Quantifying Risk Factors for Myopia: Instrument Validation and Establishing Dosage for Light Intensity and Duration

Majid Ahmed M Moafa

A thesis submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy

Faculty of Health Sciences

The University of Sydney

2019
Authorship Statement

This thesis is submitted to the University of Sydney in fulfilment of the requirement for the degree of Doctor of Philosophy.

The work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text. I hereby declare that I have not submitted this material, either in full or in part, for a degree at this or any other institution.

I understand that if this thesis is successful, it will be lodged with the University of Sydney library and made available for immediate public use.

Signed:… Majid Ahmed M Moafa………………………Date:……20/06/2019…………..
Acknowledgements

I am greatly indebted to my supervisory team, Professor Kathryn Rose, Dr Rob Heard, Professor Ian Morgan and Dr Amanda French. They have helped extend my knowledge through their boundless support, direction, patience, and professional, insightful comments. Without their regular and prompt encouragement, inspiration, and guidance, this thesis would not have been completed.

My deepest love and gratitude goes to my parents for their encouragement, everlasting love, and guidance throughout my entire life. Without their support, prayers, and encouragement, I would not have come this far. These thanks extend to my siblings, extended family and my friends for their nonstop encouragement.

Last, but definitely not least, my sincere gratitude and love belongs to my amazing wife, Alkhansa, for her continuous support, care, patience, and unconditional love. My words are inadequate to express my love and appreciation. I also thank my precious children, Ayman, Ayham and Banan, whose love, smiles, warm hugs, and kisses have been, for me, a source of happiness, hope, and determination.
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<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>ACD</td>
<td>Anterior Chamber Depth</td>
</tr>
<tr>
<td>AL</td>
<td>Axial Length</td>
</tr>
<tr>
<td>AL/CR</td>
<td>Axial Length/Corneal Radius ratio</td>
</tr>
<tr>
<td>ALSPAC</td>
<td>Avon Longitudinal Study of Parents And Children</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>AUC</td>
<td>Area Under the Curve</td>
</tr>
<tr>
<td>BHVI</td>
<td>Brien Holden Vision Institute</td>
</tr>
<tr>
<td>CI</td>
<td>Confidence Interval</td>
</tr>
<tr>
<td>CLEERE</td>
<td>Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error study</td>
</tr>
<tr>
<td>COMET</td>
<td>Correction of Myopia Evaluation Trial</td>
</tr>
<tr>
<td>CNV</td>
<td>Choroidal-neovascularisation</td>
</tr>
<tr>
<td>CR</td>
<td>Corneal Radius of curvature</td>
</tr>
<tr>
<td>CREAM</td>
<td>Consortium for Refractive Error And Myopia</td>
</tr>
<tr>
<td>D</td>
<td>Dioptries</td>
</tr>
<tr>
<td>DNA</td>
<td>Deoxyribonucleic acid</td>
</tr>
<tr>
<td>FDM</td>
<td>Form-deprivation myopia</td>
</tr>
<tr>
<td>GWAS</td>
<td>Genome-wide association studies</td>
</tr>
<tr>
<td>GOALS</td>
<td>Guangzhou Outdoor Activity Longitudinal Study</td>
</tr>
<tr>
<td>ICCs</td>
<td>Intraclass Correlation Coefficients</td>
</tr>
<tr>
<td>LDL</td>
<td>Light Data Logger</td>
</tr>
<tr>
<td>NHANES</td>
<td>National Health and Nutrition Examination Surveys</td>
</tr>
<tr>
<td>NICER</td>
<td>Northern Ireland Childhood Errors of Refraction study</td>
</tr>
<tr>
<td>NIES</td>
<td>Norfolk Island Eye Study</td>
</tr>
<tr>
<td>OLSM</td>
<td>Orinda Longitudinal Study of Myopia</td>
</tr>
<tr>
<td>OR</td>
<td>Odds Ratio</td>
</tr>
<tr>
<td>RESC</td>
<td>Refractive Error Studies in Children</td>
</tr>
<tr>
<td>ROC</td>
<td>Receiver Operating Characteristic curve</td>
</tr>
<tr>
<td>SAVES</td>
<td>Sydney Adolescent Vascular and Eye Study</td>
</tr>
<tr>
<td>SCORM</td>
<td>Singapore Cohort study Of the Risk factors for Myopia</td>
</tr>
<tr>
<td>SD</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>SNPs</td>
<td>Single nucleotide polymorphisms</td>
</tr>
<tr>
<td>SER</td>
<td>Spherical Equivalent Refraction</td>
</tr>
<tr>
<td>SMS</td>
<td>Sydney Myopia Study</td>
</tr>
<tr>
<td>UK</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
</tr>
<tr>
<td>UV</td>
<td>Ultraviolet</td>
</tr>
<tr>
<td>VA</td>
<td>Visual Acuity</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
</tbody>
</table>
Abstract

Aims
The increasing prevalence of myopia in the last 50 years all around the globe has established myopia as a major issue of public health concern. This thesis highlights myopia occurrence, its prevalence, its measurement and prevention strategies through the lens of a few environmental factors, particularly the protective effect of time spent outdoors. Hence, this thesis focuses on exploring, investigating, and developing an accurate and cost-effective measure for quantifying the risk factors for myopia, especially based on the time spent outdoors.

Methods
The thesis tested the agreement of a diary, a questionnaire and a light data logger as measures of light exposure, under ideal conditions, and from the findings developed an electronic questionnaire with some additional features. The modified electronic questionnaire has built-in feedback on the estimation of time spent which constrains the responses on exposures over a 24-hour period by providing feedback to the respondent if responses are not valid.

Results
The data suggests the questionnaire might overestimate the time spent on all activities including time spent outdoors. Further development and refinement of the style and mode of deployment of questionnaires is needed to make them a useful cost-effective adjunct to measures obtained.

Conclusion
Time spent outdoors has been established as a risk factor myopia. This lifestyle factor can be easily modified and thus in this regard educational intervention is needed which will play a great role in reducing the overall prevalence of myopia. Identifying the required dosage level requires a measuring instrument which is reliable and can be applied at a population level.
Chapter one

Part 1 – The epidemiology of myopia

1.1.1 Introduction

1.1.1.1 Definition of myopia:

Myopia or short-sightedness is a condition in which an image of the object close to a person appear to be clear while objects that are far away appear blurred. In epidemiological studies, myopia is often defined as Spherical Equivalent Refraction (SER) of less than or equal to -0.50 dioptres (D), and it is often clinically classified as low myopia (SER ≤ -1 D to -3 D), moderate myopia (SER < -3 D to -5 D)\(^1\) and high myopia in which SER is defined as less than – 5 D in some studies\(^2\) or < -6 D in others.\(^3,4\) In this condition, the axial length (AL) of the eye is not matched to the optical power, and the light rays come to a focus in front of the retina. Low myopia is categorized as a mild form of nearsightedness. Being low means the degree or extent of severity. In people suffering from myopia, including low myopia, long-distance vision is blurred, because the light rays from distant objects come to focus in front of the retina, and thus the blurred image cannot be corrected using accommodation.

1.1.1.2 Axial myopia:

Axial myopia is defined as myopic refraction due to increased axial length. It has been reported by previous studies that people with high axial myopia are at increased risk of developing rhegmatogenous retinal detachment, glaucoma optic neuropathy, and myopic retinopathy, to name only a few.\(^5\) However, a question is raised that what is the cutoff value to differentiate between moderate axial myopia and high axial myopia. If the characteristic of high axial myopia is lengthening of the globe, chiefly at the posterior pole, then the cutoff
value for high axial myopia may be defined as the refractive error or axial length at which the size of the optic disc and the parapapillary atrophy noticeably increases. It has been discovered by hospital-based and population-based investigations that the optic disc and the parapapillary atrophy start to lengthen at about a value of −8.00 dioptres of refractive error or an axial length of ∼26.5 mm.\(^5\) Beyond these values, the incidence of myopic retinopathy and glaucomatous optic neuropathy sharply escalates.\(^5\)

**1.1.1.3 Non-pathological myopia:**
Non-pathological myopia is also commonly referred to as physiological, simple or school myopia. The degree of non-pathological myopia is usually mild to moderate (up to −5 D) and the onset usually begins during childhood or adolescence.\(^6\) School myopia appears during the school years and stabilizes by the late teens or early twenties.
Refractive error is the most common type of ocular morbidity and myopia is the most common type of refractive error, as opposed to hyperopia.\(^7\) In this context, school children are considered a high-risk group because any uncorrected refractive error can seriously affect their learning abilities and physical and mental development.\(^8\) Moreover, planning of a youth’s career is very much dependent on visual acuity, especially in jobs such as the navy, military, railways and aviation. These considerations warrant early detection and treatment of refractive errors.\(^9\)

**1.1.1.4 Prevalence of myopia:**

**1.1.1.4.1 Prevalence of myopia among the general population**
Myopia is the most prevalent refractive error worldwide. The highest reported prevalence rates (>60%) are among people in industrialized nations and urban settings in East Asia, such as Taiwan,\(^10\) Singapore,\(^11\) Japan,\(^12\) South Korea,\(^13,14\) and some cities in China\(^15,16\). The reported prevalence is moderately high (20-50%) among individuals in the United States,\(^17\) Australia
and Western Europe. The table below (Table 1) indicates some myopia prevalence rates in selected countries. Globally, myopia and high myopia prevalence rates were estimated at 27% (1.893 billion) and 2.8% (170 million) of the total global population as at 2010. Estimates by the Brien Holden Vision Institute (BHVI) indicate that the global prevalence is likely to increase to 52% and 10% for myopia and high myopia respectively by 2050.

1.1.1.4.2 Prevalence of myopia among children

The prevalence rates apparent in children between the ages of 5 and 15 years in a number of countries have been investigated by Refractive Error Studies in Children (RESC). The reported prevalence of myopia in East Asian children residing in urban areas remains high. The most recently available percentages are 18.3% in Hong Kong, 28.6% in Singapore and 20% in Taiwan. Between the ages of 10 and 12, the prevalence rates increase to 61.5% in Hong Kong and approximately 50% in Singapore and Taiwan. However, the reported figures for the prevalence rates of myopia in children in East Asia residing in less urbanized areas is much lower. The prevalence percentage in rural areas in China is 2% for 6-7-year old’s, and 5.9% for those residing in semi-urban districts. For the ages of 12-13 years, the percentage is 18% in rural areas, and 36.8% in both semi-rural and semi-urban in China. The myopia prevalence rate in Malaysia has reached 10% in children at 6 years of age, and 24.8% for those aged 12. In India, children at the age of 6 residing in urban areas had reported prevalence of 5.9%, increasing slightly to 9.7% for 10-year-old children in the same areas. The prevalence figures for those living in rural areas is much lower with it being estimated at 2.8% for 6-year-old children and a little higher for those who are age 12 with a 4.8% prevalence rate.

The prevalence of myopia is lower in general among European children of Caucasian ethnicities. However, the prevalence rates can vary depending on where they reside. The lowest reported myopia prevalence rate for children aged 6 was 0.8% according to the Sydney Myopia
The reported rate in both Poland and Northern Ireland is near 3%, whereas in Chile and the United States, the reported prevalence of myopia was near 5%. This was slightly higher in England with a myopia prevalence percentage of 6.

Table 1: Selection of some studies on the prevalence of myopia among children and young in different countries over the world:

<table>
<thead>
<tr>
<th>Author</th>
<th>Year of study</th>
<th>Country</th>
<th>Sample size</th>
<th>Age (years)</th>
<th>Myopia prevalence %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matsumura &amp; Hirai</td>
<td>1996</td>
<td>Japan</td>
<td>9,420</td>
<td>17</td>
<td>65.6</td>
</tr>
<tr>
<td>Lin et al.</td>
<td>2000</td>
<td>Taiwan</td>
<td>10,889</td>
<td>7 – 18</td>
<td>84</td>
</tr>
<tr>
<td>Koh et al.</td>
<td>2009-2010</td>
<td>Singapore</td>
<td>28,908</td>
<td>17-29</td>
<td>81.6</td>
</tr>
<tr>
<td>Jung et al.</td>
<td>2010</td>
<td>South Korea</td>
<td>23,616</td>
<td>19</td>
<td>96.5</td>
</tr>
<tr>
<td>Wu et al.</td>
<td>2010</td>
<td>China</td>
<td>6,026</td>
<td>17</td>
<td>84.6</td>
</tr>
<tr>
<td>Vitale et al.</td>
<td>1999-2004</td>
<td>United States</td>
<td>Undeclared</td>
<td>12 – 17</td>
<td>33.9</td>
</tr>
<tr>
<td>French et al.</td>
<td>2009-2011</td>
<td>Australia</td>
<td>1,196</td>
<td>17</td>
<td>30.8</td>
</tr>
<tr>
<td>Jacobsen et al.</td>
<td>2004</td>
<td>Denmark</td>
<td>4,681</td>
<td>8-13</td>
<td>12.8</td>
</tr>
</tbody>
</table>

Table 1 Selection of some studies on the prevalence of myopia among children and young in different countries over the world

1.1.1.5 Complications of myopia

While myopia is readily corrected by optical means, it is more than just a benign condition. Myopia has been found to lead to other eye disorders and conditions; myopic patients, in many studies, had higher risks of posterior subcapsular cataract, nuclear and cortical cataract. The
mechanism by which myopia leads to lens changes is unknown, however, it has been associated with damage to the outer segments of rods and production of cataract causing lipid peroxidation products.\(^{38}\) Myopic adults also face higher risks for glaucoma as well as chorioretinal abnormalities and optic disc abnormalities\(^{37}\), due to the fact the increased AL causes increased cup-disc ratio, higher chances of optic nerve fiber layer defects, and greater possibility of distortion of lamina cribrosa, all of which leads to increased chances of glaucomatous changes in optic disc.\(^{39}\) In the case of low to moderate myopia, it has been suggested that a person may develop nuclear and posterior subcapsular cataracts at an earlier age as found by Pan et al., who reported odds ratios (OR ) of 2.81 (95% CI 1.94 - 4.06) for myopic people to have nuclear cataract, and OR of 1.93 (95% CI 1.49-2.49) for myopic people to have posterior subcapsular cataract.\(^{40}\) Also, Younan et al. found that OR for nuclear cataract was 3.3, 95% CI 1.5–7.4, and for posterior subcapsular cataract was OR 2.1, 95% CI 1.0–4.8).\(^{41}\) In addition, those with low myopia (up to - 3 D) are also at high risk of developing glaucoma (OR 1.65 95% CI 1.26–2.17).\(^{42}\) People with high myopia (< - 5 D myopic) are at higher risk of glaucoma as well compared to low myopia (OR 2.46, 95% CI 1.93–3.15).\(^{42}\)

As mentioned previously, when a person becomes myopic, the risk of developing uncorrectable visual impairment is much higher, with a high risk of retinal detachment that occurs when the neurosensory retina and retinal pigment epithelium become separated.\(^{43}\) If not attended to early, this can lead to permanent blindness. Moreover, high myopia (SER < -5D), which has a reported prevalence ranging from 6.8% to 21.6% in Asian countries compared to 2%–2.3% in Western countries,\(^{44}\) can develop into pathological myopia (PM).\(^{45}\) PM is arguably best defined as high myopia with specific forms of pathology which are associated with myopia.\(^{46}\) The reported prevalence of pathological myopia is between 0.9% and 3.1% among middle-aged and elderly people with high myopia in Asian countries \(^{44}\) while the prevalence of PM of the equivalent age in non-Asian people is 1.2%.\(^{44}\) It should also be noted that the prevalence of
PM amongst populations with high myopia is significant, with prevalence rates increasing with age. Other conditions can occur in conjunction with high myopia such as myopic choroidal-neovascularisation (CNV) which is one of the features of pathological myopia and that occurs when there is the growth of blood vessels from the choroid to the retina. This condition affects 10% of people with high myopia, 30% of them having both eyes affected by CNV which in the majority leads to visual impairment after five years. Further, with high myopia, there is a posterior staphyloma that is also considered as a basic form of pathological myopia. It is an outward bulge occurring in the posterior part of the eye and is classified into many types based on its location, size, and severity.

Pathological myopia is a possible disease causing visual impairment. Cataract and glaucoma are the foremost causes of blindness and visual impairment. Myopic degeneration is also an important cause of blindness worldwide. The Rotterdam study which included 6775 subjects aged 55 years and older, revealed that the major cause of impaired vision was myopic degeneration (accounting for 23.0% in adults younger than 75 years). There were 22 cases of visual impairment in subjects younger than 75 years, out of which five cases (23.0%) were caused by myopic degeneration. Although myopic degeneration is a principal cause of diminished vision in adults <75 years, it was shown by the data in this study its effect on visual impairment was small as compared to other causes that affect vision. A study of 1000 residents aged 60–80 years in Copenhagen showed that myopic macular degeneration was one of the most common reasons for bilateral blindness (accounting for 10%). Again, the total number of cases of blindness which occurred because of macular degeneration was only 100 and thus the overall impact of myopic degeneration on vision may not be large, but this is in a population with low rates of myopia and high myopia. Moreover, in a survey of adults 50 years or older in Taiwan, myopic macular degeneration was the second most common cause of correctable visual impairment (contributing 25.0% of cases). Similarly, a survey by Iwano
and colleagues in Japan of 2263 adults aged 40–79 years reported that the OR of visual impairment for myopic adults was 2.9 (95% CI 1.4, 6.0). In East Asian countries, due to a greater incidence of myopia and high myopia, myopia may be the leading cause of visual impairment. Myopia, if not corrected due to the lens prescription not being updated or myopia being not diagnosed, can also cause diminished vision. Uncorrected myopia is in fact one of the leading causes of visual impairment, but, fortunately, it can be corrected without any problem.

Therefore, myopia leads to other eye diseases with potentially vision-threatening consequences, including untreatable visual impairment and even blindness. A consequence of visual impairment is the degradation of the quality of life. A recent American study surveyed 2044 participants to measure awareness of eye health in the United States. The study found that vision loss was the most common phobia among people and the people express it as the worst condition to affect their daily life, even more than cancer.

1.1.1.6 The economic cost of myopia:

Myopia is also a highly costly disorder imposing medical costs as well as economic costs. The medical costs are related to doctors' and hospitals' expenses for screening and diagnosis, while the economic costs are in part associated with the costs of buying contact lenses and spectacles for optical correction. The costs of refractive surgery are even higher in the short term. The costs are not related only to the person with myopia but have a wider impact. These social costs include the training of ophthalmologists, optometrists and optical dispensers. In locations where the prevalence of myopia is high, the demand for these services is even greater and therefore, will impose a greater cost. All these issues need consideration when calculating the total cost of myopia. Further, there are additional community costs, known as indirect costs, largely associated with visually impaired individuals, including the provision of carers, as well as informal care, equipment, and aids that are required to help cope with visual impairment,
and lost productivity because of early retirement, absenteeism or the inability to work at full capacity, and premature mortality as a result of visual impairment.\textsuperscript{55}

In Australia, for example, the total cost of visual impairment in 2004 was estimated to be around AUD 5 billion for direct and indirect costs.\textsuperscript{55,56} Direct health costs totalled AUD 1.8 billion in 2004. Indirect costs were AUD 3.2 billion, which clearly shows that the indirect costs are higher than the direct costs. Cataract, for example, which is one of the leading causes of visual impairment and blindness, causes the largest cost in Australia (AUD 326.6 million), while correction of refractive error, another condition affecting vision, is the next, with a cost of AUD 261.3 million.\textsuperscript{55,56} Although an exact breakdown of the cost by the condition is not available, a large proportion of this refractive error cost would be associated with myopia since it is the most prevalent refractive condition. In the United States, medical costs of visual impairment have been estimated to be $7.8 billion for diagnosed and undiagnosed disorders in 2012 for adults between 18 and 39 years.\textsuperscript{57} The economic costs were $13 billion, primarily for productivity losses, and $4.9 billion for refraction correction.\textsuperscript{57} These factors make myopia a very costly disorder that requires it to be addressed as soon as it is discovered in an individual or, better, to be prevented altogether.

1.1.2 Origins of Myopia: The Genetic Theory

1.1.2.1 Twin Studies

In 1962, Sorsby and colleagues reported the correlations of individual optical components such as power of cornea, anterior chamber depth, power of lens and axial length, among 78 pairs of monozygotic twins and 40 pairs of dizygotic twins with 48 unrelated ‘control’ pairs matched for age and sex corresponding to the characteristics of the monozygotic twins.\textsuperscript{58} These correlations are shown in the table below (Table 2) using the data derived from the Table 1A of Statistical Note on the Components of Ocular Refraction in Twins.\textsuperscript{59} Based on the fact that monozygotic twins share 100\% of their genes, while dizygotic twins share only 50\%
of their genes, they concluded that the higher correlations between the monozygotic as compared to the dizygotic twin pairs indicated that the characteristics of optical components were inherited. The expectations for a fully genetic condition are correlations of 1.00 for MZ, 0.5 for DZ, ordinary siblings, and parents and their children, with lower correlations for more distant relatives such as cousins (0.125). Sorsby had earlier stated that all refractive states were genetically determined and that the only question remaining was whether environmental factors played any role at all.58 These strong statements led to a general acceptance that all refractive errors were genetically determined, which was articulated by the UK Medical Research Council in the introduction of Sorsby's study. “It may, therefore, be taken as established that the dimensions of the optical components, the efficiency of the mechanism coordinating the growth of the components and thus the refraction of the eye are all genetically determined. The modes of inheritance and the possibility that environmental factors have a minor modifying influence are the principal problems now awaiting clarification”.

Table 2: Coefficients of Correlation for the optical components of the study groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Coefficient of Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Power of Cornea</td>
</tr>
<tr>
<td>Monozygotic Pairs</td>
<td>0.934</td>
</tr>
<tr>
<td>Dizygotic Pairs</td>
<td>0.591</td>
</tr>
<tr>
<td>Control Pairs</td>
<td>0.075</td>
</tr>
</tbody>
</table>

Table 2 Coefficients of Correlation for the optical components of the study groups

* The meaning of Control Pairs was not explained in the paper

This conceptualisation of myopia as a genetic disease was reinforced by examining the occurrence of myopia in both twin and family studies. A statistical measure frequently used in
these studies is *heritability*, which measures how much variation in a phenotypic trait (such as refraction) can be attributed to genetic variation among individuals in a population if certain assumptions are made.

In 1988, Terikari et al.\textsuperscript{60} conducted a study on nearly 12,000 monozygotic and dizygotic Finnish same-sex twins using data from the Finnish Police Force on use of glasses while driving to correct distance vision as a marker for myopia. They used the Falconer method for estimation of heritability and the following assumptions were made: all genetic effects on refractive errors are additive only, matching for possession of a driver’s license and refractive error is random, and that MZ and DZ pairs share equal environmental influences relevant to refractive errors that affect the far vision. The study established heritability rates of myopia in male and female twin pairs aged 28-39 years of 0.84 and 0.98 respectively.\textsuperscript{60} Using a more direct measure of refraction (non-cycloplegic auto-refraction) Hammond and colleagues, studied 226 monozygotic and 280 dizygotic female twin pairs aged 49 to 79 years.\textsuperscript{61} They calculated heritability using an AE (additive genes/ unique environment) model for spherical equivalent and an ADE (A stands for additive genetic effects, D for non-additive genetic (or dominance) effects, and E for nonshared environment effects) model for astigmatism. The authors found that the correlation for refractive error was 84% to 86% in monozygotic twin pairs, and 47% to 48% in dizygotic twin pairs, with all refraction approximately 76% heritable.

Lyhne et al.\textsuperscript{62} reported on determinants of refraction from a small study of twin pairs (114) using cycloplegic refraction, ultrasound measurements of ocular biometry and also including an environmental factor believed to be associated with refractive error, educational attainment (see section 1.5.1). They estimated heritability using the aetiological model based on structural equations, and this model makes the assumption of no gene-environment interaction for ocular refraction. This study also found high heritability for ocular refraction (>0.93) and ocular components.\textsuperscript{62} Consistent with Lyhne’s study, Dirani et al.\textsuperscript{63} (2006) examined refraction and
ocular biometry in 345 monozygotic and 267 dizygotic Australian twin pairs aged between 18 and 88 years. Objective refraction and ocular biometry were measured after dilation with 1% tropicamide. Heritability estimates were made using ADE model. They found that the heritability of refraction was 0.88 among male/male MZ twins compared with 0.75 among female/female MZ twins. The heritability of axial length was 0.94 amongst males and 0.92 amongst females. They again concluded that variation in refractive error was due to genetic factors. The study also found that higher education was associated with SER and AL, P < 0.05.63 But this study also reported that the correlation in educational achievements is higher in MZ twins than DZ twins, which, to the extent that education is an environmental factor, suggests that the common environment assumption has been violated. But the heritability of educational achievements is also high, and thus it can be argued that the environmental factor of education is genetically determined.

Also, Kim et al. (2013) determined the heritability of myopia and other ocular biometry among some Korean twins and families (240 MZ twin pairs, 45 DZ twin pairs, and 938 siblings).64 In this study heritability was estimated using AE effects model for spherical equivalent, axial length, and corneal astigmatism and for anterior chamber depth ACE (A stands for additive genetic effects, C stands for common environment, and E for unique environment) model was used. They found that Intraclass Correlate Coefficient (ICC) - which is defined as the coefficient that measures the relationship between paired measurements from the same subject, i.e., right and left eyes - for MZ twin pairs for SER, axial length, anterior chamber depth and corneal astigmatism were 0.83, 0.87, 0.90 and 0.72 respectively. The ICC values for DZ twin pairs for SER, axial length, anterior chamber depth and corneal astigmatism were much lower, 0.46, 0.56, 0.71 and 0.28 respectively, and close to the equivalent ICC values for siblings, 0.40, 0.47, 0.47, and 0.25. They concluded that genetic contribution to myopia among Korean people was established.64 These studies have consistently reported high heritability.
However, not all studies of the genetic inheritance of refractive state have found such high levels of heritability. Lin and Chen conducted a study in Taiwan of 90 monozygotic twin pairs and 36 dizygotic twin pairs aged 7 to 23 years. Subjective and objective retinoscopy and cycloplegic autorefraction were applied, and axial length was measured ultrasonographically. The estimated heritability was as low as 0.24, 0.25, and 0.27 for refraction, corneal curvature, and axial length respectively. This low heritability estimate may be because the prevalence of myopia was already very high in this population, which could result in high correlations in both MZ and DZ twins. Angi et al. evaluated heritability of refractive error (cycloplegic autorefraction) and axial length (ultrasound measurement) amongst 19 monozygotic and 20 dizygotic twin pairs, with a mean age of 5 years. Heritability was estimated using $h^2 = 2(r_{mz} - r_{dz})$, where $r$ was obtained using $V_b$ (variance between pairs) – $V_w$ (variance within pairs). They found that the heritability of refractive error was 0.08–0.14, which was low, and they stated that the observed variability in refractive errors was nongenetic in origin. This study had a limited number of twin pairs (<40), and the mean age of participants was five years which means the full development of final adult refraction was not complete. This study also noted no difference in myopia prevalence between urban and rural environments, an issue relevant to the role of environmental factors in myopia (discussed below). In 2009, Tsai et al. studied 58 twin pairs (41 monozygotic and 17 dizygotic twin pairs), and 13 siblings (average age 37). These subjects all had myopia and a similar standard of educational attainment with more than 12 years of schooling. Refractive status was examined through cycloplegic auto-refraction and A-scan for axial length measurements. Heritability was estimated using a Bayesian linear mixed model. The heritability rate was low at 0.331 for refraction, but the Pearson’s correlation (r) was high for both the MZ and DZ twin pairs (0.893 and 0.728 respectively). The axial length had a moderate heritability (0.670) with correlations of 0.931 and 0.596 for the monozygotic and dizygotic twin pairs respectively. They concluded that both genetic and environmental
factors played a role in myopia, but made no comments regarding the higher heritability values for axial length. However, this was a small sample size with limited power. All twins were myopic with the DZ twins having more negative power than the MZ pairs. They also used both eyes of each twin pair.

In summary, twin studies have given high heritability values based on higher correlations in monozygotic pairs than in dizygotic twin pairs (Table 3). There is thus no doubt that the heritability of refraction as a continuous variable or myopia as a condition is high in twin studies. But because of the assumptions that are made to calculate heritability – that a multifactorial mode of inheritance is operating - it is not clear how generalisable these values are to more distant family relationships where environmental differences are likely to be more significant.
Table 3: Heritability and correlations rates among monozygotic pairs and dizygotic twin-pairs

<table>
<thead>
<tr>
<th>Author</th>
<th>Phenotype</th>
<th>n</th>
<th>MZ Pairs</th>
<th>Heritability rate</th>
<th>Correlation or ICC</th>
<th>n</th>
<th>DZ Pairs</th>
<th>Heritability rate</th>
<th>Correlation or ICC</th>
<th>n</th>
<th>Siblings or Control Heritability rate</th>
<th>Correlation or ICC</th>
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<tr>
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<td></td>
<td></td>
<td>0.65</td>
<td>0.51</td>
<td></td>
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<td></td>
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</tbody>
</table>

Table 3 Heritability and correlation rates among monozygotic pairs and dizygotic twin pairs
1.1.2.2 Parental Studies

Parental studies are another line of evidence that has been used to support the idea that myopia is genetically inherited where multiple parental studies report a positive correlation between parental myopia and myopia in their children, indicating heritable myopia susceptibility \(^{44-49}\), given the fact that parents also create environments for their children. Thus if myopic parents create different environments, this association could be due to non-genetic causes.

Zadnik et al. studied 716 children aged 6 to 14 years, noting that children born to myopic parents had a higher risk of developing myopia than children with non-myopic parents.\(^6^8\) These researchers noted that 11% of children with both parents myopic, 5% of children with one of the parents myopic and 2% with non-myopic parents developed myopia\(^6^8\) suggesting that this condition is inherited with the family. Also, Yap et al.\(^6^9\) conducted a study among 2888 Chinese children between 7 and 17 years old, finding that children with both parents myopic were at higher risk of being myopic than children with non-myopic parents.\(^6^9\) Ip et al.\(^7^0\) (2007) conducted a study on the impact of parental myopia on 2353 children at the age of 12 and found the myopia rate was 7.6%, 14.9%, and 43.6% for children with none, one, or two myopic parents.\(^7^0\) Lam et al.,\(^7^1\) also followed up 7560 Chinese children to find out the effect of parental myopia on children. They found that the annual change in myopia (SER) was increased with the number of myopic parents. The increase was by -0.02 D, -0.07 D and -0.22 for children with none, one, and two myopic parents, respectively.\(^7^1\)

Zhang, Qu, and Zhou conducted a meta-analysis of 16 studies with 31,677 participants to establish the relationship between one or two parents having myopia and the child’s risk of developing the condition.\(^7^2\) This meta-analysis involved 8,393 cases of myopia from different studies. The findings of their analysis provided evidence of a significant relationship between parental myopia and the risk of developing the same condition among children. The OR of a
myopia parent giving birth to a myopic child was 1.96, 1.53 and 2.13 at 95% confidence for cross-sectional, prospective cohort, and case-control studies respectively. When both parents were myopic, the odds ratios rose to 2.96, 2.10, and 2.96 respectively.\textsuperscript{72} Mutti et al. conducted a similar study but added other factors that could have led to myopia cases among the participants.\textsuperscript{73} The additional factors included visual activities of children and achievement in the standardised test. Three hundred and sixty-six children in the eighth grade participated in the study. Of all the factors, parental myopia had the strongest association with juvenile myopia. The findings provide further proof that the children with two myopic parents are at a higher risk of developing myopia.\textsuperscript{73} However, the studies did not provide conclusive evidence that the high risk was due to genetic inheritance.

Xiang et al.\textsuperscript{74} studied 1,567 children aged 12-15 years and noted that highly myopic parents increased the risk of developing myopia in their children. However, the researchers also found that 43.5% of myopic children did not have parents with myopia, implying that factors other than genetics must be playing a role in the determination of refractive error. From this study, the authors concluded that while genes influence the development of the condition, environmental factors also affect the occurrence of the disease and affect its severity. In another study on broader sample size, (4364 children in Guangzhou), Xiang et al.\textsuperscript{74} found that 68.2% of children with myopia had parents who did not have myopia.\textsuperscript{74} The authors also noted that despite the lack of myopia in the parents, most children with myopia developed the disease by the time they were 15 years old.\textsuperscript{74} The figure is highly important as the number of patients who have been myopic are teenagers who are prone to environmental, societal and educational pressures; where the myopic diagnosis in such a young age might leave a negative impact or develop to a significantly higher level with the passage of time. The authors suggest that this high “baseline” level of myopia at the age of 15 years is associated with environmental pressures including increased educational pressures and urbanization.\textsuperscript{74} These population-
based epidemiological studies on myopia indicate that myopia can occur due to non-genetic as well as genetic factors.

1.1.2.3 Family Studies

Familial studies have estimated the odds ratios of myopia for siblings from 2 to 5.61. Even more significant familial aggregation is shown when more extreme refractive errors are compared to the milder forms. Furthermore, the offspring of parents with myopia typically feature longer eyes and can be more likely to have myopia onset during their early childhood years or adolescence. Segregation analysis conducted on population-based samples has been found to be consistent with an inheritance pattern for ocular refraction which is complex and involves several shared environmental factors and/or genes.

Through the familial linkage analysis, 23 loci associated with myopia have been defined. Linkage analysis mainly deals with rare genetic forms of myopia, of which there are 100-200 and is performed when there is a clear concentration of myopia within families.

In linkage studies, researchers study families and investigate the pattern of similarity in myopia in different family members. Then they look for segregation of a genetic region in affected individuals in families. The first locus for high myopia, MYP1 on Xq28, was identified by Lam et al. in Hong Kong Chinese families, and also reported by Schwartz et al. Young et al. conducted a linkage study among eight American families with a total of 82 individuals. They conducted a genome screen for myopia-susceptibility loci in several media from large multigenerational families with autosomal dominant high myopia (≤6 D). There was a significant linkage at 18p11.31 for 7 families. Young et al. conducted the study again with a large Italian/German family, and found significant linkage of high myopia to a second locus at the 12q21-23 region. Farbrother et al. conducted another linkage study on 51 families in the United Kingdom (total of 251 individuals) and found that the MYP3 locus on 12q was more
common for high myopia among the U.K families (approximately 25%).\textsuperscript{90} \textit{MYP3}, a second locus for fully penetrant nonsyndromic high myopia, was found on 12q in a single, large, German-Italian family (two-point LOD score 3.85 for markers \textit{D12S1706} and \textit{D12S327} at 12q21-23).\textsuperscript{91} Subsequently, a third locus has been recognized on 17q in a single large family of English-Canadian lineage (two-point LOD score 3.17 for marker \textit{D17S1604} on 17q21-22, dichotomization criterion −5.00 D RE MMM), and there has been an indication of a fourth locus on 7q in a study of 23 small families in France.\textsuperscript{91} No evidence was established for participation of the \textit{MYP2} or \textit{MYP3} loci (dichotomization criterion −0.75 D RE least minus meridian with onset before 17 years of age) in linkage analysis by Mutti et al. of juvenile-onset myopia in 53 nuclear families.\textsuperscript{92}

Some family studies of myopia also cover the correlations between siblings affected with the condition. Guggenheim et al. conducted a study among 315 children in Singapore. The study aimed to determine the contribution of familial factors to ocular component dimensions and refractive error.\textsuperscript{93} All the participants had one or two myopic siblings. The familial factors studied were shared genes and family environment which includes diet, social relations, emotional relations, entertainment, education, physical aspects of the living space, familial contacts etc. The correlation between siblings in refractive errors was 0.447 (95\% CI 0.314 to 0.564). The correlations of ocular component dimensions among siblings were equally significant. Guggenheim et al. established that significant factors in the refractive development of children are shared genes and/or shared environment in Singapore. Since the time spent in near work tasks is strongly interrelated between siblings, epidemiological studies will be advantaged by accurate, quantitative measures of refractive error in parents and more distant relatives in order to begin to separate genetic and environmental sources of disparity.\textsuperscript{93} Siblings that grow up in the same environment are likely to suffer from myopia. Further research is necessary to explain the variance in the level of risk among siblings.\textsuperscript{94}
In the Genes in Myopia GEM family study, the researchers investigated shared environment estimates and heritability for myopia and associated ocular biometric traits by exploring familial correlations and heritabilities of spherical equivalent (SER) and ocular biometric traits in extended families with myopia. The study included 132 parentages which contained 723 participants. The selection criteria were that participants needed to have myopia and either one affected sibling or one affected parent. Using partial coherence interferometry together with an IOL Master (Carl Zeiss, Oberkochen, Germany), the team measured corneal curvature (CC), lens power, anterior chamber depth (ACD) and AL for each participant. The researchers also used a Topcon SL-1E slit lamp (Topcon Corporation, Tokyo, Japan) to measure anterior segments in older participants such as those over 45. Analysis adjusted for shared environmental effects, sex, age and total years of education, along with the ascertainment process. Familial associations suggested that both genes and environment influence SER, whereas ocular biometric traits are influenced only by genes.

1.1.2.4 Syndromic myopia

There are a large number of genetically inherited forms of myopia. The Online Mendelian Inheritance in Man (OMIM) database in PubMed currently shows that myopia had been described in more than 250 syndromic and highly inherited conditions associated with specific genetic mutations. One of the frequent characteristics of these forms of myopia is the early age of onset, and most myopia associated with these syndromic conditions is severe. Inherited syndromes such as the Knobloch syndrome, Stickler’s syndrome and Marfan syndromes are all associated with high myopia. Inherited syndromes such as the Knobloch syndrome, Stickler’s syndrome and Marfan syndromes are all associated with high myopia.

The existence of genetically inherited forms of familial myopia does not prove that all myopias have a genetic basis. However, it remains possible that where myopia is severe and has an early onset, genes may play a more significant role in the development of these cases of myopia than those of later onset and more moderate levels of myopic refraction.
Genetic forms of myopia are rare and affect a small percentage of the population suffering from myopia. Hence, the existence of hereditary forms of myopia does not explain the high prevalence of myopia in different parts of the world. Other factors apart from genetics must be increasing the prevalence of myopia and a number of possible factors have been suggested including education, near work, urbanization, prenatal factors, socioeconomic status, cognitive ability, the season of birth, light, and time spent outdoors.  

1.1.2.5 Genome-wide association studies (GWAS)

Single nucleotide polymorphisms (SNPs) represent the most common genetic variations in any population. They generally occur throughout one’s deoxyribonucleic acid (DNA), once on average in each three hundred. Each SNP represents a difference in a single DNA building block, called a nucleotide. SNPs as discovered by GWAS account for only a small fraction of the genetic variation of many complex traits in human populations. SNPs generally have no effect on health but may influence an individual’s risk of developing a certain disease. Scientists use SNPs as biological markers that enable them to locate genes that are associated with a particular condition.

To investigate the genetic factors for myopia in the general population studies similar to the heritability analysis in twins, GWASs and a series of replications in follow-up association studies have identified numerous associations with myopia, although some are uncertain.

When applied to human data, GWA studies compare the DNA of participants having varying phenotypes. The main advantage of these studies is that researchers can determine the contribution of identified genetic variations to some conditions including myopia. These participants may be classified on the basis of whether they have the disease (cases) or not (controls), or classification can also be done on the basis of phenotypic traits, such as blood pressure. A DNA sample is obtained from each participant and many genetic variants are read using SNP arrays. Association of any one type of variant with the disease is established if one
variant is found more frequently in participants with disease. The associated SNPs are then considered to indicate a region of the human genome that may influence the risk of disease.\textsuperscript{100} Solouki et al. \textsuperscript{101} conducted GWAS for refractive error among 5,328 individuals, and they found a significant association at chromosome 15q14. The OR of myopia compared to hyperopia for homozygous individuals who have two copies of the same variant at a particular locus for a particular trait, was 1.83, while the OR for heterozygous individuals who have two different alleles at the locus, was 1.41.\textsuperscript{101} In contrast, Hysi et al.\textsuperscript{102} observed an association with an SNP at a genetic region 15q25, thus identified the association of myopia with chromosome 15q25 among 4,270 individuals. The OR for homozygous individuals was 1.16.\textsuperscript{102} In Singapore, Li et al. analysed 3 cohorts among the Chinese population with the total 4047 participants. They identified a strong high myopia correlation with the CTNND2 gene on chromosome 5p15.\textsuperscript{103} Additionally, among 1088 individuals, Han Chinese, Shi et al. found a strong association between high myopia and genes at 13q12.12. The OR for homozygotes was 1.64 compared with OR 1.32 for heterozygotes.\textsuperscript{104} There have been two large population studies examining this issue using GWAS. The first is the Consortium of Refractive Error and Myopia (CREAM), which is an international collaborative initiative between researchers studying cohorts of both European and Asian ethnicities. The CREAM study used 31 cohorts with a total of 55,177 participants representing four different continents.\textsuperscript{105} They performed a meta-analysis of 14 SNPs on 15q14 and 5 SNPs on 15q25. They found at locus 15q14 a significant risk of myopia versus hyperopia with OR 1.88 for homozygous and OR 1.33 for heterozygous, while at locus 15q25 was not significant.\textsuperscript{105} A comparatively smaller sample size of CREAM (in total 45,758 individuals) was published in 2013. They identified around 24 new loci that were associated with refractive errors.\textsuperscript{106} The second one was performed by the direct-to-consumer genomics company 23andMe (Mountain View, CA, USA).\textsuperscript{107} It was from an American population of European
origin who responded to a questionnaire asking the age of onset of myopia and selecting those aged between 5 to 30 years. There were 45,771 participants in total.\textsuperscript{107} The study identified 20 loci significantly associated with myopia development. Using a subset of 8,323 myopic participants who developed myopia before the age of 10, Kiefer et al. replicated 10 of the novel loci identified.\textsuperscript{107} This study replicated similar GWAS findings from the CREAM consortium that had used actual measures of refraction.\textsuperscript{108} By combining datasets from CREAM and 23andMe, Tedja et al. conducted a large GWAS meta-analysis in 160,420 participants, which was then replicated in 95,505 participants.\textsuperscript{109} They identified 139 independent susceptibility loci through single variant analysis and 22 additional loci through post-GWAS methods.\textsuperscript{109} However, GWAS analysis still can only explain a very small proportion of myopia variance by genetic factors.\textsuperscript{110}

Heritability measures what amount of variation of a phenotypic trait in a population can be attributed to genetic variation among individuals in that population, based on certain assumptions. GWAS results can also be used to define SNP heritability.\textsuperscript{111} SNP heritability is the fraction of variance of a phenotypic trait as explained by SNPs.\textsuperscript{111} GWAS makes multiple comparisons and thus the probability cut-off for significance needs to be adjusted for them. This means that many associations are not significant on a genome-wide basis. SNP-heritability seeks to get around this by ignoring the criterion for genome-wide significance and taking all associations which show simple significant association. The logic is that most of these might prove to be significant if the sample size was greater. It could thus be possible that many SNPs have effects on the traits that are too small to be demonstrated, but which collectively could account for much or all of the missing heritability. Since 2005, GWAS has matured into a powerful tool to identify SNPs that can be reproducibly associated with a variety of human phenotypes.

\textbf{1.1.2.5.1 The Modest Size of Genetic Effects:}
The modest size of genetic effects found up till now confirms that the these conditions are caused by multifactorial patterns and indicates the need for more research to explore the effects of genes in more complex diseases. There is general agreement that some approaches for finding missing heritability will be beneficial. Methods include targeted or whole-genome sequencing in people with extreme phenotypes, especially those having family members that can be contacted with consent and also consent obtained for frequentative phenotyping; usage of extended reference panels of genomic variation such as those of 1,000 Genomes to improve coverage of existing and future GWAS; finding of existing GWAS for associations with structural variants and evidence of gene-gene interactions; upgraded approaches for finding of CNVs and other variants applied to large well-phenotyped groups and families; and expansion of sample sizes for various complex diseases through larger individual studies and meta-analyses, also including people of non-European descent. Although the identified SNPs only explain 5-10% of the variance in refraction, SNP-heritability explains only 25-35% of the variance. Measured time outdoors and near work, topics of discussion in later chapters, explain much less variance comparatively, based on figures from existing questionnaires. This issue is addressed in detail later in the thesis.

Considering the raw estimates concerning the stated relationship, SNP’s and variance proportion seem to be directly proportional because increasing the SNP’s results in increase variance whereas prediction error seems to be reduced to a significant level. When an adjustment to the estimates is being made considering the aspects of prediction error, the variance proportion as well as the number of SNP’s become independent. Studies have estimated that the estimates of heritability are very high specifically when it is related to refractive error; for families, it is 15% to 70%. However, the individuals who are considered to be related share a common environment, are considered to be inflated.
1.1.3 Weakness in twin and family studies

Family and twin studies on myopia are faced with crucial weaknesses that question their validity. Twin studies have been the pillar on which the argument that myopia as genetic is largely founded. Twin studies compare myopia prevalence in monozygotic or identical, and dizygotic or non-identical twins, and have found higher within-pair correlations in monozygotic twins. The genetic theory assumes that the range of discordance in the environment seen in MZ twin pairs is the same as in DZ pairs. But it is not clear that this assumption is valid. Myopia appears to be strongly linked to education, and educational outcomes can differ between genders. Monozygotic twins are always of the same gender, whereas dizygotic twins can be different genders, and where there are different educational activities of males and females, monozygotic twin pairs may share more similar environments than dizygotic twin pairs. Further, the environmental similarity of monozygotic twin pairs as a group may be higher than the environmental similarity of dizygotic twin pairs even if the dizygotic twins are of the same gender.

1.1.4 Evidence that is not compatible with the genetic theory

The genetic theory cannot explain rapid changes in the prevalence of myopia, yet prevalence has significantly been increasing globally over the past forty to fifty years, and become a significant issue of public health concern. A study by Wojciechowski and Cheng argues that all genetic loci discovered to date demonstrate that refractive development is a heterogeneous process which is mediated by a range of overlapping and biological processes. The gene pools in populations cannot change rapidly. The genetic theory in relation to myopia, the approach fails profoundly in explaining the rapid increase of the condition because of the low rate of genetic change over time.

Many studies have documented the increase of prevalence among one population between generations or equivalent ages in the same population. In 1969 a cross-sectional study reported
an inter-generational increase in the prevalence of myopia in Alaskan Inuit.\textsuperscript{116} It was reported that the prevalence of myopia had changed from less than 5\% in older generations to over 60\% in the youngest generation.\textsuperscript{116,117} These findings were confirmed by Morgan et al. in 1973.\textsuperscript{118,119} At that time the evidence of rapid changes in myopia prevalence between generations was disbelieved, mainly because it was not compatible with the then widely-accepted genetic theory.\textsuperscript{120} However, this was followed by an increasing body of evidence of rapid changes within decades in myopia prevalence in Southeast Asia, which challenged the genetic theory. In Taiwan, the prevalence of myopia was more than 80\% in both 15 years old and 18 years old groups in 2000, up from 64.2\% and 74\%, respectively, in 1983.\textsuperscript{10} The rate of myopia in young Singaporean adults recorded between 1974 and 1984 was 26.3\%,\textsuperscript{121} while the rate of myopia in an equivalent group of young Singaporean adults in 2010 was 81.6\%.\textsuperscript{11} In the last three decades, the prevalence increased to more than 80\% in 17 years olds\textsuperscript{15,16} from 64\% in some Chinese cities.\textsuperscript{122} In Japan, the prevalence of myopia was 49.3\% in those who were 17-year-olds in 1984 and increased to 65.6\% in those who were 17-year-olds in 1996.\textsuperscript{12} A high prevalence of myopia has also been described in other East Asian urban populations such as South Korea.\textsuperscript{13,14} It was discovered by Jung et al. that the prevalence of myopia rose to the exceptionally high rate of 96.5\% in 19-year-old male conscripts in 2010,\textsuperscript{14} while the prevalence in 19-year-olds was 56.4\% in 2004.\textsuperscript{123} With the rise in the prevalence of myopia overall, rates of high myopia have also increased. It was 10.9\% in 1983 in Taiwan but increased to 21\% in 2000 in young adults.\textsuperscript{10} Approximately 15\% of Singaporean young adults had high myopia in 2010\textsuperscript{11} which increased from around 10\% in 1997.\textsuperscript{124,125} In South Korea, the rise in high myopia was even more dramatic, up from 12.9\% in 2004\textsuperscript{123} to 20.61\% in 2010.\textsuperscript{14} Also, Wu and Edwards conducted a study in Hong Kong among 3131 children aged 7 to 17 and their parents and grandparents to determine whether the genetic influences had remained stable or environmental factors had more impact in the younger of three generations of
families. They found that the prevalence of myopia was 5.8%, 20.8% and 26.2% in grandparents, parents, and children respectively, an increase too rapid to be explained by genetic changes, which suggests environmental factors may play a role in myopia development.

However, the rise in the prevalence of myopia is not just in developed countries in East and Southeast Asia. In the United States, researchers have reported from the National Health and Nutrition Examination Survey (NHANES), which examined vision and refractive data in a large population sample aged 12 to 54 years in 1971-2 and a second sample in the same age range in 1999 to 2004. These surveys showed that 25 percent of those examined in the early 1970s were deemed to be myopic, compared with 30 percent examined three decades later in the second study. This rise in the prevalence of myopia also appeared in Western and Northern Europe. In Australia where the overall prevalence of myopia is low at age 17 years in children of European Caucasian origin (17%), there are indications of an increase in the prevalence of myopia but again low compared with global changes. The prevalence of myopia at 12 years old in the Sydney Myopia Study (SMS) was 11.5% in 2005, but this rate increased to 18.9% in the Sydney Adolescent Vascular and Eye Study (SAVES) in 2013.

The second study by Williams et al. sought to examine the correlation between myopia and intelligence based on the fact that both can be heritable. A total of 1500 subjects aged between 14 and 18 from a twin birth cohort were included. The phenotypic correlation between intelligence and refractive error was reported to be -0.116. Further, both traits were determined to be heritable based on the bivariate twin modelling. The genetic factors were considered to explain at least 78 percent of the phenotypic correlation. The genetic variants for intelligence and refractive error offer some degree of explanation of the reciprocal variance which indicates a genetic pleiotropy. Consequently, the results highlight that shared genetic factors play a key role in covariance observed between myopia and intelligence.
One possibility for explaining the high prevalence of myopia in East and Southeast Asia is that their genetic background may predispose them for sensitivity to environmental factors. However, evidence from Tedja\textsuperscript{109} suggests there is little difference between the myopia-associated genes in European and East Asian populations. It, therefore, gives no support to the idea that the higher prevalence can be explained by genetic differences. The SNP-heritability is very low in the East Asians, consistent with the idea that environmental factors are more important\textsuperscript{109}. Moreover, there are studies which assert the confirmation that environmental factors are playing a role in the prevalence of myopia even among groups of similar ethnicity. Rose et al.\textsuperscript{129} (2008) conducted a comparative study of two cohorts of 6 and seven-year-old Chinese children living in Sydney and Singapore to determine the prevalence and risk factors of myopia. They found that the prevalence of myopia among Chinese students in Sydney (3.3\%) was much lower than the prevalence of myopia among Chinese students in Singapore (29.1\%) (P<.001) and found that the primary environmental factor that varied was the time children spent outdoors. Furthermore, the prevalence of myopia in young adults of Indian origin who were born and lived in Singapore is 68.7\%\textsuperscript{124} compared to less than 20\% in young adults in India\textsuperscript{27} suggesting again that environment, specifically that of Singapore, has a role. It appears to be characteristic of humans that people living in a “myopigenic” environment are susceptible to developing myopia. Generally, environment has more effect on incidence of myopia as compared to genes, and changes in environment have been found to be an important cause of increased incidence of myopia all over the world.\textsuperscript{130}

\textbf{1.1.5 Determining Environmental Risk Factors for Myopia}

Since changes in gene pools cannot account for the rapid increases in the prevalence of myopia, there have been many attempts to identify relevant environmental risk factors. Over the past decades, myopia prevalence has high levels in different places. The studies reveal that in the high-income countries in Asia such as China, South Korea and Singapore, 80\%-90\% the
school-leaving population becomes myopic by 17-18 years of age\textsuperscript{14,19,45} as compared to the U.K.’s 10%.\textsuperscript{131}

Research studies suggest that the increasing rates of myopia cannot be explained only by genetic change because population gene pools cannot change rapidly and the rate of myopia prevalence was low in older cohorts comparing to the recent studies. Singapore can be referred to as an example.\textsuperscript{11} The quick increase has been associated with some environmental factors such as education, near work activities or outdoor activity and light exposure.

1.1.5.1 Education Level

High achievement in an academic sense has been linked to myopia prevalence for a long time, at least since Kepler in 1611.\textsuperscript{132} According to Morgan et al. almost every study that has looked at scholarly achievements and myopia has found a link.\textsuperscript{133} The causal link between education and myopia has recently been confirmed by mendelian randomisation analysis in a recent paper by Mountjoy et al. in the British Medical Journal.\textsuperscript{131} The scholars investigated 67,798 men and women from England, Scotland, and Wales. They compared completed education years and refractive error. They found that university graduates were, on average, \(-1\) dioptre more myopic than persons who finished school at age 16. A study of 4,21,116 Singaporean young male adults who did the compulsory medical examination for military conscription between 1974 to 1991, found myopia prevalence based on visual acuity was 15.4% among males with no formal education, but increased to 57.5% among diploma holders and 65.1% among university graduates.\textsuperscript{121}

Another study examined data from 157,748 males recruited for military service in Israel. All males aged 17 to 19 have to do a medical examination. In this study, myopia was identified by measuring visual acuity by Snellen chart at 6 meters, followed by refraction for participants whose visual acuity was less than 6/7.5. All participants were divided into five groups depending on the number of school years completed. The researchers found that the prevalence
of myopia among people who completed 8 school years or less was 7.5%, and this percentage increased among those who completed 9 years to 8.8%, 11% for 10 school years completed, and 10.9% for 11 school years completed. The prevalence was significantly increased to 19.7% for those who completed 12 school years and more. This led the researchers to state that the correlation between myopia and level of education is well confirmed as an indication of the environmental factors contributing to the development of myopia.134

1.1.5.2 Near Work

It has been thought that near work is a risk factor for myopia. Angle and Wissmann, wishing to explore the use-abuse theory of myopia, that is, the continual use of eyes in near work causing myopia, reported in 1980 on data collected in a US Health Examination Survey (1966-70) of children 12-17 years old.135 Myopia was defined by the wearing of minus lenses in spectacles or reduced vision that was improved by testing vision while wearing minus lenses. Measures of near work included minutes per day in reading, performance on a reading test and completed level of schooling. They also collected additional demographic (social) variables. They found the R-squared value in multiple regression analysis predicting the level of myopia from demographic variables, including age (0.017), sex (0.003), race (0.013), income (0.010) and region (0.009) in the USA, was significantly improved with near work measures as predictors to be 0.066, 0.067, 0.067, 0.069 and 0.070, respectively (P≤ 0.05).135

In the same year, Richler and Bear reported a study of 957 participants in Newfoundland aged from 5 to 70, categorised into five age groups; 5-14 years, 15-29, 30-44, 45-59 and 60 years and above.136 They similarly aimed to determine the association between myopia and near work. Refractive status was assessed by retinoscopy and refined by subjective refraction. Near work was quantified by daily hours spent in reading, sewing, knitting and any other tasks performed at a distance of 50 cm or less. Also, education was measured by completed years in formal schools. Both greater near work and increases in the educational level were associated
with more negative refraction. The correlations of near-work and education level with refraction were moderate (varying between -0.489 to -0.187 depending on age group) but significant (p <0.05) for all the age groups under age 60. They were not significant in those aged 60 or older.¹³⁶

These early studies have since led to an extensive examination of near-work in population-based studies with inconsistent results, some finding an association but others not. Mutti et al. found a very weak association between near work and myopia (OR was 1.018 among 366 American students in grade 8).⁷³ In contrast, Saw et al. investigated the relationship between near work and myopia among 957 schoolchildren aged 7 to 9 years in Singapore and Xiamen, China. They found the OR was 3.50 for children who read more than 2 books a week.¹³⁷ Ip et al. examined 2339 schoolchildren in Sydney Myopia Study (SMS), and found the OR for myopia was 1.5 for children who spent more than half an hour in continuous reading, and OR 2.5 for students who read closer than 30 cm.¹³⁸ Similar findings were obtained by other studies.¹³⁹-¹⁴¹

In contrast, Lu et al.¹⁴² studied 998 children in rural China regions, and found that there was no difference between myopic and non-myopic children in spending time in near work activities, such as homework (35.3±25.9 for myopic versus 34± 24.4 diopter-hrs/week for non-myopic, p = 0.62), watching TV (6.8± 5.3 for myopic versus 6.2±5.2 diopter-hrs/week for non-myopic, p = 0.22) and playing video games/computer use (18.9± 24.9 for myopic versus 21.8 ± 24.7 diopter-hrs/week for non-myopic, p = 0.11).¹⁴² Wu et al. found a non-significant relationship between near work activities and myopia among 145 students in a rural area in Taiwan. The OR was 0.9 for reading and writing (P=0.805), 1.0 for computer (P=0.70), and 0.7 for other near work activities (eg, playing piano/violin, calligraphy and painting) (P=0.593).¹⁴³
A recent systematic review by Huang et al. presented results on the link between near work activities and myopia. Twelve cohort studies and 15 cross-sectional studies identified in the MEDLINE, Embase and Cochrane library were considered which involved 25,015 children aged between 6 and 18. Among the studies evaluated, ten cross-sectional studies presented evidence to suggest that near-work activities are possible risk factors for myopia. However, other studies failed to support these findings. Despite the variation in the meaning of near work by the different studies, the forest plot for the overall studies considered in the study indicated that near work is associated with myopia. Also, Huang et al conducted two separate subgroup analyses based on near work definition. They found that the link between near work and myopia demonstrated a two percent increment in odds of myopia with additional diopter-hour of time spent on near work per week (OR =1.02; 95% CI = 1.01–1.03), and also children who spent more time in near work were more likely to be myopic (OR ex=1.85; 95% CI = 1.31–2.62). Consequently, the study concluded that there was an association between myopia and near work activities (odds 1.14 95% CI 1.08-1.20). Further, an increasing myopia prevalence could be linked to an increased diopter-hours of near work. The explanatory power of near work and time outdoors (discussed in section 1.5.3) presents a more practical alternative with the potential to yield accurate and comprehensive measures.

1.1.5.3 Outdoor Activity

1.1.5.3.1 Supporting Evidence and Hypothesis

Several studies have concluded that time spent in outdoor activities can protect from myopia (Table 1.4). The first of these studies was a three-year longitudinal study conducted by Parssinen and Lyyra examining the factors linked to the myopic progression rate among 238 schoolchildren (n=119 boys and n=119 girls) with myopia in Finland. The participants were from grade three to grade five (mean age 10.9 years), and cycloplegic
refraction was applied. There was a questionnaire to measure time spent by children in indoor activities, such as reading and other near work activities outside the school, and outdoor activities during weekdays and weekend days. To calculate mean daily time spent outdoors, the researchers multiplied time outdoors for school days by five, and time outdoors for weekend days by two, summed the products and divided by seven. The myopia progression rate was slow among participants who spent more time outdoors (3.2± 1.4 hours/day) compared to participants who spent less time outdoors (2.5± 1.1 hours/day, P=0.0003). The means of annual myopia progression for boys followed up for three years were -0.56 D, -0.46 D and -0.43 D. The means of yearly progression rate of myopia among girls were higher, at -0.79 D, -0.57 D and -0.46 D. The slow progression group contained more boys, perhaps because boys spent more time outdoors. A more conclusive analysis would have been to report means based on differences in time spent outdoors for each year group. Unfortunately, this information is not reported in the paper, so conclusions must remain speculative.

The Orinda Longitudinal Study of Myopia (OLSM) in the US studied 366 participants from grade 8. OLSM is a community-based cohort study of risk factors for predicting the onset of juvenile myopia between 1991 and 1996. Cycloplegic auto-refraction was used to determine refractive status for participants, and a questionnaire to calculate weekly time spent in some activities such as reading or studying for school assignments, reading for pleasure, watching television, playing video/computer games or working on the computer at home, and engaging in sports activities. They found that the average time spent weekly in sports activities for non-myopic persons (mean ± SD) was 9.7 ± 6.2 hours compared to myopic persons 7.4 ± 6.7 hours (P < 0.005). Subsequently, Jones et al. in their survey based on OLSM to predict future myopia (n=514), observed that emmetropic children spend more time in sporting and outdoor activities than myopic children. The study focused on three variables— the number of hours spent in outdoor
activities, number of myopic parents, and proportion of reading hours – on a weekly basis. The average time spent in sports/outdoor activity (mean±SD) for non-myopic children (n=403) was 11.65± 6.97. In this non-myopic group, 29.3% had no myopic parent, 49.9% one myopic parent, and for the remaining 20.8%, both parents had myopia. In contrast, the myopic children (n=111) spent on average less time outdoors, mean±SD = 7.98±6.54, and were more likely to have both parents myopic. The percentage of myopic children with no myopic parent was 11.7%, with 43.2% having one myopic parent and 45.0% both parents myopic. The observation was if children spent up to 5 hours in outdoor activities weekly, the probability of becoming myopic in future could be 0.3 if one or none of the parents were myopic to 0.6 if both parents were myopic. Spending more than 14 hours outdoors weekly decreased the chance of becoming myopic to 0.2 for children with both parents myopic and less than 0.1 for children with non-myopic parents. Thus, protection through increased time spent outdoors occurred, regardless of how many myopic parents a child had, which suggests that a protective effect of time outdoors occurs irrespective of parental myopia. The protective effect is a potent factor in inhibiting the onset of myopia.

Another report by CLEERE (Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error) focused on a sample size of 1318 subjects where 587 were emmetropes (between −0.25 and +1.00 D), and 731 were incident myopes (−0.75 D or more myopia on cycloplegic autorefraction in both meridians). Data from myopic children was compared in relation to ethnicity, age, and sex over a five year span of the study. Parents supplied annual data on the activity of their children through a questionnaire which was administered to determine the length of time spent in outdoor and indoor activities. This study indicated that myopic children spent less time in sporting and outdoor activities than emmetropic children by 1.1 to 1.8 hours per week, before and after myopia onset. However, children who engaged in outdoor activities or sports had a lower risk of developing myopia - with a probability of
myopia onset from 0.20 to 0.60, for the highest (over 14 hours per week) and lowest (0–5 hours per week) quartile respectively. These outcomes strongly indicate that myopia development was potentially triggered by engaging less in outdoor activities.

In 2008, the Sydney Myopia Study (SMS), a population-based study examining schoolchildren – 1,765 year 1 (mean age 6.7 years old) and 2,367 year 7 (mean age 12.7 years old) - in Sydney, Australia, published systematic evidence regarding the relationship between time spent outdoors on myopia prevalence. The study did a comprehensive eye examination on two groups, year 1 and year 7 children (n=4132), which included cycloplegic refraction as well as questionnaires by both children and their parents. It was established that there was an inverse relation between myopia and time spent outdoors. Only 1.5% of children in year 1 had myopia, and the mean SER was +1.26 D (95% CI, 1.19 –1.33). The average hours spent outdoors per day, including outdoor sports, playing out of doors, and other outdoor leisure activities were 2.32. Children in year 1 without myopic parents spent an average of 2.46 hours outside per day, while children with myopic parents spent less time outside with an average of 2.14 hours per day (P =0.0005). Engaging in outdoor activities was linked to a lower myopia rate amongst children conducting a significant quantity of near work, the OR was approximately 0.50. Children who spent less time outdoors and more time in near work were at higher risk for myopia, with an OR of 2.6 (95%CI, 1.2– 6.0; P =0.02). Furthermore, comparing myopia prevalence amongst children from two of Sydney’s main ethnic populations, those of East Asian and European descent (mean SER +0.88 and +1.49 respectively), indicated that lower myopic prevalence amongst children of European descent was linked to a greater quantity of time spent in outdoor events, 2.49 hours outdoor per day for European and 1.57 hours outdoor per day for East Asian ethnicity. This study conducted separate analyses of indoor sport and outdoor leisure activities such as bushwalking, playing outdoors and family picnics as well as outdoor performed sports, and indicated that the overall time spent in outdoor activities has a
protective effect against myopia. Sports activities indoors had no effect on myopia development (year 7, P = 0.9).\textsuperscript{146}

Thus far, the basis of epidemiological studies examining myopia and time spent outdoors was mainly on samples of people of European ancestry with a low myopic prevalence. Dirani et al.\textsuperscript{147} in the Singapore Cohort Study Of Risk factors for Myopia (SCORM), using the Sydney Myopia Study activity questionnaire, examined 1249 participants of East Asian descent. Cycloplegic auto-refraction to evaluate the refractive status and a questionnaire to determine outdoor activities were applied. The validity of this and other questionnaires used to measure time in outdoor activities is discussed in Chapter 4. Time spent outdoors was classified into leisure activities and sports activities, and the number of hours was recorded accordingly. Non-myopic children spent around 3.59 hours per day of total outdoor activities, and myopic children 3.09 hours per day (p <0.001), consistent with a protective effect for more time spent outdoors. In a multiple linear regression model, there was a correlation between less myopic refractions and more time spent outdoors (regression coefficient =0.17; CI 0.10 to 0.25; P<0.0001), and also shorter axial length with more time spent outdoor (regression coefficient= -0.06; CI -0.1 to -0.03; P =0.0002).

There is replication for the protective impact from time spent outdoors in a sample of East Asian descent amongst schoolchildren in Beijing from rural and urban locations, for axial length and refractive error.\textsuperscript{148} Six hundred and eighty-one children from year 1 and year 4, 370 of them living in urban areas, were examined by non-cycloplegic refraction, and their parents answered a detailed questionnaire about outdoor and indoor activities. The mean time spent outdoors daily was 1.6 ±0.8 (mean±SD) hours compared to time spent indoors studying daily 5.3 ±0.9 hours, and the comparison between time spent outdoors daily in urban and rural areas was 1.1 ±0.4 and 2.2 ±0.8 hours respectively (P<0.001). It established that more indoor study (P = 0.02), less outdoor activity (P = 0.001), urban region of habitation (P<0.001), maternal
myopia (P = 0.03), and older age (P<0.001) have an association with longer ocular axial length thus myopia.\textsuperscript{148}

The protective effects of time outdoors are further supported by findings from the Sydney Adolescent Vascular and Eye Study (SAVES). It is the follow-up study to the SMS, examined 2059 children in two longitudinal cohorts of ages (6 and 12). A full ocular examination included cycloplegic auto-refraction.\textsuperscript{141} They found that children with myopia had spent less time in outdoor activities (16.3 and 17.2 hours per week in the younger cohort and older cohort respectively) in comparison with non-myopic children (21 and 19.6 hours per week in the younger cohort and older cohort respectively). However, myopic children in the younger cohort performed more time in near work (P=0.02), while there was no significant difference in near work in the older cohort (P = 0.06). In receiver operating characteristic (ROC) curves analysis, time outdoors was a significant predictor of incident myopia for the both younger (AUC 0.64, P<0.0001) and older (AUC 0.58, P=0.001) cohorts. In a stepwise ROC analysis for incident myopia, the addition of time outdoors significantly improved the model in the younger (AUC from 0.84 to 0.86; P<0.0001), but not older cohort (AUC from 0.89 to 0.88; P<0.0001 for the change in AUC from the model without time outdoors to the model with time outdoors) suggesting that the protective effect of time outdoors is greater in younger children.\textsuperscript{141}

Time spent outdoors for children aged 8-9 years was critical in predicting if children developed myopia according to Avon Longitudinal Study of Parents and Children (ALSPAC).\textsuperscript{149} Children in ALSPAC were evaluated by non-cycloplegic auto-refraction from age 7 (n=7,747) to age 15 (n=4,837) after which they were classified as either emmetropic (≥−0.25 diopters) or myopic (≤−1 diopter). Their physical activity was measured by an accelerometer. The variables linked to incident myopia were evaluated using Cox regression. They established that the time spent on outdoor activities affected new cases of myopia. Furthermore, the study showed that greater time spent outdoors had a greater protective effect on myopia development than did simply
engaging in physical activity alone. The hazard ratio for incident myopia (95% CI) was 0.66 (0.47–0.93) for a high versus low amount of time spent outdoors, and 0.87 (0.76–0.99) per unit standard deviation above-average increase in moderate/vigorous physical activity. Several studies have reported a protective impact for significant time spent in outdoor activities on myopia. A study conducted in Amman, Jordan, examined 1777 schoolchildren aged 12 to 17 years, 313 of whom were myopic. A questionnaire was administered to determine the time spent in outdoor and indoor activities. Myopia was self-reported by participants or from the school medical records which contain a yearly updated eye test. The researchers found that non-myopic children spent more time playing an outdoor sport (4.04 ± 2.82 hours per day) compared to myopic ones (1.87 ± 2.33 hours per day, \( P < 0.0001 \)). Children spending a greater time engaging in the sports were at lower risk of developing myopia (OR 0.89, 95% CI 0.86–0.93). A study was conducted amongst 207 Turkish medical students between December 2003 and March 2004 and then followed up one year later. Cycloplegic auto-refraction and biometric measurements were applied to all participants. They also answered a detailed questionnaire about their outdoor and indoor activities at age ≤ 7, such as time spent playing video or computer games, watching TV or playing outdoors, and parental myopia. In this cohort aged in their early 20s, 32.9% were myopic, which was a relatively low rate of myopia, and 50% were emmetropic. Analysis of indoor and outdoor activities showed that the time spent outdoors at age 7 and before was greater in the students without myopia (68.4% of non-myopic students) compared to those with myopia (48.6% of myopic students), \( P=0.009 \). A similar protective effect was found in a small rural sample from Taiwan in 2010. Eyes of 145 children, age 7-12, were examined by auto-refractor with cycloplegia, and a detailed questionnaire about indoor and outdoor activities was answered by the parents. The prevalence
of myopia was 31%, and more outdoor activity reduced the odds for myopia, OR 0.3 95% CI (0.1–0.9), P= 0.025.

A study with similar findings was conducted on 5,601 Polish school children (2688 boys and 2913 girls), all of whom fell between the ages of 6 and 18, with the mean age of the sample population at 11.9 ± 3.2 years.155 The study involved examining the students based on the following tests: cover test, distance visual acuity testing, questionnaire (to collect data regarding sociodemographic, education, and family history), anterior segment evaluation and a cycloplegic retinoscopy after the installation of 1% tropicamide.155 Myopia was defined to be an SER lower than -0.5D. The study found that more time spent in reading and writing lead to a higher prevalence of myopia, as well as working on a computer leading to the same. However, the study also found that watching television did not have an influence on the overall prevalence of myopia amongst the study participants. The study found that outdoor activity decreased the prevalence of myopia.155 This finding is in parallel with other findings which suggest that environmental factors play a significant role in the prevalence of myopia, particularly in younger populations.

1.1.5.3.2 Rebound Effect when Outdoor Exposure is stopped:
In a study done by Guo et al.156 to assess the influence of the outdoor program on myopia progression in school children, rebound effect was observed in the study group, two years after the end of outdoor program, as compared to control group; with a more marked axial elongation. The study group and control group no longer differed in axial length and elongation after 4 years of follow-up.156

1.1.5.3.3 Evidence against a role for Outdoor Activity
While numerous studies have cited protective influences of time spent outdoors versus myopia development, a few studies have reported a lack of effect on time spent outdoors. A highly myopic sample (n=998) of Guangdong province, China, based on uncorrected visual acuity
(VA) assessment, spent little time outdoors, with an average of only 6.1 hours each week. There was no difference between myopic students and non-myopic in spending time outdoors (6.0 and 6.2 hours/week, respectively, P=0.88). On the other hand, in studies characterised by evidence of outdoor activity’s protective effect, non-myopic children spent more than 10 hours in outdoor activities. This may be indicative of a potential threshold for the quantity of time spent on outdoor activities each week necessary for acquiring enough protection from myopia development. Therefore, it is likely that the negative findings were due to a generally below-threshold amount of time spent outdoors, and a lack of variation in time spent outdoors and indoors.

Another study conducted in a preschool sample did not find any correlation between myopia and time spent in outdoor events. The study was carried out on Singaporean Chinese children aged six to 72 months (n=3009) collecting information on outdoor activity, near work, family history of myopia and cycloplegic refraction. The research concluded that family history was the most robust element influencing pre-school myopia (adjusted OR=1.91; 95% CI 1.38 to 2.63) whilst neither outdoor activity nor near work was associated with myopia prevalence. Myopia prevalence at this early age was likely to be too low for a meaningful comparison to environmental factors as children of this age are less engaging in outdoor or near work activities. The authors suggested that genetic rather than environmental factors influence the development of myopia in young children. This study may have found a more meaningful association if they had treated refractive error as a continuous variable, to examine if less hyperopic refraction was related to less time spent outdoors. Given the methodological flaws in these studies, they provide only weak evidence against the protective effect of time spent outdoors on the development of myopia.

Jones-Jordan et al. (2012) investigated the association between time spent outdoors and myopia progression among 835 children with myopia (< -0.75 D) from the CLEERE study.
Cycloplegic autorefrraction was performed. The activities were measured through a questionnaire that asked the parent: “During the school year, how many hours per week (outside of regular school hours) would you estimate this child: 1) studies or reads for school assignments; 2) reads for fun (pleasure); 3) watches TV; 4) uses a computer/plays video games; and 5) engages in outdoor/sports activities?” The estimated effect of an average of 10 additional hours of activity per week on myopia progression before annual progression associated with outdoor activity was 0.02 D (99% CI -0.02 to 0.06), and estimated effect after annual progression was 0.01 D (99% CI -0.03 to 0.06), with average over progression 0.03 D (99% CI -0.03 to 0.08). It was a small effect and not significant. There would have been an insufficient range of refractive errors in the sample to find an association between myopia and time outdoors because all of the participants were myopes. Also, those participants spent less time outdoors (7.98 hours ± 6.54) compared with other children (11.65 hours ± 6.97) in the previous study by the same research team. So, it may have been difficult to detect effects on progression in myopes because of the overall lower exposures.

1.1.5.3.4 Clinical Trials Studies Supporting the Light Exposure and Outdoor Activity Hypothesis

Currently, the largest trial of the impact of time spent outdoors on myopia development involved a partnership between Guangzhou Student Health Bureau in the Guangzhou Ministry of Education and the Zhongshan Ophthalmic Center, and was held in 12 schools selected to represent the Guangzhou system between October 2010 and October 2013. Participants were 952 children in the intervention group and 951 in the control group with a mean age of 6.6 years (n=1903 students). There was randomization of schools to the intervention arms (treatment) and Grade 1 learners took part in the intervention as per the policy stated by the Ministry of Education; however, participants had provided full eye examination with
cycloplegia and informed consent. As an intervention, children were provided with an extra 40-minute outdoor activity class at the end of their school day in addition to their normal curriculum. Parents were also encouraged to engage their children in outdoor activities after-school hours.

Education programs were rolled out in the intervention group to acquaint parents with the significance of allowing children to participate in outdoor activities during school holidays, on weekends and after school. These programs were extended to children while at school, and parents who would implement them at home. The major issue associated with this type of trial was compliance. Thus, the Ministry of Education and the research team made random visits to schools to ensure that the program was being implemented properly by the teachers. Schools had to comply by creating extra lessons in addition to the normal curriculum. All children were issued with standard questionnaires annually. The effect of this intervention was a significant reduction in the incidence of myopia resulting from the addition of the extra outdoor class. The rate of cumulative incidence myopia in the intervention group was 30.4%, whereas it was 39.5% in the control group (difference of -9.1% [95% CI, -14.1% to -4.1%]; P < .001). Also, there was a decrease in myopia development as determined by the mean spherical equivalent refraction (difference of 0.17 D [95%CI, 0.01 to 0.33 D]; P =0.04) for 3-year change SER of the intervention group compared to the control group. A difference of 0.17 D is within the bounds of measurement error if applied to the measurements of individuals, but when applied to the mean scores of large groups has a chance of only 0.04 of being explainable as measurement error. The small difference in the SER was representing a 23% relative reduction in incident myopia after 3 years of the intervention. The intervention was a minor change in the behaviour of participants, consisting of only 40 minutes per day extra outdoor activity. The protective effect could be increased if the time outdoors was increased, as suggested by the
OLSM that the risk for myopia decreased by increasing time outdoors to between 10 and 14 hours in total per week. To supplement this study, there is another Chinese publication on the outcomes from a trial conducted in Chengdu, China. There were 41 children for an intervention group and 39 children for a control group with age 7-11 years. The intervention group was instructed to do near- and middle-vision activities less than 30 hours per week and more outdoor activities than 14-15 hours per week. The trial found that myopia progression reduced significantly from — 0.52D a year in the control group to —0.38D in the intervention group (The 95% CI was not reported in the original paper). Similar outcomes have been found in a pilot intervention in a region in southern Taiwan with 571 children (333 in the intervention group and 238 in the control group), aged 7-11 years, who participated in the study, and provided full eye examinations with cycloplegia in 2009 and 2010. The intervention entailed emptying classrooms and switching off classroom lights during school breaks, and children were urged to engage in outdoor activities. The total amount of time in recesses was 1 hour and 20 minutes each day. Amongst non-myopic participants, there was reduced refraction in myopic shift from - 0.44 ± 0.64 D to - 0.26 ± 0.61 D after one year of the study (P = 0.020). At the last examination in the study, SER were -1.03 (±1.84 D) in the intervention group and -1.33 (±1.92 D) in the control group. The intervention group had considerably lower mean progression of refractive error in the myopic direction than the control group (- 0.25 compared with -0.38, P= 0.029). In relation to the intervention measure, the percentage of new myopic cases was somewhat reduced within the control school from 17.65% to 8.41%. However, other variables such as gender, myopic parents, activities related to reading and writing, usage of computer and television and other near-work activities, were not significantly statistically different in myopic
and non-myopic students respectively. The conclusion showed that myopia onset and development was more notably affected by the time spent outdoors.\textsuperscript{152}

\textbf{1.1.5.3.5 Protection mechanisms}

There are various biological mechanisms that have been suggested to account for the protective effect of time outdoors. A commonly proposed mechanism is that a uniform dioptic field outdoors and increased fixation distance leads to reduced accommodation and therefore, prevents myopia development. There are some issues with this as a proposed mechanism. Firstly, as discussed earlier (section 1.5.2) the relationship between near work and myopia is inconsistent, however, near work is still a risk factor for myopia. Also, there is evidence from animal studies that accommodation does not play a role in the development of myopia.\textsuperscript{161} McBrien et al. studied the functional morphology of the intra-ocular muscles of grey squirrels (n=5, age 12-33 months). They found that there was no accommodation effect to induce experimental myopia.\textsuperscript{161} Furthermore, looking at something at a distance of 6 meters, which is easily achievable indoors, is very close in terms of the accommodative load to longer distances. Finally, even in the outdoor environment, it is unlikely that children maintain distance fixation, rather, it is much more likely that fixation is predominantly on near objects such as other individual’s faces, toys and other playthings.

Another commonly-held hypothesis is that time outdoors is simply a substitution for the time in near work. In other words, children that spend greater time outdoors must perform less near work because they are not indoors reading or doing homework. Some studies attempted to explore this potential substitution effect. The OLSM found that the OR of risk for myopia when children spent more time in near work during time outdoors was from 0.97 to 1.04.\textsuperscript{153} Also, the SMS found low OR (approximately 0.05) as a risk for myopia when children spent more time outdoors and more time in near work at the same time as well.\textsuperscript{146} This shows that it is quite possible for children to spend high time in near work while staying outdoors without it affecting
myopia progression. Thus, this is not a sufficient explanation for the protective effect of time outdoors.

Another suggested mechanism is the narrowing of pupil size with exposure to bright light can give rise to a ‘pinhole’ effect. While this theory could potentially have some merit, the main evidence against this is that pupil constriction occurs under much lower light levels than those typically found outdoors in the daytime. In addition, a study of animals, which were chicks (discussed in detail in section 1.5.3.5), using artificial pupils did not find any significant impact. 162

A suggestion was proposed that increasing levels of vitamin D due to high exposure to sunlight, which is the major source of vitamin D, could be related to protection from myopia development. Mutti et al. 163 and Choi et al. 164 found that low levels of vitamin D were related to increased prevalence of myopia. However, supplements of vitamin D used in efforts to explore the hypothesis experimentally and epidemiologically do not support a significant association 165 despite the fact that humans exhibited myopia and Vitamin D receptor polymorphisms associations. 163 With respect to spectral composition, the latest studies have revealed that animal rearing in blue light tends to retard myopia development, while red light tends to increase it. 90,91 This is attributed to variations in the wavelengths’ focal point in the eye. 166,167 However, such effects are generally small compared to those produced by other environmental changes such as light intensity and are solely observed in environments with limited light rather than in association with the variation that exists between outdoors and indoors. 168 The most recent Mendelian randomization study was conducted by Cuellar-Partida et al. to determine the relationship between 25(OH)D level, which represents the concentration of vitamin D and the protective effect of time outdoors from myopia development. 169 They conducted a meta-analysis of GWAS data from European and Asian CREAM with a total of 45758 participants. The researchers used the SNPs in the DHCR7, CYP2R1, GC and CYP24A1
genes that have effects on 25(OH)D concentration. They found that the effect of 25(OH)D on myopia was -0.02 D (95% CI 0.09 to 0.04) per 10 nmol/l increase in 25(OH)D concentration in Caucasians and 0.01 D (95%CI -0.17 to 0.19) per 10 nmol/l increase in Asians. This small effect leads to the conclusion that there is no direct impact of vitamin D levels on the protective effect of time outdoors on myopia, because people, who had alleles associated with lower levels of 25(OH)D did not have increased myopia, as would be expected if lower vitamin D levels caused more myopia. 169

Of the differences between indoor and outdoor environments, Rose et al.146 hypothesised that light intensity, which is significantly higher in the outdoor environment, was the most likely candidate to play the main role of protective effect. They suggested that in response to bright outdoor light, retinal dopamine-a known growth inhibitor-would be released, acting to retard eye growth and prevent myopia. This hypothesis is called the “light–dopamine hypothesis”. Retinal dopamine release and synthesis are well-established to be low during the night and high during the day.170 For example, the rate of dopamine release increases in chicks with increasing intensity of light in a log-linear fashion.171,172 Dopaminergic function is highly controlled in experimental durations of instigating high rates of ocular growth.173 In addition, dopamine agonists decrease experimental myopic development.174,175

1.1.5.3.6 Animal Studies Supporting the Light Exposure Hypothesis

Myopia has been experimentally induced in animal models, largely chicks and primates. In this context, two primary methods have been used. The first is form-deprivation myopia (FDM) and the second is lens-induced myopia (LIM) using minus lenses to create hyperopic defocus.162,176-178

Ashby et al.162 investigated the effect of light intensity on experimental myopia development in chicks. There were two separate experiments. In experiment 1 FDM myopia development was induced in chicks (n=36) by wearing of translucent diffusers for five days, which allowed
light to pass through but reduced its intensity and scattered it. Chicks were left without the diffusers for 15 minutes daily under normal laboratory light (500 lux), intense laboratory lighting (15,000 lux), or daylight (30,000 lux), while a control group (n=9) wore the diffusers for the whole period under normal light of 500 lux. In experiment 2 there were three lighting conditions; (1) low laboratory lighting (50 lux, n = 9), (2) normal laboratory lighting (500 lux, n = 18), or (3) intense laboratory lights (15,000 lux, n = 9). All chicks wore the translucent diffusers for all the time of the experiment. Chicks in group 1 and group 3 (low and high light) were exposed to light in their category for 6 hours daily from 10 am to 4 pm for 4 days, then they were kept with their diffusers under 500 lux for the remaining time of the light phase with group 2 which stayed the whole period under 500 lux with the diffusers. Axial length and refraction were measured at the beginning and end of all treatments, with corneal curvature measured additionally in Experiment 2. The eyes of the chicks in the Experiment 1 showed noticeable change. There was less axial length elongation under daylight condition (8.81 ± 0.05 mm; P < 0.01). Chicks also had a lesser myopic refraction (-1.1 ± 0.45 D; P < 0.01) under the daylight condition. The same result was seen under intense laboratory lighting condition, where chicks had a short axial length elongation (8.88 ± 0.04 mm; P <0.01), and also less myopic refractions (-3.4 ± 0.6 D; P < 0.01). This happened when the chicks were left uncovered under the sunlight or intense laboratory light for 15 minutes every day as compared to those chicks that were in the usual light intensity of the laboratory (8.98 ± 0.03 mm, -5.3 ± 0.5 D) when their diffusers were taken off. When there was a high light intensity in the laboratory at the time when the diffusers were taken off, there was less axial length elongation with the myopic refraction also becoming less. Accordingly, high illumination, either sunlight or intense laboratory lights, inhibited experimental myopia development.
As outlined above in Experiment 2, a comparison was made between the eyes of the chicks. The results showed chicks having short eyes (8.54 ± 0.02 mm; P < 0.01) and lesser myopic refraction (+0.04 ± 0.7D; P < 0.001) was due to the elevated illuminance (15,000 lux), whereas the axial length for chicks who were kept in ordinary light intensity (500 lux) was 8.64 ± 0.06 mm, and refraction was -5.27 ± 0.86 D. Conversely, under the low illumination (50 lux) (AL=8.61 ± 0.02, SER= -5.45 ± 0.61), the FDM was not increased any more than the chicks which were under normal lighting conditions (500 lux).162 Ashby et al. stated that the development of myopia is repressed when the chicks are exposed to high illuminances, either powerful laboratory lights or sunlight. Accordingly, it was suggested that exposure to greater light intensity on a daily basis could have a protective effect against the development of myopia among schoolchildren.162

Ashby together with his team conducted further research to uncover why intense light connects with compensation for imposed optical defocus.176 The study tested whether the light’s protective effect is mediated by dopamine, using a dopamine antagonist. The study measured axial length and refraction at the inception and conclusion of each treatment. The study was carried out by way of two individual experiments. For experiment A, chicks were monocularly fitted with -7 or +7 D lenses for a period of 5 days under conventional laboratory lighting (500 lux, n = 12 for negative lenses and 16 positive lenses, respectively) or intense ambient lighting (15,000 lux, n = 12 and 16). For experiment B, the chicks wore diffusers for 4 days under conventional laboratory lighting (500 lux, n = 9) or intense ambient lighting (15,000 lux, n = 24). Animals exposed to intense lighting were intravitreally inoculated with either a vehicle solution (0.1% ascorbic acid, n = 9) or the dopamine antagonist spiperone (500 μM, n = 9). The other group (n=6) acted as the control. High illuminance (15,000 lux) reduced deprivation myopia by approximately 60% (from 3.2±0.1 to -4.0±1.1 D) compared to normal illuminance (500 lux) (from 3.1±0.3 to -9±1.0).176
Earl Smith and his team used 27 monkeys to establish whether high levels of light, which ideally have a protecting influence against form-deprivation myopia, similarly impede the growth of lens-induced myopia in primates. This was achieved by imposing hyperopic defocus on them via 3 diopter (D) lenses secured in front of one eye. It was placed on them aged 24 days and continued for 50 to 123 days. A proportion of the monkeys (n=15) were exposed to normal lighting in the lab (~350 lux) whilst the rest (n=12) were exposed to auxiliary lighting (25,000 lux) for six hours in the middle of the 12-hour daily light cycle, and there were 37 monkeys as controls. Researchers evaluated axial dimensions, corneal power, and refractive development by using ultrasonography keratometry, and retinoscopy respectively. They found that the accelerated vitreous chamber elongation was seen in the monkeys reared in normal and high light due to hyperopic defocus, which in turn, formed refractive error-related myopic shifts. It is of note is the degree of myopia that not changed by the high light regimen (high light: -1.69 ± 0.84 D versus normal light: -2.08 ± 1.12 D; P = 0.40). After the lens was removed, the high light monkeys experienced recovery from the induced myopia and the high lighting regimen did not affect the recovery process.

Overall, there is significant evidence in favour of the light-dopamine hypothesis; however, the evidence is somewhat inconsistent, for while FDM development in chickens is retarded by bright light, as was also the case in monkeys, in chicken, LIM development is retarded. Only limited effects regarding LIM development were observed in monkeys, long considered to be a suitable model for myopia in humans.
Part 2 - The Use of Questionnaires in Determining Environmental Risk Factors for Myopia

1.2.1 Introduction

Collectively, the evidence for a significant protective role of time spent outdoors, supported as it is by epidemiological data, cross-sectional, longitudinal and ecological, and intervention trials, with a clear biological pathway involving light-stimulated dopamine release, is very strong. However, most of the quantitation of time outdoors has been carried out with essentially unvalidated questionnaires. The development of these questionnaires has not been particularly systematic, leading to several controversies.

One criticism that has been raised is that the amount of variance explained by time outdoors (and near work) is small, and in many analyses, the percentage of variance explained by these two factors is less than or close to that explained by identified genetic factors. It may be that the questionnaires are not sufficiently accurate to provide good information on individual exposures, which is required for calculations of this kind. This would imply that better means of measuring these exposures are required.

1.2.2 Questionnaire design

The term “questionnaire” defines a method of data collection which helps in gathering standardized data from a large number of people. As a consequence, questionnaires are suitable for data collection in the medical and health fields mainly because they assist in ensuring the collection of information is uniform, making the data standard. In an individual study, questionnaires present to each participant the same set of questions, asked in the same format. If using closed-ended questions which require a uniform set of responses, for example, it is possible to have uniform responses, such as “yes”, “no”, or a limited set of response choices. Uniformity allows for consistency and easier statistical analysis of data. Open-ended questions, where the participant is free to record a response in their own words, can lead to new insights,
but these present difficulties both in response rates and, in studies of large populations, in the analysis of the variable information collected.\textsuperscript{180}

When using questionnaires, the participants may be asked to write responses to written questions or they may be administered by an interviewer who records the responses. If open-ended questions are used, the most reliable method is for the interviewer to digitally record the participant’s responses and transpose them later. However, close-ended questions can also be used and responses recorded in a particular structure and formal written way again so uniform responses can be collected and collated assisting subsequent analysis. In addition to individual questionnaires, group questionnaires can be used, where a specified group answers the questions and the answers are recorded as a whole group response. There are different modes of delivery of questionnaires including face-to-face interviews, direct handing of the questionnaire to the participant that can either be filled out in the researcher’s presence or the participant can fill out the questionnaire elsewhere and return it at a later date. There is also email, internet, telephone and postal delivery. The discussion of questionnaires that follows will particularly focus on written, telephone, face-to-face interviews and internet (electronic) accessed questionnaires.

\textit{1.2.2.1 Written Questionnaires}

Written questionnaires use standardized questions delivered and responded to, in a paper format. This method has various advantages when compared to other forms of questionnaires. First, they are cost-effective especially in comparison to face-to-face interviews. This aspect particularly comes into play in the epidemiological field where a researcher has to collect information from a large number of people and more so if the population being surveyed needs to be recruited from a large geographical area. These can be delivered directly by the researcher to the participant or through a voluntary or employed agency that delivers and collects the questionnaire on the researcher’s behalf or they can be posted, usually with a reply-paid
envelope to assist the return of the questionnaires. Postal questionnaires usually have the disadvantage of poorer response rates but may be appropriate if seeking an extremely large or whole-of-population response,\(^\text{181}\) where the low response rate is partially mitigated by the size of population contacted. However, bias in the characteristics of respondents cannot be controlled.

Another advantage of a written questionnaire is that the researcher can potentially include a large number of questions, increasing the factors surveyed and hence the cost-effectiveness of the tool. Because the respondent can complete the questionnaire in their own time, there appears to be greater tolerance of longer questionnaires administered in this manner though the evidence is variable.\(^\text{182}\) Written questionnaires are also advantageous in that they are, if well designed, relatively easy to analyse. Tabulation and data entry is straightforward especially with the different computer software packages available to electronically detect responses and if data is entered manually it is standard practice to independently double-enter the data, reducing errors in data entry. Many people also have prior experience of using written questionnaires in a range of forums so find them both familiar and easy to use. Written questionnaires can also reduce internal bias because of the uniform questions and absence of verbal or visual cues. Participants also generally find them less intrusive than telephone or face-to-face interviews. For these reasons, written questionnaires have been extensively used in ophthalmic epidemiology research.\(^\text{73,153,183-186}\)

There are, however, limitations associated with written questionnaires, including the inability to probe and thus gain more information directly from the respondent. They also offer the respondent little flexibility to seek clarification of questions or to provide more details and the opportunities which are available when using face-to-face interview-style questionnaires. The answers are also very dependent on the structure and order of the questions. There is also a possibility of reduced response rates among certain groups such as elderly people due to a lack
of personal contact. Literacy levels can also create limitations because those people with poor education levels or whose first language is not that used in the questionnaire may not be able to understand the questions or to even see the importance of completing the questionnaire. This can be partially overcome by offering assistance or providing the questions in the person’s language. However, the main disadvantage of written questionnaires, especially those that have been used in ophthalmic epidemiology, is lack of rigorous validation processes which is only partially reduced by the repeated use of the same or similar questions across a variety of studies which have obtained similar results.

1.2.2.2 Telephone or Face to Face questionnaires

Verbally conducted questionnaires require the respondent to answer the questions asked via telephone or in-person. This type of questionnaire has particular advantages and disadvantages. This method may produce a better response rate compared to written questionnaires.\textsuperscript{187} The informal discussion with the interviewer also helps to provide contextual insights. Additionally, the method can help to ensure that the researcher gathers correct data through clarification. In the face-to-face situation, the interviewer can also capture the non-verbal and verbal cues that could shed light on the relevance and appropriateness of questions to the individual participant and improve the accuracy of responses. Unfortunately, if the interviewer is not well trained and/or prompts too much this can bias the responses obtained and/or recorded by the interviewer. This is partially prevented if the interview is recorded and responses entered independently.

The major drawback of this method is that it is costly, additionally so if conducted by telephone, or if hiring a place to conduct the interview is necessary or if the interviewer has to travel some distance to individual interviews. These are in addition to costs associated with the necessary employment and training of staff as well as the time consumed in gathering each interview. If transcription services and/or software are also employed, then this adds to the
costs. The process also makes data entry harder because some of the answers could deviate from the purpose of the questionnaire. This method of administering questionnaires tends to limit the size of the sample due to the labour time and cost of the method. While questionnaires administered by telephone overcome geographical costs, in themselves they lack visual aids to facilitate the collection of reliable data and participants can find them intrusive and inconvenient.

1.2.2.3 Electronic questionnaires

Electronic questionnaires use computers or more recently hand-held digital devices to deploy and return information. Many companies offer an electronic questionnaire delivery service for a minimal fee, making questionnaires convenient and easily available. Just like written questionnaires, electronic questionnaires are efficient in terms of costs. Another advantage is that it offers automation of data entry and real-time access. This aspect indicates that the respondents can input their data, which is then digitally stored as entered. This process removes data entry errors and costs, making analysis quicker and easier to perform and the results of the analysis can be available immediately and in an ongoing manner. Real-time access means that electronic questionnaires are efficient in matters of deployment and return. It is, therefore, one of the fastest modes of questionnaire delivery and analysis. Another advantage includes the convenience to the respondents and the incorporation of design flexibility, such as not presenting questions that are not relevant to each individual respondent based on their answers to initial questions, thereby saving their time in completing the questionnaire.

There are, however, disadvantages including uncertainty as to the respondent’s identity and possible bias in sampling. For example, those people who lack access to electronic devices would be unable to participate. It is also difficult to draw probability samples based on e-mail addresses and website visitations. As this is a relatively new form of questionnaire delivery, there is little evidence of the likely response rates using this method compared to others, while
the suggestion is that researcher may need to use a mixed mode of delivery in order to maximize response. There are many strategies that can be deployed to improve response rates in all modes of questionnaires which will not be discussed here but have been detailed in a relatively recent Cochrane review.

1.2.3 The development of questions in myopia research to explore environmental factors: time spent outdoors

Early studies of environmental factors in the development of myopia used strategies such as testing literacy, questioning teachers about school attendance, establishing current reading habits as well as years of schooling, asking subjects to report the hours per day spent in near work or schooling level as part of entry into the military. Parssinen and Lyyra's study in 1993 is considered to be the first study to examine time spent in an outdoor activity as part a series of questions in their questionnaire administered at the 3-year follow-up of their cohort. Their questionnaire surveyed the length of time school children spent on near-work outside the school on weekdays and weekend days, either reading or other in other near-work activities, and included a single question regarding participation in sport and outdoor activities. The inclusion of this question regarding sport and outdoor activities arose from Parssinen’s observation that myopia appeared to be occupation-related to those with a lot of near work and conversely that farmers were rarely myopic (personal communication with supervisor KR, 2017). From this point of view, the location of the sporting activity (indoors or outdoors) was not seen as relevant. While Pärrssinen and Lyyra focused on near work and its relation to myopia progression, they also found that only boys (not girls) who spent more time in sport/outdoors had slower myopia progression compared to those who spent less time outdoors. They speculated that this effect could be due either to gazing into the distance or less time spent on near work. The faster rate of myopic progression in girls compared to boys
could not be explained by any of the measured variables including time spent in sports and outdoor activity.

The inclusion of a question about participating in outdoor activities and sport then appeared in the subsequent studies. The use of a question regarding time spent in sports was reported for the Orinda Longitudinal Study of Myopia (OLSM) in 2002\textsuperscript{73}; however, there is no indication that such a question was used prior to 1993, though the exact date at which the question on sports was added to OLSM is unclear. As reported in 2002, 5 questions were asked of the 8th-grade children and their parents. They were how many hours per week the child spent in activities out of school time: (1) studying for school assignments; (2) reading for pleasure; (3) watching television; (4) playing video/computer games or working on the computer at home; and (5) engaging in sports activities.\textsuperscript{73} An association was found between myopia and less time playing sport that the authors attributed to either a more introverted personality in children with myopia or the wearing of glasses inhibiting participation or that sport may have a true protective effect.

Though the origins of the questions in various studies are difficult to ascertain, the subsequent studies of environment and myopia were apparently largely based on the Parssinen and Lyyra’s and the OLSM questions and their findings regarding sports and outdoor activity. The Singapore Cohort Of the Risk factors for Myopia (SCORM) study explored a variety of factors including socioeconomic status, outdoor and near-work activity administered in face-to-face clinic interviews as reported in 2000.\textsuperscript{194} At this time they did not find an association with hours spent outdoors and the progression of myopia in the children aged 6-12 years of age. In 1999 the SCORM study commenced a parent-administered questionnaire,\textsuperscript{195} including questions on the number of hours spent on outdoor games and activities per week. The findings from this phase of SCORM reported in 2006,\textsuperscript{195} found no association with time spent outdoors/games per week with incident myopia in complex multivariate analysis.
The Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error (CLEERE) study commenced in 1997 was an extension of the OLSM, adding three more locations to broaden the ethnic mix of the OLSM which was based in California, and was predominantly of children of ‘white’ or European Caucasian origins. This extended study appears to have continued to use the original OLSM questions regarding time on sports, with the addition of time outdoors.\(^{153}\)

In 2004 using a similar format of questions but modified to be more age and culturally appropriate, Jacobsen et al\(^{196}\) studied a cohort of Danish university students who were asked via interview the amount of time they spent reading scientific literature (not including classes and lectures at the university), reading a newspaper or other literature, using a computer and how many hours per week, on average, they spent exercising during the past 6 months. Exercising included riding a bicycle which was the common mode of transport for the students. Here an inverse association between physical activity and incident and progression of myopia was found.

A similarly adapted questionnaire was used (2003-4) to study risk factors for myopia in a sample of Turkish medical students.\(^{151}\) However, this questionnaire focused on early childhood behaviours in addition to questions to quantify current levels of near work. While asking for standard socio-demographic data and parental history of refractive errors, questions were also asked about lifestyle and activities before age seven including time spent playing video or computer games/watching TV and outdoor activity. Interestingly, even though there was a potential for recall bias in this mode of questioning, the study found that time spent outdoors before the age of seven was protective for myopia.

The Avon Longitudinal Study of Parents and Children (ALSPAC) a large study in the Bristol region of England, seems to have asked questions about outdoor time that were independent of Parssenin and the OLSM questions. This study commenced recruitment for its longitudinal
birth cohort between 1991-92 and at age 8-9 (2000) asked via parent-administered questionnaire ‘‘On a (weekend day)/ (school weekday), how much time on average does your child spend each day out of doors in (summer)/(winter)” followed at age 11 by objective measures of physical activity.\textsuperscript{149} The findings of these questions and measures reported in 2012 indicate that the questions posed may have been more concerned with general health, rather than the development of myopia. However, the study did find that increased time spent outdoors was predictive of lower rates of incident myopia independent of the physical activity level of the children.

1.2.4 Later development of questions: the Sydney Myopia Study’s and beyond.

The Sydney Myopia Study started recruitment in 2003, and the specific and detailed methodology of the study was published in 2005 by Ojaimi et al.\textsuperscript{197} The questionnaire was distributed through the schools that had been randomly selected to participate. It was designed to be parent-administered exclusively for the 6-year-old cohort, while the older children aged 12 years were encouraged to complete part of the questionnaire in conjunction with their parents to increase their engagement in the study. While a large range of health and lifestyle questions were asked (193 items in total, see questionnaire in appendix 1) the questions regarding risk factors for myopia were specifically designed (by one of the investigators, Dr Kathryn Rose) to unravel the potential contradictions that had arisen over physical activity versus time outdoors versus viewing distances.

The questionnaire was comprised of two separate sections. The first section on environmental exposures asked about outdoor activities, such as walking, and sedentary activities, such as reading and watching TV. The other section asked the parents to specify how much time was spent doing each activity, and where it was done. The questionnaire asked about indoor activities, where “indoor” referred to the inside of either a classroom or a large school hall. The
questionnaire asked how much time in terms of hours had been spent in an indoor vs. outdoor activity on a weekday or weekend. The questionnaire then also asked about activity during school breaks/vacations, the type of housing the child lived in if there was joint time spent in two different housing types, an in-depth assessment of the child’s diet, smoking-exposure history, and sun exposure. It asked about the numbers of hours spent weekly on exercise and daily amount of time spent on near work. Additionally, the questionnaire asked about the ocular history of the participants and the parental use of glasses. It also focused on the health of both the participant and their parents.

The preliminary findings of this study were reported at the Association for Research in Vision and Ophthalmology (ARVO) in 2006. Crucially the SMS was able to report that time spent outdoors in passive leisure activities was as protective for myopia as was sport while indoor sport had no protective effect. These findings were completed and reported in 2008.

The findings of the SMS shifted emphasis from near work to time outdoors. In the interim between ARVO 2006 and publication by Rose et al in 2008, Jones et al (2007) published their findings from OLSM on time spent in sport and outdoor activities, yet labelled their graphs exclusively with the term “sport”. This continued to generate confusion between sports as a specific form of activity and time outdoors. Speculation about the possible biological mechanisms has also generated another set of controversies, particularly between the light-dopamine hypothesis, potential for physical activity increasing blood flow to the eye, or distance viewing/patterns of defocus acting as ‘stop’ eye growth signals, even UV exposure and increased Vitamin D, the latter two factors now seen as a consequence of time outdoors not a cause of myopia. Subsequent animal studies have supported the light-dopamine hypothesis.
The inclusion of a significant proportion of children of East Asian origin in the SMS also allowed the comparison of findings from the SMS with age and ethnicity matched children from the SCORM study, again showing the major influence of time spent outdoors on the development of myopic refractive error in young children. Communication between the lead investigators in SMS and SCORM had led to a change in the SCORM questionnaire, adopting the SMS environmental questions for later phases of the SCORM study.

The intrinsic value of the SMS questionnaire was its ability to produce detailed data about risk factors eliminating some previous uncertainties about outdoor activity and sports. The study was able to conclude that an increased number of hours spent outdoors was inversely associated with more myopic spherical equivalent refractive error. Level of activity or sport itself did not matter and time spent outdoors in passive leisure, picnics and barbecues had as much protective effect as time spent on sport; so, the decrease in myopia was simply a function of being outdoors. This finding opened the doors for further more directed research and for public health organisations to act on a potentially modifiable risk factor to curb the myopia epidemic. However, in ascertaining this level of detail, the SMS questionnaire was overly long and contained some areas of exploration of risk factors that proved not to be associated with myopia. There was a need for a shortened and more focused version of the SMS questionnaire.

1.2.5 WHO questionnaire

In 2006, the World Health Organisation (WHO) invited a group of epidemiologists working in the myopia research to a meeting on Myopia Progression and Risk Factor Assessment Surveys in Singapore and later in Guangzhou, China. They were an expanded group of the Refractive Error Study in Children (RESC) consortium who had previously published extensively on the prevalence of eye disease and refractive errors in children aged between 5 to 15 years. The consortium now included the SMS group, in particular, Professor Kathryn Rose. The consultative group (the RESC consortium) formulated a standardized questionnaire
based on the SMS questionnaire to be used to measure time outdoors and other factors that had been hypothesized and shown to play a role in myopia. The WHO supported the development of this standard questionnaire (see the original version of the RESC WHO questionnaire in appendix 2) because of the significance of the time outdoors for myopia development. At the conclusion of the meetings, it was agreed that this questionnaire could be modified for different countries based on differing school systems and cultural habits and for samples of differing ages, for example, university versus school-aged students.

There were 25 questions in total in the WHO RESC questionnaire, ordered in a chronological manner from the start of the day to night-time. These questions were asked separately about activities in weekdays and weekend. It asked about the time and duration of sleep, activities done before travelling to school or work, the time, means and duration of travel, activities done before schoolwork, time and duration of school or work and the time, means and duration of travel from school or work. The questionnaire also asked about the duration spent on indoor activities like reading, watching television, using computers, indoor sports, schoolwork and work by participants. Participants had to choose the best answer that suited their case from the list of options or stating the numbers of hours that they spent in some activities. In effect, this survey tool was very different from the SMS since it did not ask about all possible activities, but rather took the form of a more diary-style of instrument describing how time was spent across the day. In the Guangzhou Outdoor Activity Longitudinal Study (GOALS) an intervention trial of increased time outdoors published in 2015, He et al. utilized a modified version WHO RESC questionnaire. They broadened the information collected to obtain information about the child’s education level, and ocular history as well as the same for all immediate family members. They also removed the question regarding time spent outdoors reading as the children uniformly answered in the negative to this question (personal communication with supervisor KR in 2012).
1.2.6 The use of light data loggers and diaries

Questionnaires always have the potential for recall bias. The need for validation against more objective forms of assessing exposure to light is obvious. As will be discussed in Chapter 3, wearable light data loggers are a suitable objective validation tool, but there is a considerable cost and logistical disadvantages in employing these in large-scale studies. As will be reported in later chapters, we found there is often only moderate agreement about time spent indoors and outdoors between the light data logger and questionnaire data. As reported in later chapters, we and others\textsuperscript{199} have found that the data obtained from diaries are more closely correlated with data captured with light loggers than with questionnaire data. Nevertheless, diaries also impose a significant burden on respondents, particularly if required to be completed over a considerable period of time. While light data loggers will need to be utilized as the most objective measures, supplementary data could still be collected via questionnaire, but an attempt must be made to improve the accuracy of recording the locations of time spent. As reported later in the thesis, this leads to the development and preliminary validation of an electronic questionnaire with features not included in previous questionnaires, designed to ease the respondents' burden and increase the accuracy of responses.

Part 3 - The relationship between changes in refraction and changes in eye biometry

1.3.1 Eye Biometry

The neonatal eye represents one of the most well-developed sensory organs in the body. The axial length (AL) defined as the distance between the corneal surface and the interference peak that corresponds to the Bruch’s membrane, is consistent with the total refractive power in an emmetropic eye, with a sharp image formed on the retina. On the other hand, longer AL renders the light focused in front of the retina (myopia) while shorter AL indicates a hyperopic eye.
In an adult, the optical power should measure approximately 60 diopters (D) and the AL is approximately 24 mm. The main refractive elements that constitute the optical power of the anterior eye are the corneal power (providing about 42 D) and the refractive power of the lens (accounting for about 18 D).\textsuperscript{200} In neonates, the refractive power is high (85 D) while the AL is short (17 mm), indicating that they are hyperopic.\textsuperscript{200} The relationship between ocular AL and the refractive power is balanced during development by a distinct mechanism, namely emmetropization, to yield an optimal optical working system. Changes in ocular biometry are generally the structural basis of the age-dependent myopic shift in refraction in children which leads to myopia. Several studies show that the corneal power remains stable after 2 years of age.\textsuperscript{201-205} The AL increases, with refraction correspondingly shifting in a myopic direction.\textsuperscript{201-205}

In addition, refractive errors depend on a number of biometric components, including vitreous chamber length, lens thickness, and anterior chamber depth (ACD).\textsuperscript{206} The latter refers to the space that is aqueous humour-filled and that is located in the eye, specifically between the iris and the innermost surface of the cornea (also known as the endothelium). Both vitreous chamber length and ACD represent parts of the AL, while lens thickness plays a less prominent role in refraction.

AL, AL/Corneal Radius (CR) ratio, and ACD are correlated negatively with refractive error.\textsuperscript{29} These correlations indicate that longer eyes, those in which axial elongation has outpaced changes in corneal curvature (which hardly changes after 2 years of age) are more likely to be myopic, or in this sample, less hyperopic. Focusing on the AL/CR ratio, it refers to the division of the axial length by the mean or average corneal radius of curvature. It has been shown that AL/CR values greater than 2.9 may indicate a proclivity to be myopic. Among an Australian population (predominantly hyperopic children aged 6 years), the peaked distribution of SER
was apparent and the distribution of AL/CR was peaked with a mean of 2.906\textsuperscript{29} while Gwiazda et al.\textsuperscript{207} found that approximately 95% of myopic children had AL/CR ratio higher than 3. Interestingly, there was a higher correlation between AL/CR ratio and refractive errors, as compared to that between AL and refractive error. He et al.\textsuperscript{208} found that the AL/CR ratio can provide a more precise explanation for the variation of the spherical equivalent (SE) when compared to AL alone (AL/CR ratio and AL can explain 65.7\% versus 43.1\% of the SE total variance, respectively). Other studies have corroborated this finding yet the SE-attributable variability was remarkably different. SE variation explicable by AL and AL/CR ratio was 39\% and 51\% in a Nigerian population,\textsuperscript{209} and 35\% and 60\% in an Iranian population\textsuperscript{210} while 84\% of SE variation was attributable to AL/CR ratio in a study conducted in New Zealand.\textsuperscript{211} This may be an intrinsic ethnic difference, but different levels of myopia may provide a better explanation. Furthermore, gender may account for the better correlation between SE and AL/CR compared to AL alone because the latter is shorter and the corneal power is higher in girls than boys.\textsuperscript{209}

1.3.2 Methods for Measuring Optical Components

Technological developments have empowered optical specialists to measure different optical components with the aim of predicting and detecting abnormalities. For example, specialists often try to measure components such as surface curvature of the cornea, axial length, anterior chamber depth, as well as the corneal thickness. Opticians use corneal topography, which denotes an imaging technique, to generate holistic maps of the surface curvature of the patient’s cornea.

The axial length is measured in millimetres using advanced technological techniques such as ultrasonography. Ultrasound techniques used to determine the axial length can either be contact or non-contact. Single or dual rotating Scheimpflug photography devices are available to measure anterior segment parameters and they provide non-contact, user-independent
measurements without the need for realignment.\textsuperscript{212,213} Novel optical biometry devices are based on partial coherence interferometry, which provides reliable and accurate measures.\textsuperscript{214} They include IOLMaster (Carl Zeiss Meditec, Germany) and the more recently-introduced device Lenstar (Haag-Streit AG, Switzerland). Ultrasonic scans and slit lamp techniques are used to determine the anterior chamber length or depth.

As for corneal parameters, there are a variety of instruments that can be used to measure the corneal curvature or power but the most common are a keratometer, a corneal topography device or IOLMaster.\textsuperscript{215} Often corneal curvature is important in IOL calculations as well as in corneal refractive surgery. Measurement of corneal curvature using a keratometer involves focusing on the determination of the size of an image that the cornea’s paracentral points reflect. By using the convex mirror formula, it becomes possible to derive the anterior corneal curvature. Empirical estimation of the corneal power is achieved by the use of Snell’s law of refractions with simplified optics.\textsuperscript{215}

In choosing to focus on AL/CR in the current study, the value of the component is evidenced in the influence that interactions between the corneal curvature radius and axial length have on the individual eye components (with regards to compensatory adjustments) during the initial two years of life.\textsuperscript{216} The cornea is stable by the age of 5 years, and it seems that the continued AL elongation is partially compensated by the loss of lens power.

With regards to the ACD, using several slit lamp photography, anterior segment optical coherence tomography, or ultrasound microscopy, the average ACD is 2.05 mm with a range of 1.8 to 2.4 mm.\textsuperscript{217} In emmetropic individuals, the increase in ACD stops at earlier stages when compared to myopic patients.\textsuperscript{218} However, with older age, the depth decreases largely due to decreased lens thickness and farsightedness develops.\textsuperscript{219} Therefore, while the lens is thickening, it is losing power.
1.3.3 Development of Eye Biometry in Early Ages

An infant is usually born with an eye that is 70% of its adult size, and the infant’s eyes are predominantly hyperopic at birth, with an eye that is too short. To reach emmetropia, the eye has to elongate.\textsuperscript{205} In the first phase, over the first two years after birth, the cornea and lens lose power, but the axial length increases.\textsuperscript{201-205} This leads to a tightening of the distribution of refraction, with a peak around 1.0 to 1.25 D.\textsuperscript{220,221} After that, the lens continues to lose power\textsuperscript{222,223}, and axial length continues to increase, but the cornea is stable.\textsuperscript{201-205}

The default direction of eye growth would be towards relative elongation to reach a definite emmetropic state. In a longitudinal investigation, Mutti et al.\textsuperscript{224} have recently indicated that the early structural and optical development of the eye includes reaching emmetropization within the first 2 years of life after a rapid exponential phase followed by a slower quadratic phase, in which AL elongation is compensated essentially by the reduction of lens power in all children under study (aged 3 months to 7 years). Importantly, on average, the AL of an eyeball from a new-born measures approximately 17 to 17.3 mm then reaches to 20.6 mm with an average of 2.5 to 3.8 mm increase at the end of the first year of age.\textsuperscript{205,225} The rate of AL elongation then reduces, such that the mean AL reaches up to 21.5 mm and 21.9 mm in the second and third year, respectively.\textsuperscript{226} AL continues to grow at least up to 18 years of age with a rate of growth of 0.4 mm/year.\textsuperscript{227}

Multiple studies have confirmed this growth pattern. Tideman et al.\textsuperscript{228} found that the median AL increased significantly in European children until 15 years of age, followed by a slower rate of increase into adulthood. Similarly, Bhardwaj et al.\textsuperscript{227} reported an increase in the mean AL in the participants aged 11-20 years (23.23 ± 0.48 mm in males and 23.42 ± 0.46 mm in females) as compared to those aged 0-10 years (22.28 ± 0.50 mm in males and 21.93 ± 0.67 mm in females). Among 872 Chinese children, multiple linear regression models indicated a significant association between longer AL and increased age (P = 0.005).\textsuperscript{229}
Differences in AL were also reported in relation to body height and gender. A longitudinal study conducted on Chinese children aged 7-15 years indicated that AL is positively correlated to body height since both are increased annually at rates of 0.22 ± 0.17 mm and 3.93 ± 3.02 cm, respectively. The greatest increases in AL elongation were observed in younger participants (aged 8 years) and in females although females had smaller stature. Likewise, a large retrospective study of children aged 4-18 years has shown that longer AL was associated with older age (standardized correlation coefficient $\beta = 0.35$, $p < 0.001$) and body height ($\beta = 0.22$, $p < 0.001$). However, males had longer AL when compared to females. Indeed, both male gender and older age were also associated with longer AL in several studies based in Australia, the United States, and Taiwan. Despite the lack of a significant difference in the AL at birth and after 3 years in a study conducted by Lim et al., the authors found that eyes with longer AL, larger surfaces and larger volumes at baseline have shown significantly smaller increases in AL over the study period but this was not associated with refractive error development.

Corneal changes also play a crucial role in refractive status. At birth, the average horizontal diameter of the cornea ranges between 9-10.5 mm and the vertical diameter is greater by approximately 9.9-10.5 mm. The subsequent changes in the corneal diameter are associated with changes in the corneal curvature. Keratometry values obtained at birth range between 47-48.06 D and these values are rapidly decreased in the first 2-4 weeks of life. During the first year of life, the cornea loses 3-5 D of power. Corneal flattening continues until the third year of age, where multiple cross-sectional studies of the general population and school-aged children have shown relative stability in the corneal power after such age. However, a few studies revealed that the vertical meridian power decreases slightly with age (43.52 D and 42.49 D in children aged 4 and 14 years) and ultimately to an average of 42 D at age 20.
A recent cross-sectional study among Chinese children has revealed a significant difference in CR at 3 and 6 years of age (7.81 ± 0.27 mm versus 7.87 ± 0.28 mm, respectively, p for trend <0.001). Similarly, another cross-sectional investigation that targeted children aged 7-9 years has reported a greater CR in the older group while a slight, but significant, flattening in corneal curvature has been reported in an observational study of children aged 6-12 years. Intriguingly, Scheiman et al. showed a statistically significant correlation between AL and CR at baseline and after 14 years of follow-up. Conversely, corneal power remained constant in 1133 preschool children in China and no significant difference in CR was found in children aged 7 years and their counterparts aged 14 years in the Anyang childhood eye study. Therefore, it seems that more longitudinal studies are warranted to investigate the correlation between CR and age in children. Gender differences have been reported elsewhere in the literature, indicating a stronger corneal power in females as compared to males in several studies.

The crystalline lens is another element that significantly adapts to changes implied in the AL and subsequently the impact on the refractive status. Lens power decreases up to 9-10 years of age and the rate of power loss is seemingly accelerated with higher AL elongation rates and this emerges as a major compensatory mechanism that maintains emmetropia. Iribarren et al. found a significant negative correlation between lens power and AL (p<0.01) among children aged 6-9 years in the Singapore Cohort study Of the Risk factors for Myopia (SCORM) study. The rate of reduction in lens power is slowed remarkably after the age of 10 years and, given the continued AL elongation after 10 years of age, it is plausible that these changes may be responsible for the development of myopia. From another perspective, given the aforementioned regulatory role of lens power on emmetropia during the first ten years of life, axial elongation during the second decade may be regulated by other factors rather than decreased lens power.
The depth of the anterior chamber, vitreous chamber, and lens thickness are important ocular dimensions that play a crucial role in determining the refractive status of the eye. In a Turkish study, both larger vitreous chamber and deeper anterior chamber were typically observed in males, while lens thickness decreased in older children (11-12 years) as compared to those aged 2 years (lens thickness decreased from an average of 3.67 mm in those aged 2 years to 3.51 mm in older children). Reduction in the lens thickness has been emphasized in three studies employing children between 6-14 years of age and 7-18 years of age. Generally, lenses tend to be thinner as a compensatory action to the associated increase in AL in the physiological eye growth and this might pose a role in the development of myopia. Overall, AL increases in a triphasic manner. The increase is greatest during the first 2-3 years of life. Meanwhile, the cornea and lens lose power leading to tightening of distribution of refraction. Parallel with the corneal flattening during the first year of life, a tremendous reduction of the dioptric power takes place and hence the eye’s power decreases from 90 D at term to 75 D at one year of age. Changes in the cornea and lens should be perfectly balanced with the changes in AL to reach an ultimate emmetropia. Following the third year of life, the cornea remains stable while the AL increases and the lens continues to lose power up to 10 years of age, where the rate of power reduction decreases significantly. Therefore, axial elongation may be the major determinant of refraction during childhood. Furthermore, given the significant role of AL/CR ratio on determining SE variance, AL/CR ratio, but not CR or AL alone, can be an additional determinant of refraction.

1.3.4 Changes in Eye biometry in Myopia

As stated above, myopia is a condition of the eye characterised by an excessive eye length, especially of the vitreous chamber, that is greater than that of the focal length defined by the anterior eye. In most cases, myopia results from an overgrowth of the axial length, particularly the vitreous chamber. Myopic eyes have ocular dimensions that differ significantly
from that of emmetropic eyes – 24.2mm (transverse) x 23.7mm (sagittal) x 22.0-24.8mm (axial).

Axial length in myopia is greatly increased. Change in axial length has been linked directly by many studies as the primary cause of myopia.\textsuperscript{225,227,244,249-252} Increases in axial length have been associated with an increment in the distance that the rays have to cover before converging in the retina. As such, increased axial length results in a convergence of rays before they reach the retina. The over-focus created on the image leads to the generation of blurred images for objects that are far, while near objects appear clear.

On the other hand, Mutti et al.\textsuperscript{253} have shown that the myopic eyes have lost their compensatory changes in the crystalline lens which normally persist in emmetropes. These changes include stopped thinning, flattening and loss of lens power following one year of the onset of myopia. A three-year longitudinal study has revealed no significant correlation between the changes in lens thickness and the progression of myopia although corneal flattening was associated with such condition.\textsuperscript{202}

1.3.5 Summary of Biometry

In summary of this section, the development of the eye is a complex procedure that entails critical changes in the dimensions that define growth and development. Different ocular components develop at different rates and characteristics, with the ultimate aim being the formation of a functionally competent visual organ. During the first 2 years of life, an active process, namely emmetropization, shapes refraction distribution wherein the AL elongates and cornea and lens lose power to balance the refractive status. However, after 2 years, the cornea becomes relatively stable while other refractive determinants continue to change. The main essence of myopia is that the AL increases beyond the focal length defined by the power of the lens and cornea indicating that AL has a significant role as a refractive parameter. However, the AL/CR ratio showed a more prominent role in the refractive status given its closer
association to refraction when compared to AL alone. Therefore, the AL/CR ratio can be regarded as a useful marker of myopia progression.

**Part 4- Justification and aims**

The prevalence of myopia has been rapidly increasing over the world in the last fifty years and become a major issue of public health concern. Several studies have highlighted the prevalence of myopia among school-aged children, especially in some locations and ethnicities. Such a rapid rise in prevalence cannot be attributed to genes only and now it is generally accepted that the increase has to be attributed to environmental factors. There is strong evidence of the protective effect of time spent outdoors, as one of the environmental factors, on the development of myopia. However, the extent of this protective effect and the levels of light exposure at which it occurs are not yet well understood, largely because measures of light exposure which can be applied to large populations remain under-developed. Therefore, an accurate and cost-effective measure for time spent outdoors is needed. Questionnaires remain the most cost-effective way of determining exposure to the outdoors in large-scale studies. A well-validated questionnaire will be necessary for accurate measurements that will provide reliable data on the impact of interventions to prevent myopia development. We hypothesize that a modified electronic questionnaire will help in determining the outdoor exposure in a more effective way. This thesis tried to validate the WHO questionnaire and developed an electronic questionnaire. Therefore, the aims of this thesis are as follows:

1. To use data collected on time spent outdoors using the WHO Refractive Error in School Children questionnaire for validation against a diary of daily activities and objective measures of light exposure using a light data logger (LDL). This aim will be addressed in chapter 3.
2. To establish an effective method of measuring time spent outdoors in children, adolescents and young adults to be used in intervention projects to prevent further increases in the prevalence of myopia, by developing an electronic questionnaire based on the results on chapter 3. This aim will be addressed in chapter 4.

3. To examine the changes in children’s eye biometry in the context of myopia development.

4. To investigate risk factors associated with eye biometry changes and to determine the relationship of risk factors to time spent outdoors. The third and fourth aims will be addressed in chapter 5.
Chapter Two

2. Methodology

This chapter describes the methods used to address all four aims. The first section of this chapter describes the methods used to validate the instruments and addresses the aims one and two of this thesis. The second section describes methods used in the Sydney Adolescent Vascular and Eye Study (SAVES), the longitudinal follow-up of the two age cohorts from the Sydney Myopia Study (SMS)\textsuperscript{35,197} that addresses the third and fourth aims of the thesis.

2.1 Part one: validation of a questionnaire

This part describes the methods used to cover the first and second aims of the thesis. While as aims 1 and 2 both are ultimately intended for use with children and younger adults, the point of the current study is to examine the WHO questionnaire under ideal conditions by using highly educated adult participants who can give knowledgeable feedback about its strengths and weakness, rather than using it in a population who are less likely to be able to use it accurately. The study of aims 1 and 2 will be addressed in chapter 3 and 4 respectively.

2.1.1 Participant and sample size

The study included 100 participants with 51 males and 49 females. The participants were university students. Most were aged between 19 and 29. There were also 8 postgraduate students, aged above 40 years old, with one participant 51 years old at the time of data collection. The recruitment of the participants took place via advertisements that were placed on the notice boards in the campus of the Faculty of Health Sciences, the University of Sydney as well as announcements done on the electronic bulletins of the Faculty. The participants were
given all the study details and then signed the consent form (Appendix 3 and 4). Every participant was also given a unique identifier code. All study documents including those returned by participants were kept in the locked drawer at the office of the Head of the Orthoptics Department, which is a locked office and accessible only by the researchers. The study was approved by the University of Sydney Human Research Ethics Committee and was carried out in accord with the Declaration of Helsinki.

2.1.2 Materials

The study used three data collection instruments, a questionnaire, a light data logger, and a diary. They are described below.

2.1.2.1 Questionnaire

The study adopted the World Health Organisation Refractive Error in School Children (RESC) questionnaire (Appendix 2). The questionnaire was discussed in detail in chapter 1, section 1.2.5. The RESC questionnaire underwent a slight modification to be appropriate for Australian university students and young adults as opposed to children and was used in this study to collect information about the average time that the participants spent outdoors as well as indoors. Only minor changes to the questionnaire were needed to make it suitable for the current university student sample, mainly replacing some terms such as “children” with “university students”, and “school” with “university” (Appendix 5). The questions about the mode of travel from home to university and vice versa, and time taken in travel were also changed to fit the university student sample because they could travel by themselves.

2.1.2.2 Light Data Logger (LDL)

The study also used a small HOBO light data logger (model UA-002-64; Onset Computer Corporation, Bourne, MA, USA), which is a temperature/LDL, recording light intensity as well
as luminance in units of lux. The LDL comprises a small waterproof, polypropylene case with the light meter along with a temperature sensor. The LDL was put in a translucent holder on an armband fixed firmly onto the outer clothing of the participants’ upper arms during waking hours for the four days of the study (comprising two weekdays and two weekend days). Light intensity was recorded every 10 minutes for the four days of the study, both indoors and outdoors.

2.1.2.3 Diary

The 4-day diary was a slightly modified version of the one that Dharani et al. used in a study designed to increase sunlight exposure in Singaporean children (appendix 6). An example of the modification was the alteration of terms, for instance, replacing the term “children” with “university students” to fit the new participants. The change from the diary adjusted some of the terms to suit local usage as well as the lifestyle of the students in the university. The diary grouped the participants’ daily activities into eight types that included sleep, travel, university, workplace, passive activity that included watching television, movies, video-games, the computer/reading for pleasure, as well as cooking. There were also other daily tasks that involved physical activity like sport, gym, shopping, bike riding, walking, along with gardening; the other classification was additional time outside of the university classes like studying or completing assignments; and additional activities that could be specified. The participants simply wrote the number of the activity in the box. The 24-hour diary recorded the start as well as the end time of every activity, and whether the activity was outdoors (outside any building) or indoors (inside any building or structure). See appendix 7.
2.1.2.4 Focus Group Discussion

The focus groups were conducted to explore participants’ experiences of the light exposure measurement methods described below, to gather information about the ease of use of these methods, and if there were any issues and/or inconveniences participants had noted concerning the completion of the diary and/or wearing the LDL. The questions for the focus group were primarily structured and set out as outlined below. The questions were refined from an unpublished pilot study undertaken by the researchers in the Discipline of Orthoptics, Faculty of Health Sciences, undertaken as a part of a teaching project. The pilot study included 48 students. The students attached the LDL on their external clothes all through the hours that they were awake for the 7 days of the pilot study. The LDL recorded the light intensity every 2 minutes. After that, participants attended a focus group discussion for an hour, and then all comments were considered when designing the current study.

- Did any of you have any problems wearing the light data logger?
- Is there anything we could have done to make it easier to wear the light data logger?
- Were you able to remember to wear the light data logger each day and what do you think might have made it easier to remember?
- Did you note any time when you felt that the light logger may not be recording the same information you were recording in your questionnaire and can you remember what was happening?
- Was there anything you found difficult to code in the questionnaire?
- How easy or hard was it to complete the questionnaire and how do you think it could be improved?
Was there any time when filling out the questionnaire that you felt you could not accurately reflect what you were doing in the options provided, can you think of any examples?

Is there anything we have forgotten to ask or any other comments you might like to make?

Unstructured questions were used to broaden the discussion if necessary, for example: ‘One of the things we are interested in is, any comments other people may have made about the light data logger when you were wearing it?’

The pilot study showed the questions and processes for the focus groups were effective, so the same questions and procedure were used for the current study.

### 2.1.3 Procedures

In the validation study, which is the first half of this thesis, participants filled out the WHO RESC questionnaire, which took around 15 minutes. After the participants had completed the questionnaire they were given the other study materials and instructed in their use. They wore the LDL for four days during all activities, excluding sleeping, swimming or bathing/showering, when they were advised to keep it nearby so that the sensor was in a light exposure similar to the one they were in. In the meanwhile, participants also documented their daily activities in the 4-day diary. At the end of the 4-day period, the LDL was returned and individual light data downloaded to a computer file and coded with the participant’s unique study identifier number.

After the four days, the same participants in the validation study attended the focus group session. There were 10 groups, each group contained ten participants. The attendees of the focus group varied between females and males as shown in table 4. The focus groups took place in the Discipline of Orthoptics rooms, in the Faculty of Health Sciences at the University.
of Sydney. Notes were taken from the sessions. This was to establish any problems and possible resolutions and the feasibility of using either instrument for future studies.

Sleeping time was excluded because the aim was to measure activity during the day and light exposures, but sleep is mostly at night, generally in the dark. Travel time was excluded also, for two reasons. Firstly, the LDL proved very sensitive to incident light direction, so vehicle orientation to the sun could determine whether the LDL recorded an indoor or outdoor light level. Secondly, focus group responses revealed disagreement between questionnaire respondents about whether travel should be rated as indoor or outdoor time thereby suggesting that the questionnaire responses regarding travel would be unreliable.

Table 4: The Composition of Focus Groups Session

<table>
<thead>
<tr>
<th>Group Number</th>
<th>Number of Females</th>
<th>Number of Males</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
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<tr>
<td>Total</td>
<td>49</td>
<td>51</td>
<td>100</td>
</tr>
</tbody>
</table>

2.1.4 Statistical Analysis for Validation Study (Research Aims 1 and 2)

Power calculations for a standard correlation suggest that using conventional values for alpha of 0.05 and power of 0.8, a sample size of 100 could detect a correlation of 0.28, which equates
to a moderate effect size by conventional criteria. Detectable correlation after 10% dropout would be 0.30, also a moderate effect size.\textsuperscript{254}

Ten-minute time periods recorded by the LDL as $>1,000$ lux were classified as being outdoors, and $<1,000$ lux were classified as indoors.\textsuperscript{199,255,256} The threshold lux level to determine the difference between indoor and outdoor lighting, was established independently to offer a reliable indicator of being outdoors in our pilot studies, performed by the researchers in the Discipline of Orthoptics (mentioned previously in section 2.1.2.4). The threshold was consistent with an additional three studies\textsuperscript{199,255,256} that had used the same methods. Some have suggested increasing the cut-off to 1,500,\textsuperscript{257,258} but data from our pilot study suggested the 1000 lux cutoff was a more suitable criterion for being outdoors. In the pilot study, 48 university students wore LDLs for one week and completed a 7-day activities diary documenting whether they were indoors or outdoors, the 1,000 lux outdoors cut-off agreed with student reports for over 67% of the 2-minute periods of recorded the light intensity. Agreement for time spent outdoors decreased slightly to 63% when the outdoors cutoff was increased to 1,500 lux.

The questionnaire and diary data were entered into Microsoft Excel and SPSS (version 22, IBM Corp, Armonk, NY, USA) software. The diary and LDL information were matched by time period with the questionnaire recordings of indoors and outdoors. The questionnaire averaged participant’s activities during the whole week. Taking each 10-minute period as either “indoors” or “outdoors”, allowed calculation of the total time of activities spent indoors and outdoors for all three recording devices, over two weekdays and two weekend days. Dividing the weekday and weekend totals by two produced times indoors and time outdoors on a typical weekday and weekend day as estimated by the LDL, the diary and the questionnaire. Weekdays were analysed separately from weekend days because information from the pilot study indicated students’ activities on the weekend varied considerably from typical activities during the week, and this variation could potentially influence the time spent outdoors.
There was one missing weekend day for one participant. In this case, we took the average of two weekdays as we did for all data, but we replaced the missing day by another weekend day for the same participant. Levels of agreement between the instruments were determined by using paired t-tests and calculating intraclass correlation coefficients (ICCs).

Analysis of data of 8 postgraduate students was consistent with the rest of the sample, and it has been embedded in the results.

For the focus groups discussion, a thematic analysis was performed. During the discussions, notes of the participant’s answers to the questions were made. Their feedback and answers were summarised and grouped into themes.

2.2 Part two: Biometric changes

The second section of this chapter describes the methods used in addressing aims 3 and 4 of the thesis. These methods are already published and have been described in the following section: 2.2.1.35,197

2.2.1 Participants and sample size

In 2004 and 2005, the SMS sampled 2353 children aged 12 and 1765 children aged 6.35,146,197

The SMS was a population-based cross-sectional study of children recruited from a sample of 55 Sydney metropolitan schools, randomly chosen within socio-economic strata. The SAVES, which is the longitudinal follow-up of children who took part in the SMS, started in 2009 and continued to mid-2011. Thirteen out of the 34 original primary schools were re-examined prior to the younger group going on to join secondary school. Children in a similar year group within these schools who did not participate in the original research were also invited to play a part, and an additional 230 children were inspected. Children who had shifted to secondary school from the additional 21 primary schools were followed up either at that secondary school or individually at another study school in their region or an eye clinic. Twenty out of the 21
secondary schools in the SMS were re-examined. Once more, learners in a similar year group were also invited to take part, and 475 other students were inspected. It was not possible to visit one school before the students had finished their last year, although these students were invited individually to take part.

2.2.2 The measurement of eye biometry

Axial length, anterior chamber depth and keratometry were measured by the IOL Master (Carl Zeiss, Meditec AG Jena, Germany). The advantages of this method are that it can perform high-resolution measures of axial length, anterior chamber depth and corneal curvature and also does not require contact with the eye. The IOL master has excellent repeatability when used by different examiners and can be performed with or without pupil dilation. Five valid readings of axial length, five valid readings of anterior chamber depth and three valid readings of keratometry were recorded.

2.2.3 Procedures

The Human Research Ethics Committee, University of Sydney; and the Catholic Education Office; and the New South Wales Department of Education and Training offered the ethical approval for the research (The University of Sydney ethics approval number for SAVES was 04-2008/10538 and the approval was given on the 23rd April 2008. The Department of Education ethic approval for SAVES was 20080901 on 20th April 2009). The research followed the Declaration of Helsinki tenets. Before involvement, written permission was obtained from participants who were above the authorized age of permission (18 years) or parents, and verbal approval was obtained from all participants prior to the examination.35,197 The entire sample experienced a complete eye check at both follow-up and baseline that incorporated cycloplegic autorefraction (RK-F1, Canon, Japan, and Tokyo). Cycloplegia was induced by 1 drop of tropicamide 1% and 1 drop of cyclopentolate 1% administered in 2 series, 5 minutes apart,
following corneal anesthesia with 1% of amethocaine hydrochloride. Approximately 20 to 30 minutes after the last cycle of cycloplegic eye drops, autorefraction was done.

The self-identified ethnic origin of both parents determined ethnicity by means of ethnic classes compatible with the Australian Standard Classification of Cultural and Ethnic Groups, as formerly defined. The ethnic groups used in this research were East Asian, European Caucasian, South Asian (Indian/Sri Lankan/ Pakistani), South American, Middle Eastern, Melanesian/ Polynesian, African, Indigenous Australian, and assorted ethnicity. Because of numbers, the analysis divided the sample into only three major ethnic classes: East Asian, European Caucasian, and “Other”, which was comprised of all other groups. East Asian and European Caucasian ethnicities were the most common.

2.2.4 Definitions

The spherical equivalent refraction (SER) was used to determine the refractive standing of the right eye (worked out as sphere + ½ cylinders). Significant hyperopia was described as an SER of ≥ +2.00 D and myopia as an SER of ≤-0.50 D since it is the current consensus threshold value for myopia. Astigmatism was described as ≥ 1.00 D cylinder refraction. During this investigation, the axis of astigmatism was not considered. Further subdivision of the refractive error was done for some analyses into high myopia (SER < -5 D), moderate myopia (SER < -3 D to -5 D), mild myopia (SER ≤ -1 D to -3 D), mild hyperopia (≥ +0.50 to < +2.00 D), emmetropia (≥ -0.50 to < +0.50 D), and significant hyperopia (≥ +2.00 D).

2.2.5 Statistical Analysis Research Aims 3 and 4

The statistical analysis software SPSS (version 22, IBM Corp, Armonk, NY, USA) was used for data analysis in this study. Only data of the right eye was used for all the calculations. Pearson Correlation Coefficients (PCC) were used to measure the correlation of SER and the parameter AL, ACD, CR and AL/CR, and also within groups (Gender, SER category and
Ethnicity). Multivariate regression was used to determine the variables which predicted SER, AL, ACD and CR.
Chapter Three

Risk Factors for Longitudinal Biometric and Refractive Changes in Australian Schoolchildren

As previously discussed in Chapter 1, changes in refraction depend on changes in ocular biometry. This chapter has a dual purpose: to investigate the potential changes in children’s eye biometry in the context of myopia development and the associated risk factors, in particular, the impact of time spent outdoors on eye biometry. This chapter is formatted as a journal article.

3.1 Introduction

Refractive errors in children are influenced by the major refractive elements of the eye. The axial length (AL) which comprise the distance from the cornea to the retina, is in concordance with the total refractive power in the emmetropic eyes, and a sharp image will be formed on the retina. The optical power of the cornea, represented as corneal radius of curvature (CR) or corneal power and with crystalline lens power, are major determinants of ocular refractive power. An adequate balance between ocular AL and refractive power determinants during development is crucial to reach an emmetropic state.\textsuperscript{200} AL can be measured directly, and changes in AL appear to account for most of the changes in SER which result in myopia.\textsuperscript{29,201,260} Changes in the power of the lens are also important, but they cannot be measured directly.

The development of myopia in children during this period is controlled by the ultimate quality of the retinal image. Changes in refraction over a 5 year follow-up period have been reported for the Sydney Myopia Study – Sydney Adolescent Vascular and Eye Study.\textsuperscript{141} The impact of potential risk factors such as parental myopia, near work and time outdoors on the progression of refraction was documented. Distinct environmental factors, such as greater levels of near work and less time spent outdoors, have been associated with the development of myopia in
children aged 6 years. The aim of this study was to determine what longitudinal changes in biometric parameters were observed in this follow-up study, and which of these explained the changes in refraction, and whether they were regulated by risk factors in the same way that refraction was regulated.

3.2.1 Methodology

The methodology of this study has already been published in the Sydney Myopia Study (SMS) and Sydney Adolescent Vascular and Eye Study (SAVES), and only a summary of the elements central to the current study is presented below. The ethics approval for the study was obtained from the Human Research Ethics Committee, University of Sydney and the Department of Education and Training, State of New South Wales, Australia. Written, informed consent was obtained from parents of children prior to participation, and consent for cycloplegia was also obtained verbally from children at the time of the examination.

The SMS study investigated a sample from Australian schoolchildren from a stratified cluster-sample of 55 schools across the Sydney metropolitan area, in Years 1 (aged 6 years) and Year 7 (aged 12 years) between 2003 and 2005. The Sydney metropolitan area was selected. It is the largest city in Australia, with a diverse population. A total of 2353 children aged 12 and 1765 children aged 6 were examined, out of which 1.4% were myopic in younger cohort and 11.5% were myopic in older cohort. Children who participated in the SMS study were followed-up after 5-6 years as part of the SAVES study from 2009 to 2011. Children in the younger cohort were aged 12 years at follow-up and children in the older cohort were aged 17 years.

3.2.2 Recruitment

The study sought consent from each school through the principal for the participation of the children in the first instance. Following this, an information session was organized with each of the principals and other stakeholders including teachers and parents before undertaking the
study. This session offered the research team an opportunity to explain the study objectives and any implications for the study participants.

3.2.3 Examination process

The IOLMaster TM (Carl Zeiss, Meditec AG Jena, Germany) was used in the determination of the AL and anterior chamber depth (ACD) and keratometry was used in the determination of the corneal power and CR. The average of 5 readings was taken for each biometric parameter. Cycloplegic autorefraction using the Canon RK-F1 (Canon, Tokyo, Japan) was used for all children at both baseline (SMS) and follow-up (SAVES). The cycloplegia protocol included 1 drop each of cyclopentolate 1% and tropicamide 1% administered in 2 cycles, 5 minutes apart, following corneal anesthesia with amethocaine hydrochloride 1%. Adequate cycloplegia was confirmed by a lack of pupillary constriction to light and near stimulus, where the latter was defined as a lack of response to focusing on a near object, after which autorefraction was performed.

3.2.4 Questionnaire

A questionnaire was administered to parents of children in the younger cohort and to children in the older cohort. Socio-demographic information was gathered including the type of housing, childbirth history, obstetric history, parental education, existing medical history of the child and the history of eye disorders in the family including, parental myopia. The questionnaire also asked for estimates of the number of hours spent per week and weekend day in a number of different activities. Time outdoors per week was calculated by the weighted addition of time spent on weekdays and weekend days performing outdoor leisure and sporting activities. Time spent in near work included reading, doing school homework, and playing hand-held video games. The questionnaire was translated into different languages to match the ethnicities of participants in the study (Appendix 1).
3.2.5 Statistical Analysis

Statistical analysis was performed in SPSS (version 22, IBM Corp, Armonk, NY, USA). To examine the changes in refraction and biometry of the right eye with age, t-tests were used to compare the mean spherical equivalent refraction (SER) and biometric measures including AL, ACD, CR and AL/CR between baseline and follow-up. Pearson Correlation Coefficients (PCC) were calculated between change in SER and change in each biometric parameter to determine the biometric factors that contributed most to change in SER. This analysis was repeated with stratification by gender to determine any differences between males and females. Multiple linear regression models were used to determine the respective change in each biometric measure that accounted for the change in SER for the older and younger cohort.

To investigate the influence of risk factors (parental myopia, time outdoors and near work time) the mean SER change and AL change was compared between tertiles using Analysis of Variance (ANOVA). This analysis was conducted for the whole cohort and repeated for children with myopia at baseline only. To examine multivariate associations, a linear regression model was constructed using either SER or AL change as the outcome and risk factors as predictors. Models were adjusted for age, follow-up time, baseline refraction and ethnicity.

3.3 Results

3.3.1 Changes in refraction and biometry between baseline and follow-up

A total of 1084 children in the younger and 1557 children in the older cohort were in the SAVES cross-sectional study. 863 children in younger cohort and 1196 children in older cohort were a part of SAVES longitudinal follow-up, and had complete refraction data over an approximately 5 to 6 year follow up period. In the younger follow-up cohort, 1.4% were myopic at baseline while in older cohorts 13% were myopic at baseline. Table 5 shows the refractive and biometric changes between baseline and follow-up in both cohorts. Refraction
decreased in the younger cohort from 1.31D to 0.59D between baseline and follow-up, a change of -0.72D (p<0.001). Over the same period, there were a number of changes in biometric measures. CR slightly, but significantly increased from 7.80 to 7.83 (p<0.001), and there was an increase in ACD from 3.53 to 3.59 (p<0.001). The largest changes were in AL which increased between baseline and follow-up from 22.61 to 23.41mm (p<0.001). Consistent with the changes in AL and CR, AL/CR ratio increased from 2.90 to 2.99 (p<0.001).

Analyses of the relationship between increased AL and change in refraction in adult eyes suggest that there should be a myopic shift in the refraction of approximately -2.75D for each mm of axial elongation.261,262 In this case, an elongation of 0.8mm was accompanied by a myopic shift in refraction of only -0.72D. This shortfall is common in studies on children, where there is continuing loss of lens power, but this parameter was not calculated in this study.

Similarly, in the older cohort, there was a myopic shift in SER between baseline and follow-up, decreasing by -0.29D from 0.37D to 0.08D (p<0.001). This change was somewhat less than noted in the younger cohort. Again, consistent with this, AL increased by 0.25 mm from 23.42 to 23.67 (p<0.001), and AL/CR ratio also increased from 3.01 to 3.03 (p<0.001) (Table 5). As in the younger cohort, CR increased marginally but significantly, from 7.78 to 7.80 (p<0.001). However, in the older cohort, there was no change in ACD between baseline and follow-up, suggesting that lens thinning has largely ceased by this age. In this case, AL increased by 0.25mm, which would correspond to a myopic shift in the refraction of – 0.69D, compared to the shift measured of -0.29D. Again, this shortfall can probably be explained by the loss of lens power. Thus, in both cases, changes in axial length seem to account for a major part of the refractive change that has taken place, but in both cases, some of the expected increases are off-set by probable reductions in lens power.
Table 5: Baseline, Follow-up and Significance Values of Refraction and Ocular Biometry Changes for Younger and Older Cohorts

<table>
<thead>
<tr>
<th>Biometric parameter</th>
<th>YOUNGER COHORT (12 yrs)</th>
<th>OLDER COHORT (17 yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Follow-up</td>
</tr>
<tr>
<td>SER (D)</td>
<td>1.31</td>
<td>0.59</td>
</tr>
<tr>
<td>CR (mm)</td>
<td>7.79</td>
<td>7.83</td>
</tr>
<tr>
<td>ACD (mm)</td>
<td>3.53</td>
<td>3.59</td>
</tr>
<tr>
<td>AL (mm)</td>
<td>22.61</td>
<td>23.41</td>
</tr>
<tr>
<td>AL/CR</td>
<td>2.90</td>
<td>2.99</td>
</tr>
</tbody>
</table>

Table 6 shows the Pearson correlation coefficients between change in SER and change in biometric parameters. The biometric measure which accounted for the majority of change in SER was AL, with a strong and significant negative correlation between AL change and SER change in both cohorts. Conversely, change in CR and ACD were only marginally correlated with change in SER, suggesting that these biometric measures have little impact on changing SER at these ages. Interestingly, AL/CR change was most significantly correlated with change in SER for both cohorts, indicating that it is a good surrogate measure of a refractive change.
Table 6: The Strength and Direction of Association of Changes between Refraction and Ocular Biometry along with Significance Values for Younger and Older Cohorts

<table>
<thead>
<tr>
<th>Biometric parameter</th>
<th>YOUNGER COHORT (12 yrs)</th>
<th>OLDER COHORT (17 yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PCC</td>
<td>p-value</td>
</tr>
<tr>
<td>CR (mm)</td>
<td>0.001</td>
<td>0.99</td>
</tr>
<tr>
<td>ACD (mm)</td>
<td>-0.08</td>
<td>0.02</td>
</tr>
<tr>
<td>AL (mm)</td>
<td>-0.83</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>AL/CR</td>
<td>-0.88</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 6 The Strength and Direction of Association of Changes between Refraction and Ocular Biometry along with Significance Values for Younger and Older Cohorts

**PCC: Pearson correlation coefficient**

When stratified by gender, the correlations between change in ocular biometry and change in SER showed a similar pattern to that seen in the whole cohort (table 5.3.3). Overall, strong correlations were evident between change in SER and change in AL and AL/CR in both cohorts and for both gender groups, and a weak and non-significant relationship was seen with CR change. For both males and females in the older and younger cohort, there was a weak correlation between change in SER and change in ACD, which was only significant for females in the younger cohort.
Table 7: The Strength and Direction of Association of Changes between Refraction and Ocular Biometry along with Significance Values for Younger and Older Cohorts Classified by Gender

<table>
<thead>
<tr>
<th>Biometric parameter</th>
<th>Gender</th>
<th></th>
<th></th>
<th></th>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Male</td>
<td></td>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>PCC</td>
<td>p-value</td>
<td>95% CI</td>
<td>PCC</td>
<td>p-value</td>
<td>95% CI</td>
<td>p-value</td>
</tr>
<tr>
<td>CR (mm)</td>
<td>YOUNGER COHORT (12 yrs)</td>
<td>-0.002</td>
<td>0.96</td>
<td>-0.094, 0.117</td>
<td>-0.003</td>
<td>0.95</td>
<td>0.004, 0.263</td>
<td></td>
</tr>
<tr>
<td>ACD (mm)</td>
<td></td>
<td>-0.03</td>
<td>0.57</td>
<td>-0.148, 0.116</td>
<td>-0.14</td>
<td>0.01</td>
<td>-0.214, -0.061</td>
<td></td>
</tr>
<tr>
<td>AL (mm)</td>
<td></td>
<td>-0.83 &lt;0.001</td>
<td>0.889, 0.756</td>
<td>-0.84 &lt;0.001</td>
<td>0.922, 0.727</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AL/CR</td>
<td></td>
<td>-0.84 &lt;0.001</td>
<td>0.895, 0.786</td>
<td>-0.91 &lt;0.001</td>
<td>0.945, 0.887</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CR (mm)</td>
<td>OLDER COHORT (17 yrs)</td>
<td>0.02</td>
<td>0.58</td>
<td>0.104, 0.334</td>
<td>0.05</td>
<td>0.21</td>
<td>0.111, 0.388</td>
<td></td>
</tr>
<tr>
<td>ACD (mm)</td>
<td></td>
<td>-0.07</td>
<td>0.09</td>
<td>-0.133, -0.003</td>
<td>-0.06</td>
<td>0.15</td>
<td>-0.135, 0.004</td>
<td></td>
</tr>
<tr>
<td>AL (mm)</td>
<td></td>
<td>-0.80 &lt;0.001</td>
<td>0.847, 0.721</td>
<td>-0.82 &lt;0.001</td>
<td>0.861, 0.761</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AL/CR</td>
<td></td>
<td>-0.82 &lt;0.001</td>
<td>0.861, 0.769</td>
<td>-0.83 &lt;0.001</td>
<td>0.871, 0.759</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7 The Strength and Direction of Association of Changes between Refraction and Ocular Biometry along with Significance Values for Younger and Older Cohorts Classified by Gender
Table 8: The Strength and Direction of Association of Changes between Refraction and Ocular Biometry along with Significance Values for Younger and Older Cohorts Classified by Ethnicity

The table 8 highlights the Pearson correlation coefficient and P-value of the younger and older cohort stratified by ethnicity, classified as East Asian, European Caucasian, and Other ethnic groups. Results revealed a strong negative relationship between AL (mm) and AL/CR with the SER, which indicates that axial length elongation and higher AL/CR ratio are associated with more myopic refraction values. These findings were consistently significant for both younger and older age groups and across all three ethnic groups (p<0.001 for all). Indeed, this suggests the lack of a significant impact of age and/or ethnicity on the correlation between refractive error, axial length, and AL/CR ratio.
Table 9: Multiple Regression Model of Refraction Change and Ocular Biometric Parameters Changes

<table>
<thead>
<tr>
<th>Cohort</th>
<th>YOUNGER (12 yrs)</th>
<th>OLDER (17 yrs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$R^2 = 0.80$</td>
<td>$R^2 = 0.70$</td>
</tr>
<tr>
<td>Variables</td>
<td>B</td>
<td>p-value</td>
</tr>
<tr>
<td>CR (mm)</td>
<td>4.40</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>ACD (mm)</td>
<td>0.06</td>
<td>0.103</td>
</tr>
<tr>
<td>AL (mm)</td>
<td>-1.74</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 9 Multiple Regression Model of Refraction Change and Ocular Biometric Parameters Changes

Table 9 reports multiple regression analysis predicting SER change from the biometric parameters CR, AL and ACD, one model for younger and the other for older children. Both models show high $R^2$ values, 0.8 for the younger and 0.7 for the older cohorts, suggesting the predictors contribute substantially to predicting SER change. In both models, both CR and AL were significant predictors of SER changes. In particular, every 1 mm increase in the CR, favouring increased corneal power, predicted a 4.4 D increase in SER in the younger group ($p<0.001$) and a 3.06 D increase in SER in the older group ($p<0.001$). Conversely, every 1 mm increase in the AL predicted SER changes by -1.74 D and -1.94 D in the younger and older groups, respectively, indicating a likelihood of myopia development.

3.3.2 The influence of risk factors on refractive and biometric change

The impact of parental myopia, near work and time outdoors on the changes observed in SER and AL was examined in both cohorts and including children with all baseline refractive errors. Children with one or two parents myopic had a significantly greater myopic shift in SER and greater AL elongation compared to children without myopic parents (Figure 1).
Figure 1: Changes in refraction and axial length according to parental myopia A) mean changes in spherical equivalent refraction (SER) and B) mean changes in axial length (AL).

Time outdoors also significantly influenced AL elongation and SER change with those spending less time outdoors demonstrating much greater SER and AL compared to children who spent greater time outdoors (Figure 2). In contrast, near work time was not significantly associated with SER change in either cohort (Figure 3). There was a trend towards increased
AL growth for children who spent greater time in near work, however, this only reached significance in the older cohort. Axial elongation averaged 0.28mm in the highest near workgroup but only 0.25mm in the lowest (p=0.008).

**Figure 2: Changes in refraction and axial length according to time spent outdoors A) changes in spherical equivalent refraction (SER) and B) changes in axial length (AL)**

*Figure 2 Changes in refraction and axial length according to time spent outdoors A) changes in spherical equivalent refraction (SER) and B) changes in axial length (AL). For the younger cohort; low (≤16 hours), moderate (>16 - ≤23 hours) and high (>23 hours), older cohort; low (≤13.5 hours), moderate (>13.5 - ≤22.5 hours) and high (>22.5 hours).*
Figure 3: Changes in refraction and axial length according to near work A) changes in spherical equivalent refraction (SER) and B) changes in axial length (AL).

A multiple regression model for change in SER and AL was constructed with near work, time outdoors, and parental myopia as predictors, with adjustment for age, ethnicity, follow-up time and baseline refraction. These models explained 9% and 11% of the variation in SER change for the younger and older cohort, respectively. In the younger cohort, time outdoors and
parental myopia were significantly associated with SER change. Conversely, in the older cohort, only parental myopia had a significant impact (Table 10).

The predictors included in the model for AL change explained a greater proportion of the variation compared to the models for SER, with an $R^2$ of 0.21 for younger and 0.16 for the older cohort. In these models, a similar pattern of significance to that seen with SER emerged. In the younger cohort, time outdoors and parental myopia were again significant predictors of AL change and in the older cohort, only parental myopia was significant.

**Table 10: Multiple Regression Model of Risk Factors for Change Refraction (SER)**

<table>
<thead>
<tr>
<th>Cohort</th>
<th>YOUNGER (12 yrs) $R^2 = 0.09$</th>
<th>OLDER (17yrs) $R^2 = 0.11$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factors</td>
<td>$\beta$</td>
<td>p-value</td>
</tr>
<tr>
<td>Time outdoors</td>
<td>0.011</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Near work</td>
<td>-0.006</td>
<td>0.1</td>
</tr>
<tr>
<td>Parental myopia</td>
<td>-0.178</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*Model adjusted for follow-up time, ethnicity, baseline refraction and age.

The above table 10 depicts multiple regression models of risk factors for change in SER which suggests that time outdoors and parental myopia are significantly associated with SER because the p-value is <0.05. The table highlights R square value for both younger and older cohorts which are 0.09 and 0.11 respectively. For the older cohort, the only influential variable is parental myopia. Time outdoors and near work are not really influential risk factors for change in SER in the older cohort, although the impact of time outdoors is close to significant.
Table 11: Multiple Regression Model of Risk Factors for Change in Axial Length (AL)

<table>
<thead>
<tr>
<th>Cohort</th>
<th>YOUNGER (12 yrs)</th>
<th></th>
<th>OLDER (17yrs)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R² = 0.21</td>
<td></td>
<td>R² = 0.16</td>
<td></td>
</tr>
<tr>
<td>Factors</td>
<td>β</td>
<td>p-value</td>
<td>B</td>
<td>p-value</td>
</tr>
<tr>
<td>Time outdoors</td>
<td>-0.005</td>
<td>0.001</td>
<td>-0.001</td>
<td>0.2</td>
</tr>
<tr>
<td>Near work</td>
<td>0.003</td>
<td>0.06</td>
<td>0.001</td>
<td>0.2</td>
</tr>
<tr>
<td>Parental myopia</td>
<td>0.097</td>
<td>&lt;0.001</td>
<td>0.051</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*Model adjusted for follow-up time, ethnicity, baseline refraction and age.

Table 11 shows the multiple regression model of risk factors for change in AL which depicts the factors affecting myopia. The result shows that, with respect to both younger and older cohorts, parental myopia is the only consistent risk factor. Moreover, data indicated that time spent outdoors was a significant predictor of changes in the AL in the younger cohort, but not the older one.

### 3.3.3 The influence of risk factors on refractive and axial change in baseline myopes

The analysis of the impact of risk factors on SER change and axial elongation was repeated for children with myopia at baseline. The trends of time spent outdoors influencing SER change and AL elongation are present, and follow the same pattern as seen in the whole cohort (Figure 4). However, the trends for SER change did not reach statistical significance. In contrast, for AL elongation, this did reach significance in the older cohort, but not the younger cohort (Figure 4 B).
Figure 4: Impact of time spent outdoors on children having myopia at baseline A) changes in spherical equivalent refraction (SER) and B) changes in axial length (AL)

3.4 Discussion

SER and ocular biometry changed between baseline and follow-up, with the greatest change observed in AL. AL increased by a mean of 0.8 mm in the younger cohort, and 0.25mm in the older cohort. This was consistent with AL elongation that has been reported in the Orinda...
longitudinal study of children aged between 6 and 14 years through a two-year follow-up that increased by an average of 0.73 mm for 194 children with emmetropia.\textsuperscript{263}

The changes in ACD were small. The Orinda longitudinal study of myopia (OLSM) of emmetropic children showed an increase of the anterior chamber by a mean of 0.19 mm for children aged 6 to 14 years.\textsuperscript{263} Shih et al.\textsuperscript{264} found that the children suffering from myopia experience a significantly greater increase in ACD than hyperopic or emmetropic children and that change in ACD was inversely correlated with the changes in lens thickness to maintain a constant ratio of anterior segment to AL. There is also a moderate correlation between East Asians and ACD in the younger cohort.

A higher AL/CR ratio is a risk factor for the development of myopia. My findings are partly consistent with the finding of He et al.\textsuperscript{208} that AL/CR ratio in Chinese schoolchildren who found that the AL/CR ratio explained SER variance better than AL alone, as was previously reported by Grosvenor and Scott.\textsuperscript{265}

The regression analysis considered SER change as a dependent variable and biometric parameters as independent variables. The value of R-Square for the younger cohort was 0.80. It indicates that 80\% of the variability in SER is explained by the biometric parameters considered in this study.

For the risk factors, parental myopia is a strong predictor of the development of children’s myopia as seen in the study. The refractive change for children within the younger and older cohort with one or both parents who are myopic was consistently greater than for those without myopic parents. The effect of parental myopia on the axial length of their children is consistent. The children who have both parents who are myopic have the longest axial elongation. These findings are consistent with several others on the impact of myopic parents on the likelihood of children developing myopia.\textsuperscript{70,73,153}
However, in the younger cohort, the children who spent more time outdoors had a slower AL elongation as well as smaller SER changes. This effect was not apparent in older children. This might be attributed to the greater linear growth rate of AL experienced in younger children.\textsuperscript{266} It is evident that time outdoors slows down the AL growth and reduces the likelihood of myopia development. The results obtained are similar to earlier studies whereby outdoor activities are indicated to have a protective role in the development of myopia among children.\textsuperscript{129,141,143,145-152} It is thought that the exposure to bright light and subsequent pupil constriction can help reduce visual blur.\textsuperscript{267} Enhancing the release of retinal dopamine, which is a well-established inhibitor of AL elongation\textsuperscript{268}, by bright light may be another explanatory mechanism. Such a hypothesis was further supported in animal studies because the protective effect was blocked by dopamine antagonists.\textsuperscript{146,177,269}

When examining children with baseline myopia, a similar relationship is evident between myopic progression, axial elongation and time outdoors. While the differences in refractive change and axial growth between tertiles of time outdoors were large in the younger cohort, these did not reach statistical significance. This is likely because there were only a small number of children with myopia at baseline in this cohort. Similar, but less dramatic variation by tertiles of outdoor time was present in the older cohort where eye growth is slowing, and based on the whole cohort analysis, we could have expected time outdoors to have less effect on progression. However, the influence of time outdoors on axial elongation did reach significance in the older cohort possibly because of the larger numbers.

The study shows that parental myopia is the strongest predictor that has been consistently significant in all models. The results also highlight that the relationship between SER and AL (mm) and AL/CR does not vary with different ethnicities. The impact of genetics may be solely exerted or combined with environmental factors.\textsuperscript{70}
If the effect of parental myopia is genetic, it can be clearly demonstrated that a number of cross-sectional studies revealed a significant effect of parental myopia on the size of the pre-myopic eye and that having both parents with myopia is associated with an increased risk of axial elongation when compared to those having one or no myopic parents.\textsuperscript{68,73,270,271} Evidence from the Han Chinese population study\textsuperscript{272} suggested a role of four single nucleotide polymorphisms (SNPs) reported in two genes, (one SNP on the VIPR2 gene and three SNPs on the SNTB1 gene) in the increased susceptibility to myopia development. Furthermore, Verhoeven et al.\textsuperscript{106} have indicated in their genome-wide meta-analysis that 16 novel loci have been associated with myopia in individuals of European and Asian descent, among which there were eight shared loci between both cohorts. The functional aspects of the relevant genes included remodelling of the scleral extracellular matrix, eye development, neurotransmission, and retinoic acid metabolism.\textsuperscript{106} However, a more recent genome-wide meta-analysis\textsuperscript{109} revealed minor differences in myopia-associated SNPs among ethnic groups.

On the other hand, if the effect of parental myopia is environmental, the effect of parental lifestyle factors may be evident. In particular, highly-educated parents may expect higher educational achievement from their children and hence place greater educational demand on them.\textsuperscript{273} Moreover, children are encouraged to read more frequently if their parents are extensive readers.\textsuperscript{157}

One limitation of the current study is that the validation of the questionnaire showed inconsistent outcomes in extensively detailed studies. As such, there was a need to validate the questionnaire’s items against objective measures. Nonetheless, this was not possible in the current thesis given the established time constraints although expert validation has been carried out. Another notable limitation is that the statistical analysis did not include between-group comparisons of the impact of parental myopia and time spent outdoors with changes in AL and SER in the younger and older groups.
3.5 Conclusion

Consistent with the results of many other studies, the major biometric parameter associated with the myopic shifts in refraction measured in the SAVES study was axial elongation. Using the standard relationship between axial elongation and refractive change of -2.75D/mm, axial elongation more than accounted for changes in refraction with a shortfall in refractive change which is common in studies of the children of this age, where there is a continuous loss of lens power. The risk factors shown to affect changes in refraction showed similar effects on axial elongation, confirming the relationship between the two.

The questionnaire used revealed important results that confirm the association between time spent outdoors and refraction in relation to AL alone and AL/CR ratios. Evidently, time spent outdoors exerts a modulatory effect on the refractive development by modulating AL. Indeed, this might have an important implication, because these measures could be used as a surrogate measure of changes in spherical equivalent refraction. This may facilitate future studies, because, while accurate measurement of refraction requires the use of cycloplegic eye-drops, both AL and CR can be measured accurately without the use of cycloplegia. This should facilitate obtaining high participation rates in future studies.

The current study is unable to resolve the issue of whether genetics through the impact of parental myopia is due to genetic inheritance or the role of environment. One reason is that, as made clear in Chapter 1, current questionnaires measuring important environmental factors are not accurate. Nevertheless, the information obtained from a series of such questionnaires is consistent in its direction and implications, and the idea that time outdoors protects from the development of myopia has been confirmed with randomised clinical trials in children and in experimental studies on animals. Thus the direction of the effects are not in doubt. However, the inaccuracy of the measurements may explain why variations in time outdoors explain only a low proportion of the variance in refractive error, necessitating more precise measurements.
for more detailed definition of protective exposures. Further well-structured cohort studies with
good control and follow-up of children, and better-validated questionnaires, or objective
measurement of environmental exposures, are required to resolve this issue.
Moreover, other studies have indicated that the use of questionnaires is, or may be, inferior to
other methods such as diaries and light meters to gauge outdoor activity. The following chapter
(four) compares the correlations of the three different methods to ascertain their usefulness in
measuring outdoor activity, with recommendations for future use.
Chapter Four

Comparison of instruments quantifying time spent outdoors for studies of myopia

The initial results of this chapter have been published in the annual meeting of the Association for Research in Vision and Ophthalmology (ARVO), 3-7 May 2015 in Denver, Colorado. The approval number of ARVO was 2161629 (See appendix 8). This chapter is in the format of a journal article because it is prepared to be published.

4.1 Introduction

The prevalence of myopia has rapidly increased in East Asia over the past 10 to 20 years and has become a major public health concern. The prevalence of myopia now exceeds 70% to 80% in young urbanised adults in Singapore, Taiwan, South Korea and Chinese cities. Of greatest concern has been the increase in the prevalence of high myopia to exceed 20% of young adults in some studies.

This rise in the prevalence of myopia has occurred not just in East Asia. In the US, two large cross-sectional national health surveys of adolescents and adults using the same design and similar ocular protocols, conducted in 1971-2 and again in 1999-2004, showed that the prevalence of myopia had risen from 25% to over 42% in the intervening period in these representative population samples. However, the prevalence rates might be overestimated as they were primarily derived for comparison purposes using problematic methodology used in the first survey. Using better methodology that was only applicable to second survey, a more reliable estimate of actual prevalence was (33.1%) and other evidence from a multinational cross-sectional study (25.4%).

In Australia, there is no single study that included older and younger participants to study the
generational increase in myopia prevalence. Nevertheless, comparison of the individual studies that report refractive error rates in older\textsuperscript{123,257} and younger\textsuperscript{37} populations, shows much smaller generational increases in the prevalence of myopia. The increase, in part, may be due to changing ethnic demographics of the younger compared to the older population. Such rapid rises cannot be attributed solely to genetics, and now it is generally accepted that the increases are likely to be due to changes in exposure to environmental factors.\textsuperscript{45,277} It was as early as 1883 when Cohn\textsuperscript{278} first revealed a linkage between prolonged and intense education and myopia development and this was subsequently corroborated by recent cross-sectional studies.\textsuperscript{155,279} Considering different age categories, results have shown that myopia correlates with IQ and academic scores in children\textsuperscript{280,281} and in adults who received more years of education.\textsuperscript{193,279} On the other hand, lower rates of myopia have been reported with increased time spent outdoors.\textsuperscript{140,145,146,151,153} A recent report of a simple intervention of keeping school-children outside during recess time at school has proven to be associated with a reduced incidence of myopia,\textsuperscript{282} as was increasing time outdoors at the end of the school day.\textsuperscript{159} An extensive and detailed questionnaire was developed for the Sydney Myopia Study (SMS)\textsuperscript{197} to examine the impact of lifestyle on the prevalence of myopia. This questionnaire aimed to establish the time spent on a variety of daily activities of children and their location, namely, outdoors or indoors in small or large rooms. The findings of the SMS demonstrated that a crucial measure was whether activities were conducted indoors or outdoors, with outdoor activities being shown to be protective for myopia.\textsuperscript{146} In 2006, under the auspices of the World Health Organisation (WHO), a group of epidemiologists working in the area of myopia was invited to a meeting on Myopia Progression and Risk Factor Assessment Surveys in Guangzhou, China. This meeting collaboratively developed a revised questionnaire, simplifying the detail that was sought in the SMS questionnaire and formulated a standardised questionnaire to be used to measure time outdoors and other factors that have been
hypothesised to play a role in myopia. Versions of this questionnaire were modified for different locations, with a Chinese version used in a successful randomised trial of increased outdoor time for school children.\textsuperscript{159}

Studies on the association between light exposure outdoors and myopia are limited by uncertainties over the validity of measures of light exposure by using questionnaires, which are cost-effective but subject to recall bias. For progress in this regard, objective measurements of light exposures need to be used to assess the validity of the questionnaires.

Recently, a few small studies (n= 117, n= 35 and n= 102 respectively)\textsuperscript{283-285} have used light data loggers (LDL) (LDL was used first time in 2012 which is described in section 4.2.1 page 107) to measure exposure to ambient light levels. Two studies\textsuperscript{283,284} focused exclusively on the validity of the questionnaire against an LDL, while the third study\textsuperscript{285} had an additional aim of comparing daily light exposure and physical activity level among children with myopia. In addition, Alvarez and Wildsoet\textsuperscript{286} compared light exposure data collected objectively using a specific wearable sensor to subjective data obtained by a questionnaire. The authors reported a poor agreement between the methods and hence recommended cautious interpretation of studies relying on these questionnaires solely. In general, almost all of the aforementioned LDL-based investigations concluded that the importance of time spent outdoors to myopia was probably related to daily light exposure rather than physical activity level,\textsuperscript{285} as initially hypothesised.\textsuperscript{146}

This chapter aims to compare data collected on time spent outdoors using the World Health Organization (WHO) Refractive Error in School Children (RESC) questionnaire to that collected by a daily diary and to an objective measure of light exposure using an LDL. Questionnaires are relatively quick and easy to complete, easily analysed and can potentially provide information about typical behaviour. Diaries can provide detailed and explicit
information about particular time periods but are more time consuming to complete. However, questionnaires can be affected by the faulty recall, as can diaries if filled out retrospectively. Therefore, there is a need to compare the results obtained with questionnaires to more objective data, in this case that obtained from the light data logger. Questionnaires and diaries have to be validated by population and location before they can be accepted as reliable for quantifying time spent outdoors, and for establishing the role outdoor light levels play in the development of myopia.

4.2.1 Materials and Methods

The total number of participants and the process of recruitment for this study has been described in chapter two, section 2.1.1. Participants were divided into ten groups with 10 participants in each one. There was a group every week during the first semester of 2014 (from March till June, i.e. the study was conducted in autumn and winter) at the University of Sydney. The sample consisted of highly educated, knowledgeable adults rather than the ultimate target population of children because the plan was to test the questionnaire under ideal conditions. If anyone was going to be able to use the questionnaire accurately, it was the current sample. The University of Sydney Human Research Ethics Committee approved the study on 28 October 2013 under number 2013/880. It adhered to the tenets of the Declaration of Helsinki.

The WHO questionnaire, which was a paper-and-pencil one, was slightly modified to be appropriate for Australian university students and young adults, as opposed to children. This modification was guided by feedback from focus groups conducted as part of a pilot study in 48 university students who wore LDLs for one week and completed an earlier version of a 7-day diary documenting whether they were indoors or outdoors. This revised version was used to collect information regarding the average duration of time that participants in this study spent outdoors and indoors.
Participants were provided with a questionnaire on Wednesday, and instructed to start filling it out that day. After the participants had completed the preliminary questionnaire, which asked them to estimate the average time spent on activities on a typical day, they were given the other study materials (the LDL and diary) which were returned the following Monday. The three recording instruments therefore covered the same time period, as far as was feasible. They wore a small HOBO LDL (model UA-002-64; Onset Computer Corporation, Bourne, MA, USA), the description of this instrument and the way in which it was used has been presented in chapter two, section 2.1.2.2. Participants wore the LDL during all activities, excluding sleeping, swimming or bathing/showering, when they were advised to keep it nearby so that the sensor was in a light exposure similar to the one they were in.

In this study, a 10-minute recording interval for the LDL was chosen because pilot studies found that shorter intervals (120 seconds or less) produced excessive data volumes while requiring an unrealistically high level of accuracy in diary-keeping without increasing reliability. However, thirty-minute periods were not sufficiently sensitive samples of location/behaviour. Ten-minute intervals gave the most accurate picture of daily activities and exposure to sunlight, without generating an excessive burden on participants in documenting diaries.

At the end of the 4-day period, the LDL was returned and individual light data downloaded to a computer file and coded with the participant’s unique study identifier number. During the same 4-day period, participants also documented their daily activities in a diary, which was a slightly modified version of that used in a study designed to increase sunlight exposure in Singaporean children. The modifications and contents included in the diary have been described in chapter two, section 2.1.2.3. During the four days of the study, participants received text messages every morning from the main researcher to remind them to wear the LDL and record their activities in the diary.
At the conclusion of the four days, participants attended a half-hour focus group and discussed with the researchers their observations, experiences and any concerns and/or inconveniences they had noted about completing the diary and/or wearing the LDL (See section 2.1.2.4.). This was to help establish any problems and possible resolutions and the feasibility of using the instruments for future studies.

Sleeping time and travelling time were excluded, the reason for which has been mentioned in chapter two, section 2.1.3.

4.2.2 Statistical Analysis

Statistical analysis has been described in detail in chapter two, section 2.1.4.

4.3 Results

There were no dropouts and no data was incomplete. There was a significant agreement between the LDL and diary. The ICCs and p-values are presented in Table 12. For indoor conditions during both weekday and weekends the agreement was strong (ICC 0.885 and 0.894, respectively). However, in outdoor measurements, the level of agreement was weaker (ICC weekday, 0.256; weekend, 0.332), but still statistically significant.
Table 12: intraclass correlation coefficient (ICC) between questionnaire, light data logger (LDL) and diary data for time spent indoors and outdoors on weekdays and weekend days among university students in Australia

<table>
<thead>
<tr>
<th>Day</th>
<th>Instrument</th>
<th>ICC</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor weekdays</td>
<td>LDL &amp; questionnaire</td>
<td>-0.078</td>
<td>-0.269, 0.120</td>
<td>0.78</td>
</tr>
<tr>
<td></td>
<td>Diary &amp; questionnaire</td>
<td>-0.05</td>
<td>-0.243, 0.147</td>
<td>0.689</td>
</tr>
<tr>
<td></td>
<td>LDL &amp; diary</td>
<td>0.894</td>
<td>0.846, 0.927</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Indoor weekend</td>
<td>LDL &amp; questionnaire</td>
<td>0.262</td>
<td>0.070, 0.435</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>Diary &amp; questionnaire</td>
<td>0.379</td>
<td>0.198, 0.535</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>LDL &amp; diary</td>
<td>0.885</td>
<td>0.833, 0.921</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Outdoor weekdays</td>
<td>LDL &amp; questionnaire</td>
<td>0.102</td>
<td>-0.096, 0.291</td>
<td>0.156</td>
</tr>
<tr>
<td></td>
<td>Diary &amp; questionnaire</td>
<td>0.201</td>
<td>0.005, 0.381</td>
<td>0.022</td>
</tr>
<tr>
<td></td>
<td>LDL &amp; diary</td>
<td>0.256</td>
<td>0.063, 0.430</td>
<td>0.005</td>
</tr>
<tr>
<td>Outdoor weekend</td>
<td>LDL &amp; questionnaire</td>
<td>0.112</td>
<td>-0.086, 0.301</td>
<td>0.133</td>
</tr>
<tr>
<td></td>
<td>Diary &amp; questionnaire</td>
<td>0.391</td>
<td>0.211, 0.545</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>LDL &amp; diary</td>
<td>0.332</td>
<td>0.146, 0.495</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

In contrast to the high correlations between the LDL and diary, the agreement between the LDL and the questionnaire was weaker but statistically significant for being indoors on the weekend (ICC 0.262, P=0.004). Agreement for the other three periods (indoor weekday, outdoor weekday and outdoor weekend day), was not statistically significant. Agreement between the two written measures (questionnaire and diary) was similar to the strength of agreement between the LDL and questionnaire, but still significant in all conditions except indoors on weekdays.

Comparison of the total time spent indoors and outdoors showed that the average times recorded indoors and outdoors with the questionnaire were not the same as those recorded by
either the LDL or diary. Using the questionnaire, overestimation of time spent was obvious for time spent outdoors on both weekday and weekend days, as it was for an indoor time during a weekday. Conversely, there was an underestimation of time spent indoors on a weekend day when using the questionnaire compared to the LDL and the diary (Table 13).

Questionnaire responses differed significantly from the measures obtained with the other two instruments. Specifically, participants overestimated their recorded questionnaire weekend outdoors time by an average of more than two hours on a daily basis compared to the LDL and diary. The diary and LDL were relatively similar on both week and weekend days (Table 13)

On the other hand, there was a significant difference in the diary between females and males in time spent indoors in the typical weekday (P=0.003). The same thing happened in the questionnaire in time spent indoors in the typical weekend (P=0.01). In the time spent outdoors during the typical weekday, there was a significant difference between males and females in the diary (P=0.006). Also, there was a significant difference between both genders in the questionnaire in time spent outdoors in a typical weekend (P=0.02) (Table 13)
Table 13 Mean hours per day spent indoors and outdoors during weekdays and weekend days measured by questionnaire, light data logger (LDL) and diary by genders among university students in Australia

<table>
<thead>
<tr>
<th>Gender</th>
<th>Day</th>
<th>Instrument</th>
<th>Mean (hours)</th>
<th>SD</th>
<th>95% CI</th>
<th>Mean (hours)</th>
<th>SD</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weekdays</td>
<td>indoors</td>
<td>Questionnaire</td>
<td>12.93</td>
<td>2.24</td>
<td>12.28, 13.57</td>
<td>13.06</td>
<td>2.43</td>
<td>12.36, 13.71</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LDL</td>
<td>12.17</td>
<td>2.78</td>
<td>11.36, 12.98</td>
<td>11.18</td>
<td>2.73</td>
<td>10.43, 11.94</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Diary</td>
<td>12.29</td>
<td>2.66</td>
<td>11.51, 13.06</td>
<td>10.61</td>
<td>2.87</td>
<td>9.81, 11.40</td>
</tr>
<tr>
<td></td>
<td>Weekend</td>
<td>indoors</td>
<td>Questionnaire</td>
<td>10.15</td>
<td>4.21</td>
<td>8.92, 11.37</td>
<td>8.07</td>
<td>4.09</td>
<td>6.93, 9.21</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LDL</td>
<td>12.23</td>
<td>3.08</td>
<td>11.33, 13.12</td>
<td>11.69</td>
<td>3.46</td>
<td>10.72, 12.65</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Diary</td>
<td>12.07</td>
<td>3.26</td>
<td>11.12, 13.01</td>
<td>10.80</td>
<td>3.81</td>
<td>9.74, 11.86</td>
</tr>
<tr>
<td></td>
<td>Weekdays</td>
<td>outdoors</td>
<td>Questionnaire</td>
<td>1.62</td>
<td>1.23</td>
<td>1.26, 1.97</td>
<td>1.94</td>
<td>1.97</td>
<td>1.39, 2.49</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LDL</td>
<td>0.97</td>
<td>0.94</td>
<td>0.58, 1.13</td>
<td>0.84</td>
<td>0.81</td>
<td>0.61, 1.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Diary</td>
<td>0.99</td>
<td>0.90</td>
<td>0.48, 0.99</td>
<td>1.42</td>
<td>1.42</td>
<td>1.02, 1.81</td>
</tr>
<tr>
<td></td>
<td>Weekend</td>
<td>outdoors</td>
<td>Questionnaire</td>
<td>3.10</td>
<td>1.90</td>
<td>2.52, 3.63</td>
<td>4.15</td>
<td>2.43</td>
<td>3.48, 4.83</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LDL</td>
<td>1.07</td>
<td>1.35</td>
<td>0.68, 1.47</td>
<td>0.80</td>
<td>0.98</td>
<td>0.53, 1.07</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Diary</td>
<td>1.24</td>
<td>1.50</td>
<td>0.80, 1.67</td>
<td>1.69</td>
<td>1.75</td>
<td>1.20, 2.17</td>
</tr>
</tbody>
</table>

4.3.1 Thematic analysis of focus group discussion

Theme 1: Experience of filling out the questionnaires

All the respondents shared different types of experiences regarding filling out the questionnaire. Most of the respondents faced difficulty in filling out the questionnaire and were confused at the time of completing it whether they were answering correctly or not. Also, most
of them felt annoyed while filling it out and some found the questions repetitive. Participant 1017 faced difficulty in reflecting activities as the activities are likely to change with the change in the University schedule. Indoor activities can be increased for a week with a greater number of assignments. Participant 1051 found the questionnaire repetitive. Participant 1017 found it difficult to fill out the questionnaire as it required recalling the activities of the whole past week. Participant 1028’s concerns were related to transportation and walking activities. According to Participant 1050, it would be better if the questionnaire were in electronic or memo form. On the other hand, participant 1048 said that the questionnaire was simple, but some questions reflected new concepts that were not known previously to the participant and were difficult to understand.

Respondent 1020 found the questions repetitive but took it as a positive point saying that the activities also remained the same for almost all days of the week. The respondent, however, was a little confused about recording activity as indoor or outdoor in case of sitting near the window or a brighter place. Respondent 1035 faced difficulty in remembering the exact timings of activities.

**Theme 2: Problems wearing the light meter**

Respondents were asked if they faced any difficulty in wearing light meter and the answer of most of the respondents was negative. One of the respondents, 1017, faced difficulty in wearing the light meter due to bad weather as she continually felt concerned whether the meter was dry or not. Participant 1011 found the light meter bulky and hard to wear on the upper arm and suggested wearing it on the lower arm. Also, the curved shape of the meter bothered the respondent. Another participant found it easy to attach the light meter to her bag as she always put her bag on her shoulder and the light meter would face the same light as the respondent. She attached the meter to the strap of the bag and did not put it inside the bag. Participant 1094, however, faced difficulty in wearing the light meter and found it hard. The respondent found it
difficult to wear while working in the kitchen. The respondent felt hesitant to wear the light meter while doing shopping as other people would notice it. So, at that time, the respondent attached the light meter to the strap of the handbag. The respondent, however, made sure that the light meter was facing the sunlight and was not hidden behind the bag.

**Theme 3: Remember to wear the light meter**

Most of the respondents said that they were able to remember to wear the light meter. Also, most of the respondents highlighted a similar way of remembering and that was by putting the light meter with their important things, i.e. phone, glasses, etc. In addition, the text messages from the researcher every morning also reminded them to wear the light meter.

**Theme 4: Difficulty coding the Diary**

A few respondents faced difficulty in different situations. Participants 1025 faced a little difficulty in recording transport time as he used to travel by walking. It was confusing whether walking would be considered as physical activity or travelling. In the same way, participant 1030 found it difficult to code walking on his way to university, and also participant 1034 found it difficult to code walking activities. They got confused about travelling and physical activity. The confusing point was to consider walking as physical activity or travelling because the participants were on their way to university, and the coding number was different in the diary for travelling and walking. Participant 1051 found it difficult to record every little activity. The respondent found it difficult to track routine activity, i.e. going out shopping for 5 minutes, or half an hour or even more. These small activities were difficult to record due to the requirement of exact timing for going out and coming in.
Theme 5: Feedback on the study

Generally, the respondents considered the study as a great and meaningful study. They considered the study a great effort and considered it useful for seeking the attention of the public. Also, they considered the study a unique experience.

4.4 Discussion

This study aimed to compare the current version of the WHO light exposure questionnaire against an objective measurement using the HOBO LDL, and a subjective but detailed measurement, the 4-day diary, in order to find a method of effectively measuring time spent outdoors in young adults. Ideally, this method could then be adapted as necessary for children and adolescents, considering their differences in lifestyles and general time spent outdoors. The original plan was to adapt the questionnaire to children if it proved successful with the adult sample. Agreement on time spent outdoors was less, although slightly stronger than the level of agreement established by Dharani et al.\textsuperscript{199} using a 7-day diary and LDL in young children, which reported ICCs of 0.21 during the school term and 0.28 during holiday time.

As the university students reported spending most of their time indoors, this will minimise errors in judgment of time spent indoors. If someone is indoors for 8 hours a day, and there is a 30-minute difference between the LDL and the diary entry, proportionally, that is a 6.25% error. In contrast, if someone is outside for only 2 hours a day, and there is a 30-minute difference between the LDL and the diary entry, that is a 25% error. So in the circumstances where one portion of time measured is much smaller than the other, as in this case for outdoor and indoor time, the difference between the LDL and questionnaire may be amplified for time spent outdoors, resulting in weaker ICC measures than those found for time spent indoors.

In this study, participants were fully mature, well-educated adults, well able to recall their activities easily and complete their diaries accurately, and this is reflected in the strong
correlation between measures of time using the LDL and the diary. In contrast, in the study by Dharani et al.,\textsuperscript{199} where the correlation was not as strong, parents may not have been able to complete the diaries of their children accurately, especially when children were away from their parents at the school.

The measures of indoor and outdoor time recorded using the diary versus the LDL were relatively similar, with both instruments recording close to 11 hours spent indoors and 1 hour outdoors on a weekend day and weekday. This agreement could have been because the diary was used continuously, or at least daily, and participants could easily recall what they did during the day.

In contrast, the LDL and questionnaire did not show as much agreement. This may be because the questionnaire was completed as an estimate of the average time spent on activities on a typical day. This depended on participants' recall of past events, their ability to estimate a general pattern of activity, and in part on their interpretations of the questions asked. In contrast, the diary asked them to document their activities over the same period that was assessed by the LDL. The participants were, therefore, able to more accurately record their pattern of activity.

Both the diary and LDL have the limitation that the days sampled may not reflect an average or typical pattern of behaviour. Because the participants were university students, their schedule was not constant and changed during the semester, with activities varying from week to week. In some weeks they may have spent more time indoors doing indoor work on assignments and studying, with less time outdoors than normal. In confirmation of this variability, 34 of 100 participants indicated in their diaries that their study days recorded were not typical. This was also reflected in their LDL recordings and may have also led to the weaker level of agreement with their answers to the questionnaire.
The weather may have also played a role in the low agreement. Participants filled out the questionnaires based on what they regarded as their average routine, but when the weather was rainy for example, they stayed indoors instead and spent more time outdoors if a day was sunny (sunlight intensity on extreme of thickest storm cloud very cloudy days isn $<$200 lux). This would affect records made in the diaries and LDL recordings.

Alvarez and Wildsoet\textsuperscript{286} noted the importance of weather as a factor in explaining people's behaviour when indoors and outdoors. However, in relation to myopia, the important thing is the amount of time people spend outdoors regardless of what they do in that environment, because the protective effect of time outdoors most likely operates through high-intensity sunlight according to the light-dopamine hypothesis of Rose et al.,\textsuperscript{146} or to the dioptric properties of the outdoor environment.\textsuperscript{287}

Overall, LDLs are objective tools that might enhance the validity and accuracy of measurements provided by diary data. However, the cost and issues of practicality may preclude their use in large-scale studies. This analysis shows that participants in this study commonly overestimated time spent outdoors, consistent with other reports, indicating that questionnaires are not particularly accurate in quantifying the duration of time spent outdoors. This study has provided evidence of the inaccuracy of the type of paper-and-pencil questionnaire used as a technique in measuring time spent outside for young adults.

Overall, LDLs are objective tools that might enhance the validity and accuracy of measurements provided by diary data. However, their cost and issues of practicality may preclude their use in large-scale studies. This analysis shows that participants in this study commonly overestimated time spent outdoors, consistent with other reports, indicating that questionnaires are not particularly accurate in quantifying the duration of time spent outdoors. This study succeeded in highlighting the inaccuracy of the type of questionnaire used as a
technique in measuring time spent outside for young adults. Since young adults supposedly have better recollection than both children and adolescents, it is safe to say that this type of questionnaire would prove problematic for the younger age groups. This inaccuracy of questionnaire explains why variations in time outdoors explain only a low proportion of the variance in refractive error, requiring further well-structured cohort studies with good control and follow-up of children, and better-validated questionnaires, or objective measurement of environmental exposures, to resolve this issue.

Despite this, there has been a consistent finding that when the number of hours/week spent outdoors outside of school hours exceeds approximately 10–14 hours, there is an association with the prevention of myopia. This implies that the protective effect must be robust to be consistently detected, even with an imperfect instrument. However, in order to develop a targeted health strategy, more accurate quantification of the required exposure to sunlight is needed. Therefore, the study helped to also show that a more effective questionnaire format, or another measurement method altogether, is needed in further intervention projects for children.

The study deduced that the most effective method for measuring time spent outside for young adults is a combination of the LDL and diary recording. The greater correlation between the diary and LDL data suggests an alternative questionnaire design based on a 24-hour clock, simulating a diary, might be more accurate than the current questionnaire format. In the new questionnaire, time spent on any activity would be calculated within the 24 hours of the day. In this format, hours spent sleeping would be deducted from the original 24 hours and so on as time spent on each new activity is added. Improved diary-style questionnaires may have the potential to obtain more accurate estimates of time outdoors than a traditional questionnaire. These methods can be adapted for application in projects for the other age groups as well. However, as discovered by Dharani et al, it should be noted that there are many other things to
consider when applying these measurement techniques to the younger age groups, particularly with children. A diary or even a diary-like questionnaire may not be applicable for the youngest age group since their recording skills are either non-existent or severely lacking. An issue also arises when discussing the use of the LDL for the younger age groups in future intervention projects. It should be considered that younger children may not be able to effectively use the LDL, may not remember to put it on when needed, may take it off, may misplace it or may even break it. All of these can affect the accuracy of the measurement techniques, and since children are in fact the most important target age group for these studies, it is vital that the data collected is accurate. However, since the youngest age group is also likely to be the most supervised, parents, guardians and other supervisors can be tasked with the recording of the questionnaire or diary in general, and also with ensuring the LDL is worn at appropriate times and kept safe. All things considered, if proper adaptation and mitigation measures are put in place, a more diary-like questionnaire technique may prove effective for young adults and could also be applied to the children and adolescents. Nonetheless, a diary that employed sampling on a seasonal basis might be preferable when compared to a questionnaire.

The questionnaire used in this study was a paper-and-pencil version. Accordingly, it was less convenient to use than an electronic version accessible with phones or other devices. A more accessible electronic version of the questionnaire, with the instantaneous calculation of total times, may prove more accurate. Development of such an instrument is described later in this thesis (Chapter 4).

4.5 Limitations and Recommendations

A limitation of the study is the sample taking. Only one group of 100 adult participants in the same environment was used in order to determine the effectiveness of the method, which was designed originally for children, so this small sample size limited the power of this study. However, the point of the current study was to examine the WHO questionnaire under ideal
condition rather than use it in a population less likely to be able to use it accurately. Therefore, the sample consisted of people who were the most likely to be able to use the questionnaire accurately. However, the results of this study show the questionnaire has failed under ideal conditions, thus, it is unlikely to be useful for children.

Another limitation, the study as a whole did not account for time of year when statistically analysing the sample population and differences in ethnic background because there were not enough students of East Asian background to perform comparative analysis. The power of a study is the likelihood that it will detect an effect if it exists. Not accounting for differences in the aforementioned parameters can lead to correlations that may not be accurate for specific types of people, even though the results show correlation as a whole group. However, the current study was testing whether the questionnaire was potentially usable as a population-level instrument, not for specific groups.

Therefore, it is recommended for future studies to modify the current questionnaire and diary to be more effective. Additionally, it is important to do a subgroup analysis to determine if a specific method is beneficial to different degrees in different subgroups. This can help to bring up the question of why a specific method may work over the other for different groups, help with measurement method plans and can overall, help with creating the most effective intervention projects. However, correlations subgroup analysis will be underpowered in this study since the sample population is small. Ideally, the sample size of the study should be larger so that subgroup effects can be better detected, as these may be important.

Consistent with the vital importance of factors that could improve the efficacy of outdoor interventions to preclude the onset of myopia, there is a need to look for reliable and integrated tools and methods for recording real-time activities for time spent outdoors. For instance, Actiwatch Spectrum is a wrist-borne device that has been used to measure light exposure every 30 seconds and other daily activities in recent studies. Interestingly, in July 2016,
Clouclip (Hangzhou Jingzhi Mirror Technology Co., Ltd., China) was launched as the first spectacle-mounted device with promising capabilities of quantifying light exposure as well as recording head tilts, illuminance and viewing distance. Likewise, AKESO (Eyecare Ltd., China) is another spectacle-integrated device which has been developed by Beijing Tongren Hospital. Indeed, these devices might provide adequate and comprehensive information about the potential risk factors for myopia that might be effective for all age groups and all-day times. Furthermore, the recorded data of the spectacle-integrated smart devices can be instantly uploaded to a supporting application. However, their use for constant recording might be relatively inefficient and hence, could be limited to randomized studies at the moment. More precise and reliable data regarding the recently-developed devices and the emergence of novel methods are anticipated in the next few years.
Chapter Five

As established in Chapter 4, the WHO questionnaire gives only poor agreement with data collected objectively using a data logger in a group of university students. Agreement with data collected with a diary for the same period and the objective data from a data logger was better. Since questionnaires are the easiest instruments to use, I have further developed the WHO questionnaire, by turning it into an electronic questionnaire, which constrains the responses on exposures over a 24-hour period, by providing feedback to the respondent if responses are not valid. This can be used to collect general estimates of exposures, or it can be used as a diary to collect data on a particular time, over which objective data can also be obtained.

This chapter is about the development of the electronic questionnaire and reports information on its content validity based on a review by a panel of experts. The chapter describes aspects required to measure content validity. This development has produced a version ready for field studies to establish concurrent validity using the LDL as the objective standard.

Prior to any collection of data a questionnaire should be checked for content validity. Review by the expert panel was for this purpose. Changes from the paper and pencil questionnaire were minimal because the intention was to test if the form of delivery of the questionnaire is relevant to its accuracy. Changing form of delivery AND content simultaneously would be inadvisable because the effects of either change could not be assessed.

5.1 Development of an electronic questionnaire

A new electronic questionnaire was created and managed through the REDCap website (https://redcap.sydney.edu.au/surveys/?s=ImrEJhCH5e, see appendix 9). REDCap is a secure data collection tool that was created in 2004 by Vanderbilt University in the United States, and it is free for universities and organisations. It is available to be hosted by institutions on their webserver behind a firewall. The questionnaire described here is hosted by the University of Sydney, and is supported by the Information and Communications Technology (ICT)
Department at the University of Sydney. According to university policy, all students have to use REDCap for their research and survey. Also, the data in REDCap can be exported in many forms such as Microsoft Excel sheet or SPSS for more analysis.

For this myopia questionnaire, the WHO questionnaire was used as a base, covering similar questions and presenting the questions in chronological order for the day after establishing wake and sleep time. It tracks the participant's activity for 24 hours minus the hours of sleep. The questionnaire is effectively simulating a diary, but instead of giving responses for specific days, it asks for generalised estimates. This may make it easier for participants to recall their daily activities, and to record the start and finish times of their various activities. A further feature of the questionnaire is that it electronically calculates and deducts time immediately from the 24-hour clock according to a participant's answers. The questionnaire cannot be completed and submitted if the total of hours is more or less than 24 hours for a day. For example, if someone answers that they sleep for 8 hours at night, on the screen appear 16 hours left of your day, and the number of hours continues decreasing with each answer and so on. This technique helps to increase the accuracy of the questionnaire by avoiding over or underestimation of time spent on various activities.

Moreover, there are many features and facilities in the electronic questionnaire that make it easy for researchers and participants. One of them is that the questions in the electronic version can be made more appropriate and relevant to each individual participant according to their answers on where they spend most of their time during a typical week or weekend day. This takes account of different time frames whether attending schools, universities, workplaces or staying at home. Figure 5 and figure 6 show the example of this branching. This branching keeps the questionnaire as short as possible, saving the participant's time. Additionally, it does not confuse the participants by asking them questions which earlier responses indicate are irrelevant to them. Also, when the participant answers yes on some questions, new relevant
questions will appear on the screen. However, when the participant answers no, some questions will disappear (Figures 7 and 8). Thus, there is no need to say leave a section blank and move to further question number, as it is normally done in written questionnaires.

**Figure 5:** The front page of the questionnaire before choosing where a participant is likely to spend a typical weekday.

![Figure 5: The front page of the questionnaire before choosing where a participant is likely to spend a typical weekday](https://redcap.sydney.edu.au/surveys/?s=ImrEjhCH5c)
Figure 6: The front page of the questionnaire after choosing where a participant is likely to spend a typical weekday. University is the example here with notice that there is a new list of questions about the university.

Furthermore, there is a method of creating an equation to calculate the outdoor time easily and exactly. This equation calculates outdoor time from a variety of activities including when the participant travels from one place to another by walking or using a bicycle or motorbike. Past calculations of whether travel time was indoor (train or bus) or outdoor have had poor
correlation with a light data logger and had to be excluded in some of our pilot studies. It is anticipated that the new electronic questionnaire will aid accuracy in quantifying the time spent outdoors, avoiding excessive or missing information. This remains to be tested in a sufficiently sized sample against a wearable and cost-effective light data logger. The development of cheaper light data loggers than the current expensive wrist-worn Actiwatch (Phillips, USA) is in progress.

**Figure 7**: Shows an example of branching when participant answers yes, with notice that there are more relevant questions.
**Figure 8:** Shows an example of branching when participant answers no, with notice that there are some questions disappeared.

5.2 The electronic questionnaire validation

The establishment of face validity is the first step in questionnaire validation. It examines the questions from a common-sense perspective. One of the approaches is to consult experts who know well the objectives of the study and can devote time to assessing the relevance of the questions related to the study topic. Another approach is to avail the services of a
psychometrician who is an expert in evaluating the questionnaire construct regarding leading questions, confusing questions, and double-barreled questions. The expert review also focuses on content validity. In this form of validity, the content of the questions are examined to ensure that the content measures the issues relevant to the research question of the study, and any critical point is not left out or overlooked.

The field validation cannot begin until face and content validity have been established. Hence, the information in this chapter is not only a validation study but also an essential prerequisite for later concurrent validity studies. The content and face validity of the electronic questionnaire need to be established before proceeding to further validity studies. In the new electronic questionnaire, the researcher selected the method of expert comments because the study topic is specific to a particular field of medicine. Only qualified and experienced experts can analyse the questionnaire for its relevance and highlight errors and omissions in the questionnaire design, scale, and content.

Four experts had previously been involved in developing non-electronic surveys on time usage, three of them were experienced in using such questionnaires about myopia, and one had experience in developing and using electronic questionnaires. Out of these four experts, one of them was a professor in Orthoptics, the second one was a professor in Biology, one was a senior lecturer holding PhD in Psychology, and the last one was a lecturer in Orthoptics holding PhD in Orthoptics. The below sections describe the feedback and opinions of the experts.

5.3 Amending the Questionnaire based on Expert Comments

5.3.1 Title

Experts mentioned an error in the title of the questionnaire. The title erroneously mentioned children whereas the original topic was investigating myopia among adolescents. Thus, the suggestion was to use a general title of the questionnaire to be more appropriate with all
populations. Hence, the title was changed to be: ‘Questionnaire of quantifying time spent indoors and outdoors by study participants.’

5.3.2 Consent and Participation Information Statement

The informed consent of the participants is based on five clauses. A formal informed consent form should be developed because one of the experts highlighted that this information is missing at the moment especially a participant information statement (PIS). Some portions of the informed consent are also included in a PIS. Hence, it will be a good idea to provide a PIS to the participants at the time when they are deciding whether to join the study. Once potential participants agree to participate in the study, then they will get access to the electronic questionnaire, which will start with the consent form.

5.3.3 Connection to the University of Sydney

The fifth clause of the consent mentions the connection to the University of Sydney that is not relevant. A participant may or may not have any relationship with the University of Sydney. Hence, there is no need for mentioning this relationship as one of the affecting relationships.

5.3.4 Rephrasing the Questions

Experts also suggested rephrasing different questions. Most of these suggestions are related to removing redundancy and ensuring conciseness. An example is as follows:

*Regarding spending your time after leaving university and before sunset during a typical weekday, how long time do you spend indoors?*

Expert suggestion: *After leaving university and before sunset during a typical weekday, how long do you spend indoors?*

The second one is more concise and to the point and the expert version should be adopted. Another suggestion is regarding the use of the correct form of the verb. An example is as follows:
After wake up, how long time do you spend indoors during a typical weekday before sunset?

Expert suggestion: After waking up, how long do you spend indoors during a typical weekday before sunset?

The expert version uses the present participle (waking up) instead of the first form of the verb (wake up). Also, it reduces a long time to just long. The expert version should be adopted.

The experts also emphasised using English (Australia) as the standard for the questionnaire. Hence, the entire questionnaire should be set to this language setting and examined for corrections.

5.3.5 Definition of Weekend

One of the experts showed concern over the use of the term ‘weekend’. Saturday and Sunday are usually considered as the weekend. However, in the work environment, it may not always be the case. For example, people who work in shifts may also have to work on Saturdays and Sundays. Their off days may be different from Saturday and Sunday. Hence, at the beginning of the questionnaire, point 4 should be added that should define the weekend as follows:

Weekend: Day(s) when the person is free from regular work or academic routine.

5.3.6 Time-involving Activity

One expert also highlighted that the concept of time-involving activity should be introduced in the questionnaire. The questionnaire should add a statement that the researcher is interested in the primary time-involving activity of the participant. It is because the study evaluates the development of myopia among adolescents and the participants may be students only studying, students also working, and employees doing multiple jobs. The experts otherwise agreed that the questionnaire entirely covered the content required to gather information relevant to the relationship between time usage and myopia.
5.3.7 Conclusion of the electronic questionnaire validation

The researcher took into account all expert comments, and the questionnaire has been amended accordingly. The experts who have knowledge of the relevant issues surrounding measurement of light exposure agreed that the questionnaire broadly covers the issues which are needed to make it a comprehensive measure of time outdoors, as an index of light exposure. The researcher also developed a formal informed consent and a participation information sheet. Questions were also rephrased as per the experts’ suggestions. Other changes included the definition of the weekend and the mention of time-involving activity. In conclusion, the questionnaire has both face and content validity based on the experts’ panel.

5.4 Summary of the current state

Questionnaires addressing myopia have changed over time. Evidence from the above discussion shows that the early questionnaires focused only on “near work” and “reading for pleasure” but by the early 1990s questions about time spent outdoors and in sport had started to emerge. However, the rigorous validation of these questionnaires is not complete. Preliminary data extracted from the study in chapter 4 and the unpublished study conducted at the school (chapter 2) suggests there may be an overestimation of time spent on all activities including time spent outdoors. Further development and refinement of the style and mode of deployment of questionnaires mean that they will be a useful cost-effective adjunct to measures obtained. It is, however, important to point out that a major limitation of the questionnaires will be that they are unable to quantify precisely the light intensity lux/duration patterns needed to inform science and public health approaches to the prevention of myopia. This will be the role of light data loggers.
Chapter Six

Discussion and Conclusion

6.1 Summary of Findings

It is now generally accepted that environmental factors, such as time outdoors and near work, can have a major role in determining the prevalence of myopia. This makes the accurate measurement of those factors important for future studies on the aetiology of myopia, particularly those that aim to develop preventive interventions based on increasing time outdoors. Unfortunately, almost all the research in this area has been conducted using questionnaires of various kinds. The inherent inaccuracy of the questionnaires as instruments largely due to recall bias contrasts with the extensive literature that has found an association between increased time spent outdoors, and the prevention of myopia.\textsuperscript{129,141,143,145-152} However, on the basis of “what is believed to be true” and the various findings in those research studies that point towards the time spent outdoors, this thesis cannot ignore this important environmental factor, yet it tries to quantify the occurrence and importance of “time spent outdoors” by using an advanced electronic questionnaire.

The amount of time children have to spend outdoors to be protected from myopia also shows some consistency. Jones et al.\textsuperscript{153} found that if children with both parents myopic spent 14 or more hours outdoors weekly, it significantly decreased their chance of becoming myopic. The Sydney Myopia Study (SMS) showed that even for children doing high levels of near work, approximately 19 hours per week outdoors could reduce their odds of becoming myopic to the same level as children who did low levels of near work.\textsuperscript{146} And in the comparison of the age ethnicity matched children from SMS and Singapore, children of East Asian ethnicity living in Sydney averaged nearly 14 hours per week outdoors, with a myopia rate of only 3\%, while matched children in Singapore averaged only 3 hours per week outdoors with a myopia rate of 30\%.\textsuperscript{129} The implication of these findings is that approximately 15 hours spent outdoors per
week, outside school time, could considerably reduce the risk of becoming myopic in young children, despite the number of parents they have who are myopic and the amount of near work the child does.

While this has translated into two successful intervention trials of increased time spent outdoors, the precise quantification of how much exposure to sunlight is necessary to confer the protective effect, both in duration and intensity, remains to be achieved. With differing available sunlight intensities in different locations, this may have to be explored across a range of locations. In order to address this question, objective light data loggers (LDL) in combination with more sophisticated and well-validated questionnaires (see Chapters 4 and 5) are necessary. The research presented in Chapter 4, aimed to validate the WHO RESC questionnaire and an age-appropriate diary against the HOBO LDL in a sample of university students. This age sample was chosen to remove the difficulty observed in the study by Saw et al. where the diary completed by parents about their young child’s activities proved to be inaccurate when compared to LDL measures of light intensity. The authors hypothesized that this was because the parents were not with the child for the entirety of the day.

In Chapter 3, I confirmed that increase in axial length (AL) was the major determinant of change in SER in the SMS and SAVES studies and that this was modulated by time outdoors, as well as near work and parental myopia, and was different in the two age cohorts. This understanding of the natural history of change in AL and axial length/corneal radius ratio (AL/CR) provides the opportunity to use these measures to track the development of refraction using a non-invasive technique (IOLMaster) at more frequent intervals in longitudinal studies of myopia protecting interventions. In the context of using the IOLMaster for epidemiological study sampling, the disadvantage of low portability of IOLMaster cannot be ignored. This limitation makes it hard for the IOLMaster to be conveniently used in epidemiological study sampling.
In Chapter 4, I have shown that a questionnaire developed from the WHO RESC questionnaire adapted for university students gives measurements for time outdoors which only moderately correlated with those obtained by objective measurements with a HOBO LDL. Correlations were better when results from a diary were compared to the objective measurements but were still not strong. This conclusion is generally consistent with other studies on validation of time outdoors questionnaires, which show at best moderate correlations with objective measures.\textsuperscript{199,283-285}

Further, the study noted there were significant difficulties in wearing the HOBO LDL, which is designed to be worn as a pendant. This created problems with the light sensor rotating towards the wearer or being obscured by clothing. While I developed a satisfactory solution to this issue by using an iPod pouch with a clear front designed to be worn on the upper arm, it was thought that this mode of wear would not translate to a larger study in children. Focus groups among the university students commented that members of the public obviously noticed the devices and as they also have a small flashing red light when active, this added to the students not being comfortable to wear them for long periods in public. While there is a wristwatch LDL available (Actiwatch, Phillips, USA), this is too expensive to be used in large intervention trials. We await the ongoing development of two new less expensive devices Clouclip (China) and FITwatch (Singapore) which may provide more feasible LDLs. However, it is likely that LDLs will have to be used in combination with diaries in addition to the questionnaires in order to develop a more complete picture of lifestyle behaviours and time spent outdoors across the year. Most LDLs have a limited battery life (so far maximum of one week) so in order to download the individual data, these currently need to be collected by the researcher at the end of a relatively short period of time. The same is the deduction of chapter-4 which emphasises that to measure the time spent outside for young adults, the most effective method is no other than the combination of the LDL and diary recording based on a 24-hour
clock which would provide more accurate results to obtain more accurate estimates of time outdoors than a traditional questionnaire. Further, there may be some concern that if left with the child for too long and the device malfunctions, considerable data may be lost. This means continuous wearing of LDLs across a long period of time is still not feasible, although again new devices in development may address some of these limitations.

As discussed in chapter 5, questionnaires that have been used previously to estimate both times outdoors and near work have all shown limitations. While the Sydney Myopia Study questionnaire made a significant breakthrough by expanding what was usually one question on time outdoors and sport, into a series of questions which enabled it to be established that the important factor for was the total time outdoors, rather than sport, this questionnaire was too long and detailed for future use. This led to the collaborative development of the WHO RESC questionnaire, which adopted a diary-style of the chronological ordering of a more limited set of questions. In order to address common over-estimation of time on activities, I have developed an electronic questionnaire with built-in feedback on estimations of time spent that will hopefully limit this factor. It should be noted that our questionnaire has only been tested on university students since they were the “best-case scenario” and if they could not use it reliably, then there is no real prospect that children could.

Further to the development of appropriate questionnaires for longitudinal intervention studies, baseline and outcome measures have to be obtained, as well as interim measures to observe seasonal effects in the progressive development of refractive errors in children.\textsuperscript{294} Use of cycloplegic auto-refraction to obtain spherical equivalent refraction is the gold standard measure for population studies of refractive error, particularly in children. However, as this is a relatively invasive procedure, it is important to limit its use to baseline and final follow-up of a study of possibly two years duration. Longer studies may need annual measures. However, repeated use of cycloplegic refraction over a period of approximately 6 months to capture
seasonal differences in progression of refraction would likely decrease participation rates to a significant extent. To this end, other less invasive measures need to be used. In this regard, studies have pointed out various non-cycloplegic methods that are helpful in the categorization of refractive errors, particularly in children. For example, Sankaridurg et al. provide a comprehensive comparison of the less invasive methods in this regard. The researchers used raw data based on non-cycloplegic methods and around 61% of the eyes were classified as myopic, hyperopic, and emmetropic. When the researchers used visual acuity (VA) and age in the model, the percentage of correctly classified eyes reached 77%. The results indicate that there is a need to explore non-invasive methods further so that the overestimation and the error ratios could be reduced, and these methods could be incorporated in epidemiological studies on a large scale, especially where the participants discourage invasive methods or invasive methods are not available or recommended.

An important issue is that there will be certain activities of the participants that would be performed either indoors or outdoors such as mobile phone usage, or watching videos. They may be performed outside but they would also be classified as near-work. For example, if a participant watches a 2 hours movie on their mobile phone while sitting outside or surfs the internet outside through their mobile phone for 3 hours then that activity might fall in the category of time spent outdoors due to performing the activity outside in open air, yet the activity itself is related to the near-work situation due to the usage of mobile phone. The question then arises as to how this multifaceted activity would be recorded in the questionnaire (as shown in appendix 7) so that it reflects both the indoor and outdoor activities. In this situation, the participant needs to fill the code of activity in the “Name and code of the activity” column as shown in appendix-7, and write the code of activity such as 5 that represents the passive activity. After that, the participant can select both “indoor” and “outdoor” checkboxes. This would signify that despite it being an outdoor activity, still, it happened to be a near-
sighted activity normally performed indoors. When the researcher would perform the data
analysis, such a scenario would be quantified both as indoor and outdoor.

6.2 Directions for Future Research

Further work in this area requires reliable instruments that are more appropriate for use in large-
scale studies of the development of myopia and intervention trials that might be used to prevent
its onset. Importantly, with feasible cost-effective LDLs, such intervention studies may be able
to answer the crucial question of whether changes in lifestyle such as increased time outdoors
might slow the progression of myopia in children already myopic. To pursue this research
without well designed and validated instruments will not increase our understanding of the
development and progression of myopia from its current state of knowledge. Further validation
of the REDcap electronic questionnaire may show that the up-graded questionnaire is sufficient
in its own right, or as an adjunct to the use of appropriate LDLs. Such questionnaires will give
the researcher a greater understanding of how opportunities to spend more time outdoors could
be integrated into a child’s day. Nevertheless, even an accurate questionnaire has limitations.
We will still need information on the light intensity, and temporal pattern of exposure to light,
which questionnaires will never be able to provide.

The recent development of the Clouclip, which gives objective measures of light intensity
exposures, in addition to objective measures of time spent close to an object such as a book or
a screen, may also provide an objective measure of near work. The FITwatch, which is a light
data logger alone, may prove to be very acceptable for young children to wear. But again,
though promising, these LDLs need to be validated as reliable instruments and calibrated
against current LDLs such as the HOBO LD and Actiwatch so that the research already
conducted can be integrated with new studies in this area.
6.3 Conclusion
All this has to be placed in the context of myopia prevention. Time outdoors has emerged as potentially the only easily-modified lifestyle intervention which can have a large impact in preventing or reducing myopia. Further studies need to be undertaken to find out which form of information collection (questionnaire, diary and LDL) best quantifies time spent outdoors, because the information provided by focus groups raises issues which need to be addressed. The beneficial effects of increasing time outdoors in preventing myopia have been demonstrated in two clinical trials, and in nation-wide implementation in Taiwan. There is clearly a tension between education and myopia prevention, and further studies in this area may help to refine current protocols for public health interventions by more accurately establishing minimal parameters required to obtain the effect and that do not conflict in a major way with the requirements of schooling.
References


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Appendices

Appendix 1: The SMS Questionnaire 197,296
Common questions and answers

What is myopia?
People with myopia, or short-sightedness, are usually not able to see objects in the distance clearly, so that they may find it hard to read signs, play ball games or to read off the classroom board.

What occurs in the eye?
The eye normally focuses light on the back of the eye (retina) so that you can see objects clearly. However, in a myopic eye, which is too long, the light is focused in front of the retina, so that objects are blurred.

When and why myopia occurs?
Myopia usually develops during a child’s school years. The exact cause is not known. However, it can occur in some families (genetic) or in association with some diseases. Recent evidence also suggests that some environmental factors may play a part.

Why myopia is a problem?
While vision problems can usually be corrected with glasses, myopia can cause other eye diseases as a person gets older. In addition, there is evidence that the number of people with myopia is increasing worldwide.

The purpose of this study
The National Health and Medical Research Council has funded the Sydney Myopia Study to look at factors contributing to the development of myopia. You and your child are invited to participate in this large study that will involve children from all over Sydney.

This questionnaire will give us important information relating to you, your child and your family. Please take as much time as necessary to complete it. All of the answers you provide will be regarded as strictly confidential.

In a few weeks we will provide your child with a complete eye test, and a report will be sent to you. We recently tested children at a school in Sydney and found they really enjoyed the experience.
Guidelines

- Where possible we would like one parent or chief child carer to take responsibility for completing the questionnaire in consultation with other family members/caregivers.

- We use the word "parent" or "chief child carer" to cover those the child lives with, who are primarily responsible for the care of the child on a day to day basis. Some children will not be living with both, or even one of their biological parents. In relation to pregnancy and parental health, we require information about the biological parents. We recognise that this will be difficult to provide in some situations, and we ask you to note if this is a problem in completing parts of the questionnaire.

- Please attempt to answer every question. In some circumstances you will be directed to skip questions because they don’t apply to you.

- If you have difficulty with a question, please give the best response you can and make a comment in the margin.

- Please feel free to ask our staff for assistance. They can be contacted on the telephone numbers below.

Please note: While it would greatly assist the examiners if the questionnaire was completed prior to your child’s examination, it will be possible to collect it from you later.

Statement of confidentiality

Information that would permit the identification of any person completing this questionnaire will be regarded as strictly confidential. All information provided will be used only for the Sydney Myopia Study and will not be disclosed or released for any other purpose without your consent.

You may correct any personal information provided at any time by contacting:

Administration
Centre for Vision Research
Westmead Hospital
Telephone: 9845 9077
Fax: 9845 8345

Dr Kathryn Rose
Project coordinator,
School of Applied Vision Sciences,
Faculty of Health Sciences,
University of Sydney.
Telephone: 9351 9464
Fax: 9351 9359
Email: k.rose@fhs.usyd.edu.au

Professor Paul Mitchell
Project principal investigator,
Department of Ophthalmology,
Centre for Vision Research,
University of Sydney,
Westmead Hospital.
Telephone: 9845 7960
Fax: 9845 8345
Email: paul_mitchell@wmi.usyd.edu.au
ABOUT YOUR CHILD

Personal information

1. Your child’s name: ____________________________ ____________________________
   (First name) (Family name)

2. Your child’s address: ________________________________

3. Suburb __________________________
   Postcode __________

4. How long has your child lived in the above suburb?
   __________ / __________
   (years) (months)

5. Since your child was born, where else has he/she lived?

<table>
<thead>
<tr>
<th>Location</th>
<th>Length of time at location</th>
<th>Age of child</th>
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6. Gender (please tick):
   □ Female    □ Male

7. Date of birth: ____________________________
   (day) (month) (year)

8. In which country was your child born:
   ________________________________

9. Your child’s school is:
   ________________________________

10. Your child’s grade is: __________

Parental contact: ______________________

Telephone day: ______________________

Telephone night: ____________________

Mobile: ____________________________

Email: ____________________________
Could you please provide us with the name and address of three people we could contact to obtain a forwarding address for you if you were to move?

☐ No (go to question 15)
☐ Yes (please fill in details below)

11. Contact 1

Name ____________________________ Telephone _____________________
Address ____________________________
Relationship ________________________

12. Contact 2

Name ____________________________ Telephone _____________________
Address ____________________________
Relationship ________________________

13. Contact 3

Name ____________________________ Telephone _____________________
Address ____________________________
Relationship ________________________

General Practitioner (GP)

Please state the details of your child’s usual G.P.

14. Who is your child’s GP? ________________________________

15. What is the address of his/her surgery? ________________________________

__________________________________________________________

When did your child last visit his/her GP? _________ weeks/months ago (please circle)

16. On average, how many times per year does your child visit the GP? ________ per year

17. Please tick the box if you do not want a report outlining the results of the examination to also be sent to your nominated GP.

☐ I don’t want a report to be sent to my child’s GP.
This section has questions relating to your child’s hearing and vision. The questions are important because certain hearing and eye conditions can affect your child’s schooling. Basic hearing tests can be performed by a doctor or nurse. A detailed hearing test is performed by an audiologist (hearing practitioner) and a report is given to you.

18. Has your child ever had his/her hearing tested?
   - No (go to question 27)
   - Yes
   - Unsure (go to question 27)

19. If yes, what age? _______ Who performed the test? ____________________________

21. Did you receive a report?
   - No
   - Yes
   - Unsure

22. Were there any abnormalities found with your child’s hearing?
   - No
   - Yes
   - Unsure

23. Did your child visit a local doctor or a hearing specialist for further testing?
   - No
   - Yes
   - Unsure

24. Were you told what was wrong with your child’s hearing?
   - No (go to question 27)
   - Yes
   - Unsure (go to question 27)
   - If yes, the problem was? ____________________________

25. How many months/years ago was the problem reported? _____ / _____
   - (years)
   - (months)

26. Which ear was involved?
   - Right ear
   - Left ear
   - Both ears
   - Unsure

In the past, your child may have had an eye test. This could have been part of a screening program at school, performed by a nurse or orthoptist, or a detailed eye examination by a medical eye specialist (ophthalmologist) or optometrist.

27. Has your child ever had his/her vision tested?
   - No (go to question 37)
   - Yes
   - Unsure (go to question 37)

28. If yes, what age? ______________ Who performed the test? ______________________
29. Did you receive a report?
   □ No □ Unsure □ Yes

30. Were there any reported abnormalities with your child’s eyes?
   □ No □ Unsure □ Yes

31. Did your child visit a local doctor or eye practitioner for further testing of the problem?
   □ No □ Unsure □ Yes

32. Were you told what was wrong with your child’s eyes?
   □ No (go to question 35) □ Unsure (go to question 35) □ Yes
   If yes, the problem was? ________________________________

33. How many months/years ago was the problem reported? □ □ / □ □
   (years) (months)

34. Which eye was involved?
   □ Right eye □ Left eye
   □ Both eyes □ Unsure

35. Does your child have any other sight problems?
   □ No (go to question 37) □ Unsure (go to question 37) □ Yes

36. What other sight problems does your child have?
   □ Totally blind in both eyes □ Partially blind in both eyes
   □ Totally blind in 1 eye only □ Partially blind in 1 eye only
   □ Glaucoma □ Trachoma
   □ Cataract □ Don’t know
   □ Other (please describe) ________________________________

37. Is your child colour blind?
   □ No □ Unsure □ Yes
The following section asks you about any visits your child may have had to an eye practitioner. An eye practitioner includes:

- Ophthalmologist (eye specialist)
- Optometrist
- Orthoptist (eye therapist)

38. How long has it been since your child last consulted an eye specialist or optometrist?
   - □ Never (go to question 42)
   - □ 2 to less than 5 years
   - □ Less than 1 year
   - □ 5 years or more
   - □ 1 to less than 2 years
   - □ Don’t Know (go to question 42)

39. Does your child attend regular eye examinations?
   - □ No
   - □ Unsure
   - □ Yes

40. If yes, please fill in the details of the eye practitioner below. If you are unsure about the type of practitioner he/she is, tick the box marked “other” and state the name and suburb.

   □ Ophthalmologist (Medical Eye Specialist) __/__/____ (date last seen)
   Name: ____________________________________ Suburb: ___________________

   □ Optometrist __/__/____ (date last seen)
   Name: ____________________________________ Suburb: ___________________

   □ Orthoptist __/__/____ (date last seen)
   Name: ____________________________________ Suburb: ___________________

   □ Other __/__/____ (date last seen)
   Name: ____________________________________ Suburb: ___________________

41. Please tick how often the eye practitioner is seen (refer to the eye practitioner that the child sees most often)
   - □ More than once in 6 months
   - □ Once a year
   - □ Every 6 months
   - □ Less frequently than once a year

42. Does your child currently wear glasses or contact lenses to correct, or partially correct, his/her eyesight?
   - □ No (go to question 45)
   - □ Glasses
   - □ Contact lenses
43. How often are the glasses or contact lenses used?
   - All the time
   - Only when eyes feel tired
   - Sometimes
   - Hardly ever

44. What sight problems do your child’s glasses or contact lenses correct or partially correct? (You may tick more than one box)
   - Astigmatism
   - Short-sightedness / Myopia
   - Long-sightedness / Hyperopia
   - Don’t know
   - Other (please describe) ____________________________

45. Has your child worn glasses or other optical correction such as contact lenses in the past?
   - No (go to question 49)
   - Unsure (go to question 49)
   - Yes
     If yes, please state the date and age when prescribed ____________________

     Date stopped: _________ / ________
     (month) (year)

     Reason stopped ____________________________

46. How often did your child use their glasses / contact lenses?
   - Most of the time
   - Sometimes
   - Only when eyes felt tired
   - Hardly ever
We would like to know what glasses were previously prescribed. There are two ways we can find out this information. Firstly, by looking at your child’s old glasses during his/her examination at school, OR, by viewing the prescription that the eye specialist / optometrist wrote out.

47. Do you have your child’s old glasses?
   - [ ] No (go to question 48)
   - [ ] Unsure (go to question 48)
   - [ ] Yes (could the child please bring the glasses with them to the examination)

48. Do you have a copy of your child’s last prescription?
   - [ ] No
   - [ ] Unsure
   - [ ] Yes

If yes, please attach the prescription or a copy of it to this page in the space provided below. Alternatively, you may write it down with the date it was prescribed:

__________________________________________________________

__________________________________________________________

[ ] Please tick if you want the original prescription to be returned to you

(Attach prescription here)
49. Has your child ever had any one or more of the following treatments for myopia (short-sightedness)?
   - [ ] Bifocals
   - [ ] Progressive lenses
   - [ ] Atropine eye drops
   - [ ] None of the above
   - [ ] Don’t know

50. Has your child ever worn an eye patch?
   - [ ] No
   - [ ] Unsure
   - [ ] Yes
   - If yes, for how long? ___________

51. Have you ever been told by a doctor or optometrist that your child has a strabismus (turned or lazy eye)?
   - [ ] No (go to question 53)
   - [ ] Unsure (go to question 53)
   - [ ] Yes

52. Has your child received treatment for this condition?
   - [ ] No
   - [ ] Unsure
   - [ ] Yes (please describe) ________________________________

53. Has your child ever sustained any serious injury to the eyes or area around the eyes?
   - [ ] No (go to question 55)
   - [ ] Unsure (go to question 55)
   - [ ] Yes
   - If yes, explain the injury (please describe) ________________________________
   ________________________________

54. Do you feel your child’s vision was affected by the injury?
   - [ ] No
   - [ ] Unsure
   - [ ] Yes

55. Has your child ever had eye surgery?
   - [ ] No
   - [ ] Yes (If yes, what was it for? Please tick)
     - [ ] Strabismus (turned eye or lazy eye)
     - [ ] Other (please describe) ________________________________
56. Is your child currently using any eye drops/ointments?
   □ No  □ Unsure  □ Yes

   If yes, please write down the name of all eye drops/ointments currently used.

<table>
<thead>
<tr>
<th>Name of eye drop/ointment</th>
<th>Times per day</th>
<th>Date started (month/year)</th>
<th>Reason for using</th>
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57. Has your child ever used eye drops/ointment in the past?
   □ No  □ Unsure  □ Yes

   If yes, please write down the name of all eye drops/ointments previously used.

<table>
<thead>
<tr>
<th>Name of eye drop/ointment</th>
<th>Times per day</th>
<th>Duration of usage</th>
<th>Age at time of usage</th>
<th>Reason for taking</th>
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Your child may have never been diagnosed with an eye condition, however we would like to know about any concerns you or others might have with his/her eyes or vision.

58. Has your child ever complained of any eye or vision problems in the past?
   □ No (go to question 60)  □ Unsure (go to question 60)
   □ Yes

59. Please tick below all symptoms experienced by your child:
   □ Blurred vision when looking in the distance  □ Double vision
   □ Sore eyes (how often?) __________________________
   □ Other (please describe) ________________________

60. Does your child experience a headache when reading or doing close work?
   □ No (go to question 63)  □ Unsure (go to question 63)
   □ Yes

61. If yes, how often? _________ and at what time of the day? (e.g. 2:30 pm) __________

62. How long do the headache symptoms last? (e.g. 30 min)  [ ] / [ ]
63. Has anyone ever thought there might be a problem with your child’s eyesight?
   □ No (go to question 65)  □ Unsure (go to question 65)
   □ Yes

64. What was thought to be wrong with his/her eyes?
   □ Squint (eyes not looking in same direction)  □ Don’t know
   □ Colour blind
   □ Something else (please describe) 

65. Do you think your child might need to wear glasses?
   □ No  □ Unsure
   □ Yes  (please give the reason) 

66. Have you noticed your child to have a turned or lazy eye?
   □ No (go to question 70)  □ Unsure (go to question 70)
   □ Yes

67. What age was your child when you first noticed this?  □ □ years □ □ months

68. Which eye was affected?
   □ Right eye  □ Left eye

69. Has a doctor checked this?
   □ No
   □ Yes
   If yes, how many year(s)/month(s) were there between the first time you noticed this and the time your child was seen by the doctor? □ □ years □ □ months

**General Medical Details**

This section will ask you questions relating to your child’s general medical health. We are interested in both past and current medical conditions, and medicines that your child may have taken. A chronic illness or disability is a condition that has been detected in the past and is currently still ongoing, requiring treatment.

70. Has your child ever been diagnosed with a chronic illness or disability?
   □ No (go to question 75)  □ Unsure (go to question 75)
   □ Yes

71. What was the nature of the illness or disability? (Please name or describe) 

72. Does your child still have this condition?
   □ No  □ Unsure
   □ Yes
73. Does your child receive treatment for this condition?
   □ No (go to question 75) □ Unsure (go to question 75)
   □ Yes

74. Please tick the treatment(s) given:
   □ Medicine prescribed □ Surgery □ Given injections
   □ Physiotherapy □ Speech therapy □ Dental treatment
   □ Naturopathy □ Chiropractic treatment
   □ Homeopathic treatment □ Counselling / guidance
   □ Other (please describe)__________________________________________________

75. Has your child visited a doctor in the last 2 weeks?
   □ No (go to question 82) □ Unsure (go to question 82)
   □ Yes
   If yes, what was the reason that you took your child to the doctor? (Please describe)
   ______________________________________________________________________

76. Was any treatment given?
   □ No (go to question 82) □ Unsure (go to question 82)
   □ Yes

77. Please tick the treatment(s) given:
   □ Medicine prescribed □ Surgery performed or recommended
   □ Referred to another practitioner (specify)_______________________________
   □ Other (specify)_____________________________________________________

78. Has your child had a second reason to visit a doctor during the last 2 weeks?
   □ No (go to question 82) □ Unsure (go to question 82)
   □ Yes

79. What was the illness or injury that caused your child’s second visit to the doctor? _______
   ______________________________________________________________________

80. Was any treatment given?
   □ No (go to question 82) □ Unsure (go to question 82)
   □ Yes
81. Please tick the treatment(s) given:

☐ Medicine prescribed  ☐ Surgery performed or recommended
☐ Referral to another practitioner/doctor
☐ Other (please describe)________________________________________

Questions 82 – 89 refer to an illness that was severe enough to require your child’s admission into hospital or day surgery. For example, appendicitis.

82. Has your child had a major illness in the past that has required admission to hospital or day surgery?

☐ No (go to question 90)  ☐ Unsure (go to question 90)
☐ Yes

83. Please describe the reason for your child’s admission? ___________________________

84. At what age did this occur? _________

85. Did your child have surgery?

☐ No (go to question 87)  ☐ Unsure (go to question 87)
☐ Yes

86. Please name or describe the **surgical procedure** ___________________________

87. What was the name of the hospital and in which suburb was it located? ____________

88. Has your child had more than one admission to hospital or day surgery?

☐ No (go to question 90)  ☐ Unsure (go to question 90)
☐ Yes

89. Please list the name of the hospital, the suburb in which it was located, the reason for the admission and the date of the admission.

- Hospital: _____________________________
  Suburb: _____________________________  Date: _____ / _____ / _____ (day/month/year)
  Reason: ____________________________________________________________________

- Hospital: _____________________________
  Suburb: _____________________________  Date: _____ / _____ / _____ (day/month/year)
  Reason: ____________________________________________________________________
We wish to ask about any medications that your child is currently using, these include both prescribed and non-prescribed medications. Please note that vitamins, inhaled medicines, skin lotions, eye-drops, laxatives, homeopathic and herbal remedies should also be included.

90. Has your child taken any medication(s) in the last 2 weeks?
   - □ No (go to question 91)
   - □ Unsure (go to question 91)
   - □ Yes (If yes, please list all the medications in the table below)

<table>
<thead>
<tr>
<th>Medication name</th>
<th>Method of intake (ie. oral, injected)</th>
<th>Number of times per day</th>
<th>Date started</th>
<th>Reason for taking</th>
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91. In the past has there been any prescribed or non-prescribed medication(s) that your child has taken every day or nearly every day for a period of at least 3 months?
   - □ No (go to question 94)
   - □ Unsure (go to question 94)
   - □ Yes

   If yes please list:
   1) Prescribed medication in Table A;
   2) Non-prescribed medication in Table B.

92. TABLE A: Please list all medications which were prescribed by a local doctor.

<table>
<thead>
<tr>
<th>Medication name</th>
<th>Method of intake (ie oral, injected)</th>
<th>How many times a day</th>
<th>Duration in weeks</th>
<th>Reason for taking</th>
<th>Age at time</th>
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<td>5</td>
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</tr>
</tbody>
</table>
93. **TABLE B:** Please list all medications which were purchased over the counter (that is, a doctors prescription wasn’t needed to purchase these medications)

<table>
<thead>
<tr>
<th></th>
<th>Medication name</th>
<th>Method of intake (ie oral, injected)</th>
<th>How many times a day</th>
<th>Duration in weeks</th>
<th>Reason for taking</th>
<th>Age at time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
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</tr>
</tbody>
</table>

*We would like to ask you about common medical conditions. Certain conditions have proven to be associated with myopia.*

94. Has your child ever been told by a doctor or nurse that he/she has asthma?
   - [ ] No (go to question 96)
   - [ ] Yes
   - [ ] Unsure (go to question 96)

95. Does your child still get asthma?
   - [ ] No
   - [ ] Yes
   - [ ] Unsure

96. Do you (the mother) smoke?
   - [ ] No
   - [ ] Yes

97. Do other people living in your home smoke inside the house?
   - [ ] No
   - [ ] Yes

If you answered *Yes* to **Questions 96 or 97**, please complete the table below.

<table>
<thead>
<tr>
<th>Cigarettes/day</th>
<th>Mother</th>
<th>Father</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10/ day</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11-20/ day</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-40/day</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41+/day</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
98. Was there any delay in your child’s early development?
   □ No  □ Unsure
   □ Yes (Please tick below)

   Delayed development in:
   □ Sitting
   □ Walking
   □ Talking
   □ Other (please describe) ________________________________

99. Has your child experienced any difficulties with learning at school or pre-school?
   □ No  □ Unsure
   □ Yes  
   If yes, please describe_____________________________________

100. Have you ever been told that your child has Attention Deficit Disorder (ADD) or Attention Deficit Hyperactivity Disorder (ADHD)?
   □ No (go to question 103)  □ Unsure (go to question 103)
   □ Yes

101. What age was your child when you were first told that he/she had Attention Deficit Disorder (ADD) or Attention Deficit Hyperactivity Disorder (ADHD)
   □ □ Years  □ □ Months  □ Don’t Know

102. Is your child receiving treatment for this disorder?
   □ No  □ Unsure
   □ Yes

103. Has your child ever been diagnosed with any of the following? (Please tick)
   □ Epilepsy  □ Meningitis
   □ Marfan Syndrome  □ Down Syndrome
   □ Stickler Syndrome  □ Diabetes
   □ Toxoplasmosis
   □ Other (please describe) ________________________________
Birth History

Gestation and neo-natal.
The following questions are about your child’s birth and early years.
If you still have your health record book (the blue/yellow book) it may help to look at it. These books record birth details.

Birth Details: Extract from Personal Child Health Record- TRANSCRIBE FROM:

NSW  Blue Book  Page 39
WA  Yellow Book  Page 45
SA  Blue Book  Page 38
Tas  Blue Book  Page 57
Qld  Blue Book  Page 20
Vic  Yellow Book  “Birth, Vit K, Hep B, Newborn Examination” section

104. Do you have your child’s State Child Health Record (the blue/yellow book) available?
   ☐ No
   ☐ Yes

105. Delivery Type
   ☐ Normal
   ☐ Breech
   ☐ Caesarean
   ☐ Vacuum extraction
   ☐ Forceps
   ☐ Other
   ☐ Don’t know

106. What was your child’s birth weight? _______ Grams or _______ Pounds _______ Ounces

107. Birth length _______ cms

108. Birth head circumference _______ cms

109. What was your child’s gestation period? ☐ ☐ weeks (go to question 111)
   ☐ Unsure (go to question 110)

If your child’s gestation period in weeks is unknown, please try to answer the following question.

110. Was your child born
   ☐ Late (42 weeks or more)
   ☐ On time (37-41 weeks gestation)
   ☐ Early (33-36 weeks gestation)
   ☐ Very early (32 weeks or less)
111. Was your child admitted to a Neonatal Intensive Care Unit (NICU) after birth?
   □ No  □ Don’t know
   □ Yes

112. Was your child admitted to a Special Care Nursery (SCN) after birth?
   □ No (go to question 114)  □ Don’t know (go to question 114)
   □ Yes

(If your child was admitted to a NICU or SCN please answer the following question)

113. If known, please write down date of discharge. ❌/❌/❌

114. Was this a multiple pregnancy? (eg. twins or triplets)
   □ No, single birth  □ Don’t know
   □ Yes, twins
   □ Yes, triplets
   □ Yes, more than triplets

115. Was your child born:
   □ In a hospital or birthing centre? (Please name the hospital or birthing centre he/she was born in and the suburb)
     Name of hospital ____________________________________________________
     Suburb ________________________________ State ____________
   □ At home
   □ Other (please describe) ____________________________________________

116. Did you use your child’s health record book to answer the above questions?
   □ No  □ Yes

117. Has your child ever been breastfed?
   □ No (go to question 119)  □ Don’t know (go to question 119)
   □ Yes

118. What is the total time your child was breastfed?
   □ Longer than 3 months
   □ Longer than 1 week but less than 3 months
   □ Less than one week
   □ Unsure
The mother’s health during pregnancy can influence her child’s development. We would like to know about specific conditions the mother may have experienced during the pregnancy.

119. Were there any problems with the pregnancy?  
☐ No   ☐ Unsure   ☐ Yes   (If yes, please describe) ____________________________

120. During the pregnancy, did the mother:
- Have high blood pressure needing treatment? (admission to hospital or medication)  
  ☐ Yes   ☐ No   ☐ Don’t know
- Have diabetes needing insulin injections?  
  ☐ Yes   ☐ No   ☐ Don’t know
- Have diabetes but didn’t have insulin injections?  
  ☐ Yes   ☐ No   ☐ Don’t know
- Have a high fever anytime during the pregnancy?  
  ☐ Yes   ☐ No   ☐ Don’t know
- Have Rubella (German measles)?  
  ☐ Yes   ☐ No   ☐ Don’t know
- Have Mumps?  
  ☐ Yes   ☐ No   ☐ Don’t know
- Have other health problems? (Please describe) ____________________________

121. During the pregnancy, did the mother ever smoke cigarettes, cigars, pipes or other tobacco products?  
☐ No (go to question 124)   ☐ Don’t Know (go to question 124)   ☐ Yes

122. How often did the mother smoke cigarettes, cigars, pipes or other tobacco products, while she was pregnant with the child?  
☐ Daily   ☐ Not at all
☐ At least weekly, not daily   ☐ Don’t know
☐ Less often than weekly

123. During the pregnancy, did the mother:  
☐ Reduce the amount of tobacco she smoked
☐ Try and give up smoking but were unsuccessful
☐ Successfully give up smoking
☐ None of the above
☐ Don’t know
124. During the pregnancy, did the mother share a home with people who smoked indoors?

☐ No  ☐ Unsure  ☐ Yes

If yes please specify approximately how many cigarettes were smoked indoors in a day during the pregnancy________

125. During the pregnancy, did the mother take any prescribed medications?

☐ No  ☐ Unsure  ☐ Yes (please write down the names of the medications and for how long they were taken in the table below)

Please list all medications which were prescribed by a local doctor

<table>
<thead>
<tr>
<th>No.</th>
<th>Medication name</th>
<th>Method of intake (ie oral, injected)</th>
<th>How many times a day</th>
<th>Duration in weeks</th>
<th>Reason for taking</th>
</tr>
</thead>
<tbody>
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<td>12</td>
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</tbody>
</table>
126. During the pregnancy, did the mother take any over-the-counter medications?

- [ ] No
- [ ] Unsure
- [ ] Yes (please write down the names of the medications and for how long they were taken in the table below)

**Please list all medications which were purchased over the counter (ie a doctors prescription wasn’t needed to purchase these medications)**

<table>
<thead>
<tr>
<th>Medication name</th>
<th>Method of intake (ie oral, injected)</th>
<th>How many times a day</th>
<th>Duration in weeks</th>
<th>Reason for taking</th>
</tr>
</thead>
<tbody>
<tr>
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<td>15</td>
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</tbody>
</table>
In recent years, researchers have studied the impact a child’s environment may have on vision. We are interested in all the activities your child engages in on a regular basis.

127. Please tick the average number of **hours per day** that your child spends doing the following activities.

<table>
<thead>
<tr>
<th>Activity</th>
<th>ON A SCHOOL WEEKDAY</th>
<th>ON A SCHOOL WEEKEND</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not at all</td>
<td>Less than 1 hour</td>
</tr>
<tr>
<td>a) Playing out of doors (in a backyard, at the park, riding a bike)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>b) Outdoor leisure activities (BBQs, picnic, beach, walk)</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>c) Watching T.V/ videos / DVDs</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>d) Playing video games eg. Playstation</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>e) Drawing or writing</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>f) Playing with toys, hobby or craft</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>g) Cooking, making or constructing things</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>h) School homework</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>i) Reading books for pleasure</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>j) Playing musical instruments</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>k) Using a computer or playing computer games</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>l) Playing <strong>hand-held</strong> computer games</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>m) Playing with and caring for pets</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>n) Going shopping</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
128. Please tick the activities your child does and the number of *hours per week during the school term* that he/she spends doing the activity. Please also indicate whether this activity is usually done outdoors, in a hall or gym sized room, or in a classroom sized room or smaller.

**DURING THE 7 DAYS OF THE WEEK**

<table>
<thead>
<tr>
<th>YES</th>
<th>Number of hours per week spent in this activity</th>
<th>Outdoors</th>
<th>In a hall or gym</th>
<th>In a classroom or smaller</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>Dancing, gymnastics or callisthenics</td>
<td>☐</td>
<td>_____ hrs per week</td>
<td>☐</td>
</tr>
<tr>
<td>b)</td>
<td>Little athletics</td>
<td>☐</td>
<td>_____ hrs per week</td>
<td>☐</td>
</tr>
<tr>
<td>c)</td>
<td>Swimming</td>
<td>☐</td>
<td>_____ hrs per week</td>
<td>☐</td>
</tr>
<tr>
<td>d)</td>
<td>Football, soccer, rugby, league, AFL</td>
<td>☐</td>
<td>_____ hrs per week</td>
<td>☐</td>
</tr>
<tr>
<td>e)</td>
<td>Netball, basketball</td>
<td>☐</td>
<td>_____ hrs per week</td>
<td>☐</td>
</tr>
<tr>
<td>f)</td>
<td>Tennis</td>
<td>☐</td>
<td>_____ hrs per week</td>
<td>☐</td>
</tr>
<tr>
<td>g)</td>
<td>Kanga cricket</td>
<td>☐</td>
<td>_____ hrs per week</td>
<td>☐</td>
</tr>
<tr>
<td>h)</td>
<td>Skating, riding a scooter, rollerblading</td>
<td>☐</td>
<td>_____ hrs per week</td>
<td>☐</td>
</tr>
<tr>
<td>i)</td>
<td>Baseball/ softball</td>
<td>☐</td>
<td>_____ hrs per week</td>
<td>☐</td>
</tr>
<tr>
<td>j)</td>
<td>Attending a youth group/club e.g. cubs, brownies etc</td>
<td>☐</td>
<td>_____ hrs per week</td>
<td>☐</td>
</tr>
<tr>
<td>k)</td>
<td>Attending a religious centre</td>
<td>☐</td>
<td>_____ hrs per week</td>
<td>☐</td>
</tr>
<tr>
<td>l)</td>
<td>Other, please describe below</td>
<td>☐</td>
<td>_____ hrs per week</td>
<td>☐</td>
</tr>
</tbody>
</table>

129. Please list other activities: _____________________________________________

________________________________________

________________________________________

________________________________________

24
Questions about Holidays

In the last year your child would have had on average about 12 weeks of school holidays. During those weeks, he/she may have spent some considerable time doing different activities at home or in a different location. Please indicate below where and for how long your child spent his/her holidays. More than one box may be ticked.

130. For the 6 weeks of summer, Christmas holidays

☐ At home, or at a relative’s or friend’s home for the day
☐ In vacation care or at a camp
☐ Away from home, travelling or in one location
☐ Other (please describe) ____________________________

Duration (if greater than 2 days) ______________________

131. During these holidays, please estimate the amount of time that your child spent indoors and outdoors during the day.

☐ Most of the time indoors
☐ Mainly indoors and occasionally going outdoors for a day, or up to 2 hours outdoors per day
☐ About equal amounts of time indoors and outdoors
☐ Mostly outdoors and occasionally spending a day indoors, or up to 2 hours indoors per day
☐ Most of the time outdoors

132. Describe the activities that your child liked to do most often during these holidays.

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

133. The 2 weeks of holidays at the end of term one, the Easter break

☐ At home, or at a relative’s or friend’s home for the day
☐ In vacation care or at a camp
☐ Away from home, travelling or to stay in one location
☐ Other (please describe) ____________________________

Duration (if greater than 2 days) ______________________

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
134. During these holidays, please estimate the amount of time that your child spent indoors and outdoors during the day.

☐ Most of the time indoors
☐ Mainly indoors and occasionally going outdoors for a day, or up to 2 hours outdoors per day
☐ About equal amounts of time indoors and outdoors
☐ Mostly outdoors and occasionally spending a day indoors, or up to 2 hours indoors per day
☐ Most of the time outdoors

135. Describe the activities that your child liked to do most often during these holidays.

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

136. The 2 weeks of holidays at the end of term two, the winter holidays

☐ At home, or at a relative’s or friend’s home for the day
☐ In vacation care or at a camp
☐ Away from home, travelling or to stay in one location
☐ Other (please specify)

Duration (if greater than 2 days)

_________________________________________________________________

137. During these holidays, please estimate the amount of time that your child spent indoors and outdoors during the day.

☐ Most of the time indoors
☐ Mainly indoors and occasionally going outdoors for a day, or up to 2 hours outdoors per day
☐ About equal amounts of time indoors and outdoors
☐ Mostly outdoors and occasionally spending a day indoors, or up to 2 hours indoors per day
☐ Most of the time outdoors

138. Describe the activities that your child liked to do most often during these holidays.

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
139. The 2 weeks of holidays at the end of term three, these include the October long weekend.

☐ At home, or at a relative’s or friend’s home for the day __________________________
☐ In vacation care or at a camp __________________________
☐ Away from home, travelling or to stay in one location __________________________
☐ Other, please specify __________________________

Duration (if greater than 2 days)

140. During these holidays, please estimate the amount of time that your child spent indoors and outdoors during the day.

☐ Most of the time indoors
☐ Mainly indoors and occasionally going outdoors for a day, or up to 2 hours outdoors per day
☐ About equal amounts of time indoors and outdoors
☐ Mostly outdoors and occasionally spending a day indoors, or up to 2 hours indoors per day
☐ Most of the time outdoors

141. Describe the activities that your child liked to do most often during these holidays.

_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________
_____________________________________________________________________________

Near/distance work questions.

142. Can your child read independently?

☐ No ☐ Unsure ☐ Yes

143. Please tick one of the following

☐ Someone reads to my child on a regular basis (almost every night)
☐ Someone reads to my child often
☐ Someone reads to my child occasionally
☐ Someone reads to my child infrequently

144. How many books or magazines does your child finish reading in a week?

☐ books or magazines per week
145. How often does he/she borrow books from a library?
   □ Never
   □ Less than once a week
   □ Around once a week
   □ More than once a week

146. Does your child place his/her face abnormally close to the book while reading/writing?
   □ No (go to question 148)  □ Unsure (go to question 148)
   □ Yes

147. If your child’s reading/writing distance is abnormally close, please estimate how close by ticking one box.
   □ 0 – less than 10 centimetres (0 – less than 4 inches)
   □ 10 – less than 20 centimetres (4 – less than 8 inches)
   □ 20 – less than 30 centimetres (8 – less than 12 inches)
   □ Unsure

148. Does your child use a mobile phone either to make calls or play games on?
   □ No  □ Unsure
   □ Yes

149. When your child is watching TV, how close to the T.V does your child sit?
   □ Less than one metre (less than 3 feet)
   □ 1 – 2 metres (3 – 6 feet)
   □ 2 – 3 metres (6 – 9 feet)
   □ Greater than 3 metres (greater than 9 feet)

150. When your child plays video games, like Playstation, how close to the screen does he/she sit?
   □ Less than one metre (less than 3 feet)
   □ 1 – 2 metres (3 – 6 feet)
   □ 2 – 3 metres (6 – 9 feet)
   □ Greater than 3 metres (greater than 9 feet)

151. What is your child’s main method of transport to school?
   □ Car
   □ Train/bus
   □ Walking
   □ Other (please describe) ________________________________
152. How many minutes does it take one way for your child to get to school? 

minutes

153. If your child is driven to and from school, what activity is he/she most likely to do during the journey?  

☐ Read a book  ☐ Talk to other people in the vehicle  

☐ Play hand held games  ☐ Sleep  

☐ Look outside the window  

☐ Other (please describe) ________________________________

154. Did your child attend preschool?  

☐ No (go to question 156)  ☐ Unsure (go to question 156)  

☐ Yes

At what age did your child first attend preschool?  

☐ ☐ /  ☐ ☐  (years) (months)

155. How many days per week did your child attend preschool?  

☐ ☐  (days)

156. Has your child had any periods of prolonged absence from school due to illness, travel or any other reason?  

☐ No (go to question 159)  ☐ Unsure (go to question 159)  

☐ Yes (please give details below)

157. If yes, how many days or weeks? ________  Reason for absence: _________________________

158. Please tick when the absence occurred:  

☐ Preschool  

☐ Kindergarten  

☐ Grade 1

159. How many days was your child absent from school in the last year?  

☐ Up to 5 days  

☐ 6 – 20 days  

☐ More than 20 days

160. Does your child receive any tutorials, coaching or community classes outside school hours?  

☐ No  ☐ Unsure  

☐ Yes

If yes, please state how many hours per week.  

☐ ☐  (hours)
This section will ask about your child’s biological (natural) parents and family members to identify genetic associations. Children with parents who are myopic are more likely to develop myopia. In addition, people with particular ethnic backgrounds seem to develop myopia more than others. We realise that some parent(s) may not be the biological parent(s) and in some cases not have the knowledge to complete some sections. If this is the case, please tick unsure. Where possible it is preferable that the biological parent completes this section.

Biological Parents

161. Please tick the box that applies to your child:
- Both parents are the biological parents
- Current father is the biological father and current mother is not the biological mother
- Current mother is the biological mother and current father is not the biological father
- Current father is the biological father and no mother present (single father)
- Current mother is the biological mother and no father present (single mother)
- Both parents are not the biological parents
- Other (please describe) _______________________________________

162. Country of birth of both biological parents?
- Mother ________________________________________  □ Tick if unsure
- Father ________________________________________  □ Tick if unsure

163. What is the ethnic origin of the child’s biological parents? (Provide more than one ethnic group if applicable; e.g. If the father’s mother is Caucasian and father’s father is East Asian, then you would tick both boxes in the father’s column.)

<table>
<thead>
<tr>
<th>Mother</th>
<th>Father</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caucasian (European)</td>
<td>□</td>
</tr>
<tr>
<td>East Asian</td>
<td>□</td>
</tr>
<tr>
<td>Indian/ Pakistani/ Sri Lankan</td>
<td>□</td>
</tr>
<tr>
<td>African</td>
<td>□</td>
</tr>
<tr>
<td>Melanesian/ Polynesian</td>
<td>□</td>
</tr>
<tr>
<td>Middle Eastern</td>
<td>□</td>
</tr>
<tr>
<td>Indigenous Australian</td>
<td>□</td>
</tr>
<tr>
<td>South American</td>
<td>□</td>
</tr>
<tr>
<td>Unsure</td>
<td>□</td>
</tr>
</tbody>
</table>

Other (please describe) _______________________________________
164. Date of Birth of the biological mother:

Date of birth: _____ / _____ / _____ (dd/mm/yy)  □ Tick if unsure

165. Please tick all medical conditions the child’s biological mother may have had or currently have?

□ High Blood Pressure  □ Cancer  □ Asthma
□ Diabetes  □ Heart disease  □ Stroke
□ Unsure  □ Other (please describe)____________________

166. Date of birth of the biological father:

Date of birth: _____ / _____ / _____ (dd/mm/yy)  □ Tick if unsure

167. Please tick all medical conditions the child’s biological father may have had or currently have?

□ High Blood Pressure  □ Cancer  □ Asthma
□ Diabetes  □ Heart disease  □ Stroke
□ Unsure  □ Other (please describe)____________________

**Biological Family Members**

168. Have any of the child’s biological family members ever been diagnosed with the following? (Including mother, father, grandparents or any other family member)

*(Please specify which biological family members on the lines below)*

□ Marfan’s syndrome  □ Stickler syndrome
□ Noonan syndrome  □ Down syndrome
□ Turner’s syndrome  □ Unsure
169. Please state whether anyone in your child’s biological mother’s family has had a cataract operation?

*(Age when surgery first performed)*

- [ ] Mother
- [ ] Mother’s father
- [ ] Mother’s mother
- [ ] Mother’s brothers
- [ ] Mother’s sisters
- [ ] Unsure

170. Is there anyone in your child’s biological mother’s family with any other eye condition?

*(Condition)*

- [ ] Mother
- [ ] Mother’s father
- [ ] Mother’s mother
- [ ] Mother’s brothers
- [ ] Mother’s sisters
- [ ] Unsure

171. Please state whether anyone in your child’s biological father’s family has had a cataract operation?

*(Age when surgery first performed)*

- [ ] Father
- [ ] Father’s father
- [ ] Father’s mother
- [ ] Father’s brothers
- [ ] Father’s sisters
- [ ] Unsure

172. Is there anyone in your child’s biological father’s family with any other eye condition?

*(Condition)*

- [ ] Father
- [ ] Father’s father
- [ ] Father’s mother
- [ ] Father’s brothers
- [ ] Father’s sisters
- [ ] Unsure
173. Please indicate the total number of children in the household

☐ Males  ☐ Females

174. Please list the full name, sex, year and place of birth for all brothers and sisters including biological and non-biological.

<table>
<thead>
<tr>
<th>First name</th>
<th>Family name</th>
<th>Gender</th>
<th>Year of birth</th>
<th>Place of birth</th>
<th>Same mother</th>
<th>Same father</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

175. Do any of your children living in the household have any known eye problems?

Please list:

<table>
<thead>
<tr>
<th>Name</th>
<th>Eye Problem</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>
176. This table refers to all children except your child involved in the study.

<table>
<thead>
<tr>
<th>Children</th>
<th>Does the child wear glasses or contact lenses?</th>
<th>At what age did the child start wearing glasses?</th>
<th>What does the child wear glasses and/or contact lens primarily for?</th>
<th>Does the child have astigmatism?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. First name:</td>
<td>□ Yes □ No □ Don’t know</td>
<td>□ Seeing clearly in distance (e.g. television, movies) □ Reading, working at a computer, or other close work □ Equally important for distance and close work.</td>
<td>□ Yes □ No □ Don’t know</td>
<td></td>
</tr>
<tr>
<td>_________</td>
<td>If no, please move on to the next child</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. First name:</td>
<td>□ Yes □ No □ Don’t know</td>
<td>□ Seeing clearly in distance (e.g. television, movies) □ Reading, working at a computer, or other close work □ Equally important for distance and close work.</td>
<td>□ Yes □ No □ Don’t know</td>
<td></td>
</tr>
<tr>
<td>_________</td>
<td>If no, please move on to the next child</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. First name:</td>
<td>□ Yes □ No □ Don’t know</td>
<td>□ Seeing clearly in distance (e.g. television, movies) □ Reading, working at a computer, or other close work □ Equally important for distance and close work.</td>
<td>□ Yes □ No □ Don’t know</td>
<td></td>
</tr>
<tr>
<td>_________</td>
<td>If no, please move on to the next child</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. First name:</td>
<td>□ Yes □ No □ Don’t know</td>
<td>□ Seeing clearly in distance (e.g. television, movies) □ Reading, working at a computer, or other close work □ Equally important for distance and close work.</td>
<td>□ Yes □ No □ Don’t know</td>
<td></td>
</tr>
<tr>
<td>_________</td>
<td>If no, please move on to the next child</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. First name:</td>
<td>□ Yes □ No □ Don’t know</td>
<td>□ Seeing clearly in distance (e.g. television, movies) □ Reading, working at a computer, or other close work □ Equally important for distance and close work.</td>
<td>□ Yes □ No □ Don’t know</td>
<td></td>
</tr>
<tr>
<td>_________</td>
<td>If no, please move on to the next child</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. First name:</td>
<td>□ Yes □ No □ Don’t know</td>
<td>□ Seeing clearly in distance (e.g. television, movies) □ Reading, working at a computer, or other close work □ Equally important for distance and close work.</td>
<td>□ Yes □ No □ Don’t know</td>
<td></td>
</tr>
<tr>
<td>_________</td>
<td>If no, please move on to the next child</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**We would like to know whether other family members including the parents have eye conditions requiring correction with glasses, contact lenses.**

177. Please fill out the tables with reference to your child’s biological family members. As a guide: indicate in the second column whether any family member has ever worn glasses or contact lenses. If your answer is No, then go to the next relative on the row below. If your answer is yes, please fill out the rest of the information in the row.

<table>
<thead>
<tr>
<th>Family members</th>
<th>Do they wear glasses or contact lenses?</th>
<th>At what age did they start wearing glasses?</th>
<th>What do they wear glasses or contact lens primarily for?</th>
<th>Do they have astigmatism?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Father</td>
<td>□ Yes</td>
<td>□ Seeing clearly in distance (e.g. television, movies)</td>
<td>□ Yes</td>
<td>□ No</td>
</tr>
<tr>
<td></td>
<td>□ No</td>
<td>□ Reading, working at a computer, or other close work</td>
<td>□ No</td>
<td>□ Don’t know</td>
</tr>
<tr>
<td></td>
<td>□ Don’t know</td>
<td>□ Equally important for distance and close work.</td>
<td>□ Don’t know</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>If no, please move on to next family member</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Mother</td>
<td>□ Yes</td>
<td>□ Seeing clearly in distance (e.g. television, movies)</td>
<td>□ Yes</td>
<td>□ No</td>
</tr>
<tr>
<td></td>
<td>□ No</td>
<td>□ Reading, working at a computer, or other close work</td>
<td>□ No</td>
<td>□ Don’t know</td>
</tr>
<tr>
<td></td>
<td>□ Don’t know</td>
<td>□ Equally important for distance and close work.</td>
<td>□ Don’t know</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>If no, please move on to next family member</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Father’s father</td>
<td>□ Yes</td>
<td>□ Seeing clearly in distance (e.g. television, movies)</td>
<td>□ Yes</td>
<td>□ No</td>
</tr>
<tr>
<td></td>
<td>□ No</td>
<td>□ Reading, working at a computer, or other close work</td>
<td>□ No</td>
<td>□ Don’t know</td>
</tr>
<tr>
<td></td>
<td>□ Don’t know</td>
<td>□ Equally important for distance and close work.</td>
<td>□ Don’t know</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>If no, please move on to next family member</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Father’s mother</td>
<td>□ Yes</td>
<td>□ Seeing clearly in distance (e.g. television, movies)</td>
<td>□ Yes</td>
<td>□ No</td>
</tr>
<tr>
<td></td>
<td>□ No</td>
<td>□ Reading, working at a computer, or other close work</td>
<td>□ No</td>
<td>□ Don’t know</td>
</tr>
<tr>
<td></td>
<td>□ Don’t know</td>
<td>□ Equally important for distance and close work.</td>
<td>□ Don’t know</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>If no, please move on to next family member</em></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5. Mother’s father</td>
<td>□ Yes</td>
<td>□ Seeing clearly in distance (e.g. television, movies)</td>
<td>□ Yes</td>
<td>□ No</td>
</tr>
<tr>
<td></td>
<td>□ No</td>
<td>□ Reading, working at a computer, or other close work</td>
<td>□ No</td>
<td>□ Don’t know</td>
</tr>
<tr>
<td></td>
<td>□ Don’t know</td>
<td>□ Equally important for distance and close work.</td>
<td>□ Don’t know</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>If no, please move on to next family member</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Mother’s mother</td>
<td>□ Yes</td>
<td>□ Seeing clearly in distance (e.g. television, movies)</td>
<td>□ Yes</td>
<td>□ No</td>
</tr>
<tr>
<td></td>
<td>□ No</td>
<td>□ Reading, working at a computer, or other close work</td>
<td>□ No</td>
<td>□ Don’t know</td>
</tr>
<tr>
<td></td>
<td>□ Don’t know</td>
<td>□ Equally important for distance and close work.</td>
<td>□ Don’t know</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>If no, please move on to next family member</em></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
178. Has anyone in your family had refractive surgery?
   □ No (go to question 181)
   □ Yes

179. If yes, what is his or her relation to the child (e.g., father, sister) _____________

180. Refractive surgery (laser surgery/ LASIK) was done at the age of _______ years old and for correction of:
   □ Myopia
   □ Presbyopia
   □ Hyperopia
   □ Don’t know
   □ Astigmatism

The questions in this section refer to the current parents caring for the child, which in some cases may not be the biological parents.

Current parents

181. Parents’ occupation(s):
   Mother’s Occupation: ______________________________________
   Current Occupation: ______________________________________
   Father’s Occupation: ______________________________________
   Current Occupation ______________________________________

182. How would you describe the mother’s employment status?
   □ Employed full time (includes self employment)
   □ Employed part time (includes self employment)
   □ Unemployed
   □ Home duties
   □ Student and working
   □ Student and not working
   □ Retired
   □ Unable to work due to health problems
   □ Pension
   □ Other _________________________
183. How would you describe the father’s employment status?
- [ ] Employed full time (includes self employment)
- [ ] Employed part time (includes self employment)
- [ ] Unemployed
- [ ] Home duties
- [ ] Student and working
- [ ] Student and not working
- [ ] Retired
- [ ] Unable to work due to health problems
- [ ] Pension
- [ ] Other ___________________________

184. What is the highest level of education completed by the mother?
- [ ] Never attended school
- [ ] Some primary school completed
- [ ] Some high school completed
- [ ] Completed School Certificate – Intermediate -Year 10 - 4th Form
- [ ] Completed HSC - Year 12 – Leaving - 6th Form
- [ ] TAFE Certificate or Diploma, including trade certificate
- [ ] University, CAE or some other tertiary institute degree
- [ ] Higher degree including a Masters or PhD
- [ ] Other ___________________________

185. What is the highest level of education completed by the father?
- [ ] Never attended school
- [ ] Some primary school completed
- [ ] Some high school completed
- [ ] Completed School Certificate – Intermediate -Year 10 - 4th Form
- [ ] Completed HSC - Year 12 – Leaving - 6th Form
- [ ] TAFE Certificate or Diploma, including trade certificate
- [ ] University, CAE or some other tertiary institute degree
- [ ] Higher degree including a Masters or PhD
- [ ] Other _____________________________________________________
186. What sort of a place does the family live in?

- [ ] Own house
- [ ] With relatives
- [ ] Own flat/unit
- [ ] Don’t know
- [ ] Rented house
- [ ] Rented flat
- [ ] Other (please describe) ________________________________

Please answer these questions about your child’s home. This information will be used to study whether a child’s dwelling affects development.

187. Please tick the box that best describes the dwelling structure your child lives in:

- [ ] Separate house
- [ ] Semi-detached, row or terrace house with:
  - [ ] One story
  - [ ] Two or more stories
- [ ] Flat attached to a house
- [ ] Other flat/unit/apartment:
  - [ ] In a 1 or 2 storey block
  - [ ] In a 3 storey block
  - [ ] In a 4 or more storey block
- [ ] Caravan/tent/cabin in a caravan park, houseboat in a marina, etc.
- [ ] Caravan not in a caravan park/houseboat not in a marina, etc.
- [ ] Improvised home/campers out
- [ ] House or flat attached to a shop, office, etc.

188. Does your child live regularly in another dwelling structure for 2 days or more per week on average?

- [ ] No (go to question 190)
- [ ] Yes
189. If yes, please tick the box that best describes the dwelling structure your child lives in regularly for greater than two days per week:

- [ ] Separate house
- [ ] Semi-detached, row or terrace house with:
  - [ ] One story
  - [ ] Two or more stories
- [ ] Flat attached to a house
- [ ] Other flat/unit/apartment:
  - [ ] In a 1 or 2 storey block
  - [ ] In a 3 storey block
  - [ ] In a 4 or more storey block
- [ ] Caravan/tent/cabin in a caravan park, houseboat in a marina, etc.
- [ ] Caravan not in a caravan park/houseboat not in a marina, etc.
- [ ] Improvised home/campers out
- [ ] House or flat attached to a shop, office, etc.

**Greenspace Questions**

190. From the front door of your dwelling, how many other residential dwellings can you see?

- [ ] Less than 5
- [ ] 5-10
- [ ] Greater than 10

191. From the front door of your dwelling, how many commercial buildings can you see?

- [ ] None (go to question 193)
- [ ] Unsure (go to question 193)
- [ ] Less than 5
- [ ] Greater than 5

192. Of these, how many high rise buildings, including apartments, flats and offices are included?

- [ ] None
- [ ] Unsure
- [ ] Less than 5
- [ ] Greater than 5

193. Is it possible to get a view of the horizon from the ground floor of your dwelling?

- [ ] No
- [ ] Unsure
- [ ] Yes

39
The date when the questionnaire was completed: [ ] [ ] / [ ] [ ] / [ ] [ ]

(Day) (Month) (Year)

Name of person filling out the questionnaire:
Name______________________________ Relationship to child____________________

Names of other people consulted in filling out this questionnaire:
Name______________________________ Relationship to child____________________
Name______________________________ Relationship to child____________________
Name______________________________ Relationship to child____________________
Name______________________________ Relationship to child____________________

Thank you for completing this questionnaire. We look forward to seeing your child at the examinations.
Appendix 2: WHO Questionnaire
## CONTACT DETAILS

Child ID

Child Name: ______________________________________________

Home phone: _____________________

Mobile phone: _____________________

Email: ____________________________

## QUESTIONS ABOUT HOW YOU SPEND A TYPICAL SCHOOL/WORK DAY

1) **SCHOOL/WORK:** How many days per week do you attend school or work [ ]
   (days)

2) **SLEEP:** When do you usually go to sleep at night? [ ]
   (hour) . [ ]
   (minute)

3) **SLEEP:** What time do you usually wake up in the morning?[ ]
   (hour) . [ ]
   (minute)

4) **BEFORE YOU LEAVE FOR SCHOOL:** After you wake up in the morning and before you leave for school/work, do you spend any time outside?
   - [ ] Not at all
   - [ ] less than an hour
   - More than one hour (please specify) [ ]
   (hours)

5) **TRAVEL:** What time do you leave home to go to school/work? [ ]
   (hour) . [ ]
   (minute)

6) **TRAVEL:** How do you travel to school/work and for how long?
   - [ ] Bus, train or tram [ ]
   - [ ] Car [ ]
   - [ ] Walking, bicycle or motorbike [ ]
   (minutes)
7) **TRAVEL:** What time do you arrive at school/work?

8) **SCHOOL/WORK:** After you arrive at school/work, do you spend any time outside before school starts?

☐ Not at all

☐ less than an hour

More than one hour (please specify) ☐ ☐

(hours)

9) **SCHOOL/WORK:** What time do you usually start school/work

10) **SCHOOL/WORK:** In the middle of your school/work day, do you spend any time outside?

☐ Not at all

☐ less than an hour

More than one hour (please specify) ☐ ☐

(hours)

11) **SCHOOL/WORK:** What time do you usually finish school/work

12) **SCHOOL/WORK:** After school/work finishes, do you spend any time outside before leaving to go home?

☐ Not at all

☐ less than an hour

More than one hour (please specify) ☐ ☐

(hours)

13) **TRAVEL:** What time do you leave school/work to go home?

14) **TRAVEL:** Do you travel to home the same way as you traveled in the morning?

☐ Yes

☐ No, if so how do you travel? ☐ Bus, train or tram

☐ Car

☐ Walking, bicycle or motorbike ☐

(minutes)
15) **TRAVEL:** What time do you arrive at home?

16) **AFTER YOU ARRIVE HOME:** After you arrive home and before nighttime do you spend any time outside?

- ☐ Not at all
- ☐ less than an hour
- ☐ More than one hour (please specify) ____________ ____________ (hours)

*We would now like to ask you about how you spend your time when you are not in school or asleep. We need to know how long you are indoors or outdoors and what kinds of activities you do. We will start with indoor activities. Remember do not include school/work or sleep time. Indoor time can include bus, car or train travel, but not walking, riding a bicycle or motorbike.*

17) On a typical school/work day, **WHILE YOU ARE INDOORS**, for how long (per day) do you do the following activities:

17a) Read printed material for pleasure, for example reading a magazine or novel?

- ☐ Not at all
- ☐ less than an hour
- ☐ More than one hour (please specify) ____________ ____________ (hours)

17b) Read printed material or do handwriting for study/work?

- ☐ Not at all
- ☐ less than an hour
- ☐ More than one hour (please specify) ____________ ____________ (hours)

17c) Use computers for study/work/pleasure?

- ☐ Not at all
- ☐ less than an hour
- ☐ More than one hour (please specify) ____________ ____________ (hours)
17d) Watch television/go to the movies?
   - Not at all
   - less than an hour
   - More than one hour (please specify) [Hours]

17e) Play sports or exercise indoors?
   - Not at all
   - less than an hour
   - More than one hour (please specify) [Hours]

17f) Are there any other indoor activities that you would do for more than 2 hours in a typical day?
   - Not at all
   - Yes 1. Please specify the activity ____________________ [Hours]
   - 2. Please specify the activity _______________ [Hours]
   - 3. Please specify the activity ___________________ [Hours]

18) OUTDOORS: How many hours do you spend outdoors in a day? [Hours] DO NOT include school/work/sleep

18a) While you are outdoors, do you do any close work activities such as; reading for pleasure or study, use computers or watch television?
   - No (if answered no, proceed to question 18b)
   - Yes Please specify the activity ____________________ [Hours]
   - Another? Please specify the activity ___________________ [Hours]
18b) Play sports or exercise outdoors?
- Not at all
- Less than an hour
- More than one hour (please specify) [ ] [ ] (hours)

18c) Are there any other outdoor activities that you would do for more than 2 hours in a typical day, for example walking, gardening or shopping outside?
- Not at all
- Yes Please specify the activity ____________________ [ ] [ ] (hours)
- Another? Please specify the activity ____________________ [ ] [ ] (hours)

QUESTIONS ABOUT HOW YOU SPEND A TYPICAL NON-SCHOOL/WORK DAY

19) **SCHOOL/WORK**: Do you attend any academic tuition classes, for example mathematics or language or music classes on a typical non-school/work day?
- Not at all
- Less than an hour
- More than one hour (please specify) [ ] [ ] (hours)

20) **SLEEP**: When do you usually go to sleep at night? [ ] [ ] . [ ] [ ] (hour) (minute)

21) **SLEEP**: What time do you usually wake up in the morning? [ ] [ ] . [ ] [ ] (hour) (minute)

22) **INDOORS**: How many hours do you spend indoors in a day DO NOT include sleep or academic tuition classes [ ] [ ] (hours)
23) On a typical non-school/work day, **WHILE YOU ARE INDOORS**, for how long (per day) do you do the following activities:

23a) Read printed material for pleasure, for example a magazine or novel?
- [ ] Not at all
- [ ] less than an hour
- [ ] More than one hour (please specify) [ ] [ ] (hours)

23b) Read printed material or do handwriting for study/work?
- [ ] Not at all
- [ ] less than an hour
- [ ] More than one hour (please specify) [ ] [ ] (hours)

23c) Use computers for study/work/pleasure?
- [ ] Not at all
- [ ] less than an hour
- [ ] More than one hour (please specify) [ ] [ ] (hours)

23d) Watch television/go to the movies?
- [ ] Not at all
- [ ] less than an hour
- [ ] More than one hour (please specify) [ ] [ ] (hours)

23e) Play sports or exercise indoors?
- [ ] Not at all
- [ ] less than an hour
- [ ] More than one hour (please specify) [ ] [ ] (hours)
23f) Are there any other indoor activities that you would do for **more than 2 hours** in a typical day?

- [ ] Not at all
- [ ] Yes

1. Please specify the activity ____________________ (hours)
2. Please specify the activity ____________________ (hours)
3. Please specify the activity ____________________ (hours)

24) **OUTDOORS:** How many hours do you spend outdoors in a day **DO NOT** include school/work/sleep

25) On a typical non-school/work day, **WHILE YOU ARE OUTDOORS**, for how long (per day) do you do the following activities:

25a) While you are outdoors, do you do any close work activities such as; reading for pleasure or study, use computers or watch television?

- [ ] No *(if answered no, proceed to question 18b)*
- [ ] Yes

2. Please specify the activity ____________________ (hours)
3. Another? Please specify the activity ____________________ (hours)

25b) Play sports or exercise outdoors?

- [ ] Not at all
- [ ] less than an hour
- [ ] More than one hour (please specify) (hours)
25c) Are there any other outdoor activities that you would do for **more than 2 hours** in a typical day, for example walking, gardening or shopping outside?

☐ Not at all

☐ Yes  Please specify the activity _________________  (hours)

☐ Another?  Please specify the activity _________________  (hours)

Comments: ________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
Appendix 3: Participant Information Statement
Development of myopia among adolescents: a validation of instrument study

PARTICIPANT INFORMATION STATEMENT

(1) What is the study about?
Myopia or short-sightedness has recently been shown to be prevented if you spend more time outdoors as a child. You are invited to participate in a study that aims to validate a questionnaire about time spent indoors and outdoors, to be used in a wider study on the prevention of myopia among adolescents. We will validate the questionnaire against objective measure of time spent indoors and outdoors using a light-intensity or luminosity (LUX) data logger. The project will also assess the feasibility of each tool through focus groups.

(2) Who is carrying out the study?
The study is being conducted by Majid Moafa, a high research degree student under the supervision of Associate Professor Kathryn Rose.

(3) What does the study involve?
We will start by asking you to fill out a questionnaire to describe how you spend your time on a typical weekday and week end. This will take approximately 15 minutes to complete. We will then ask you to wear on your upper arm on outer clothing during waking hours for 4 days a small (58×33×23 mm) lightweight (18 grams) data logger that records the ambient light every 10 minutes. The logger will then be returned and the data downloaded to a computer file, coded with your participant number only. During the same period, you will be asked to document your time indoors and outdoors in a diary, choosing an appropriate activity code. At the conclusion, you will be invited to attend a one hour focus group to discuss with the researchers any observations, concerns or inconveniences you had noted about completing the diary and/or wearing the light data logger. You can withdraw from the study at any time without prejudice. Due to the group nature of the focus group although you are free to withdraw at any time due to the group nature of the focus group you cannot withdraw individual data once the session has commenced.

(4) How much time will the study take?
15 minutes to fill out the initial questionnaire, 4 days for each participant of wearing the light data logger and a further hour for the focus group session.

(5) Can I withdraw from the study?
Being in this study is completely voluntary - you are not under any obligation to consent and - if you do consent - you can withdraw at any time without affecting your relationship with The University of Sydney or other institutions relating to your research.

(6) Will anyone else know the results?
All aspects of the study, including results, will be strictly confidential and only the researchers will have access to information on participants.
A report of the study may be submitted for publication, but individual participants will not be identifiable in such a report.

(7) Will the study benefit me?
We cannot and do not guarantee or promise that you will receive any benefits from the study.

(8) Can I tell other people about the study?
Yes, you can.

(9) What if I require further information about the study or my involvement in it?
When you have read this information, if you require further information Associate Professor Kathryn Rose will discuss it with you and answer any questions you may have. If you would like to know more at any stage, please feel free to contact Associate Professor Kathryn Rose at the email address above.

(10) Is there more information?
All participants can enter in the draw for a mini iPad. The draw will take place by the end of August, 2014, after all participants have been recruited to the study. The winner will be notified by email.

(11) What if I have a complaint or any concerns?
Any person with concerns or complaints about the conduct of a research study can contact The Manager, Human Ethics Administration, University of Sydney on +61 2 8627 8176 (Telephone); +61 2 8627 8177 (Facsimile) or ro.humanethics@sydney.edu.au (Email).

This information sheet is for you to keep
Appendix 4: Participant Consent Form
PARTICIPANT CONSENT FORM

I, ........................................................................[PRINT NAME], give consent to my participation in the research project

TITLE: Development of myopia among adolescents: a validation of instrument study

In giving my consent I acknowledge that:

1. The procedures required for the project and the time involved have been explained to me, including any inconvenience, risk, discomfort or side effect, and their implications, and any questions I have about the project have been answered to my satisfaction.

2. I have read the Participant Information Statement and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.

3. I understand that being in this study is completely voluntary – I am not under any obligation to consent.

4. I understand that my involvement is strictly confidential. I understand that any research data gathered from the results of the study may be published, however no information about me will be used in any way that is identifiable.

5. I understand that I can withdraw from the study at any time, without affecting my relationship with the researcher(s) or the University of Sydney or any other institutions relating to your research now or in the future.

6. Due to the group nature of the focus group although I am free to withdraw at any time due to the group nature of the focus group you cannot withdraw individual data once the session has commenced.

7. I consent to:
   • Receiving Feedback YES □ NO □

   If you answered YES to the “Receiving Feedback” question, please provide your details i.e. email address.

   Email: __________________________________________________________

--------------------------------------------------------------------------

Signature

--------------------------------------------------------------------------

Please PRINT name

--------------------------------------------------------------------------

Date

Development of myopia among adolescents: a validation of instrument study
Version 1; 18/09/2013
Appendix 5: The Modified Version of the WHO Questionnaire
Preliminary Questionnaire

Development of myopia among adolescents: a validation of instrument study

ID: 

QUESTIONS ABOUT HOW YOU SPEND A TYPICAL UNIVERSITY DAY

1) UNIVERSITY: How many days per week do you attend university? 
   
2) SLEEP: When do you usually go to sleep at night on these days? 

3) SLEEP: What time do you usually wake up in the morning? 

4) BEFORE YOU LEAVE FOR UNIVERSITY: After you wake up in the morning and before you leave, do you spend any time outside? 
   - Not at all 
   - less than an hour 
   - More than one hour (please specify) 

5) TRAVEL: What time do you leave home to go to university? 

6) TRAVEL: How do you travel to university and how long does it take? If you go by both a vehicle and walking, tick both boxes & note how much time is spent in each mode 
   - Car, bus, train or tram 
   - Walking, bicycle or motorbike
7) **UNIVERSITY**: After you arrive at university, do you spend any time outside before it starts?
- Not at all
- less than an hour
  - More than one hour (please specify) (hours)

8) **UNIVERSITY**: What time do you usually start university (hour) (minute)

9) **UNIVERSITY**: In your university day, do you spend any time outside?
- Not at all
- less than an hour
  - More than one hour (please specify) (hours)

10) **UNIVERSITY**: What time do you usually finish university (hour) (minute)

11) **UNIVERSITY**: After university finishes, do you spend any time outside before leaving to go home?
- Not at all
- less than an hour
  - More than one hour (please specify) (hours)

12) **TRAVEL**: What time do you leave to go to home? (hour) (minute)

13) **TRAVEL**: Do you travel home the same way you traveled in the morning?
- Yes
- No, if so how do you travel?  
  - Car, bus, train or tram (minutes)
  - Walking, bicycle or motorbike (minutes)
14) **AFTER YOU ARRIVE HOME:** After you arrive home and before nighttime do you spend any time outside?

- [ ] Not at all
- [ ] Less than an hour
- More than one hour (please specify) 

We would now like to ask you about how you spend your time when you are not in university or asleep. We need to know how long you are indoors or outdoors and what kinds of activities you do. We will start with indoor activities. Remember do not include university or sleep time.

15) Before and after a TYPICAL UNIVERSITY DAY, **WHILE YOU ARE INDOORS**, how long (per day) do you do the following activities:

15a) Read printed material for pleasure, for example reading a magazine or novel?

- [ ] Not at all
- [ ] Less than an hour
- More than one hour (please specify) 

15b) Doing homework/study or attending after university classes?

- [ ] Not at all
- [ ] Less than an hour
- More than one hour (please specify) 

15c) Use computers for study/pleasure?

- [ ] Not at all
- [ ] Less than an hour
- More than one hour (please specify) 

15d) Watch television/go to the movies?
   □ Not at all
   □ less than an hour
   More than one hour (please specify) □ □ (hours)

15e) Play indoor sports or exercise indoors?
   □ Not at all
   □ less than an hour
   More than one hour (please specify) □ □ (hours)

15f) Are there any other indoor activities that you would do for more than 2 hours in a typical day?
   □ Not at all
   □ Yes  1. Please specify the activity ________________ □ □ (hours)
   2. Please specify the activity ________________ □ □ (hours)
   3. Please specify the activity ________________ □ □ (hours)

16) OUTDOORS: Before and after a TYPICAL UNIVERSITY DAY, how many hours do you spend outdoors

   DO NOT include hours during university □ □ (hours)

16a) Play sports or exercise outdoors?
   □ Not at all
   □ less than an hour
   More than one hour (please specify) □ □ (hours)
16b) Are there any other outdoor activities that you would do for **more than 2 hours** in a typical day, for example sitting, walking, gardening or shopping outside?

- [ ] Not at all
- [ ] Yes Please specify the activity ____________________(hours)
- [ ] Another? Please specify the activity ____________________ (hours)

---

**QUESTIONS ABOUT HOW YOU SPEND A TYPICAL WEEKEND**

17) **INDOOR CLASSES**: Do you attend any academic tuition classes, for example mathematics or language or music classes on the weekend?

- [ ] Not at all
- [ ] less than an hour
- [ ] More than one hour (please specify) ____________________ (hours)

18) **SLEEP**: When do you usually go to sleep at night?

[ ] hour [ ] minute

19) **SLEEP**: What time do you usually wake up in the morning?

[ ] hour [ ] minute

20) **INDOORS**: How many hours do you spend indoors in a day **DO NOT include** sleep or academic tuition classes ____________________ (hours)

21) On a typical non-university day, **WHILE YOU ARE INDOORS**, for how long (per day) do you do the following activities:

21a) Read printed material for pleasure, for example a magazine or novel?

- [ ] Not at all
- [ ] less than an hour
- [ ] More than one hour (please specify) ____________________ (hours)
21b) Read printed material or do handwriting for study?
☐ Not at all
☐ less than an hour
More than one hour (please specify) ___________ (hours)

21c) Use computers for study/pleasure?
☐ Not at all
☐ less than an hour
More than one hour (please specify) ___________ (hours)

21d) Watch television/go to the movies?
☐ Not at all
☐ less than an hour
More than one hour (please specify) ___________ (hours)

21e) Play sports or exercise indoors?
☐ Not at all
☐ less than an hour
More than one hour (please specify) ___________ (hours)

21f) Are there any other indoor activities that you would do for more than 2 hours in a typical day?
☐ Not at all
☐ Yes  1. Please specify the activity ____________________ (hours)

2. Please specify the activity ____________________ (hours)
22) **OUTDOORS:** How many hours do you spend outdoors in a day  
include university/sleep

23) On a typical non-university day, **WHILE YOU ARE OUTDOORS,** for how long (per day) do you do the following activities:

23a) While you are outdoors, do you do any close work activities such as; reading for pleasure or study, use computers or watch television?

- [ ] No (if answered no, proceed to question 23b)
- [ ] Yes Please specify the activity ________________

- [ ] Another? Please specify the activity ________________

23b) Play sports or exercise outdoors?

- [ ] Not at all
- [ ] less than an hour
- [ ] More than one hour (please specify) ________________

23c) Are there any other outdoor activities that you would do for **more than 2 hours** in a typical day, for example walking, gardening or shopping outside?

- [ ] Not at all
- [ ] Yes  Please specify the activity ____________________  \( \square \) \( \square \) (hours)

- [ ] Another?  Please specify the activity ________________  \( \square \) \( \square \) (hours)

Comments: ______________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
Appendix 6: Singapore 7-day Diary
Instructions

An important part of our research is to find out how you spend your time during weekdays and on the weekends. The 7-day Diary tells us about everything you do each day of the week.

- Please fill out the diary for the whole 24-hour time period for all 7 days. List your first activity of the day, your second activity of the day, and on to your last activity of the day.

- There should be no gaps in time. The end time for one activity should match the start time for the next activity.

- Use one line for each activity. For each activity, mention the activity’s name, start & end time.

- For each activity, please record whether you are outdoors (outside any building) or indoors (inside any building).

- It works best to fill out the diary as the day goes by, so that you will remember what you did and it will be accurate.

- This 7-day Diary is completely confidential. Only you and the research team will see it. Please be as exact as possible.

If you have any enquiries, please contact us

at

(02)9351 9464 between 9.00 am to 6.00 pm on weekdays

(Monday to Friday)
Date: / / (dd / mm / yyyy)  EXAMPLE

### Activity codes

1. School
2. Passive Indoor activities (cooking, crafts, board games etc)
3. Sleep
4. Outdoor Sports
5. Playing, Walking, strolling etc in the neighborhood/park
6. Reading / Studying
7. Computer work / computer games
8. Watching Television
9. Travelling in the Bus
10. Travelling in the Car
11. Travelling in the Train
12. Walking to or from school
13. Others (specify_________________________)

Did you wear the light meter today? (please tick below)

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<tr>
<th>YES</th>
<th>NO</th>
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</table>

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<th>Start time of activity</th>
<th>End time of activity</th>
<th>Name &amp; code of the activity</th>
<th>Outdoor/ Indoor activity (please tick)</th>
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<td>Indoors 01  Outdoors 02</td>
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</table>
Date: / / (dd / mm / yyyy)  EXAMPLE

### Activity codes

1. School
2. Passive Indoor activities (cooking, crafts, board games etc)
3. Sleep
4. Outdoor Sports
5. Playing, Walking, strolling etc in the neighborhood/park
6. Reading / Studying
7. Computer work / computer games
8. Watching Television
9. Travelling in the Bus
10. Travelling in the Car
11. Travelling in the Train
12. Walking to or from school
13. Others (specify_______________________)

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Did you wear the Light Meter today?

Yes □ 01  No □ 00
Date: / / (dd / mm / yyyy)  Friday-Page 1

Activity codes

1 School 8 Watching Television
2 Passive Indoor activities (cooking, crafts, board games etc) 9 Travelling in the Bus
3 Sleep 10 Travelling in the Car
4 Outdoor Sports 11 Travelling in the Train
5 Playing, Walking, strolling etc in the neighborhood/park 12 Walking to or from school
6 Reading / Studying
7 Computer work / computer games

Did you wear the light meter today? (please tick below)

YES ☐  NO ☐

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**Date:** / / (dd / mm / yyyy) **Friday-Page 2**

**Activity codes**

1. School
2. Passive Indoor activities (cooking, crafts, board games etc)
3. Sleep
4. Outdoor Sports
5. Playing, Walking, strolling etc in the neighborhood/park
6. Reading / Studying
7. Computer work / computer games
8. Watching Television
9. Travelling in the Bus
10. Travelling in the Car
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12. Walking to or from school
13. Others (specify_______________________)
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12. Walking to or from school  
13. Others (specify_______________________)

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**Date:** / / (dd / mm / yyyy)  
**Saturday-Page 1**

**Did you wear the light meter today? (please tick below)**  
YES ☐  NO ☐

<table>
<thead>
<tr>
<th>Start time of activity</th>
<th>End time of activity</th>
<th>Name &amp; code of the activity</th>
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| - - : - - (am/pm)      | - - : - - (am/pm)    | Name the activity ...............  
Write the code of the activity | Indoors ☐ 01  
Outdoors ☐ 02 |
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Date: / / (dd / mm / yyyy) **Saturday-Page 2**

**Activity codes**

1 School
2 Passive Indoor activities (cooking, crafts, board games etc)
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13. Others (specify_______________________)

### Did you wear the light meter today? (please tick below)

- [ ] YES
- [ ] NO

### Start time of activity
- - : - - (am/pm)

### End time of activity
- - : - - (am/pm)

### Name & code of the activity

Name the activity …………………
Write the code of the activity

### Outdoor/ Indoor activity (please tick)

- [ ] Indoors 01
- [ ] Outdoors 02

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**Date:** / / (dd / mm / yyyy)

**Sunday - Page 1**
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Date: / / (dd / mm / yyyy)  **Sunday—Page 2**

**Activity codes**

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2 Passive Indoor activities (cooking, crafts, board games etc)  
3 Sleep  
4 Outdoor Sports  
5 Playing, Walking, strolling etc in the neighborhood/park  
6 Reading / Studying  
7 Computer work / computer games  
8 Watching Television  
9 Travelling in the Bus  
10 Travelling in the Car  
11 Travelling in the Train  
12 Walking to or from school  
13 Others (specify_______________________)
### Date: / / (dd / mm / yyyy) Monday - Page 1

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<td>Sleep</td>
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<tr>
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<td>Outdoor Sports</td>
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Did you wear the light meter today? (please tick below)

- [ ] YES
- [ ] NO

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Did you wear the light meter today? (please tick below)

YES □ NO □

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- 2 Passive Indoor activities (cooking, crafts, board games etc)
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<th>Travelling in the Train</th>
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**Tuesday-Page 2**

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Date: / / (dd / mm / yyyy) Wednesday - Page 1

Activity codes

1 School
2 Passive Indoor activities (cooking, crafts, board games etc)
3 Sleep
4 Outdoor Sports
5 Playing, Walking, strolling etc in the neighborhood/park
6 Reading / Studying
7 Computer work / computer games
8 Watching Television
9 Travelling in the Bus
10 Travelling in the Car
11 Travelling in the Train
12 Walking to or from school
13 Others (specify_______________________)

Did you wear the light meter today? (please tick below)

YES □ NO □

<table>
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<th>Start time of activity</th>
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| Date: / / (dd / mm / yyyy) Wednesday - Page 2

Activity codes:

1 School
2 Passive Indoor activities (cooking, crafts, board games etc)
3 Sleep
4 Outdoor Sports
5 Playing, Walking, strolling etc in the neighborhood/park
6 Reading / Studying
7 Computer work / computer games

Other activities:
8 Watching Television
9 Travelling in the Bus
10 Travelling in the Car
11 Travelling in the Train
12 Walking to or from school
13 Others (specify_______________________)
## Activity codes

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<td>5</td>
<td>Playing, Walking, strolling etc in the neighborhood/park</td>
<td>05</td>
</tr>
<tr>
<td>6</td>
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<tr>
<td>7</td>
<td>Computer work / computer games</td>
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### Did you wear the light meter today? (please tick below)

- [ ] YES
- [ ] NO

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Date: / / (dd / mm / yyyy) **Thursday-Page 2**

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2. Passive Indoor activities (cooking, crafts, board games etc)  
3. Sleep  
4. Outdoor Sports  
5. Playing, Walking, strolling etc in the neighborhood/park  
6. Reading / Studying  
7. Computer work / computer games  
8. Watching Television  
9. Travelling in the Bus  
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Appendix 7: 4-day Diary
Instructions

An important part of our research is to find out how you spend your time during weekdays and on the weekends. The 4-day Diary tells us about what you do each day and where.

- Please fill out the diary for the whole 24-hour time period for all 4 days. List your first activity of the day, your second activity of the day, and on to your last activity of the day.

- There should be no gaps in time. The end time for one activity should match the start time for the next activity.

- Use one line for each activity. For each activity, code the activity type using the codes at the top of each page and its start & end time.

- For each activity, please record whether you are outdoors (outside any building) or indoors (inside any building or structure).

- It works best to fill out the diary as the day goes by, so that you will remember what you did and it will be accurate.

- This 4-day Diary is completely confidential. Only you and the research team will see it. Please be as exact as possible.

If you have any enquiries, please contact us

at

0411 678 771 between 9.00 am to 5.00 pm on weekdays

(Monday to Friday)
Today is Saturday, Sunday, Monday, Tuesday, Wednesday, Thursday, Friday
please circle the correct day

**Activity codes**

1. Sleep
2. Travelling (car, bus and/or train)
3. University
4. Workplace

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Did you wear the light meter today? (please tick)  

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### Activity codes

1. Sleep  
2. Travelling (car, bus and/or train)  
3. University  
4. Workplace  
5. Passive activity (watching TV, movies, video-games, computer/reading for pleasure, cooking etc)  
6. Physical activity (sport, gym, shopping, riding bike for pleasure, walking, gardening etc)  
7. Studying, completing assignments, additional out of university classes  
8. Other (specify)

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**Today is Saturday, Sunday, Monday, Tuesday, Wednesday, Thursday, Friday**

*please circle the correct day*

**Activity codes table**

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**Did you wear the light meter today?** (please tick)  
[ ] YES  
[ ] NO

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Did you wear the light meter today? (please tick)  

YES ☐  NO ☐
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Did you wear the light meter today? (please tick)  YES  ☐  NO  ☐

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Appendix 8: ARVO Approval
Wednesday, 18-Feb-2015

Dear Mr. Majid MOAFA MOpt,

Congratulations! The abstract on which you are First Author has been accepted and scheduled as a Poster Presentation for the 2015 ARVO Annual Meeting, Powerful Connections: Vision Research and Online Networking, May 3-7, 2015, in Denver, Colorado.

Presentation Number - Posterboard Number: 2937 - D0059

Abstract/Presentation Title: Development of myopia among adolescents: a validation of instrument study

Presentation Type: Poster Session

Session Number: 319

Session Title: Myopia and refractive error: Risk factors and implications

Session Date/ Times: May 5, 2015 from 8:30 AM to 10:15 AM

SUNDAY POSTER PRESENTERS are strongly encouraged to register/print their badge on Saturday.

CHANGES TO YOUR SCHEDULED PRESENTATION TYPE, SESSION, DAY OR TIME CANNOT BE MADE.

As a Poster Presenter, you are obligated to:
- Mount your poster on your assigned posterboard by 8:30am on your presentation day
- Present your abstract during your full scheduled 105-minute Session Time
- Present your abstract during the All Posters Session on your presentation day
- Keep your poster displayed on your assigned posterboard until the Poster Display End Time on your presentation day

- ALL POSTERS SESSION TIMES:
  -- Sunday and Thursday, 10:45-11:45am
  -- Monday through Wednesday, 2:45-3:45pm

- POSTER DISPLAY END TIME:
  -- Sunday: 5:00pm
  -- Monday through Wednesday: 5:30pm
  -- Thursday: 1:45pm
ACCESS TO ABSTRACTS:
- The Online Planner will be available on Tuesday, March 3, at www.arvo.org/Annual_Meeting and will include search capabilities, access to abstracts by session, and an itinerary builder compatible with the Annual Meeting’s Mobile App to plan your Annual Meeting week.

- The Annual Meeting’s week-at-a-glance is currently available for your reference: http://www.arvo.org/Annual_Meeting/Program

IMPORTANT MEETING NOTES:

- As First Author, you are obligated to register and pay the full meeting registration fee and to attend the Annual Meeting and make the presentation of your abstract, or to follow the Abstract Withdrawal Policy: http://www.arvo.org/Annual_Meeting/Abstracts/AbstractWithdrawalPolicy/

- Membership dues do not include Annual Meeting registration fees. Register by March 6 for the best registration fees: www.arvo.org/Annual_Meeting/Registration

- Failure to register for the meeting, to make your presentation or to comply with the Abstract Withdrawal Policy will result in disqualification from submitting an abstract as First Author for the 2016 ARVO Annual Meeting.

- ARVO Poster Presentation Guidelines with complete details for preparing and making your poster presentation will be available on March 3 at www.arvo.org/Annual_Meeting/Abstracts

- Poster printing is the responsibility of the presenter and will not be available through ARVO. The Poster Presentation Guidelines will include information on conveniently located printing service(s).

- Your poster must be removed within 30 minutes after the Poster Display End Time on your presentation day. ARVO is not responsible for poster materials left at day's end; they will be removed and discarded.

- First/Presenting Authors must fully disclose to ARVO and the session participants all commercial relationships relevant to the subject matter for all authors of the presentation and their spouse or partner for the prior 24 months. A full disclosure will include the name(s) of the commercial interest and the nature of the relationship(s). Indicate "None" if no relationships exist. All full disclosures must be indicated orally and on a slide at the beginning of the presentation. View the ARVO Commercial Relationships Policy for complete reporting requirements: www.arvo.org/About_ARVO/Policies/ARVO_Commercial_Relationships_Policy/

Moderators will be onsite to ensure compliance with these requirements and obligations.

Thank you for participating in this year's Annual Meeting program. If you have any questions about your participation in the Annual Meeting program, please contact arvoabstracts@arvo.org.

Sincerely,
Craig E. Crosson, PhD, FARVO
Executive Vice President and
Chair, Annual Meeting Program Committee
Appendix 9: The New Electronic Questionnaire

URL: https://redcap.sydney.edu.au/surveys/?s=ImrEJhCH5c
Questionnaire of quantifying individual's time spent indoors and outdoors

Preliminary Questionnaire

1. Please try to be as accurate as possible.
2. Please note that the questions are only about one typical weekday not about the whole week, and also is the same for weekend.
3. Numbers, you will mention here, will be calculated from 24 hours.

Please complete the survey below.

Thank you!

---

TITLE: Questionnaire of quantifying individual's time spent indoors and outdoors

In giving my consent I acknowledge that:
1. The procedures required for the project and the time involved have been explained to me, including any inconvenience, risk, discomfort or side effect, and their implications, and any questions I have about the project have been answered to my satisfaction.
2. I have read the Participant Information Statement and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.
3. I understand that being in this study is completely voluntary - I am not under any obligation to consent.
4. I understand that my involvement is strictly confidential. I understand that any research data gathered from the results of the study may be published, however no information about me will be used in any way that is identifiable.
5. I understand that I can withdraw from the study at any time, without affecting my relationship with the researcher(s) or any other institutions relating to the research now or in the future.

By checking this box, I certify that I give my consent freely to participate in this study.

☐ I Consent

First Name


Family Name


Email address


03-12-2018 9:26am
<table>
<thead>
<tr>
<th>Gender</th>
<th>Female</th>
<th>Male</th>
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<tbody>
<tr>
<td>Date of Birth</td>
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### A typical Weekday

**Questions about how you spend your time in a typical weekday**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>During a typical weekday, when do you usually go to sleep at night?</td>
<td></td>
</tr>
<tr>
<td>During a typical weekday, what time do you usually wake up in the morning?</td>
<td></td>
</tr>
<tr>
<td>Sleep time calculated</td>
<td></td>
</tr>
<tr>
<td>During a typical weekday, where are you likely to spend most of your time?</td>
<td></td>
</tr>
<tr>
<td>Options:</td>
<td></td>
</tr>
<tr>
<td>Go to school</td>
<td></td>
</tr>
<tr>
<td>Go to technical education college / university</td>
<td></td>
</tr>
<tr>
<td>Go to work</td>
<td></td>
</tr>
<tr>
<td>Stay at home</td>
<td></td>
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## School

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<tr>
<th>Question</th>
<th>Response Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>During a typical weekday, what time do you usually leave home for school?</td>
<td></td>
</tr>
<tr>
<td>During a typical weekday, what time do you usually arrive at school?</td>
<td></td>
</tr>
<tr>
<td>Calculated travelling time to school</td>
<td></td>
</tr>
<tr>
<td>How do you usually travel to school?</td>
<td>Walk or ride a bicycle, Travel by vehicle (car, bus, train, etc)</td>
</tr>
<tr>
<td>How long time do you need to arrive your school?</td>
<td>0, 15 min, 30 min, 45 min, 1 hour, 1.5 hours, 2 hours</td>
</tr>
<tr>
<td>Do you spend any time outside before starting your school?</td>
<td>Yes, No</td>
</tr>
<tr>
<td>How long time do you stay outside before starting your school?</td>
<td>0, 15 min, 30 min, 45 min, 1 hour, 1.5 hours, 2 hours</td>
</tr>
<tr>
<td>While you are at school, how long do you spend outdoors?</td>
<td>0, 15 min, 30 min, 45 min, 1 hour, 1.5 hours, 2 hours, 2.5 hours, 3 hours, 3.5 hours, 4 hours</td>
</tr>
<tr>
<td>Question</td>
<td>Options</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>While you are at school, how long do you spend indoors?</td>
<td>0&lt;br&gt;15 min&lt;br&gt;30 min&lt;br&gt;45 min&lt;br&gt;1 hour&lt;br&gt;1.5 hours&lt;br&gt;2 hours&lt;br&gt;2.5 hours&lt;br&gt;3 hours&lt;br&gt;3.5 hours&lt;br&gt;4 hours&lt;br&gt;4.5 hours&lt;br&gt;5 hours&lt;br&gt;5.5 hours&lt;br&gt;6 hours&lt;br&gt;6.5 hours&lt;br&gt;7 hours&lt;br&gt;7.5 hours&lt;br&gt;8 hours&lt;br&gt;8.5 hours&lt;br&gt;9 hours</td>
</tr>
<tr>
<td>What time do you usually leave school to go home?</td>
<td></td>
</tr>
<tr>
<td>What time do you usually arrive home after school?</td>
<td></td>
</tr>
<tr>
<td>How do you usually travel to home from school?</td>
<td>Walk or ride a bicycle&lt;br&gt;Travel by vehicle (car, bus, train, etc)</td>
</tr>
<tr>
<td>How long time do you need to arrive your home from the school?</td>
<td>0&lt;br&gt;15 min&lt;br&gt;30 min&lt;br&gt;45 min&lt;br&gt;1 hour&lt;br&gt;1.5 hours&lt;br&gt;2 hours</td>
</tr>
<tr>
<td>Calculated school time</td>
<td></td>
</tr>
<tr>
<td>Calculated travelling time to home</td>
<td></td>
</tr>
<tr>
<td>After leaving school and before sunset during a typical weekday, how long do you spend indoors?</td>
<td>0&lt;br&gt;15 min&lt;br&gt;30 min&lt;br&gt;45 min&lt;br&gt;1 hour&lt;br&gt;1.5 hours&lt;br&gt;2 hours&lt;br&gt;2.5 hours&lt;br&gt;3 hours&lt;br&gt;3.5 hours&lt;br&gt;4 hours</td>
</tr>
<tr>
<td>After leaving school and before sunset during a typical weekday, how long do you spend outdoors?</td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>○ 0 min</td>
<td></td>
</tr>
<tr>
<td>○ 15 min</td>
<td></td>
</tr>
<tr>
<td>○ 30 min</td>
<td></td>
</tr>
<tr>
<td>○ 45 min</td>
<td></td>
</tr>
<tr>
<td>○ 1 hour</td>
<td></td>
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<tr>
<td>○ 1.5 hours</td>
<td></td>
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<tr>
<td>○ 2 hours</td>
<td></td>
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<tr>
<td>○ 2.5 hours</td>
<td></td>
</tr>
<tr>
<td>○ 3 hours</td>
<td></td>
</tr>
<tr>
<td>○ 3.5 hours</td>
<td></td>
</tr>
<tr>
<td>○ 4 hours</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total hours during a typical weekday except nighttime before sleeping</th>
</tr>
</thead>
<tbody>
<tr>
<td>______________________________________________________________________</td>
</tr>
<tr>
<td>Question</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>University</td>
</tr>
<tr>
<td>During a typical weekday, what time do you usually leave home to go to university?</td>
</tr>
<tr>
<td>Calculated travelling time to university</td>
</tr>
<tr>
<td>How do you usually travel to university?</td>
</tr>
<tr>
<td>How long time do you need to arrive your university?</td>
</tr>
<tr>
<td>Do you spend any time outside before starting your university?</td>
</tr>
<tr>
<td>How long time do you stay outside before starting your university?</td>
</tr>
<tr>
<td>While you are at university, how long do you spend outdoors?</td>
</tr>
<tr>
<td>Question</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>While you are at university, how long do you spend indoors?</td>
</tr>
<tr>
<td>What time do you usually leave university to go home?</td>
</tr>
<tr>
<td>What time do you usually arrive home after university?</td>
</tr>
<tr>
<td>How do you usually travel to home after university?</td>
</tr>
<tr>
<td>How long time do you need to arrive your home after university?</td>
</tr>
<tr>
<td>Calculated university time</td>
</tr>
<tr>
<td>Calculated travelling time to home</td>
</tr>
<tr>
<td>After leaving university and before sunset during a typical weekday, how long do you spend indoors?</td>
</tr>
</tbody>
</table>
After leaving university and before sunset during a typical weekday, how long do you spend outdoors?

- 0
- 15 min
- 30 min
- 45 min
- 1 hour
- 1.5 hours
- 2 hours
- 2.5 hours
- 3 hours
- 3.5 hours
- 4 hours

Total hours during a typical weekday except night time before sleeping

______________________________
## Work

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>During a typical weekday, what time do you usually leave home to go to work?</td>
<td></td>
</tr>
<tr>
<td>During a typical weekday, what time do you usually arrive at work?</td>
<td></td>
</tr>
<tr>
<td>Calculated travelling time to work</td>
<td></td>
</tr>
<tr>
<td>How do you usually travel to work?</td>
<td></td>
</tr>
<tr>
<td>How long time do you need to arrive your work?</td>
<td></td>
</tr>
<tr>
<td>Do you spend any time outside before starting your work? DON'T include traveling time</td>
<td>Yes</td>
</tr>
<tr>
<td>How long time do you stay outside before starting your work? DON'T include traveling time</td>
<td></td>
</tr>
<tr>
<td>While you are at work, how long do you spend outdoors? If there is no time outside choose 0.</td>
<td></td>
</tr>
</tbody>
</table>

- **Walk or ride a bicycle**
- **Travel by vehicle (car, bus, train, etc)**
- **0 min**
- **15 min**
- **30 min**
- **45 min**
- **1 hour**
- **1.5 hours**
- **2 hours**
- **Yes**
- **No**
- **0 min**
- **15 min**
- **30 min**
- **45 min**
- **1 hour**
- **1.5 hours**
- **2 hours**
- **0 min**
- **15 min**
- **30 min**
- **45 min**
- **1 hour**
- **1.5 hours**
- **2 hours**
- **2.5 hours**
- **3 hours**
- **3.5 hours**
- **4 hours**
<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>While you are at work, how long do you spend indoors?</td>
<td>0, 15 min, 30 min, 45 min, 1 hour, 1.5 hours, 2 hours, 2.5 hours, 3 hours, 3.5 hours, 4 hours, 4.5 hours, 5 hours, 5.5 hours, 6 hours, 6.5 hours, 7 hours, 7.5 hours, 8 hours, 8.5 hours, 9 hours</td>
</tr>
<tr>
<td>What time do you usually leave work to go home?</td>
<td></td>
</tr>
<tr>
<td>What time do you usually arrive home after work?</td>
<td></td>
</tr>
<tr>
<td>How do you usually travel to home after work?</td>
<td>Walk or ride a bicycle, Travel by vehicle (car, bus, train, etc)</td>
</tr>
<tr>
<td>How long time do you need to arrive your home after work?</td>
<td>0, 15 min, 30 min, 45 min, 1 hour, 1.5 hours, 2 hours</td>
</tr>
<tr>
<td>Calculated work time</td>
<td></td>
</tr>
<tr>
<td>Calculated travelling time to home after work</td>
<td></td>
</tr>
<tr>
<td>After leaving work and before sunset during a typical weekday, how long do you spend indoors?</td>
<td>0, 15 min, 30 min, 45 min, 1 hour, 1.5 hours, 2 hours, 2.5 hours, 3 hours, 3.5 hours, 4 hours</td>
</tr>
<tr>
<td>After leaving work and before sunset during a typical weekday, how long do you spend outdoors?</td>
<td>0</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Total hours during a typical weekday except nighttime before sleeping</td>
<td></td>
</tr>
<tr>
<td>Staying home</td>
<td></td>
</tr>
<tr>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>After waking up, how long do you spend indoors during a typical weekday before sunset?</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>15 min</td>
<td></td>
</tr>
<tr>
<td>30 min</td>
<td></td>
</tr>
<tr>
<td>45 min</td>
<td></td>
</tr>
<tr>
<td>1 hour</td>
<td></td>
</tr>
<tr>
<td>1.5 hours</td>
<td></td>
</tr>
<tr>
<td>2 hours</td>
<td></td>
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<tr>
<td>2.5 hours</td>
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<td>3 hours</td>
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<td>3.5 hours</td>
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<tr>
<td>4 hours</td>
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<tr>
<td>4.5 hours</td>
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<tr>
<td>5 hours</td>
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<tr>
<td>5.5 hours</td>
<td></td>
</tr>
<tr>
<td>6 hours</td>
<td></td>
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<tr>
<td>6.5 hours</td>
<td></td>
</tr>
<tr>
<td>7 hours</td>
<td></td>
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<tr>
<td>7.5 hours</td>
<td></td>
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<tr>
<td>8 hours</td>
<td></td>
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<tr>
<td>8.5 hours</td>
<td></td>
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<tr>
<td>9 hours</td>
<td></td>
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<tr>
<td>9.5 hours</td>
<td></td>
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<tr>
<td>10 hours</td>
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</tr>
<tr>
<td>10.5 hours</td>
<td></td>
</tr>
<tr>
<td>11 hours</td>
<td></td>
</tr>
<tr>
<td>11.5 hours</td>
<td></td>
</tr>
<tr>
<td>12 hours</td>
<td></td>
</tr>
</tbody>
</table>

<p>| After waking up, how long do you spend outdoors during a typical weekday before sunset? |
| 0 |
| 15 min |
| 30 min |
| 45 min |
| 1 hour |
| 1.5 hours |
| 2 hours |
| 2.5 hours |
| 3 hours |
| 3.5 hours |
| 4 hours |
| 4.5 hours |
| 5 hours |
| 5.5 hours |
| 6 hours |
| 6.5 hours |
| 7 hours |
| 7.5 hours |
| 8 hours |
| 8.5 hours |
| 9 hours |
| 9.5 hours |
| 10 hours |
| 10.5 hours |
| 11 hours |
| 11.5 hours |
| 12 hours |</p>
<table>
<thead>
<tr>
<th>How long do you spend in travelling during a typical weekday before sunset?</th>
</tr>
</thead>
<tbody>
<tr>
<td>○ 0</td>
</tr>
<tr>
<td>○ 15 min</td>
</tr>
<tr>
<td>○ 30 min</td>
</tr>
<tr>
<td>○ 45 min</td>
</tr>
<tr>
<td>○ 1 hour</td>
</tr>
<tr>
<td>○ 1.5 hours</td>
</tr>
<tr>
<td>○ 2 hours</td>
</tr>
<tr>
<td>○ 2.5 hours</td>
</tr>
<tr>
<td>○ 3 hours</td>
</tr>
<tr>
<td>○ 3.5 hours</td>
</tr>
<tr>
<td>○ 4 hours</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total hours during a typical weekday except night time before sleeping</th>
</tr>
</thead>
<tbody>
<tr>
<td>________________</td>
</tr>
</tbody>
</table>
**A typical Weekend day**

**Questions about how you spend your time in a typical weekend day**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>During a typical weekend day, when do you usually go to sleep at night?</td>
<td></td>
</tr>
<tr>
<td>During a typical weekend day, what time do you usually wake up in the morning?</td>
<td></td>
</tr>
<tr>
<td>Sleep time calculated</td>
<td></td>
</tr>
<tr>
<td>Do you go to work during your a typical weekend?</td>
<td>Yes</td>
</tr>
<tr>
<td>Do you go to work during your a typical weekend?</td>
<td>No</td>
</tr>
<tr>
<td>During a typical weekend day, what time do you usually leave home to work?</td>
<td></td>
</tr>
<tr>
<td>During a typical weekend day, what time do you usually arrive at work?</td>
<td></td>
</tr>
<tr>
<td>Calculated travelling time to work</td>
<td></td>
</tr>
<tr>
<td>While you are at work, how long time do you spend outdoors? If there is no time outside choose 0.</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>15 min</td>
</tr>
<tr>
<td></td>
<td>30 min</td>
</tr>
<tr>
<td></td>
<td>45 min</td>
</tr>
<tr>
<td></td>
<td>1 hour</td>
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<td></td>
<td>1.5 hours</td>
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<td></td>
<td>2 hours</td>
</tr>
<tr>
<td></td>
<td>2.5 hours</td>
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<tr>
<td></td>
<td>3 hours</td>
</tr>
<tr>
<td></td>
<td>3.5 hours</td>
</tr>
<tr>
<td></td>
<td>4 hours</td>
</tr>
<tr>
<td>Question</td>
<td>Options</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>While you are at work, how long time do you spend indoors?</td>
<td>0 15 min 30 min 45 min 1 hour 1.5 hours 2 hours 2.5 hours 3 hours 3.5 hours 4 hours 4.5 hours 5 hours 5.5 hours 6 hours 6.5 hours 7 hours 7.5 hours 8 hours 8.5 hours 9 hours</td>
</tr>
<tr>
<td>During a typical weekend day, what time do you usually leave work to home?</td>
<td>_________________________</td>
</tr>
<tr>
<td>During a typical weekend day, what time do you usually arrive home after work?</td>
<td>_________________________</td>
</tr>
<tr>
<td>Calculated work time</td>
<td>_________________________</td>
</tr>
<tr>
<td>Calculated travelling time to home after work</td>
<td>_________________________</td>
</tr>
<tr>
<td>After waking up, how long do you spend indoors during a typical weekend day before sunset? Don't include working time if you are working</td>
<td>0</td>
</tr>
<tr>
<td>After waking up, how long do you spend outdoors during a typical weekend day before sunset? Don't include working time if you are working</td>
<td>0</td>
</tr>
<tr>
<td>Question</td>
<td>Options</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>How long do you spend in travelling during a typical weekend day before</td>
<td>0 15 min 30 min 45 min</td>
</tr>
<tr>
<td>sunset? Don't include travelling to work if you are working</td>
<td>1 hour 1.5 hours 2 hours</td>
</tr>
<tr>
<td>Total hours during a typical weekend day except night time before</td>
<td>________________________</td>
</tr>
<tr>
<td>sleeping</td>
<td></td>
</tr>
<tr>
<td>Do you have any other comments?</td>
<td>________________________</td>
</tr>
</tbody>
</table>