used each day. The PSF dosimeters were manufactured at the Sun and Health Research Laboratory (Institute of Health and Biomedical Innovation, Queensland University of Technology) and consisted of a clear central film surrounded by grey plastic support. A clip was attached to the back surface to allow attachment to clothing at a similar location to the HOBO light logger. When polysulphone is exposed to ultraviolet radiation it undergoes photodegradation and a change in optical absorbency, 28 which is a very similar process to the cellular damage and cutaneous reddening that occurs during sunburn and is therefore an effective means of measuring accumulative UV exposure.28 The optical absorbency of dosimeters at 330nm was measured both pre-exposure and post-exposure and the spectrophotometer values determined by calculating the difference between these two measures to derive the change in optical absorbency, which corresponded to the daily UV exposure.29 Measurements of UV using PSF dosimeters have been conducted previously in Queensland school children and in Danish adults.25,28

Recording Days and Diary

Two weekdays (Wednesday and Friday) and one weekend day (Saturday) were chosen as the designated experimental days to represent ‘typical’ activity days of students with respect to their university schedule. In addition to wearing the HOBO and UV dosimeter participants also completed a 24-hour light exposure diary for each of the recording days. The
start and finishing time of indoor and outdoor activities and the type of sun protection used were documented. The daily activity log was based on that used to assess agreement between diary reports of time spent outdoors and UV dosimetry.  

Data Analysis

Refractive error and ocular biometry measurements of the right eye of each of the participants were used for data analyses. Astigmatic corrections were converted to spherical equivalent refraction (SER) using the formula sphere + $\frac{1}{2}$ cylinder. The HOBO data collected for daily illuminance levels were then categorized into hours spent in sunlight ($\geq 30,000$ lux), outdoor shade ($10,000$ lux – $30,000$ lux), bright indoor/dim outdoor light ($500$ lux – $10,000$ lux) and dim room illumination ($<500$ lux). We selected these categories of illuminance based on our own measurements using a HOBO light logger under a series of different representative lighting conditions at the location and time of year that this study was conducted: including direct sunlight, office room illumination, a lecture theatre and within close proximity to a window. Nevertheless, we acknowledge that there will be a range of light levels that occur both indoors and outdoors and thus the HOBO data can only provide an approximation of outdoor activity, regardless of the illuminance cut-off levels selected. We thus calculated hours of outdoor activity based on $>10000$ lux (most definitively outdoors) and $>500$ lux (where some bright indoor activity may be included). The daily UV exposure was calculated from the change in optical absorbency of the UV dosimeters as described previously. The units of erythemal exposure are in terms of minimal erythemal exposure (MED) where 1 MED is taken as $20 \text{ mJ} \cdot \text{cm}^{-2}$.  

Statistical analyses were performed using the software program SPSS (statistical package for the social sciences). A one-way ANOVA was performed to assess whether there was a significant ($p<0.05$) refractive error group effect with respect to continuous variables. If the data were significant, then an LSD post-hoc comparison was performed. For non-continuous variables (gender, ethnicity, history of parental myopia and iris colour) the non-parametric Kruskal Wallis test was used. A simple two-tailed Pearson correlation was used to determine if UV dosimetry and HOBO illuminance levels were correlated and whether objective HOBO measures of time spent under different illuminations were correlated with self-reports in the daily activity log.
RESULTS

Refraction and biometry data

Emmetropes had a mean SER of +0.11±0.39 D and the stable and progressing myopes had a mean SER of -2.48±1.74 D and -3.61±1.47 D respectively (myopes vs emmetropes significant, F_{34,2}=25.001, p=0.001) (Table 1). Progressing myopic students experienced an average change in refraction of -1.01±0.40 D over the previous two to three years. Axial length was negatively correlated with refractive error; the greater the myopia the greater the axial length (R=0.81, p=0.001) and axial length was significantly longer in the myopic groups (p=0.001). There was no correlation between corneal power and refractive error (R=0.20, p=0.251) and no difference amongst the three groups.

There were more female (77.1%) than male participants. Students with Asian ethnicity accounted for almost half of the participants (48.6%), the remaining students had a European/Caucasian (40%) or Indian (11.4%) background. Age (F_{2,34}=0.249, p=0.781), gender (p=0.124), ethnicity (p=0.799), history of parental myopia (p=0.187) and iris colour (p=0.58) were not significantly different between the groups. There was a clear trend for students with two myopic parents to have a more myopic SER; 80% of progressing myopic students had at least one myopic parent. Seventy-five percent of participants had brown irides.

HOOB data, daily activity log and UV dosimetry

There were no significant differences in the daily illuminance experienced by the three refractive groups; e.g. emmetropes 252±192 x10^3 lux versus stable myopes 221±127 x10^3 lux versus progressing myopes 202±117 x10^3 lux (F_{2,34}=0.316, p=0.73) (Table 2). There was also no significant correlation between average daily illuminance and refractive error (R=0.153, p=0.438). The three groups spent a similar amount of time each day in sunlight and shade conditions outdoors (sun+shade = total outdoors), e.g. the emmetropes spent 0.38±0.23 h/day, the stable myopes 0.34±0.20 h/day and the progressing myopes 0.27±0.19 h/day (F_{2,34}=0.714, p=0.50). Times spent indoors under either bright (F_{2,34}=0.565, p=0.574) or dim (F_{2,34}=0.742, p=0.484) conditions were also not significantly different between groups. The number of daily alternations from indoors to outdoors per day, a measure of the frequency of large changes in light levels, was not significantly different between groups: emmetropes = 5.2±2.6 per day, stable myopes = 4.5±2.6, progressing myopes = 3.6±1.2 (F_{2,34}=1.340, p=0.276).
As for the HOBO data there was no significant difference between groups based on self-reports of daily activities recorded in the participant log (Table 2). The emmetropic participants reported spending 2.67±1.06 h/day, the stable myopic students 1.85±1.04 h/day and progressing myopic students 2.51±1.49 h/day outdoors; these durations were not different (F_{2,34}=1.614, p=0.215). Similarly time spent indoors, time spent on near work and time spent sleeping each day was the same across the three groups. Self-reported measures of time spent outdoors were much greater than the time spent outdoors (based on >10,000 lux) calculated from the HOBO data (Fig. 1) (p=0.001); the two values were not significantly correlated (R=0.27, p=0.104). This correlation was, however, improved for total bright light (based on > 500 lux) HOBO data against reports of time spent outdoors (R=0.31, p=0.067) but still was not significant. In contrast, the time spent under low illuminations calculated from the HOBO data were correlated to the reported hours spent indoors based on the activity log (R=0.521, p=0.001).

The UV dosimetry data showed significant differences across the three refractive groups (Table 2; Fig. 2). On average, the stable myopes had the greatest UV exposure (0.32±0.12 MED) followed by the progressing myopes (0.17±0.11 MED) and the emmetropes (0.17±0.09 MED) (F_{2,34}=7.041, p=0.003). Subsequent post-hoc testing showed that the significant differences were between the emmetropes and stable myopes (p=0.002) as well as the stable myopes and the progressing myopes (p=0.004); in both cases the average MEDs of these groups differed by 90%. The daily MEDs ranged from 0.07 to 0.52 across all participants and all test days; 1 MED is considered the maximum daily safe level. The average daily UV exposure of participants and the daily hours spent in sunlight based on the HOBO illuminance measures were significantly correlated (R=0.384, p=0.023). The relatively low R value of the correlation indicating that UV dose varies with other factors not just the total illumination exposed to. Chodick et al.\textsuperscript{25} report a similar correlation coefficient (R= 0.33) between total daily time outdoors and UVR dose.

**Relationships and interactions**

Illuminance and UV measurements were significantly correlated in the positive direction (Fig. 3). This finding was consistent across all testing days and was used as a means for checking data reliability as greater UV exposure should equate to more time spent outdoors under higher light levels (Wednesday, R=0.404, p=0.016; Friday, R=0.572, p=<0.001; Saturday, R=0.381, p=0.024). Although we hypothesised that there may be differences across the three measurement days, as one day was a weekend and participants...
went to University the other two days, no difference was observed. Also there were two
participants for whom the daily illuminance values measured with the HOBO were high and
the UV exposure very low. We can only assume that on these days the participants concerned
spent a large portion of time under bright indoor illuminations and little time outdoors; this
would give high illuminance and low UV exposure data.

DISCUSSION

This study investigated the relationship between refractive errors, the duration of time
spent outdoors and the light levels and ultraviolet radiation that young adult University
students were exposed to. No significant differences were observed between refractive error
groups with respect to average daily illuminance or time (h/day) spent under the different
lighting conditions (sunlight, outdoor shade, indoor bright light and indoor dim light).
However, there were significant between group differences for the daily UV dose, with stable
myopes having the highest daily UV exposure. Although much of the data were not
significant this may have been due to the relatively small sample size and lack of power of
the study. We have performed an a priori power analysis, which suggests that, for any given
predictor (e.g. daily UV exposure) if a cut-off score could be identified which was associated
with a 6-7% increased risk of progressing myopia, a sample of 963 participants would be
sufficient to capture this effect with a power of .95. Thus, a sample of 1000 participants,
allows for up to 5% dropout, and would provide sufficient power to detect a clinically
significant effect.

A possible reason daily UV exposure, but not daily illumination differences across the
groups, reached significance is that the UV measure is cumulative across the day whereas
illumination measures were taken at five minute intervals throughout the day; the HOBO
device records light intensity as a discrete/stepped amount rather than a continuous variable.\textsuperscript{31}
The UV measure represents the more accurate measure of sunlight exposure as the HOBO
logger measures across a wide spectrum of wavelengths including indoor lighting; although it
is stated in the instrument catalogue that the HOBO devices are designed to sense outdoor
rather than indoor illumination.\textsuperscript{31} The HOBO devices cannot be calibrated, which means each
individual HOBO measures a slightly different illuminance for the same incident light
intensity\textsuperscript{31} and this would add to the variability of the data. Importantly, we cannot rule out
the possibility that UV exposure data is simply a surrogate measure for outdoor activity and
exposure to bright light levels.
Based on our measures with the HOBO device, which were undertaken at representative locations and the same time of year that this study was undertaken, we used a cut off of >10,000 lux to represent outdoor illuminations. Scheuermaier et al\textsuperscript{27} used a cut off of 1000 lux as did Dharani et al\textsuperscript{32} in their study involving children. However, as reported by Dharani et al\textsuperscript{32} there is an overlap between the light levels measured outdoors on a dark cloudy day (~3500 lux) and those measured near a window indoors on a sunny day (up to ~4000 lux). Thus the criteria that we used which were based on a level >10,000 lux could have underestimated outdoor activity whereas that adopted by Scheuermaier et al.\textsuperscript{27} and Dharani et al.\textsuperscript{32} and our own bright light condition (>500 lux) may overestimate it; this would also contribute to the lack of concordance between the objective and self-reported measures of outdoor activity found in these studies. When we added bright light measures (>500 lux) to calculate the hours of outdoor activity performed, the correlation between HOBO data and self-reported measures of outdoor activity was improved but was still not significant. If the lower illumination cut off was used the young adults students performed much more weekly activity under bright light than children in a study undertaken in Singapore\textsuperscript{32} (17.57±9.78 hr versus 7.08 hrs), however if the brighter illumination cut off was used the young adults performed much less outdoor activity (2.35±1.47 hr).

Our findings, to some extent, relate to those of other studies which have observed a link between increased light intensity and myopia protection. For example, Cohen et al\textsuperscript{33} found that after 90 days, chicks exposed to a constant illuminance of 10,000 lux developed a mean hyperopic SER of +1.10 D, whereas chicks exposed to lower intensities of 500 lux and 50 lux developed a mean myopic SER of -1.20 D and -2.00 D respectively.\textsuperscript{33} Similarly, Ashby et al\textsuperscript{15} report that intense lighting of 15,000 lux inhibits the development of form deprivation myopia in chicks. The progressing myopes in our study experienced very high average daily illuminance values, which based on the animal model data, should be sufficient to prevent myopia, if light levels were the key factor controlling eye growth. Although data from chick models provide valuable insights in eye growth control processes, the findings may not be necessarily translatable to human myopia in this instance.

There were large differences between objective measurements of light intensity based on the HOBO data and UV dosimetry and self-reported estimates of outdoor exposure based on the daily activity log. A likely explanation is that outdoor time is not always spent in the sun, but is also spent in shade or in the car/bus under a lower illuminance. Another possibility is that participants over estimated their outdoor activity when completing the activity log.
Indeed, while it is usually reported that diary data of this kind is reliable,\textsuperscript{25} this does not necessarily mean it is valid. Chodick et al.\textsuperscript{25} report a significant correlation (0.57, p<0.001) between UV dosimetry and recorded time spent outdoors but this was for a greater number of participants (124) and more measurements (7 days). They also report that the correlation was greatest when outdoor activities were performed in the middle of the day and least when outdoor activities were performed in the early morning or late afternoon. Our findings highlight the importance of including objective measures in studies of activity and lighting, and suggest the possibility that measures derived from self-reported activities may not accurately represent actual light exposures.

A significant difference was observed between groups with respect to daily UV exposure; stable myopes had the highest MED levels and the progressing myopes and the emmetropes similar exposure levels. Given the limitation that myopia progression was determined retrospectively, we suggest that the finding that stable myopes have higher UV exposures and progressing myopes and emmetropes less may indicate that sunlight plays a fundamental role in preventing myopia progression in individuals who have a strong myopic tendency (through genetics and ethnicity) but has little effect on the refraction of those who are destined to be emmetropic. Data in children support this hypothesis; the effect of outdoor activity on myopia is greatest in children with two myopic parents and high genetic myopia risk.\textsuperscript{13} In addition children who combined low levels of near work with high levels of outdoor activity had the most hyperopic refractions and those who combined high levels of near work with low levels of outdoor activity had relative more myopic refraction.\textsuperscript{11} As participants were selected based on their participation in the same University course, all were likely to have had similar high levels of near activity and thus our data cannot inform the debate on the possible interaction between near work, outdoor activity and myopia. It remains to be seen whether these measured differences between refractive groups are clinically relevant but they are consistent with data from animal models.\textsuperscript{15,33,34} Although it is possible that time spent outdoors during childhood influences the refractive status of young adults and that this effect has the potential to override any observed differences due to current light exposure behaviours, the fact that many young adults have progressive myopia indicates that current behaviours are also important.

Although the current literature indicates that there may be a role for UV in the prevention of myopia this is yet to be confirmed. In a study by Ashby et al.\textsuperscript{15}, form-deprived chicks given 15 minutes of normal vision under bright natural daylight (30,000 lux) had
shorter axial lengths and less form-deprivation myopia compared to chicks exposed to intense (15,000 lux) and normal (500 lux) laboratory light during the period of diffuser removal. Secondly chicks deprived indoors under low light levels developed greater myopia than those deprived under much bright illumination. The authors suggested that high illuminance was the important determinant of their findings as the halogen lamps of laboratory lighting had a spectral distribution of 400-1000 nm (visible and infrared) and no output in the UV part of the spectrum (10-400nm) and yet inhibited myopia. More recently, Smith et al. report that high ambient indoor lighting (~25,000 lux) also retards the development of form-deprivation myopia in monkeys.

Human data demonstrates that there is a lower prevalence of pterygium and pinguecula, which are generally a result of chronic UV exposure, in myopic subjects. The authors suggest that this data supports, but does not prove, the hypothesis that childhood sun exposure is associated with a decreased risk of myopia. This finding is, however, confounded by the UV blocking effects of spectacle lens wear which might potentially alter the association between time spent outdoors and the presence of UV damage. However, Sherwin et al. reported no effect of sunglass use on signs of ocular surface UV damage (as measured using conjunctival ultraviolet autofluorescence) and an inverse relationship between the level of UV damage and the presence of myopia. Sun exposure is required to generate vitamin D. A multivariate linear model, adjusted for age and dietary nutrients, revealed higher blood levels of vitamin D (16.9 ng/ml) in non-myopic subjects compared to myopic subjects (13.5ng/ml); although the amount of time spent outdoors was similar for both groups.

We found higher UV exposure in stable myopes versus progressing myopes however this does not prove whether it is the UV light or the high light levels of sunlight more generally that are important. A further aim of this experiment was to determine whether the levels of UV exposure in young adults with different refractive errors fell within the range of safe exposure levels. The average daily UV dose for stable myopes was 0.32±0.12 MED and ranged from 0.07 to 0.52 MED across all subjects and experimental days. This is well below 1 MED, which is the maximum safe level of daily occupational UV exposure set by The National Medical Health Research Council of Australia. It may be that the high illuminations required to inhibit myopia can be produced by increasing indoor lighting rather than increasing outdoor activity, however, whether this is economically feasible is an issue that would need to be determined in future studies.
CONCLUSION

The effect of outdoor illumination and UV exposure on progressing myopia was investigated. Daily UV exposure was greatest in stable myopes and lower in emmetropic and progressing myopic students. Therefore this experiment provides some preliminary evidence to support the hypothesis that sunlight and/or UV may offer some protection against myopia. Further larger scale prospective studies are required to fully explore the relationship between light levels and impact on myopia progression.

ACKNOWLEDGEMENTS

UV dosimeters were provided by AusSun and the HOBO loggers by grant funding to KLS.

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Figure Captions

Fig. 1. Subjective (based on activity log) and objective measures of time spent outdoors for emmetropic, stable myopic and progressing myopic groups. The HOBO data represents the hours per day definitely spent outdoors (> 10x10^3 lux) whereas the HOBO bright data (>500 lux) would include some indoor activity. Choosing a cutoff of 10x10^3 lux is likely to underestimate the actual time spent outdoors and HOBO bright data would overestimate it. Data are mean±SD.

Fig. 2. Average daily UV exposure for emmetropic, stable myopic and progressing myopic groups. Data are mean±SD.

Fig. 3. Correlation between UV dosimetry and HOBO illuminance values for the three test days. Trend line values are Wednesday, full line R=0.404, p=0.016; Friday, dashed line R=0.572, p=<0.001; Saturday, dotted line R=0.381, p=0.024.
Table 1. Refraction and biometry data of emmetropic, stable and progressing myopic groups.

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<th>Progressing Myopes</th>
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<td>43.88±1.37</td>
<td>43.98±1.51</td>
<td>43.91±1.23</td>
<td>0.983</td>
</tr>
</tbody>
</table>

Data are mean±SD. Groups were compared using univariate (one-way ANOVA) analysis.
<table>
<thead>
<tr>
<th></th>
<th>Emmetropes</th>
<th>Stable Myopes</th>
<th>Progressing Myopes</th>
<th>ANOVA p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HOBO data</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Illuminance (x10^3 lux/day)</td>
<td>252±192</td>
<td>221±127</td>
<td>202±117</td>
<td>0.732</td>
</tr>
<tr>
<td>Sunlight (h/day)</td>
<td>0.17±0.11</td>
<td>0.12±0.09</td>
<td>0.10±0.09</td>
<td>0.266</td>
</tr>
<tr>
<td>Shade (h/day)</td>
<td>0.21±0.14</td>
<td>0.22±0.14</td>
<td>0.17±0.11</td>
<td>0.726</td>
</tr>
<tr>
<td><strong>Total Outdoors &gt;10x10^3 lux (h/day)</strong></td>
<td>0.38±0.23</td>
<td>0.34±0.20</td>
<td>0.27±0.19</td>
<td>0.498</td>
</tr>
<tr>
<td>Bright Indoor/ Dim Outdoors (h/day)</td>
<td>2.20±1.62</td>
<td>2.42±1.15</td>
<td>1.85±0.63</td>
<td>0.574</td>
</tr>
<tr>
<td><strong>Total Bright Light &gt;500 lux (h/day)</strong></td>
<td>2.58±1.82</td>
<td>2.76±1.18</td>
<td>2.12±0.70</td>
<td>0.549</td>
</tr>
<tr>
<td>Dim Indoor (h/day)</td>
<td>12.73±2.00</td>
<td>12.46±1.66</td>
<td>13.35±1.40</td>
<td>0.484</td>
</tr>
<tr>
<td>Alternations (no./day)</td>
<td>5.2±2.6</td>
<td>4.5±2.6</td>
<td>3.6±1.2</td>
<td>0.276</td>
</tr>
<tr>
<td><strong>Daily Log Data</strong></td>
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<tr>
<td>Total Outdoors (h/day)</td>
<td>2.67±1.06</td>
<td>1.85±1.04</td>
<td>2.51±1.49</td>
<td>0.215</td>
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<tr>
<td>Total Indoors (h/day)</td>
<td>12.63±1.47</td>
<td>13.36±1.10</td>
<td>12.95±1.22</td>
<td>0.338</td>
</tr>
<tr>
<td>Nearwork (h/day)</td>
<td>5.03±2.20</td>
<td>5.08±2.74</td>
<td>5.90±2.01</td>
<td>0.683</td>
</tr>
<tr>
<td>Sleep (h/day)</td>
<td>8.69±0.76</td>
<td>8.78±1.13</td>
<td>8.52±1.22</td>
<td>0.845</td>
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<tr>
<td><strong>UV Dosimeter Data</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UV (MED*/day)</td>
<td>0.17±0.09</td>
<td>0.32±0.12</td>
<td>0.17±0.11</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Data are mean±SD. Groups were compared using univariate (one-way ANOVA) analysis. *MED = Minimal Erythmal Dose