TIME SPENT OUTDOORS AND OTHER ENVIRONMENTAL FACTORS PREDICTIVE OF MYOPIA

A thesis presented to the graduate faculty of

the New England College of Optometry in partial fulfillment

of the requirements for the degree of Master of Science

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ABSTRACT

TIME SPENT OUTDOORS AND OTHER ENVIRONMENTAL FACTORS PREDICTIVE OF MYOPIA

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Background: The amount of time children spend outdoors as well as other environmental factors such as exposure to different light spectral compositions, activity levels, sleep habits, and near work, have all been proposed to be predictive of myopia development. This prospective study aims to investigate environmental behaviors in young children prior to the development of myopia and to evaluate the effectiveness of different subjective and objective methods to measure such behaviors.

Methods: During the Summers of 2021 and 2022, 31 children (8.26 ± 1.06 years, N=17 at High Risk for developing myopia, HR, N=14 at Low Risk for myopia, LR) participated in a 2-week trial. Behavioral measures were obtained using the Actiwatch and two separate subjective measures, Daily Surveys and PICNIC questionnaires. Objective and subjective measures of average minutes spent outdoors each day were compared between children at HR for myopia as well as those that did develop myopia with those at LR for myopia. The number of transitions from indoor to outdoor environments were also evaluated. Secondary outcome measures included light wavelength exposure, activity levels, sleep behaviors, and near work. For all children, biometry (axial length, AXL), refraction (cycloplegic spherical equivalent, SE), and other visual, health, and demographic data were obtained.

Additionally, four different wearables that can be used for objective measures of environmental factors were evaluated in three small trials conducted on young adult subjects who wore multiple devices simultaneously and completed detailed daily activity diaries. Outdoor time, transitions between indoors and outdoors and viewing distances were compared between devices. A validity test was also conducted to compare these devices to standard light meters under various lighting conditions.

Results: The average outdoor time per day measured with the Actiwatch (89.42±46.85mins) was significantly ($p<0.01$) shorter than parent Daily Survey responses (203.18±105.70mins), although a good correlation was found between the two methods ($R=0.72$, $p<0.01$). Children at HR for myopia spent less time outdoors than those at LR ($p<0.01$). The four children that developed myopia also spent less time outdoors than those at LR ($p<0.01$). A significant correlation was found between time outdoors and refraction ($p<0.01$), but not with AXL. The number of transitions per day measured with the Actiwatch were unrealistically high (Actiwatch: 37.28±13.25; PICNIC questionnaires: 4.37±5.33). No differences in activity times, sleep patterns or near work time were noted between the groups.

In the Comparison Trials, variable results were noted between the different objective methods, with the HOBO pendant, ClouClip and Vivior devices showing more comparable results than the Actiwatch. The Actiwatch also reported the highest average transitions per day. The Validity Test showed that when indoors next to a window or when outdoors in direct sun, shade, or in a car, all devices measured >1,000 lux, indicating time outdoors. For the other three conditions (inside natural light, inside full illumination and computer screen), all devices measured < 1,000 lux (except HOBO inside natural light 1097.9 lux).

Conclusions: Children at HR for myopia spend significantly less time outdoors than those at LR, supporting the hypothesis that time outdoors is protective of myopia. When used in children, objective methods give less time outdoors than subjective responses from parents. The unrealistic number of transitions from indoors to outdoors per day provided by the objective devices, particularly the Actiwatch, indicates that these wearables may sometimes underestimate the time spent outdoors. A combination of parents overestimating outdoor time and errors in objective measures seems to be the cause of the lack of correlation between the methods. The Validity test showed that the Actiwatch underestimated light exposure for all conditions compared to a standard light meter, with variable but more accurate results for the other devices. A non-statistically significant trend was noted toward increased near work times and shorter working distances in children at HR for myopia. However, the near work results were limited and generally inconclusive, therefore further work is needed to investigate the causative effects of near work duration and distance in myopia development.

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1. GENERAL INTRODUCTION

1.1. Myopia

Myopia is considered a failure of normal emmetropization (Flitcroft 2013). Normal eye growth during early childhood compensates for the changes that occur in the optical components of the eye, primarily the cornea and crystalline lens. In many children, this process is disrupted and the eye continues to grow excessively long, causing myopia. The reasons for this failure of the normal emmetropization process and consequent excessive elongation of the eye causing myopia are currently unknown.

It is well known in the eyecare community that the prevalence of myopia is rapidly increasing, and myopia is a global healthcare concern. It is predicted that by the year 2050, 49.8% of the world's population will have myopia and 9.8% will have high myopia (Holden et al. 2016). Myopia onset is also starting to occur earlier in children. The Northern Ireland Childhood Errors of Refraction (NICER) longitudinal study from the UK conducted from 2006 to 2015 concluded that children are becoming myopic at a younger age when comparing the result of their 6-7 year subjects to the age-matched group of the Sorsby study conducted in the 1950s and 1960s (McCullough et al. 2016).

Although myopia can be corrected with spectacles, contact lenses, or refractive surgery, none of these methods reduce the health risks associated with myopia. A study by Rose et al. (2000) evaluated visual function and quality of life in people with varying degrees of myopia and found that individuals with myopia were most likely to "cite concrete instances of how their eyesight adversely affected their lives" (Rose, 2000). Relying on optical correction to

safely navigate the world puts patients at risk when that correction is lost, broken, unaffordable, or inaccessible. In 2020, it was estimated that myopia's annual direct costs in the USA are $3.9 – 7.2 billion (Foo et al. 2021). Many people with myopia do not have access to optical correction of their refractive error due to cost and inaccessibility of care, even in the United States. Fricke et al. proposed that there were approximately 158 million cases of distance vision impairment caused by uncorrected refractive error worldwide in 2007 (Fricke et al. 2012). Because individuals with uncorrected myopia are visually impaired, their ability to contribute to society is hindered, leading to potential productivity loss of $121.4 billion worldwide (Smith 2009).

Even when a patient with myopia has access to eye care and their myopia is corrected, myopia is a significant health concern because it poses a high risk for blindness. Myopia, even low myopia, significantly increases the risk for myopic maculopathy, cataracts, retinal detachments, and glaucoma (Holden et al. 2016; Sankaridurg et al. 2018). The risk for these conditions increases with higher amounts of myopia but can occur at any level of myopia (Haarman et al. 2020). Individuals with myopia have a twofold to threefold increased risk of glaucoma compared with those without myopia (Mitchell et al. 1999). Due to elongation of the eye causing stretching and thinning of the retina, their incidence rate of developing a rhegmatogenous retinal detachment is also threefold greater than non-myopes (Ludwig et al. 2023). Myopic macular degeneration (maculopathy) can present with posterior staphylomas, lacquer cracks, chorioretinal atrophy, and even choroidal neovascular membranes (Williams and Hammond 2019). All of these complications associated with myopia can lead to irreversible vision loss.

Due to the increasing prevalence and complications associated with myopia, the field of myopia management, prevention, and control has gained significant attention in recent years. The ultimate goal of clinicians, scientists, and others working on the problem of myopia is to prevent myopia before it develops. However, to prevent myopia, we need to understand the mechanisms of emmetropization and its failures, which are still unclear.

Although many genetic variations have been found to be linked to myopia (Wang et al. 2022), it appears that the etiology of myopia is primarily environmental, with only 12.5% of the variability accounted for by genetics (Zhang et al. 2020). It is known that children with myopic parents are at a greater risk for myopia and that both parents being myopic poses an even greater risk (Goldschmidt and Jacobsen 2014). However, there has been substantial evidence that it is modifiable behaviors of the child that play the primary role in whether or not they become myopic. These behaviors include higher rates of near work, closer working distances, and less time outdoors (Philipp et al. 2022). The specifics of how these environmental factors play a role are still unclear. We know that most infants are born hyperopic, and their hyperopic refractive error is believed to begin the process of visually guided feedback signaling to the retina for eye growth (Chakraborty et al. 2020). We do not know what affects the emmetropization signaling process, but some proposed mechanisms include inaccurate accommodation and retinal blur, both peripherally and centrally (Rose et al. 2016). The environmental factors associated with myopia interfere with the emmetropization process and cause excessive signaling for eye elongation, but how this happens remains to be determined.

When children already have myopia, it is important to try to slow down its progression since the lower the amount of myopia they end up with when they reach adulthood, the lower the risk for associated complications (Williams and Hammond 2019, Bullimore et al. 2021). Treatments such as specially-designed spectacles and contact lenses, orthokeratology contact lenses, and low-dose atropine drops are being used for the clinical care of children with myopia (Lam et al. 2020; Fang et al. 2022; Yam et al. 2023). Although these treatment options have been successful at controlling the progression of myopia to a certain extent, they do not work on all children, and clinicians cannot predict which children will benefit from either treatment. This is because the mechanism of action of these treatments are also unknown (Sankaridurg et al. 2018).

Research on the impact of the visual environment in myopia development is necessary to understand myopia's etiology and develop successful prevention strategies and behavioral treatments. We need to establish a better understanding of children's behaviors, including how much time they spend outdoors, which light spectral compositions they are exposed to, their activity levels, sleep patterns, and how much near work they are doing, as these are all likely contributing factors in whether they develop myopia or not. The purpose of my thesis is to evaluate these behaviors in young children prior to becoming myopic.

1.2. PICNIC Study

The PICNIC study (Preventing myopia: an Investigation of Contributing Factors to Nearsightedness In Children) conducted at NECO was developed to identify factors that may predispose children to develop myopia. This longitudinal study evaluates multiple biometric,

oculometric, visual, and behavioral parameters in young children with functional emmetropia over three years to determine which factors are different in those children who develop myopia.

My thesis project is a sub-study within PICNIC that aims to evaluate the time children spend outdoors and other environmental factors that may be predictive of myopia, including exposure to different light spectral compositions, activity levels, sleep habits, and amount and type of near work.

1.3. Outdoors

Epidemiological and interventional studies have documented that spending more time outdoors reduces the risk of myopia development in children (Wu et al. 2013; He et al. 2015; Xiong et al. 2017). For example, a study done in Guangzhou, China, from 2010 to 2013 found that adding 40 minutes of outdoor activity at school resulted in a reduced incidence rate of myopia over the next 3 years in a group of 6-year-old children (He et al. 2015). A similar study in Taiwan found that encouraging children to go outside during their 80 minutes a day of recess significantly affected the control of myopia onset and myopic shift in nonmyopic children (Wu et al. 2013). Many other studies using questionnaires to assess time spent outdoors have also found results that suggest a protective effect of outdoor time on myopia development (Li et al. 2015; Guo et al. 2019; Jonas et al. 2021). This effect appears to be dose-dependent, with longer outdoor durations and likely higher light intensities being more beneficial (He et al. 2022). A recent study also found a reduction in axial elongation and myopia progression in schoolchildren over three years if parents were sent text messages

twice a day reminding them to take their children outdoors and encouraged their children to spend more time outdoors (although only on the weekends) (Li et al. 2022).

If myopia does develop, outdoor time may also slow its progression. Several studies have shown reduced myopia progression with increased time outdoors, as assessed with questionnaires (Guo et al. 2019; Pärssinen and Kauppinen 2019; Gupta et al. 2021). In the Correction of Myopia Evaluation Trial (COMET) they found slower progression of myopia in summer compare to winter months and felt this was likely being related to children's spending more time outdoors and fewer hours in school (Gwiazda et al. 2014). Another study conducted by Wu et al. from 2013 to 2015 using a school-based outdoor promotion program that encouraged 11 hours a week outside showed approximately 30% (0.23 D/0.79 D) reduction in progression in one year for their myopic subjects. Although this reduction in myopia progression is not as high as with treatments such as orthokeratology or atropine eye drops, increased outdoor time may still be beneficial in conjunction with other treatments. On the other hand, not all studies agree, and some suggest that outdoor time may not affect progression once myopia has developed (Jones-Jordan et al. 2012; Wu et al. 2013; Li et al. 2015).

It is still unclear exactly how outdoor time is protective of myopia. Previous studies have shown that the mechanism is likely related to the higher light intensity outdoors and the broad spectral composition of sunlight (Dhakal et al. 2023a). The dynamics of the outdoor environments are also likely important (Kerber et al. 2022; Read et al. 2023), as the pattern of light exposure is more dynamic outdoors (the intensity of light can vary rapidly from

130,000 to 10,000 lux just by a passing cloud) (Bhandary et al. 2021). The dioptric distances (i.e. objects being further away) in an outdoor environment are also likely to play a role (Neil Charman 2011; Flitcroft 2012). It has been suggested that a potential protective mechanism of outdoor time is that the environment consists of objects that are further away and have "fewer dioptric variations across the visual scene, providing a more uniform pattern of retinal defocus (Zhang and Deng 2020)." In contrast, an indoor visual environment contains objects that are closer at fixation and further away in the periphery, which causes higher levels of retinal defocus (Zhang and Deng 2020). It is likely a combination of all of these factors that contribute to the protective effects of an outdoor environment.

1.4. Light Spectral Composition

Sunlight is very different from artificial lights, which is likely a contributing factor to outdoor time being protective of myopia. The main differences between the two are their spectral composition and intensity. Light intensity is higher in natural light outdoors than in an artificial indoor setting. A study comparing median illuminance levels in different indoor and outdoor locations found that outdoor locations were eight times higher than indoor locations (median:1175 lux, range: 197-5400 lux vs. median: 179 lux, range 50-333 lux) (Bhandary et al. 2021). In this study, the median light levels for the outdoor locations included "Open playground" (14350 lux), "Under a glass bowl" (simulation for "glass classroom model" in outdoor location) (13300 lux), "Under translucent artificial shade" (9600 lux), "Under a porch facing south" (2200 lux), "Under a porch facing east" (685 lux), "Under big tree" (1700 lux), "Between 3 buildings" (500 lux), "Canopy" (178 lux) and

"Within 4 buildings"(17 lux) (Bhandary et al. 2021). The indoor locations included "Room with multiple large windows" (2650 lux), "Room with multiple artificial lights" (290 lux), "Room with a combination light source" (240 lux) and "Room with single artificial light" (14 lux) (Bhandary et al. 2021). These differences in light intensity between sunlight and artificial light are likely contributing to the protective mechanisms of outdoor time.

Light intensity levels alter circadian rhythms and disruptions of these rhythms have been shown to affect eye growth. Studies using a chick model have found that altering the circadian rhythms by abolishing the diurnal cues with constant darkness or constant light results in excessive ocular elongation and corneal flattening (Nickla 2013). As suggested by Dr. Nickla, this may indicate that "emmetropization requires a normal light/dark cycle to synchronize ocular rhythms, and without this, a default growth mode is adopted" (Nickla 2013). Some possible mechanisms of how this disruption causes eye growth include changes in choroidal thickening (Nickla et al. 1998b), retinal dopamine levels (Stone et al. 1989), intraocular pressure (Nickla et al. 1998a), and melatonin levels (Hoffmann and Schaeffel 1996). Animal models showing these effects have prompted studies in humans investigating the effects of circadian rhythms and the effects of exposure to different intensities of light on myopia. Studies in humans have found evidence that diurnal variations in axial length are higher in amplitude in myopes than emmetropes. Less time exposed to bright light is associated with a larger amplitude of diurnal axial length change (Ulaganathan et al. 2019). Another study found that increased daily time exposed to light levels >3000 lux per day was significantly associated with less axial eye growth whereas daily time exposed to light >1000 lux and >2000 lux did not show a significant association with eye growth (Read et al. 2015).

This indicates that the mechanisms controlling eye growth in humans may be sensitive to the intensity of light outdoors.

The other difference between natural and artificial light is that sunlight is a broadband light source containing the full spectrum of visible wavelengths, including all colors of visible light as well as infrared and ultraviolet light (Thorington 1985). Artificial lights, on the other hand, are usually narrow band and contain only some wavelengths of visible light (Thorington 1985). When comparing daytime outdoor and indoor environments, the spectral power distribution of wavelengths (short: below 500 nm, middle: 505-565 nm, long: above 620 nm) will always be higher outside regardless of location or season, meaning that the natural light spreads more evenly across the visible spectrum with no peaks for specific wavelengths (Dhakal et al. 2023a).

The spectral composition of light appears to contribute to emmetropization signals and myopia development and is believed to be related to longitudinal chromatic aberrations causing wavelength defocus and chromatic cues (Yoon et al. 2021). Blue light exposure has been shown to potentially be beneficial for normal emmetropization in animal studies when compared to red light in chicks (Foulds et al. 2013) yellow light in chicks (Rucker et al. 2015, 2018) and white light in guinea pigs (Yu et al. 2021). The timing and intensity of this light exposure also appears to play a complex but important role (Nickla et al. 2022, 2023).

These findings in animal models have prompted studies in humans regarding the effect of short-wavelength exposure on myopia. A study using violet light transmitting and blocking glasses and contact lenses found that exposure to the violet portion of the spectrum (360–400

nm wavelength) may aid in slowing myopia development (Torii et al. 2017). Another study in humans exposed to one hour of blue, red and green light between 8:00 and 11:00 AM found that red and green light resulted in axial elongation, and blue light resulted in elongation inhibition (Thakur et al. 2021). However, in a study in healthy adult subjects, exposure to blue light in the evening induced a two-fold greater circadian phase delay and twice the amount of melatonin suppression compared to green light which may have an effect on eye growth (Lockley et al. 2003). Overall, these findings in animal and human studies may indicate that increased blue light exposure during the daytime is necessary for normal emmetropization.

Although rearing chicks in blue light has been shown to cause progressive hyperopia while red light caused progressive myopia (Foulds et al. 2013) studies involving tree shrews and monkeys have shown the opposite in that red light exposure induced hyperopia (Gawne et al. 2017b, 2017a; Hung et al. 2018; Ward et al. 2018). Several clinical trials in China have begun to consider the use of red light exposure in myopia management and have shown some success in slowing progression (Jiang et al. 2022; Tian et al. 2022; Chen et al. 2023). However, the safety of these treatments has been questioned and need to be evaluated further (Ostrin and Schill 2024). All of these findings in human and animal studies indicate that the spectral composition of natural light outdoors is likely contributing to the protective effects of outdoor time against myopia, but the role of red and blue light remains unclear.

One study reporting the exposure to different spectral compositions of light in human eyes found no statistical difference in exposure to red, green, and blue light between their

myopic and emmetropic subjects (Ostrin 2017). More research is needed to investigate these conflicting findings on red light vs. blue light exposure and their effects on myopia development.

1.5. Activity Levels

It has been questioned whether the decreased risk for myopia with longer outdoor exposure may be simply due to the increased activity level that often comes with being outside. Previous studies over the last 40 years have consistently shown that lower activity levels are associated with myopia development (Pärssinen et al. 1985; Mutti et al. 2002; Khader et al. 2006; Jacobsen et al. 2008; O'Donoghue et al. 2015). However, when specifically looking at outdoor vs. indoor activity, only outdoor activities are correlated with myopia (Dirani et al. 2009). Other studies have also found evidence that outdoor time and not activity levels are protective of myopia development (Guggenheim et al. 2012; Read et al. 2014, 2015; Ostrin et al. 2017). Additional studies confirming that it is outdoor time and not physical activity will be beneficial.

1.6. Sleep

Along with circadian rhythms, research has also indicated that sleep patterns may be related to myopia. One study measuring melatonin levels and sleep patterns in adults found a delay in melatonin onset after sleep, reduced melatonin levels, greater sleep onset latency (taking longer to fall asleep), and shorter sleep duration in myopes (Chakraborty et al. 2021). In December 2023, a meta-analysis was published reviewing eighteen studies regarding sleep and myopia including 49,277 children under 19 years of age (Jin et al. 2023). There were

mixed results among the studies that they analyzed. The largest cross-sectional study of 12-19-year-old children found those who slept for 8 hours had "half the chances of myopia compared to those sleeping < 5 h, with every one-hour increase in sleep duration lowering the odds of having myopia by 10%" (Jee et al. 2016). However, when looking at all the studies as a whole, they found "no significant correlation between sleep and myopia prevalence (OR = 0.905, 95% CI = 0.782 to 1.047)" (Jin et al. 2023). Instead, they found that earlier bedtimes and later wake times may have a protective effect against myopia (Liu et al. 2020; Qu et al. 2020). However, these findings have not been seen in studies using objective measures of sleep patterns. Instead, studies using the Actiwatch have indicated no difference in sleep duration, bedtime or wake time when comparing myopic and non-myopic subjects and only more variable sleep duration and shorter sleep latency (taking less time to fall asleep) in myopes (Ostrin et al. 2020; Mirhajianmoghadam et al. 2021; Bhandari et al. 2022).

1.7. Near Work

While outdoor time has only been studied as a factor in myopia development for about 20 years, near work has been investigated as a risk factor for myopia development for centuries. Authors have "warned against near work" to prevent myopia since Bartisch in 1583 (De Jong 2018). There were many theories about the causes of myopia from the 17th-19th century, but the most common was "extra convergence on near work" (De Jong 2018). In 1813, it was first suggested that myopia occurred more in people of higher social class with more education, and in the 1970's studies began to settle the debate between the biological (genetic) theory and the use-abuse theory (Angle and Wissmann 1978, 1980). Although the

term use-abuse is no longer used to describe the interaction between near work and myopia development, many human and animal studies over the years have made it evident that it is an “interplay between genetic and the environmental factors” including near work that result in myopia and not genetics alone (Cooper and Tkatchenko 2018).

For example, a prospective study conducted in China in 2016 with N=4,814 participant children (1st to 4th grade students aged 6-10 years old) found that “independent of hereditary factors,” near work behaviors such as daily near workload, inappropriate distance for near work, inadequate lighting environments, and continuing to do near work without breaks were “risk factors for myopic shifts” (You et al. 2016). A questionnaire-based study by Lin et al. found that children with a greater near workload at baseline exhibited more myopic refractive change and were more likely to develop myopia (Lin et al. 2016). Huang and colleagues also found similar results using reports from parents, noting that a longer distance of near work and discontinuing near work every 30 minutes are protective behaviors in myopia prevalence and progression (Huang et al. 2020). Studies using objective measures of near work in children have also found that myopes spent more time in near and intermediate viewing than non-myopes (Wen et al. 2020; Bhandari et al. 2022).

In addition to myopia development in children, near work has also been shown to affect myopia progression in adults. Occupational exposure to near work has been associated with a 20% increase in the odds of myopia in studies looking at jobs with high accommodative demands, such as clinical microscopy, law students and medical students (Dutheil et al. 2023).

With the increased use of technology in children, especially since the COVID-19 pandemic and associated lock down periods, it is important that we investigate the effects of digital versus physical media and true near work versus intermediate computer distances on myopia development and progression. The creation of wearable technology allows us to measure real-time viewing distances, which has prompted pediatric studies investigate these questions (Wen et al. 2019, 2020; Bhandari and Ostrin 2022; Bhandari et al. 2022). The results of these previous studies have been limited by the difficulty in separating near from intermediate tasks. For example, Bhandari et al. discuss their choice to combine near and intermediate tasks for analysis because they considered using a computer an intermediate task for the subjective survey, but it is likely that many children actually view the computer at a closer distance (<60 cm) and would objectively be included in near tasks (Bhandari et al. 2022). All of these studies were done with children but included myopic and non-myopic subjects. Prospective studies involving near work with and without electronic devices in children before and after they develop myopia are needed. This is especially important as near work demands and electronic use continue to increase.

1.8. Subjective vs. Objective Measures of Visual Environments and Visual Behaviors

In the past, subjective questionnaires and diaries have been used to evaluate the visual environment children are exposed to, e.g., time spent outdoors, doing near work, sleep and activity levels with myopia status. These subjective measures are likely highly unreliable. More recently, studies have begun to use objective measures of light exposure (to evaluate

time spent outdoors), viewing distance (to evaluate time and distances during near work), activity levels (light, moderate and rigorous), and sleep patterns (bed/wake times, sleep duration) using various types of wearables with embedded accelerometers and light meters.

Some studies have used subjective measures for some variables and objective measures for others. For example, the Avon Longitudinal Study of Parents and Children used questionnaires to assess outdoor time and accelerometers worn on the subjects' hips to assess activity levels (Guggenheim et al. 2012). Another study used an objective cycle ergometer to confirm the accuracy of subjective responses about physical activity rather than taking real time objective measures (Jacobsen et al. 2008). Near work has only been measured objectively in recent years, due to the development of glasses-mounted devices that can measure viewing distances in real time. With the increase in availability and accuracy of devices to measure environmental behaviors, we now can compare subjective and objective outcome measures.

Studies evaluating outdoor exposure using both subjective and objective methods have shown mixed results. For example, a study conducted in 2012 on 117 children from Singapore compared results from the HOBO Pendant light meter to the answers of parents filling out a diary for one week (Dharani et al. 2012). They found a poor correlation between objective and subjective measures. Another study also found a poor correlation between subjective and objective measures in 27 young adult students from the University of California, Berkeley (Alvarez and Wildsoet 2013). However, a study of 124 radiologic technologists, all 40+ years of age, showed a good correlation between a UVR tracker and a diary, but correlation depended on the time of day and the type of activity (Chodick et al.

2008). It has been suggested that adults tend to overestimate their own time spent outdoors, but when parents respond about their children, their answers may more closely match objective measures (Ostrin 2017; Ostrin et al. 2018). A group in Australia found that their "average questionnaire-derived outdoor time was also significantly correlated with average daily light exposure" measured objectively for both the warmer and cooler days (Read et al. 2015). Due to these inconsistencies in findings, more research is needed. We specifically need studies that compare subjective and objective measurements in school -aged children during the time when they are at risk for myopia development. The more we learn about how to best measure these environmental behaviors, the closer we will be to developing preventative strategies.

One limitation of previous subjective measures of the visual environment is that most studies do not publish their questionnaires or the format of the diaries they use. More details are needed in the published reports to help understand if the subjective measures are unreliable or if the survey methods being used are not detailed enough to accurately capture the sought-after behavior. Gajjar and Ostrin addressed this concern in their recently published article about the new University of Houston near work, environment, activity, and refraction (UH NEAR) survey for myopia (Gajjar and Ostrin 2023). Their goal was to create a standard questionnaire that can be used across studies. Hopefully, this will provide more consistent subjective measures in myopia research moving forward.

Several devices have been used in myopia research to objectively track time outdoors by measuring light exposure. The Actiwatch Spectrum Plus was the initial device selected for

the assessment of time outdoors (Chapter 4), exposure to different light spectral composition (Chapter 5), activity levels (Chapter 6) and sleep patterns (Chapter 7) in children participating in the PICNIC study. This device has been validated as a tool to track light exposure in several clinical trials including children (Read et al. 2014, 2015; Ostrin 2017; Ostrin et al. 2018; Shneor et al. 2024).

As we gained access to other devices, after the initiation of my studies, we developed several comparison trials (Chapter 9). For these, the following devices were compared: Actiwatch Spectrum Plus (Figure 1.1.), the HOBO pendant (64K UA-002-64, Onset Computer Corporation) (Figure 1.2.), Clouclip M2 (Figure 1.3.), and the Vivior Mark 3+ Visual Behaviour Monitor (Figure 1.4.). The iPhone application Lux Light Meter Pro (Figure 1.5.) and the Dr. Meter LX1330B light meter (Figure 1.6.) were used as gold standard measures of amount of light.

					
Figure 1.1. *Actiwatch Spectrum Plus*	***Figure 1.2.*** *HOBO Pendant*	***Figure 1.3.*** *ClouClip Device*	***Figure 1.4.*** *Vivior Device*	***Figure 1.5.*** *Lux Light Meter Pro iPhone App*	***Figure 1.6.*** *Dr. Meter LX1330B*

The HOBO pendant has been used in some of the initial studies investigating outdoor time and myopia (Dharani et al. 2012; Schmid et al. 2013; Wu et al. 2018). It is the most cost-effective option and, therefore would be the likely choice in a large-scale study, which

makes it an important device to include in our comparisons. The Clouclip is a newer, glasses-mounted device that was specifically designed for myopia and has already been used in several studies regarding near tasks and light exposure (Wen et al. 2020; Bhandari et al. 2022; Bhandari and Ostrin 2022; Bhandari, Mirhajianmoghadam, and Ostrin 2021; Wen et al. 2020; 2021; 2019; Y. Zhang et al. 2023; Howell et al. 2021). The Vivior is also glasses-mounted and has been used in several studies with adult patients to assess typical viewing distance and lighting conditions in presbyopic patients (Pajic et al. 2020; Ribeiro et al. 2022).

2. SPECIFIC AIMS AND HYPOTHESES

The overall objective of my thesis is to use prospective studies to investigate environmental behaviors that may be predictive of myopia development in children before they develop myopia and to investigate the effectiveness of different methods to measure these behaviors.

The specific aims of my studies are:

Aim-1: To assess the association between myopia development and time spent outdoors (primary outcome measure) obtained with objective and subjective measures before the onset of myopia in young children.

For this purpose, we subjectively and objectively measured time spent outdoors in a group of young children before myopia development. Objective measures were obtained with Actiwatch Spectrum Plus wearables devices worn for a 2-week time period during the Summers of 2021 and 2022 by a total of 31 children enrolled in the PICNIC study. Subjective measures of time outdoors obtained from surveys and questionnaires completed by the parents were compared to the objective measures of time outdoors.

Hypotheses: (1) Subjective methods overestimate the time spent outdoors compared to objective measures, and (2) children who are at High Risk for developing myopia and children who have already developed myopia spend less time outdoors than those who are at Low Risk for developing myopia and those that remain emmetropic.

Aim-2: To assess the association between myopia development and secondary outcomes obtained with objective and subjective measures.

For this purpose, we analyzed Actiwatch and PICNIC questionnaire data from the 2-week trials for: daily minutes of near work, activity levels, sleep patterns, and blue, red and green light exposure.

Hypotheses: (1) Children at High Risk for myopia have lower exposure to blue light but similar exposure to green and red light compared to those at Low Risk; (2) physical activity will not be associated with myopia risk group; (3) children at High Risk for myopia and those who have developed myopia will subjectively report more time doing near work than those at Low Risk; (4) children at High Risk for myopia and those who develop myopia will have a shorter sleep duration and later bedtimes compared to those at Low Risk.

Aim-3: To create a questionnaire of children's visual environment that may be used in myopia research and as a clinical tool to help parents evaluate their child's adaptable environmental behaviors.

We evaluated a weekly activity log (Appendix II) with the families participating in the 90-day trial during the Winter of 2021. After the study had been completed, we surveyed the parents, asking for feedback on the effectiveness of the log and how to improve it. We used this feedback to improve the questionnaire and delivered it again during the second 2-week trial during the Summer of 2022.

Hypothesis: (1) a comprehensive questionnaire that depicts children's behaviors may be developed as a useful educational tool for parents.

Aim-4: To compare available objective methods to measure visual environment that can be used in myopia research.

We conducted three comparison studies while young adult subjects simultaneously wore various devices. Subjects also completed a thorough activity diary of each time they went outdoors. In an additional validity study, one subject simultaneously wore five devices to assess objective measurement methods in the short term but under different lighting conditions with two light meters.

Hypotheses: (1) Adult subjects' subjective responses will more closely match their objective measures than those in children, as provided by parents. (2) There will be a significant difference between objective measures from each device, with the average light measured by the two glasses-mounted devices being closest to those from the light meter.

3. GENERAL METHODOLOGY

Several studies were conducted as part of the thesis. Table 3.1. below provides an overview of the studies conducted. Each study is described in detail in sections 3.1 and 3.2.

Study	Subjects (n)	Length	Date	Objective	Subjective
PICNIC Summer 1	20 PICNIC children	2 weeks	July-Sept 2021	· Actiwatch	· Daily Survey (outdoor time only) via text · PICNIC Questionnaire (Appendix I) electronic
PICNIC Winter	6 PICNIC children	90 days	Dec 2021-Mar 2022	· Actiwatch	· PICNIC Questionnaire (Appendix I) electronic · Activity Log 1 (Appendix II) physical paper
PICNIC Summer 2	11 PICNIC children	2 weeks	June-Sept 2022	· Actiwatch	· Daily Survey (including sleep) via text · PICNIC Questionnaire (Appendix I) electronic · Activity Log 2 (Appendix III) electronic
Comparison Trial 1	3 adults	7 days	October 2022	· Actiwatch · HOBO	· Activity Diary: list exact times going outdoors/indoors
Comparison Trial 2	3 adults	4 days	March 2023	· Actiwatch · HOBO · ClouClip	· Activity Diary: list exact times going outdoors/indoors/in vehicle
Comparison Trial 3	1 adult	4 days	May 2023	· Actiwatch · HOBO · ClouClip · Vivior	· Activity Diary: list exact times going outdoors/indoors/in vehicle
Validity Test	1 adult	5 min per test	May 2023	· Actiwatch · HOBO · ClouClip x2 · Vivior · Dr. Meter · Light meter app	· None

Table 3.1. *Description of all the studies conducted as part of this thesis.*

3.1. PICNIC Subject Participants in Actiwatch Trials

To be enrolled in the PICNIC study, children needed to be: 6 to 8 years old at baseline, with BCVA in each eye 0.1 LogMAR (20/25 equivalent) or better, cycloplegic functional emmetropia (SE OD ≤ +2.50D and > -0.25D, SE OS ≤ +2.75D and > -0.50D), astigmatism <0.75D OD and < 1.00D OS, anisometropia < 0.75D, normal accommodation and binocular

vision, no history of eye surgery or disease, no ocular or systemic drugs that may affect vision and no history of seizures or epilepsy.

At the time of enrollment, the subjects were categorized as either High Risk (HR) or Low Risk (LR) for myopia based on the two main predictors of myopia: parental myopia and the child's refractive error at enrollment (Zadnik et al. 1999; Ghorbani Mojarrad et al. 2018; Vera-Diaz et al. 2023). Specific inclusion criteria for the HR and LR groups are defined in Table 3.2.

Parental Myopia	***Age***	***High Risk***	***Low Risk***
One or two biological parents have myopia	6 years	+1.50D ≥ M > -0.25D	+2.50D ≥ M > +1.50D
	7 years	+1.00D ≥ M > -0.25D	+2.25D ≥ M > +1.00D
	8 years	+0.75D ≥ M > -0.25D	+2.00D ≥ M > +0.75D
Zero biological parents have myopia	6 years	+1.00D ≥ M > -0.25D	+2.50D ≥ M > +1.00D
	7 years	+0.75D ≥ M > -0.25D	+2.25D ≥ M > +0.75D
	8 years	+0.50D ≥ M > -0.25D	+2.25D ≥ M > +0.50D

Table 3.2. *Specific inclusion criteria for the HR and LR groups used during recruitment. M for the right eye (OD), measured with cycloplegic open-field autorefraction.*

Children participating in the PICNIC study are evaluated every six months over 3 years. At each visit, participants have a comprehensive eye exam that includes cycloplegic refraction, dilated ocular health evaluation, and several experimental tests. These include optical quality across the periphery, static and dynamic accommodation, contrast sensitivity, psychophysical perception of blur, pattern ERGs to blurred images, posterior segment wide-

field OCT, and ocular biometry. The subject's refractive error was determined by 2gtt Cyclopentolate 1% and open-field autorefractor.

Each child scheduled for a PICNIC follow-up visit during the Summer 2021, Winter 2021, or Summer 2022 was asked to participate in the sub-studies reported in this thesis. All participants enrolled in the PICNIC study were eligible to participate, and there were no additional inclusion or exclusion criteria. If subjects and their families agreed to participate in these sub-studies, they were asked to review and sign IRB-approved addendums to their original PICNIC parent Informed Consent Form and child's Assent Form. Subjects who agreed to participate are provided with an Actiwatch Spectrum Plus (Philips Respironics, USA) watch (Figure 1.1.) and instructions for its use.

3.1.1. Objective Measures

For trials including PICNIC subjects, the Actiwatch Spectrum Plus was used to collect an objective measure of light exposure for each child. This device was chosen because the subjects participating in the PICNIC study were emmetropic and could not be glasses-mounted. The environmental factors measured by and calculated from these devices include minutes of time outdoors per day, number of transitions from inside to outside per day, average exposure per day to blue, green, and red light, minutes of light, moderate and rigorous activity per day, sleep duration, bedtime, and wake time.

3.1.1.1. The Actiwatch Spectrum Plus

The Actiwatch Spectrum Plus is a wearable technology designed to continuously capture activity levels for clinicians and researchers. The devices are lightweight, semi-waterproof, and contain an integrated color light sensor that measures light at a wavelength range of 380-750 nm and illuminance range of 0-35,000 lux (lumen per square meter). Because of this, myopia researchers have used them to assess ambient light exposure and determine if subjects are indoors or outdoors. The photodiodes measure the illuminance of white light in lux and the irradiance of the red, green, and blue components in microwatts per square centimeter ($\mu W/cm^2$) (Ostrin 2017). The device tracks activity levels via a solid-state piezoelectric accelerometer, which records activity counts per minute (cpm). Sleep measures are based on the immobility of the accelerometer. They also have a sensor that monitors if the child removes the device from their wrist. However, the watch does continue recording even when it is removed.

Previous studies using the Actiwatch chose to have the device capture data every 30 seconds and used an illuminance of 1000 lux as the cut-off for time outside. We duplicated these settings for this study's data collection and analysis (Read et al. 2014, 2015; Ostrin 2017; Ostrin et al. 2018).

Each subject who agreed to participate on the day of their visit was given a watch to be worn on the left or right wrist, per the child's preference, with the light sensor facing outward. The child was instructed to wear the watch constantly (24/7) unless swimming, as the watches are only semi-waterproof. Children were also advised to do their best to avoid

covering it with long sleeves or other clothing. If the watch was intentionally removed, the family was asked to record the time it was removed and the activity the child was doing during that time. The watch was then returned by the parents after 14 full days of wear (12 am to 12 am) The data was manually retrieved and downloaded to the software program. We had 10 Actiwatch devices available.

3.1.1.2. Study Design: 2-week trials (Summers)

Between July and September 2021, a total of N=32 children presented for a PICNIC study follow-up visit. All these children were asked to participate in the Actiwatch sub-study. Of the 32 subjects asked to participate, N=20 children were enrolled, completed the 2-week study duration, and their data are included in data processing. For the remaining 12 children, N=4 declined to participate, N=4 were not able to participate as all the available (10) Actiwatch devices were in use, N=4 agreed to participate but did not complete the 2-week duration of the study (for N= 2 the family or subject changed their mind and discontinued use of the Actiwatch, for N= 2 the Actiwatch broke or malfunctioned). Children enrolled were asked to continuously wear the Actiwatch on their left or right wrist for 14 days starting the day of the PICNIC follow-up visit.

Between June and September 2022, a total of N=55 children presented for a PICNIC study follow-up visit. Those who had already been included in the Summer 2021 (N=19) and Winter 2021 (N=4) trials were excluded, and the remaining N=32 were asked to participate in the Actiwatch sub-study. Of the 32 subjects asked to participate, N=11 children were enrolled, completed the 2-week study duration, and their data are included in data processing.

For the remaining 21 children, N=15 declined to participate, N=1 was not able to participate as all the available (10) Actiwatch devices were in use, N=5 agreed to participate but the family or subject changed their mind and discontinued use of the Actiwatch prior to completing the 2-week duration of the study. Children enrolled were asked to continuously wear the Actiwatch on their left or right wrist for 14 days starting the day of the PICNIC follow-up visit. It should be noted that we had two pairs of siblings participate in these Summer Trials (S005 and S006, S061 and S062). Demographic information for the n=31 subjects that participated in the Summer Trials are as follows:

Subject ID	Date Started Trial	Date Ended Trial	Age at start trial	Race	Risk Group	Sex
S001	7/23/2021	8/5/2021	8.44	Mixed (White/Black), non-Hispanic	Low	Male
S005	7/9/2021	7/22/2021	9.95	White, non-Hispanic	Low	Female
S006	8/11/2021	8/24/2021	8.20	White, non-Hispanic	Low	Female
S020	9/2/2022	9/15/2022	10.45	White, non-Hispanic	Low	Male
S024	9/14/2021	9/27/2021	8.29	White, non-Hispanic	Low	Male
S042	6/18/2022	7/1/2022	8.69	Black, non-Hispanic	Low	Male
S044	7/2/2021	7/15/2021	6.53	White, non-Hispanic	Low	Female
S056	7/22/2021	8/4/2021	9.25	White, non-Hispanic	Low	Female
S057	7/15/2021	7/28/2021	9.31	White, non-Hispanic	Low	Female
S059	9/11/2021	9/24/2021	7.29	White, non-Hispanic	Low	Male
S061	8/19/2021	9/1/2021	8.76	White, non-Hispanic	Low	Female
S062	8/19/2021	9/1/2021	6.80	White, non-Hispanic	Low	Male
S064	8/6/2021	8/19/2021	6.50	White, Hispanic	Low	Male
S114	7/28/2022	8/10/2022	9.35	White, non-Hispanic	Low	Female
S115	7/29/2022	8/18/2022	8.90	White, non-Hispanic	Low	Female
S122	8/20/2022	9/2/2022	7.75	Black, non-Hispanic	Low	Female
S132	9/5/2022	9/18/2022	9.55	White, non-Hispanic	Low	Male
S009	9/22/2021	10/5/2021	8.10	White, non-Hispanic	High	Male
S018	9/15/2021	9/28/2021	7.75	White, non-Hispanic	High	Female
S021	8/11/2021	8/24/2021	8.91	Black, non-Hispanic	High	Female
S028	9/8/2022	9/21/2022	8.67	White, non-Hispanic	High	Male
S029	9/24/2022	10/7/2022	8.15	White, non-Hispanic	High	Female
S049	7/2/2021	7/15/2021	8.68	Black, non-Hispanic	High	Male
S050	6/24/2022	7/7/2022	8.86	More than one, Hispanic	High	Female
S054	7/24/2021	8/6/2021	7.68	Mixed, Hispanic	High	Female
S058	9/23/2022	10/6/2022	9.45	More than one, Hispanic	High	Male
S060	9/5/2021	9/18/2021	6.51	Mixed (White/Black), Hispanic	High	Female
S065	8/6/2021	8/19/2021	6.75	Asian, non-Hispanic	High	Male
S066	7/29/2022	8/11/2022	8.07	Black/More than one race, Hispanic	High	Female
S069	8/25/2021	9/6/2021	7.26	Asian, non-Hispanic	High	Male
S072	9/24/2021	10/7/2021	7.07	Asian, non-Hispanic	High	Male

Table 3.3. *Demographics of the 31 children participating in the Summer Trials. Age in years.*

3.1.1.3. Study Design: 90-Day Trial (Winter)

During December 2021, a total of N=15 children presented for a PICNIC study follow-up visit. All these children were asked to participate in the Actiwatch sub-study. Of the 15 subjects invited to participate, N=6 children were enrolled and completed the 90-day duration of the study. For the remaining 9 children, N=2 declined to participate, N=3 were not able to participate as all the available (10) Actiwatch devices were in use, N=4 agreed to participate but did not complete the 90-day duration of the study (for N= 3 the family or subject changed their mind and discontinued use of the Actiwatch, for N= 1 the Actiwatch was lost by the subject). Children enrolled were asked to continuously wear the Actiwatch on their left or right wrist for 90 days starting the day of the PICNIC follow-up visit. In addition to the retention rate, after reviewing the data that was captured, we found that N=1 watch experienced technical difficulties and all data was lost and another N=2 subjects reported that they completed the full 90 days but did not wear the device for the full trial. With only N=3 subjects having complete data sets to analyze the decision was made not to include data from this trial in my thesis.

3.1.2. Subjective Measures

Several environmental factors were measured subjectively. This was done using various types of questionnaires given to the parents to subjectively report their child's behavior. Questions were asked regarding bedtime, wake time, total time spent outdoors, number of times outdoors, reading and other forms of near work, use of electronic devices, activities before, during, and after school, and activities on non-school days.

3.1.2.1 Daily Surveys

During the time the children wore the Actiwatch for the 2-week trials (Summers), parents received a text each evening with the question “How many hours did your child spend outdoors today (round to the nearest 15 minutes) during the daytime?” Before initiating the sub-study, parents were instructed on how to answer this question, i.e., that time outdoors includes any activity, and any time they are outside a building.

During the PICNIC Summer 2 trial only, parents were also asked two additional questions: “What time did they go to sleep last night?” and “What time did they wake up today?”.

3.1.2.2. PICNIC follow-up visits questionnaires

An electronic questionnaire Google form is emailed to all families who participate in the PICNIC study before each follow-up visit. Families are asked to answer questions about the amount of outdoor time, near work, and the child's sleep habits (Appendix I). The questions are regarding their child’s activities the week before the visit. If they have not completed the questionnaire at the time of the visit, they are asked the questions during the visit. The data obtained from the PICNIC questionnaire for the visit when the Actiwatch was dispensed (i.e. information corresponding to the week prior to the time of watch wear) were analyzed in this study.

3.1.2.3. Activity logs

During the 90-day Actiwatch devices trial, parents were given printed copies of an activity log and asked to complete it at the end of each week (Appendix II). Similar to the PICNIC follow-up visit questionnaire, this activity log includes questions about the child's outdoor time, near work, and sleep habits. The activity log is more comprehensive than the PICNIC questionnaire (Appendix I) and goes through step by step all the details of one full day. The questions are worded differently for school days and non-school days (weekends or holidays). Answers are provided as an average for school days and non-school days for the entire week. The completed logs were returned at the end of the 90 days. Many logs were not returned or were only partially completed. With only N=4 of the families completing the subjective Activity log 1 (Appendix II) in full the decision was made to discard the data from this activity log.

To improve response rate for the next rendition, Activity Log 2 (Appendix III) was delivered electronically via Google form to the families who participated in the PICNIC Summer 2 trial so that it could be tracked for completion during the study.

In an attempt to assess the efficacy of this survey, parents who completed the weekly activity log as part of the 90-day trial were also asked for their opinion on the effectiveness of the activity log survey and suggestions on how to improve it. The following questions were emailed to parents at the end of the 90-days:

- Do you think that the activity log is a good representation of the time your child spends outdoors and doing near work? Please explain.

- Do you feel that using the activity log has made you more aware of the amount of time your child is spending outdoors and doing near tasks?
- Would you consider/have you made changes to encourage more time outdoors and less near work since using the questionnaire?
- Were there any specific questions or parts of the questionnaire that you found confusing?
- Do you feel we can improve the questionnaire to make it more user-friendly? If so, how?
- Do you feel we can improve the questionnaire to more acutely capture children's daily routines? If so, how?
- Are there any times of the day that your child is outdoors or doing near tasks that we did not include in the questionnaire?

Along with the suggestion to make the log electronic, we also received consistent feedback that averaging for the week was difficult. To address this, the questions were made for each specific day of the week. This form was used during the PICNIC Summer 2 trial and sent to the parents of participating children three times; once as a baseline on the day of the visit, after the 1st week of watch wear, and again after the 2nd week. The responses to each activity log were regarding the seven days prior, thus by completing the log three times information was obtained for the seven days before the child's watch trial and the two weeks the watch was worn. However, another limitation was noted in this method. It was still difficult to encourage parents to complete the surveys and the majority of these serial activity logs were left incomplete therefore, the data from these logs were not included in analysis.

3.2. Evaluation of Devices

To assess differences in time outdoors and other parameters obtained from the Actiwatch devices, these were used simultaneously with other devices, and results were compared. Three separate trials were conducted with our research team members while simultaneously wearing multiple devices that objectively measure outdoor time.

The HOBO pendant (64K UA-002-64, Onset Computer Corporation) (Figure 1.2.) is a small, waterproof, two-channel temperature and relative light level data logger that can be worn on a lanyard around the neck (HOBO Pendant®). It measures temperature from -20° to 70°C (-4° to 158°F) and light levels 0 to 320,000 lux (0 to 30,000 lumens/ft2). It is marketed toward environmental research due to its ability to sustain extreme temperatures and water depths (30 m from -20° to 20°C [100 ft from -4° to 68°F]).

For these trials, glasses-mounted options were also included. All the subjects participating in these trials were already glasses wearers, decreasing the risk of behavior changes. The Clouclip M2 (Figure 1.3.) and the Vivior Mark 3+ Visual Behaviour Monitor (Figure 1.4.) are both glass-mounted light meters that are relatively new to the market. The ClouClip was designed for myopia research and monitoring of myopia-related behaviors. It has been used in several myopia studies and can measure viewing distances of the wearer every five seconds with a range of 0-120 cm. It has an illuminance sensor that measures every second and averages every two minutes with a range of 0-65,535 lux (ClouClip). The Vivior was also developed for eye care but is marketed toward cataract surgeons to monitor their patients' visual behaviors when planning the type of lens implant and refractive goals. It

is very similar to the ClouClip in that it measures viewing distance and ambient light and could also be used in myopia research. It also measures color, acceleration, orientation, and magnetic flux.

A more traditional light meter, the Dr. Meter LX1330B light meter (Figure 1.6.) was used as the control for the Validity Test (Digital Light Meter, LX1330B, Dr. Meter). It has a range of 0.1-200,000 lux with an accuracy of ±3% ±10 digits (0-20,000 lux), ±5% ±10 digits if over 20,000 lux and a repeatability of ±2%. In addition to the Dr. Meter, the iPhone application Lux Light Meter Pro (Figure 1.5.) was also included in the comparison.

During each of these trials, the three subjects (young adults with normal vision who work in the lab) were also asked to keep an activity diary tracking the exact time they transitioned from inside to outside or outside to inside environments. During Comparison Trials 2 and 3, they also included times that they were in a vehicle in their activity diary.

The default setting for epochs of each device were used for how often they capture data. Similar to the Actiwatch, the HOBO pendant uses 30 seconds epochs. The Vivior captures data every 1 minute, and the ClouClip every 5 seconds.

3.2.1. Comparison Trial 1

During a 7-day trial, 3 subjects were asked to wear the Actiwatch Spectrum Plus (Figure 1.1.) on their left or right wrist, per the subject's preference, with the light sensor facing outward as well as another device, the HOBO pendant (64K UA-002-64, Onset Computer Corporation) (Figure 1.2.). The HOBO pendant was worn on a lanyard around their neck,

keeping the broad-spectrum light sensor facing outward to the best of their ability. Subjects were instructed to wear the Actiwatch and HOBO devices constantly (24/7) and to only remove them for bathing or swimming. While sleeping, they were asked to keep the Actiwatch on but leave the HOBO in the same room as them, with the sensor uncovered when removed. They were also advised to do their best to avoid covering both devices with long sleeves or other clothing. If the watch or pendant was intentionally removed, subjects were asked to record the time it was removed in their activity diary.

3.2.2. Comparison Trial 2

During a 4-day trial, three subjects were asked to wear the Actiwatch Spectrum Plus (Figure 1.1.), the HOBO pendant (64K UA-002-64, Onset Computer Corporation) (Figure 1.2.) and the Clouclip M2 (Figure 1.3.). Per the subject's preference, the Actiwatch was worn on their left or right wrist, with the light sensor facing outward. The HOBO pendant was worn on a lanyard around their neck, keeping the broad-spectrum light sensor facing outward to the best of their ability. The Clouclip was mounted on the right side of their glasses with the sensors facing forward. Subjects were instructed to wear the Actiwatch, HOBO, and ClouClip devices constantly (24/7), and to only remove them for bathing or swimming. During sleep, they were asked to keep the Actiwatch on but leave the HOBO and ClouClip in the same room as them, with the sensors uncovered when removed. They were also advised to do their best to avoid covering devices with their hair, long sleeves, or other clothing. If any device was intentionally removed, subjects were asked to record the time it was removed in their activity diary.

3.2.3. Comparison Trial 3

During a 4-day trial, one subject wore four devices: the Actiwatch Spectrum Plus (Figure 1.1.), the HOBO pendant (64K UA-002-64, Onset Computer Corporation) (Figure 1.2.), two Clouclip M2 devices (Figure 1.3.) and one Vivior Mark 3+ Visual Behaviour Monitor (Figure 1.4.). The Actiwatch was worn on their right wrist with the light sensor facing outward. The HOBO pendant was worn on a lanyard around their neck keeping the broad-spectrum light sensor facing outward to the best of their ability. The ClouClip and the Vivior devices are both designed to be worn on the right side of glasses. In order to determine the best way to wear both devices in a comparison trial an additional ClouClip was used. The Vivior was attached to the right side of the subject's glasses as designed. One Clouclip was attached upside down to the left side of the glasses with the sensors facing forward and the other ClouClip was attached to the Vivior right side up with the sensors facing forward (Figure 3.1).



Figure 3.1. *Vivior and ClouClip Setup for Comparison Trial 3 and Validity Test.*

The subject was instructed to wear all devices constantly (24/7) and to only remove them for bathing or swimming. During sleep, they were asked to keep the Actiwatch on and leave

the HOBO pendant, ClouClip, and Vivior devices in the same room as them with the sensors uncovered when removed. They were also advised to do their best to avoid covering all devices with their hair, long sleeves, or other clothing. If any device was intentionally removed, subjects were asked to record the time it was removed in their activity diary.

3.2.4. Validity Test

The average light levels measured in lux by the Actiwatch Spectrum Plus (Figure 1.1.), the HOBO pendant (64K UA-002-64, Onset Computer Corporation) (Figure 1.2.), two Clouclip M2 devices (Figure 1.3.), the Vivior Mark 3+ Visual Behaviour Monitor (Figure 1.4.), the iPhone application Lux Light Meter Pro (Figure 1.5.) and the Dr. Meter LX1330B light meter (Figure 1.6.) were compared under seven different lighting conditions by one subject. The Actiwatch was worn on the subject's right wrist with the light sensor facing outward. The HOBO pendant was worn on a lanyard around their neck keeping the broad-spectrum light sensor facing outward to the best of their ability. To wear both the ClouClip and the Vivior devices (both of which are designed to be worn on the right side of glasses) the subject wore two ClouClip devices. The Vivior was attached to the right side of the subject's glasses as designed. One Clouclip was attached upside down to the left side of the glasses with the sensors facing forward, and the other ClouClip was attached to the Vivior on the right side with the sensors facing forward (Figure 3.1). The iPhone was placed face up with the Lux Light Meter Pro open (Figure 1.5.) and the Dr. Meter LX1330B light meter was placed face up (Figure 1.6.). The subject sat in each of the lighting conditions for a total of five minutes. A reading was manually taken with the Lux Light Meter Pro and the Dr. Meter

LX1330B light meter at the beginning, middle, and end of each 5-minute period. The seven lighting conditions tested were:

- Inside Natural Light (sitting at a table in the middle of a classroom with large windows and no overhead lights on)
- Inside Full Illumination (sitting at a table in the middle of the research lab with all overhead lights on and window shades closed)
- Computer Screen (sitting at a desk in front of two computer screens with all overhead lights on and window shades closed)
- Inside Next to Window (looking out a window toward the sun and light meters held facing the window)
- Outside Direct Sun (sitting outside on the ground in direct sun with no clouds)
- Outside Shade (sitting outside on a sunny cloudless day at a table completely shaded by a brick wall)
- Car Driver's Seat (sitting in a parked car on a sunny cloudless day with the light meters held at chest level with the sensors facing up)

4. OUTDOOR TIME AND MYOPIA

4.1. Introduction

Spending time outdoors is a modifiable behavior that previous studies have shown to be protective against myopia development (Dhakal et al. 2022). These studies measured outdoor time both subjectively with surveys and objectively with devices that capture outdoor time using light exposure. Although a number of glasses-mounted devices have recently become available, most clinical trials that have objectively measured outdoor time have used the Actiwatch (Read et al. 2014, 2015; Ostrin 2017; Ostrin et al. 2018). The Actiwatch is a wrist worn device that measures exposure to white, blue, green and red light and tracks activity levels and sleep patterns using an accelerometer. This was the device of choice for the trials including PICNIC subjects due to availability, because these devices have been validated by previous study and they do not need to be glasses mounted. Note that subjects participating in these studies were functionally emmetropic and did not use glasses.

When previous studies have used both a subjective and an objective measure of outdoor time, inconsistent correlations have been noted between measurement methods (Chodick et al. 2008; Dharani et al. 2012; Alvarez and Wildsoet 2013; Read et al. 2015; Ostrin 2017; Ostrin et al. 2018). It is currently unknown whether the lack of correlation between subjective and objective measures is due to poor patient recall or other limitations in the subjective measures used. Comparisons across studies are difficult because details on the questionnaires and diaries that were used in early studies are limited. Another factor to be considered is the difference between subjective responses by adult subjects about themselves

and a parent's response about their child. As myopia typically develops in elementary school-aged children who usually spend several hours at school, this poses a challenge when asking parents about their children’s behaviors throughout the day. Questionnaires must be comprehensive enough to capture all types of outdoor activities throughout the day, and include information on school and non-school days. At the time this thesis research was conducted there was still no standardized questionnaire to determine environmental behaviors related to myopia research. Developing a questionnaire that can provide accurate information that correlates with objective measures would provide a very useful tool in future myopia research. Another use of such a questionnaire would be to raise parents' and children's awareness of their environmental behaviors and prompt them to change those behaviors as a preventive strategy against myopia. This has recently been addressed with the creation of the UH NEAR survey in 2023 (Gajjar and Ostrin 2023).

In addition to improving the methods for subjectively assessing time spent outdoors, there is a need for more studies on children. To better understand how spending more time outdoors may protect against myopia and whether it can be used as a prevention strategy against myopia development, we need to investigate these behaviors in children before myopia develops. To date, there are no prospective studies evaluating environmental behaviors predictive of myopia in a pre-myopic group of children. By obtaining longitudinal prospective measures of cycloplegic refraction and ocular biometry in conjunction with measures of time outdoors prior to children becoming myopic, we will be able to understand how environmental behaviors play a role in emmetropization or its failure. For this purpose, we have taken these measures of the visual environment of a group of children with

functional emmetropia at baseline, some of whom will develop myopia during the duration of the study, others will not.

4.2. Methods

The intensity of light exposure registered by the Actiwatch every 30 seconds was used to quantify time spent in outdoor or indoor environments each day. Specifically, based on the criteria used in previous studies, the number of 30-second intervals with light intensity larger than the cutoff value of 1000 lux was used to obtain total outdoor time, with values lower than 1000 lux considered indoor time (Read et al. 2014, 2015; Ostrin 2017; Ostrin et al. 2018).

The value provided by the Actiwatch software of total minutes per day of white light exposure >1,000 lux (TALT) was used in our analyses. It is important to note that the Actiwatch has a sensor to monitor when the device is removed from the wrist. However, the watch does continue recording light exposure and activity when it is not on the wrist. The report of "off-wrist" times is provided by the software (Appendix XI) so that data may be removed from the analyses. In our studies we kept all the data provided and did not remove the times reported as "off-wrist". This decision was made because when used by young children with very small wrists, as those in our sample, the watches often report false "off-wrist" times when they have not been removed. To account for these errors, parents were asked to record details on the activities the children were performing whenever the watch was intentionally removed. This information was considered in the data analyses and manually added to the total minutes per day of white light exposure >1,000 lux (TALT). For

example, when parents reported that the watch was taken off for swimming outside, the corresponding time frame was added to the TALT value provided by the Actiwatch. When an "off-wrist" time was reported by the Actiwatch and the parents did not report that the watch was removed, the Actiwatch outcome values (TALT) were kept as given by the device (which include the "off-wrist" values). Appendix XI provides a table with the minutes of "off-wrist" data per day for each subject. It also provides a table with time manually added to the TALT values as described above. An average of 4.80 minutes per day was manually added to the TALT values to compensate for parent reported watch removal. Note that all the added times were for children classified as LR (S001 had an average of 36.82 minutes added per day, S006 an average of 52.32 minutes added, S020 an average of 32.96 minutes added, S056 an average of 10.54 minutes added, S115 an average of 4.61 minutes added, and S122 11.57 minutes added). None of the parents with children at HR for myopia provided information as to the activities they were doing when the watches reported "off-wrist" times.

The reported number of times the child went outside each day by the Actiwatch was computed as "transitions". This was done by reviewing the raw data of lux measured every 30 seconds and counting the times the light levels transitioned from below 1,000 lux to 1,000 lux or higher. Each block of time where the light levels remained 1,000 lux or higher was counted as one transition. The total minutes of outdoor time per day during the 2-week trial as well as the number of transitions computed using the Actiwatch were analyzed.

The amount of outdoor time was also measured subjectively using the Daily Surveys and the PICNIC follow-up questionnaires (Appendix I). The Daily Surveys were delivered to

parents each day of the two-week trial via text message asking “How many hours did your child spend outdoors today (round to the nearest 15 minutes) during the daytime?”. This text message also included “What time did they go to sleep last night?” and “What time did they wake up today?” during the Summer 2 trial. The PICNIC questionnaire was delivered once the day the Actiwatch was given to the families, and parents were asked to report the average minutes of time their child spent outdoors per day on school days and non-school days as well as the average number of times per day their child went outside during the entire week prior to their visit. Refractive error was measured as part of the PICNIC study with cycloplegic open-field autorefraction using M (spherical equivalent) for the right eye (OD). Axial length was also measured for the right eye (OD) as part of the PICNIC study using the Lenstar 900 Biometer.

Statistical analyses of time outdoors and transitions indoors/outdoors were assessed using SPSS. Tukey’s Hinges test was used to evaluate for outliers within the 75 percentiles. Shapiro-Wilk tests were used to evaluate for normal distribution ($p<0.05$). The average minutes of outdoor time per day measured objectively vs. subjectively were compared using Related-Samples Wilcoxon Signed Rank tests. The differences in time spent outdoors between children in the High Risk (HR) for developing myopia group, and those in the Low Risk (LR) group, as well as those who developed myopia based on the PICNIC study results were compared with Independent-Samples Kruskal-Wallis tests. Data were not separated into weekdays and weekend days as the trials were conducted during the summer when most children had no school. Correlations between measurement methods were assessed using Spearman’s Rho tests. Spearman’s Rho tests were also used to evaluate correlations between

time outdoors measured by the Actiwatch and refractive error as well as axial length. Data gathered during the Winter 2021 trial was incomplete and not used for analysis, as described in Chapter 3. Raw data for time spent outdoors and number of transitions for each participant each day, as measured objectively and subjectively, is shown in Appendix IV.

4.3. Results

Tukey's Hinges test indicated no outliers within the 75 percentiles. Shapiro-Wilk tests indicated that most data sets are not normally distributed ($p<0.05$). The average time per day spent outdoors measured by the Actiwatch (89.42±46.85mins) was shorter ($Z=4.86$, $p<0.001$) than the parent responses to the Daily Survey (203.18±105.70mins) (Figure 4.1.), with good correlation between the two methods (Spearman $R=0.72$, $p<0.001$) (Figure 4.2.).

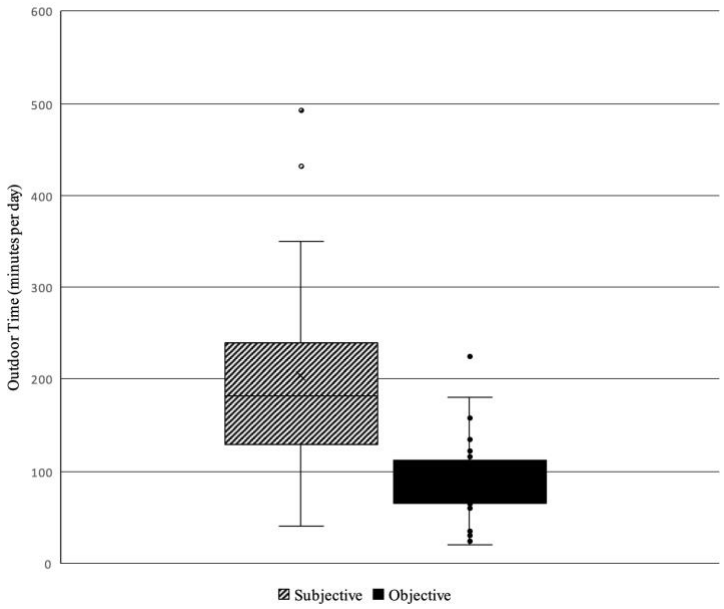


Figure 4.1. *Average daily subjective (Daily Survey) and objective (Actiwatch) measures of time outdoors for the 31 children who participated in the 2-week Summer studies.*

Interestingly, the amount of time spent outdoors reported in the PICNIC follow-up visit weekly Questionnaire (prior to delivering the Actiwatch) is even larger (school days: 393.87±185.38mins; non-school days: 292.26±280.89mins) than that provided by the Daily Survey. These times are significantly larger than the Daily Surveys outcomes ($Z=3.51$, $p<0.001$) and the Actiwatch outcomes ($Z=-4.82$, $p<0.001$). Note these weekly questionnaires ask parents to report the activities children performed the seven days prior to the visit.

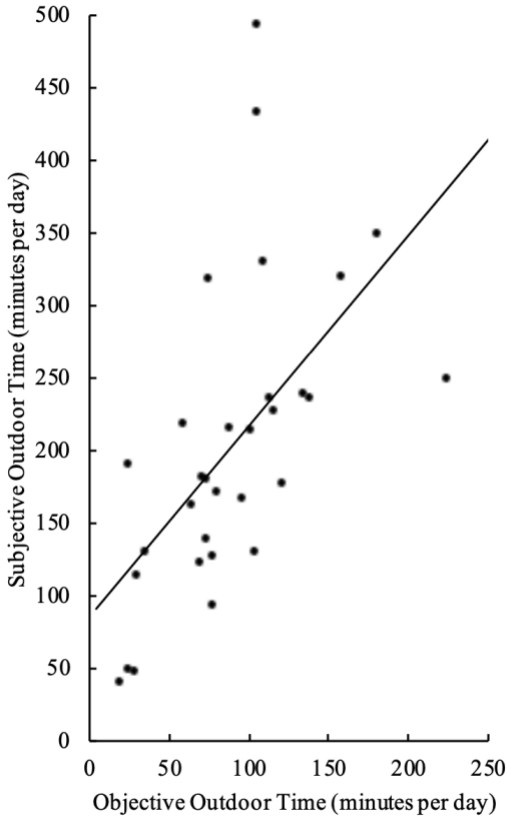


Figure 4.2. *Correlation between average daily subjective (Daily Survey) and objective (Actiwatch) measures of time outdoors for the 31 children who participated in the 2-week Summer studies.*

Children at HR for myopia (N=17) spent significantly less time outdoors (Daily Surveys: 132.07±58.71mins; Actiwatch: 59.18±27.13mins) than those at LR for myopia (N=14) (Daily Surveys: 261.74±100.39mins, H(1)=14.22, p<0.001; Actiwatch: 114.33±45.38mins, H(1)=13.92, p<0.001) (Figure 4.3.). When the PICNIC questionnaire (asked to answer what they recall happened the previous week Monday through Sunday), a similar trend was found towards less time outdoors for children at HR for myopia, but the differences were not significant (School Days: H(1)=2.69, p=0.10; Non-School Days: (1)=3.05, p=0.08).

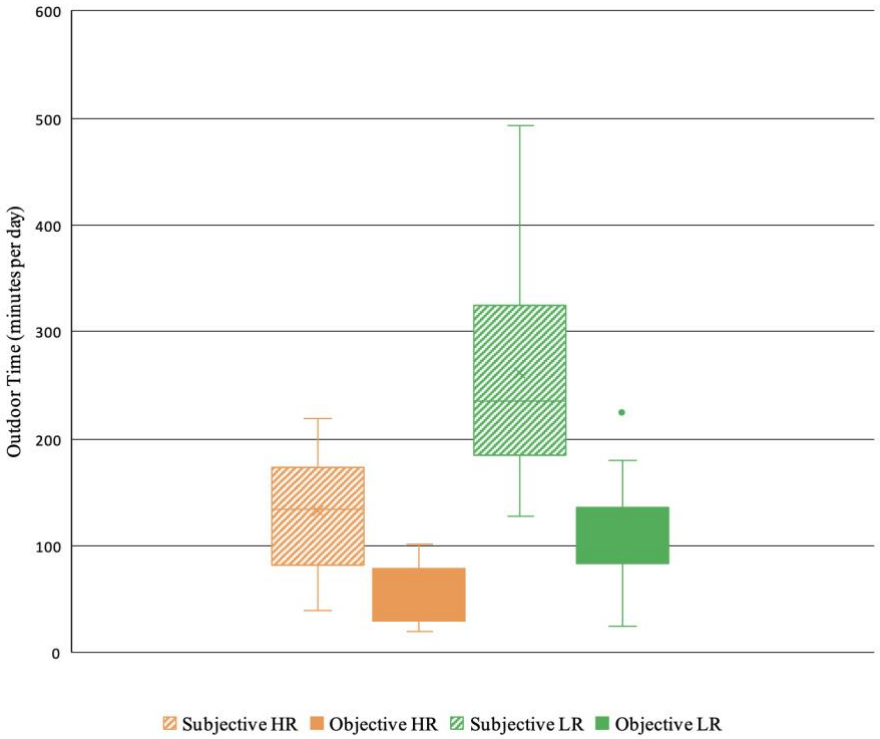


Figure 4.3. *Average daily time spent outdoors for children at HR and LR for myopia, as measured by objective (Actiwatch) and subjective (Daily Survey) methods.*

At the time of these analyses, four children enrolled in this sub-study of PICNIC have developed myopia. All four of these children were originally classified as HR. The time spent outdoors was also significantly lower (Myopes Daily Surveys: 141.76±72.44mins; Myopes Actiwatch: 66.41±31.75mins) in the small group of children who have developed myopia at this point compared to children at LR for myopia (Daily Surveys: $H(1)=14.38$, $p<0.001$; Actiwatch: $H(1)=13.96$, $p<0.001$) (Figure 4.4). Note that the overall PICNIC study is underway, and it will be at the end of the study when we will have the final number of children with HR who develop myopia.

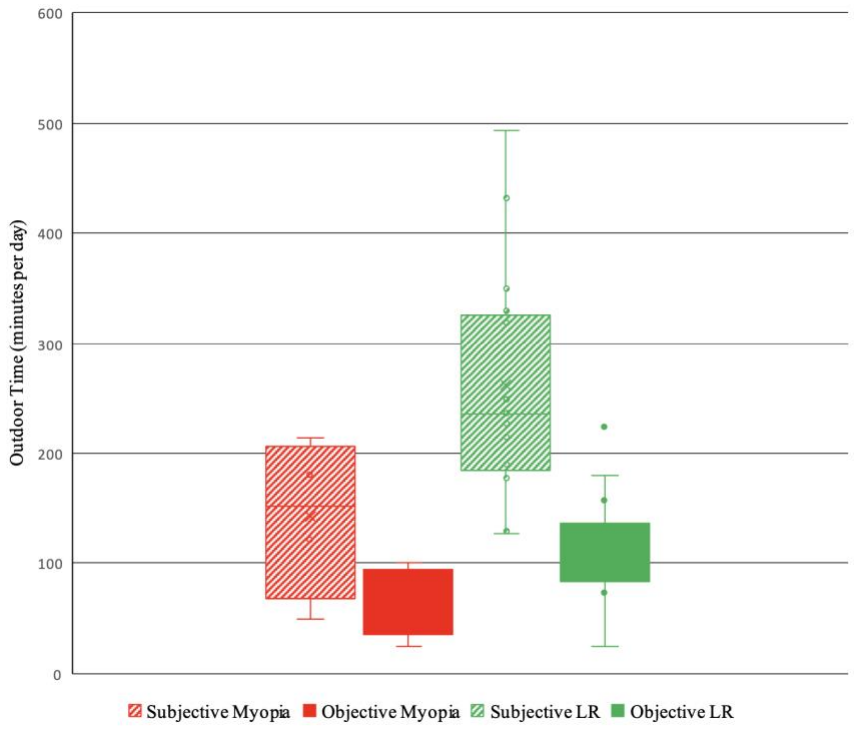


Figure 4.4. *Average daily time spent outdoors for children with myopia and at LR for myopia, as measured by objective (Actiwatch) and subjective (Daily Survey) methods.*

A significant correlation was found between time outdoors and refraction (SE, OD) for Actiwatch times (Spearman R=0.441, p=0.013) and Daily Survey times (Spearman R=0.527, p=0.002) (Figure 4.5.), but not with AXL (Actiwatch: Spearman R=0.021, p=0.912; Daily Survey: Spearman R=-0.223, p=0.227).

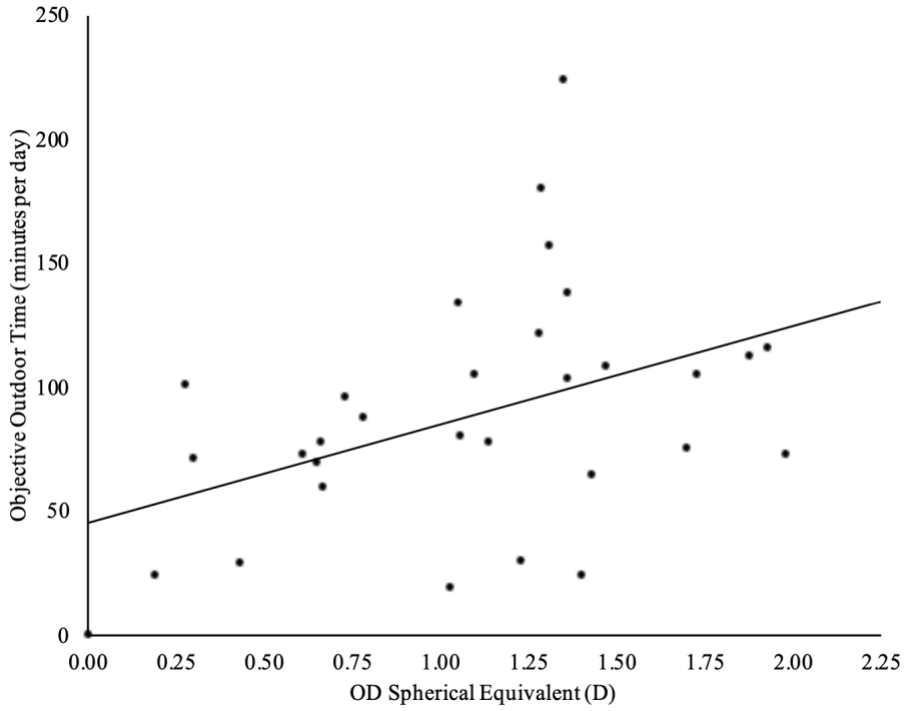


Figure 4.5. *Correlation of average daily time spent outdoors objective measures (Actiwatch) and the subject's spherical equivalent refractive error (D) in the right eye.*

The Actiwatch measures indicate that children transitioned from inside to outside 37.28±13.25 times per day on average (range 12.21 to 69.57), which is very unlikely. The PICNIC weekly questionnaires indicate that children transitioned from inside to outside 4.37±5.33 times per day on average (range 1 to 30). Since we cannot be certain with either test how many times the children transitioned from inside to outside, and it appears that the

Actiwatch is overestimating the number of transitions, we also questioned the results of time spent outdoors provided by the Actiwatch.

We therefore conducted a series of comparison studies to try to elucidate which method is most reliable and what tendency each method has to over or underestimate the time spent outdoors as well as the transitions (see Chapter 9).

4.4. Discussion

Similar to findings from previous studies, the average time per day spent outdoors measured objectively for two weeks using the Actiwatch was significantly shorter than the parents' subjective responses. This may be partially due to parents overestimating the time spent outdoors by their children, as previously hypothesized. However, the large number of transitions recorded by the Actiwatch indicates that these devices are likely underestimating the amount of time spent outdoors. Therefore, the difference between subjective and objective measures is likely a combination of underestimation by the Actiwatch and overestimation by the parents' subjective responses. One significant limitation of our study is that several participants had large amounts of data recorded by the Actiwatch as "off-wrist" (Appendix XI), likely due to the small wrist sizes of the young children participating in the studies. We kept all data and did not remove these children, or any specific days from the analyses. Even though we attempted to correct for the problem of "off-wrist" time by manually adding outdoor time during intention watch removal, only six parents reported what the children were doing during those periods (most of them swimming). All of these six children were classified as LR for myopia. Even though the average amount of time

manually added was minimal (4.80 minutes per day), this approach may have increased the differences found between risk groups. Although the Actiwatch does continue recording light exposure during these times reported as “off-wrist”, the large number of minutes noted in our study (an average of 257.92 minutes per day across all subjects) likely indicates an error in the accuracy of these devices and could be contributing to the underestimation of objective outdoor time. As expected, the subjective responses that were reported daily, via text message, were more similar to the objective measures than the subjective weekly average reported using the PICNIC questionnaires. This may be due to the difficulty in recalling accurately events from the previous week. It could also be that information is lost when averaging across seven days since children's schedules can be so varied throughout a week. Although no subjective measure is perfect, a daily record appears preferable to averaging.

As hypothesized, children at HR for myopia spent significantly less time outdoors than those at LR, this was found with both objective and subjective measures. Those few children that have already developed myopia also show significantly less time outdoors than those at LR for myopia, and a significant correlation was found between time outdoors and refractive error. These results support the hypothesis that spending more time outdoors is protective of myopia development. However, the data obtained with the Actiwatch needs to be taken with caution given the limitations listed above.

Although an analysis on the specific weather effect on outdoor time was not conducted, no obvious trends or patterns were noted among subjects that used the device during different times. The average temperate and total precipitation in Boston, MA during each subject’s

trial can be found in Appendix X. The weather reports are from the greater Boston area, where most children live, but we are unaware on the specific locations the children spent their time during the trials. For example, we did not collect information regarding traveling. Data analyses also do not control for the two sets of siblings that participated in these trials. When comparing outdoor times for subjects S061 and S062, one pair of siblings, these were very similar with no difference in their subjective averages and only a 25 min difference in their objective measures. For the second set of siblings, S005 and S006, their outdoor times were different in both their subjective (81 min difference) and objective reports (24 min difference) (Appendix IV).

We attempted to assess the possible benefit of measuring time spent outdoors for periods of time longer than two weeks. For this purpose, we conducted a study in a subgroup of children using the Actiwatch for 90 days, “the PICNIC Winter study”. However, due to the poor retention rate we did not have enough data to draw conclusions from this study. Although N=6 of the 10 subjects that participated reported that they completed the 90 days, N=1 watch was lost by a subject, N=1 entire data set was lost due to an error when transferring the data and only N=3 actually wore the device the entire duration of the study. It is clear that 90 days is likely too long for a child to participate in a study like this and that a device with the capability of cloud-based data collection would be more appropriate. For a long-term study this would be beneficial in ensuring full participation while the study is taking place rather than having to wait for them to be returned to see the data.

We were also unable to elicit sufficient information about outdoor time from Activity Log 1 (Appendix II) completed by these subjects due to vague responses from the parents, with partial or nonspecific answers. Based on feedback provided by parents in this subgroup of subjects, we developed the Activity Log 2 questionnaire (Appendix III). In this updated version, we provided more detailed instructions and examples of responses in the hope of capturing quantifiable data. However, although the responses were slightly more detailed, they were still not specific enough in many cases and were not quantifiable. This indicates that an open-response style questionnaire is not ideal for subjective measures even with detailed instructions and examples of how to answer. However, we did find that by completing the activity logs, some parents became more aware of their children's outdoor time. When asked for feedback about the logs we included the question “Do you feel that using the activity log has made you more aware of the amount of time your child is spending outdoors and doing near tasks?” Many responded “Yes, definitely”. One parent elaborated stating the form made them aware of how different her child's outdoor time is depending on the season, specifically “winter (inside MUCH more because of less daylight hours) versus summer (out all of the time).” When asked “Would you consider/have you made changes to encourage more time outdoors and less near work since using the questionnaire?" one parent stated “Yes I have found myself encouraging my kids to get outdoors and calculating how much time they are outside.” Another said “I have considered making changes not only to go outside but to do other things inside (we're indoor people, especially during winter time). Instead of driving, walk to/from school.” All these statements made by the parents are very

encouraging that the activity log could help parents become more aware of their child's behaviors and actively make changes to promote outdoor time.

Although we thought the change from a paper (Appendix II) to an electronic version (Appendix III) of the Activity log would be easier to track for completion, this revealed another limitation. Although we reminded the parents to fill out the electronic log at the 1 and 2-week mark of the trial, the parents often responded that they would do it later that day, tomorrow, etc., and never follow through. In future studies, setting up an automated message system via email or text to deliver multiple reminders would be helpful. It also may be beneficial to include incentives for each response or make compensation dependent on the full completion of all parts of the study to improve response rates.

5. LIGHT SPECTRAL COMPOSITION AND MYOPIA

5.1. Introduction

There is substantial evidence from animal studies indicating that exposure to different spectral compositions of light can alter eye growth. Chick and guinea pig models have shown that blue light can be protective against myopia (Foulds et al. 2013; Rucker et al. 2015, 2018; Yu et al. 2021), whereas tree shrew and monkey models have shown that red light exposure can induce hyperopia (Gawne et al. 2017b, 2017a; Hung et al. 2018; Ward et al. 2018). Studies investigating these effects in human subjects have also shown mixed results (Torii et al. 2017; Thakur et al. 2021; Jiang et al. 2022; Tian et al. 2022; Chen et al. 2023). One study found that exposure to only 1 hour of red and green light resulted in axial elongation, whereas exposure to blue light inhibited elongation (Thakur et al. 2021). Other more recent studies have begun to investigate the opposite, that red light may be used as a myopia treatment (Salzano et al. 2023). Several clinical trials in China have used red light exposure in myopia management and have shown some success in slowing progression (Jiang et al. 2022; Tian et al. 2022; Chen et al. 2023).

Despite these conflicting results of red vs. blue light exposure and their effects on myopia, very few studies have investigated the typical spectral composition exposure in humans. One study evaluated exposure to red, green, and blue light in adult emmetropic and myopic subjects, with the same devices we use in this work, the Actiwatch (Ostrin 2017). This study found that “for all indoor conditions, green and red were the highest spectral components and blue was the lowest”, and that the difference in exposure to red, green, and

blue light between their myopic and emmetropic subjects did not reach statistical significance (Ostrin 2017). The current study aims to investigate the effect of light spectral composition exposure in myopia development in children.

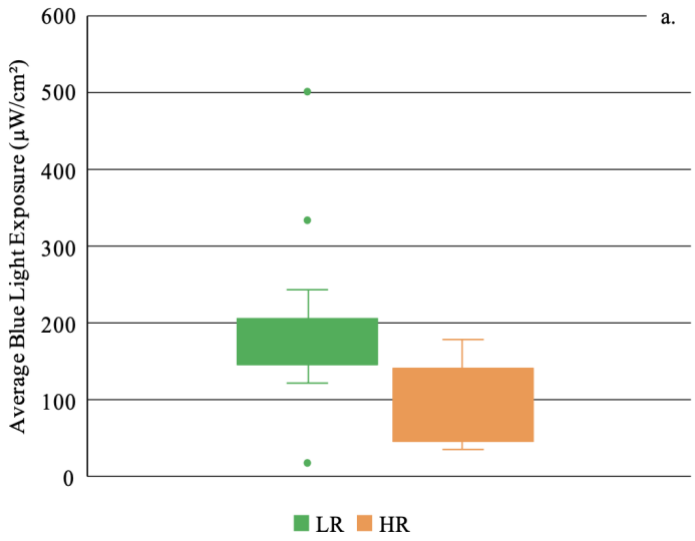
5.2. Methods

Data presented in this chapter on exposure to blue, green and red light wavelengths was obtained using the Actiwatch, with the same methodology described in Chapter 4, except that instead of using the TALT, the average exposure per day to blue, green and red light provided by the Actiwatch were used, similar to the only previous study to report wavelength exposure information (Ostrin 2017). Results of average exposure (named "Avg Exposure" in the Actiwatch output files) to each wavelength during the 14 days of the Summer Trials were assessed using SPSS. The same limitations related to "off-wrist" times described in Chapter 4 apply to the wavelengths results but no data could be added manually to the wavelengths results to compensate for parent reported intentional Actiwatch removal. Tukey's Hinges tests were used to determine and remove outliers that fell outside the 75 percentiles. Shapiro-Wilk tests were used to determine if the data sets were normally distributed ($p<0.05$). Related-Samples Friedman's Two-Way Analysis of Variance by Rank tests were used to compare the three wavelengths in the same population. Independent-Samples Kruskal-Wallis tests were used to compare the different groups of subjects (High Risk - HR compared to Low Risk - LR, and Myopes compared to LR). Spearman's Rho tests were used for correlations.

Cycloplegic refractive error and axial length were measured as part of the PICNIC study, data from the right eye (OD) was used in these analyses. Raw data for each participant per day for each wavelength is shown in Appendix V.

5.3. Results

Outliers that fell outside the 75 percentiles were present, as determined by the Tukey's Hinges tests, and were removed. Shapiro-Wilk tests indicated the majority of the data sets are not normally distributed ($p<0.05$). The average exposure per day measured by the Actiwatch was higher for red (380.64±273.67µW/cm^2) compared to green (257.10±156.20µW/cm^2) and blue (145.00±96.41µW/cm^2) lights ($p<0.001$). Children at HR (N=17) were exposed to significantly lower amounts of blue light (89.37±49.83µW/cm^2) compared to those at LR for myopia (N=14) (190.82±102.33µW/cm^2, $H(31,1)=10.08$, $p=0.001$) (Figure 5.1.a.). Similar results were found for green light (HR: 155.54±84.57µW/cm^2; LR: 340.73±153.24µW/cm^2, $H(31,1)=12.48$, $p<0.001$) (Figure 5.1.b.) and red light (HR: 201.65±96.70µW/cm^2; LR: 528.04±285.86µW/cm^2, $H(31,1)=15.13$, $p<0.001$) (Figure 5.1.c.).



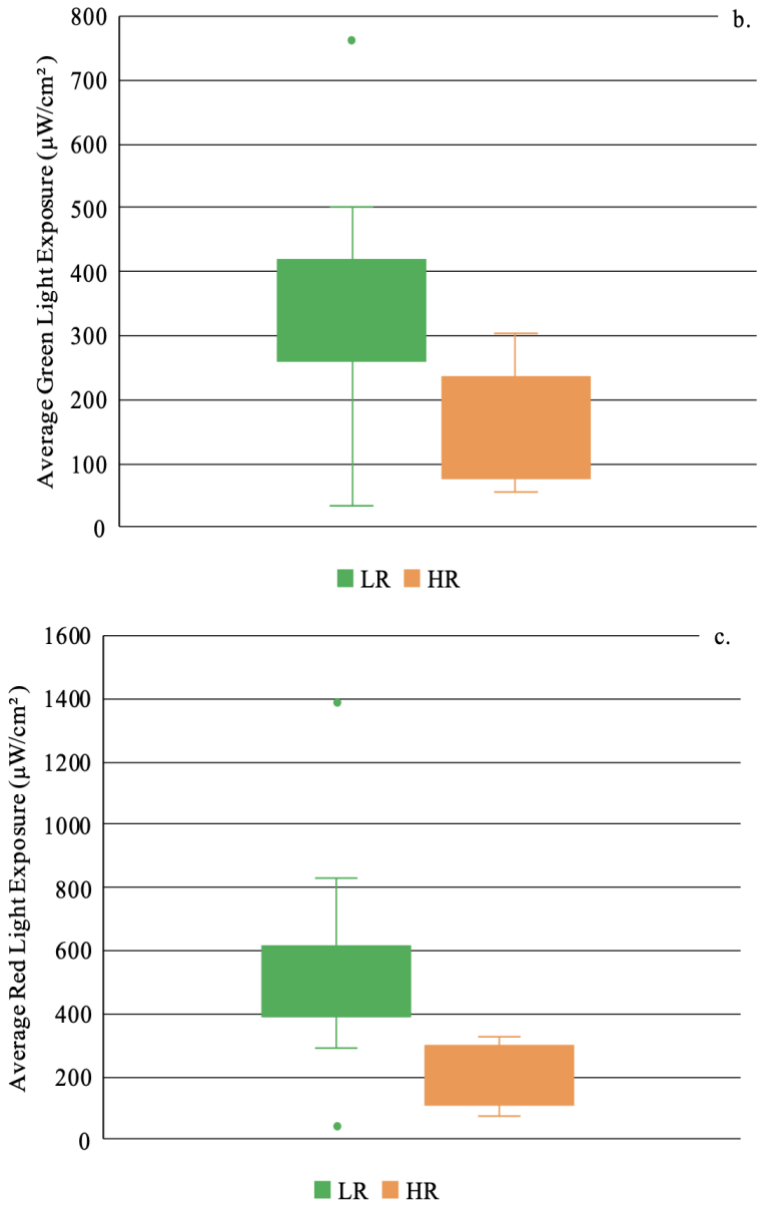
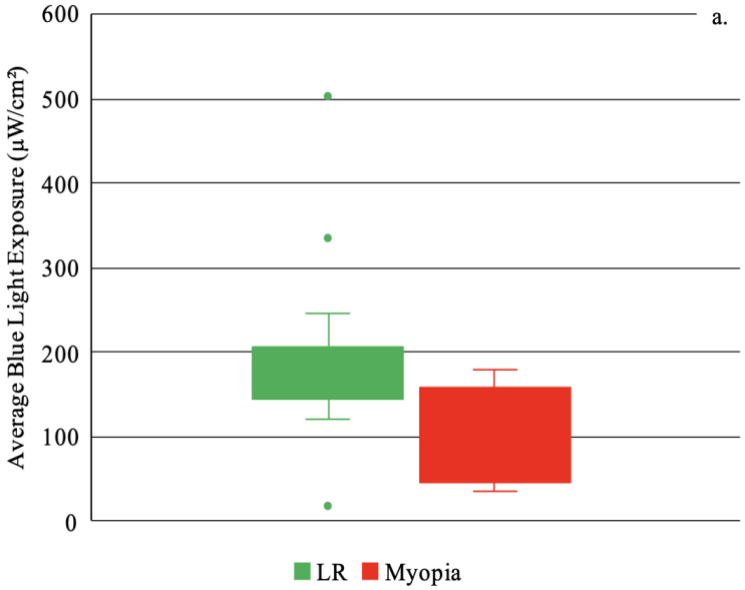
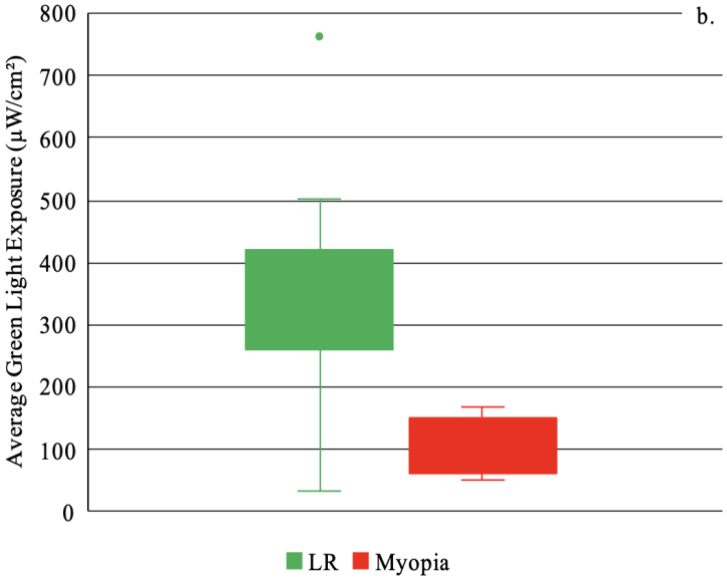


Figure 5.1. *Average daily exposure (µW/cm²) to blue (a), green (b) and red (c) light for children at HR and LR for myopia, as measured by objective (Actiwatch).*

Similar results were found for the four children enrolled in this sub-study that have developed myopia at the time of writing this thesis. These four children with myopia were exposed to less blue light (95.21±60.63µW/cm², H(21,1)=10.09, p=0.006) (Figure 5.2.a.),

green light (170.05±108.58µW/cm^2, H(21,1)=12.51, p=0.002) (Figure 5.2.b.) and red light (227.86±99.99µW/cm^2, H(1,1)=15.14, p<0.001) (Figure 5.2.c.) compared to children at LR for myopia. Note that the overall PICNIC study is underway, and it will be at the end of the study when we will have the final number of children with HR who develop myopia.





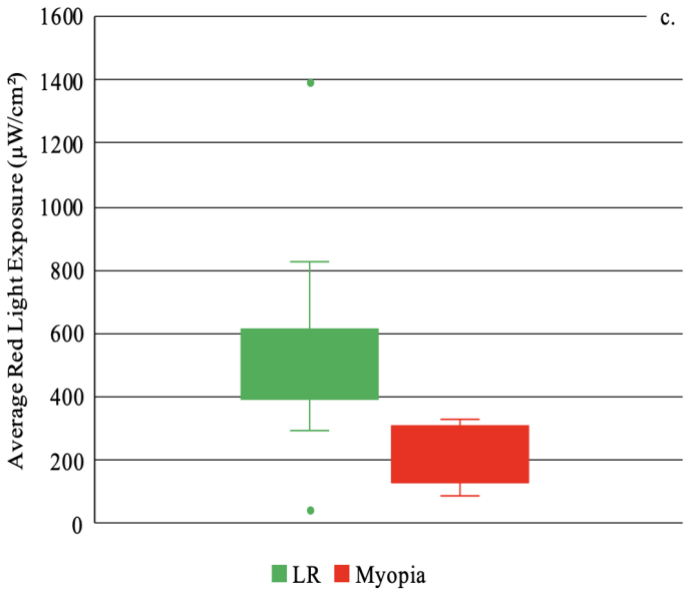


Figure 5.2. *Average daily exposure (µW/cm^2) to blue (a), green (b) and red (c) light for children with myopia and at LR for myopia, as measured by objective (Actiwatch).*

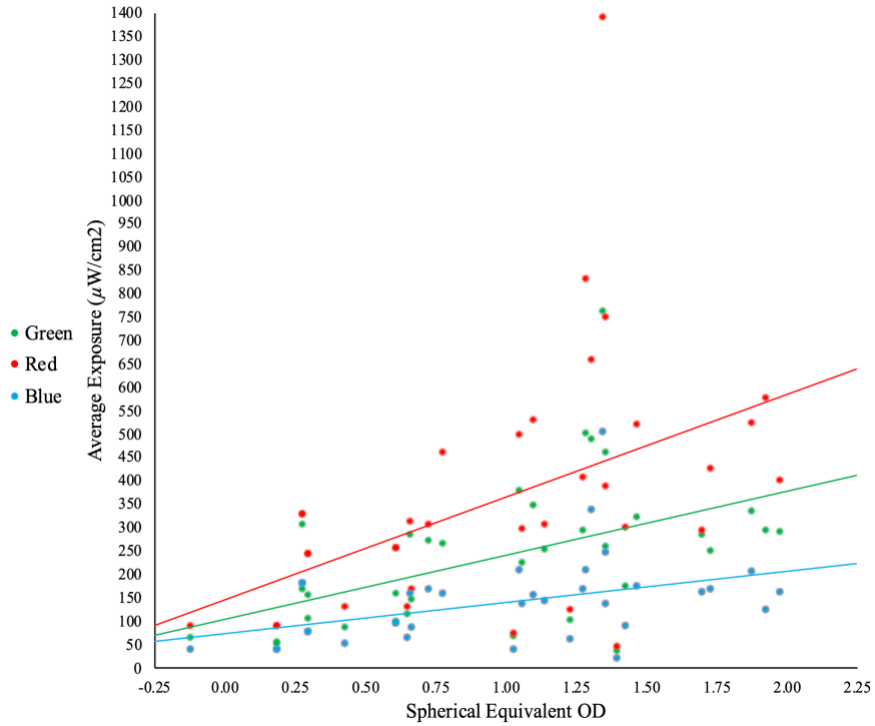


Figure 5.3. *Correlation of average daily exposure (µW/cm2) to blue, green and red light measured by objective (Actiwatch) and the subject's spherical equivalent refractive error (D) in the right eye.*

A significant correlation was found between refraction (SE, OD) and blue (Spearman R=0.398, p=0.027), green (Spearman R=0.441, p=0.013) and red (Spearman R=0.512, p=0.003) light exposure (Figure 5.3.). On the other hand, no significant correlations were noted with AXL (Spearman R blue light: R=-0.007, p=0.971; green light: R=0.043, p=0.819; red light: R=0.045, p=0.812).

5.4. Discussion

We found that the average exposure per day was highest for red light and lowest for blue light for the 31 children who participated in these studies. This study used measures of average exposure per day. Although this cannot be compared directly to the previous study by Ostrin which reported exposure to different wavelengths in children measured in specific lighting conditions (Ostrin 2017), the averages that we found are similar to the exposure she found in summer shade (red light: 163±29μW/cm^2; green light: 246±6μW/cm^2; blue light: 96 ±19μW/cm^2), with exposure to blue also being the lowest.

As expected from the results in Chapter 4, we found that children at HR for myopia were exposed to lower amounts of all wavelengths, blue, green, and red light, compared to children at LR for myopia. Interestingly, the largest difference being a reduction in red light exposure in children at HR for myopia. A previous study by Ostrin did not find a statistical difference in exposure to red, green, and blue light between their myopic and emmetropic subjects (Ostrin 2017). One limitation of our analyses is that the wavelengths comparisons were not adjusted for the total amount of light exposure. Another limitation is the large amount of time reported as “off-wrist” by the Actiwatch for many children, in spite of which

all data being kept in analysis (i.e., days with significant “off-wrist” times were not removed). Our findings are consistent with studies using tree shrews and monkeys which indicate that exposure to red light may have a hyperopia-inducing effect (Gawne et al. 2017b, 2017a; Hung et al. 2018; Ward et al. 2018). These findings also align with recent clinical trials being done in China that suggest that red light exposure could be beneficial in myopia control (Jiang et al. 2022; Tian et al. 2022; Chen et al. 2023; Dong et al. 2023). However, the safety of these treatments has been questioned and needs to be evaluated further (Ostrin and Schill 2024). More studies are needed to evaluate exposure patterns to different wavelengths of light in children before they become myopic to determine their effects on myopia development.

6. ACTIVITY LEVELS AND MYOPIA

6.1. Introduction

Although reduced physical activity has been shown to be associated with myopia, the relationship appears not to be causal. Evidence has shown that activity levels are correlated with more outdoor time, and it seems to be the time spent outdoors that has the protective effect in myopia (Dirani et al. 2009; Guggenheim et al. 2012; Read et al. 2014, 2015; Ostrin et al. 2017). No studies have previously investigated the association of physical activity in myopia development before the onset of myopia. Our unique study design can confirm whether being outdoors is protective of myopia with the need to participate in physical activity. If the activity type is irrelevant, this knowledge could simplify preventive strategies and make less intimidating for families and children less inclined to sports and exercise.

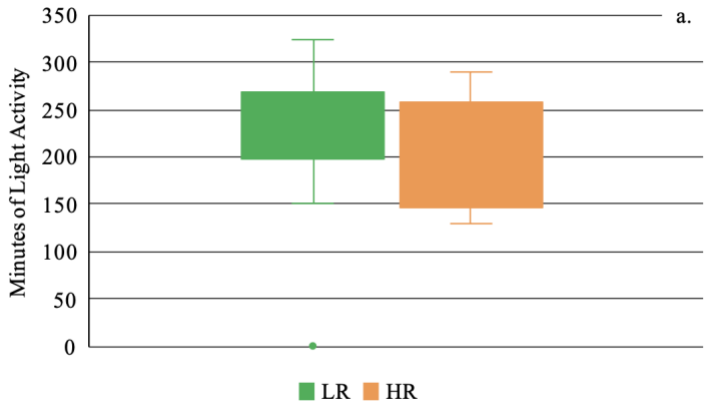
6.2. Methods

The Actiwatch accelerometer measured the daily minutes of different levels of activity during the 2-week Summer Trials. Activity levels provided by the Actiwatch accelerometer were classified as light (>320 cpm), moderate (>1048 cpm), and rigorous (>1624 cpm) based on a previous validation study (Ekblom et al. 2012). In order to classify the activity into these levels, the raw data was used instead of the average activity counts per day provided by the Actiwatch. The same limitations related to “off-wrist” times described in Chapter 4 apply to these results, although no data was added manually to the results due to non-specific activities reported by the parents during intentional Actiwatch removal. Statistical analyses of activity levels were assessed using SPSS. Tukey’s Hinges test was used to evaluate for

outliers within the 75 percentiles. Shapiro-Wilk tests were used to evaluate for normal distribution ($p<0.05$). The average time spent in each activity level as measured during the 2-week trial was compared between children in the High Risk (HR) for developing myopia group and those in the Low Risk (LR) group using Independent-Samples Kruskal-Wallis tests. Activity levels were also compared between those in the LR group and those that developed myopia using Independent-Samples Kruskal-Wallis tests. Raw data on light activity for each participant per day are shown in Appendix VI.

6.3. Results

Tukey's Hinges test indicated no outliers within the 75 percentiles. Shapiro-Wilk tests indicated that most data sets were not normally distributed ($p<0.05$). There was a trend toward shorter time spent on light activity in children at HR (209.49±55.20mins) compared to those at LR (234.87±49.22mins), with no significant difference ($H(1)=1.42$, $p=0.23$) (Figure 6.1.a). A similar trend was noted for rigorous activity levels (HR: 3.71±3.05mins, LR: 4.39±5.36mins; $H(1)=0.04$, $p=0.43$) (Figure 6.1.b). No trend was noted for moderate activity levels (HR: 18.64±13.30mins, LR: 18.32±13.72mins) (Figure 6.1.c).



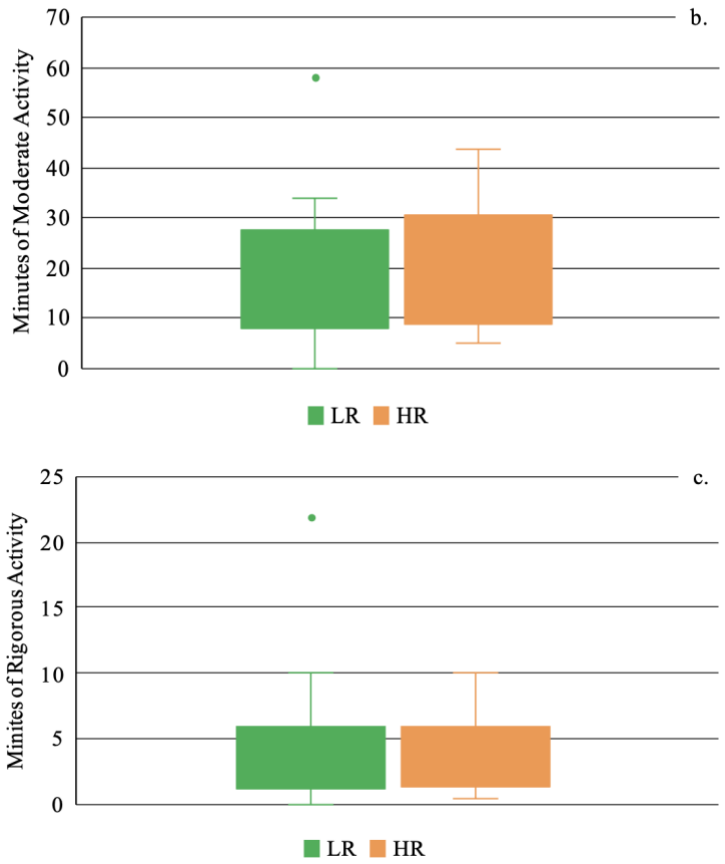


Figure 6.1. *Average minutes of Light (> 320 cpm) (a), Moderate (>1048 cpm) (b), and Rigorous (> 1624 cpm) (c) activity for children at HR and LR of myopia as measured objectively (Actiwatch) for the 31 children who participated in the 2-week Summer studies.*

The four children who have already developed myopia had a pattern that seems to indicate shorter light (Myopes: 183.36±53.82mins), moderate (Myopes: 14.24±5.41mins) and rigorous (Myopes: 2.34±1.27mins) activity levels in these children.

6.4. Discussion

Although there was a trend toward shorter times spent on light and rigorous activity levels in the HR and myopic groups compared to the LR group, there were no statistically

significant differences. In contrast, there was a significant difference in the total amount of time spent outdoors between the two groups, with children at HR for myopia, and those that have developed myopia spending less time outdoors. Consistent with previous studies, these results indicate that the protective effect of outdoor time is independent of the increased activity levels associated with being outdoors. Reduced activity may be related to myopia development, but it does not appear to be the main contributor based on the objective findings. A limitation of this study, as mentioned in Chapters 4 and 5, is that there was a large number of minutes reported as “off-wrist” time for most subjects, and all data were kept (i.e., those days with significant “off-wrist” times were not removed from the analyses).

Although we planned to also capture activity data with subjective methods, using the Activity Log 1 (Appendix II), the parents’ responses to these questions were too vague to be useful. For example, the answers to many of the questions on different activities had caveats written next to them such as “some days", “only a couple of days” or “depends on the weather.” Other activities were listed as ranges as wide as 4-6 hours or even more vaguely “60+ minutes" or “120 minutes or more.” We had also planned to categorize the activities the child did into light, moderate, and rigorous groups using metabolic equivalents similar to the Actiwatch to compare subjectively and objectively obtained activity levels (Jetté et al. 1990). However, due to non-specific responses such as “afternoon activities”, “outdoor activities", “YMCA” and “clubs” or grouping activities like “swimming, walking, and playing” together we could not categorize them. Similar issues persisted with the responses to the Activity Log 2 (Appendix III) despite the changes made to improve this questionnaire from the original Activity Log 1 (Appendix II). These findings indicate the difficulty in creating good quality

and reliable questionnaires and support the findings that an open-response style questionnaire is not optimal for subjective measures of behaviors in children.

7. SLEEP AND MYOPIA

7.1. Introduction

Previous studies have shown mixed evidence as to whether sleep patterns play a role in myopia development. Some studies using subjective measures of sleep have suggested that shorter sleep duration, later bedtimes and earlier wake times may be correlated with myopia, while others do not support these findings (Jin et al. 2023). A study evaluating sleep patterns on 11-18 year old subjects with or without myopia found that myopia was "positively associated with late bedtime during holidays but negatively correlated with daily wake time after 6 am during the semester" (Qu et al. 2020). Korean students with myopia between 12 and 19 years of age were more likely to sleep less than 5 hours (Jee et al. 2016). Another study suggested that bedtimes after 9:30PM significantly increased the risk of myopia in a patient population of children 6-10 year old with or without myopia (Liu et al. 2020). The studies as mentioned above all used subjective measures to assess sleep patterns. When measured objectively, one study showed variability of sleep duration and shorter sleep latency (taking less time to fall asleep once in bed) were related to myopia (Ostrin et al. 2020), with no differences noted in bedtime, wake up time or total average sleep duration (Ostrin et al. 2020; Mirhajianmoghadam et al. 2021; Bhandari et al. 2022).

No previous studies have investigated sleep patterns before myopia development using objective measurement methods. Understanding whether sleep patterns differ in children before they do or do not develop myopia is important to determine whether sleep patterns have a causative effect on myopia development.

7.2. Methods

Objective measures of bedtime, wake time, and total minutes of sleep per night were obtained from the Actiwatch worn by children during both Summer 2-week Trials. The same limitations related to “off-wrist” times described in Chapters 4-6 apply to the sleep results but no data could be added manually to the sleep results.

Subjective measures were obtained using the PICNIC follow-up questionnaire. From these measures we analyzed bedtime on nights before school days and non-school days, wake time on school days and non-school days, and total minutes of sleep per night on nights before school days and non-school days. Subjective measures of sleep patterns were not included in the Daily Survey for Summer 1 trial, but were added to the modified Daily Survey for Summer 2 trial. Children that participated in the Summer 2 trial were asked daily questions on bedtime, wake up time and total minutes of sleep via text message. However, statistical analysis was not conducted for these Daily Surveys as data was only available for 11 of the children that participated in this sub-study and much of the data that was available was incomplete due to a lack of response by the parents to the sleep related questions.

Statistical analyses of sleep patterns obtained from the Actiwatch and PICNIC follow up questionnaires were assessed using SPSS. Shapiro-Wilk tests were used to evaluate for normal distribution ($p<0.05$). The differences in average bedtime, wake time and total minutes of sleep per night between children in the HR for developing myopia group and those who were in the LR group were compared using Independent-Samples Kruskal-Wallis tests. Raw data on sleep patterns for each participant at day is shown in Appendix VII.

7.3. Results

For the Actiwatch data, Shapiro-Wilk tests indicated the majority of the data sets are normally distributed ($p<0.05$). Due to obvious errors in the sleep patterns reported by the Actiwatch, data from two subjects (S132 and S065) was removed from the analysis. These errors included extremely long and short sleep durations as well as bed and wake times outside of a typical sleep schedule. Tukey's Hinges tests were done on the remaining N=29 subjects to identify outliers. One subject (S054) was identified as an outlier outside the interquartile range for both bedtime and wake up time and was subsequently removed from the comparison analysis. Results were therefore available for N=12 children at High Risk (HR) and N=16 at Low Risk (LR) for developing myopia.

Average bedtime for all children and all days was 9:34PM when measured with the Actiwatch. When measured by the PICNIC questionnaire, average bedtime was earlier, 8:39PM on school nights and 9:12PM on non-school nights. A trend was noted toward children at HR for myopia having later bedtimes (Daily Surveys 9:20PM; Actiwatch 9:46PM; PICNIC questionnaire 8:45PM school nights, 9:32PM non-school nights) than those at LR for myopia (Daily Surveys 9:14PM; Actiwatch 9:25PM; PICNIC questionnaire 8:34PM school nights, 8:55 PM non-school nights), but these findings did not reach statistical significance for objective Actiwatch measures ($H(28,1)=0.11$, $p=0.75$) (Figure 7.1.) or the PICNIC questionnaire school nights ($H(31,1)=0.37$, $p=0.54$) or non-school nights ($H(31,1)=2.75$, $p=0.097$).

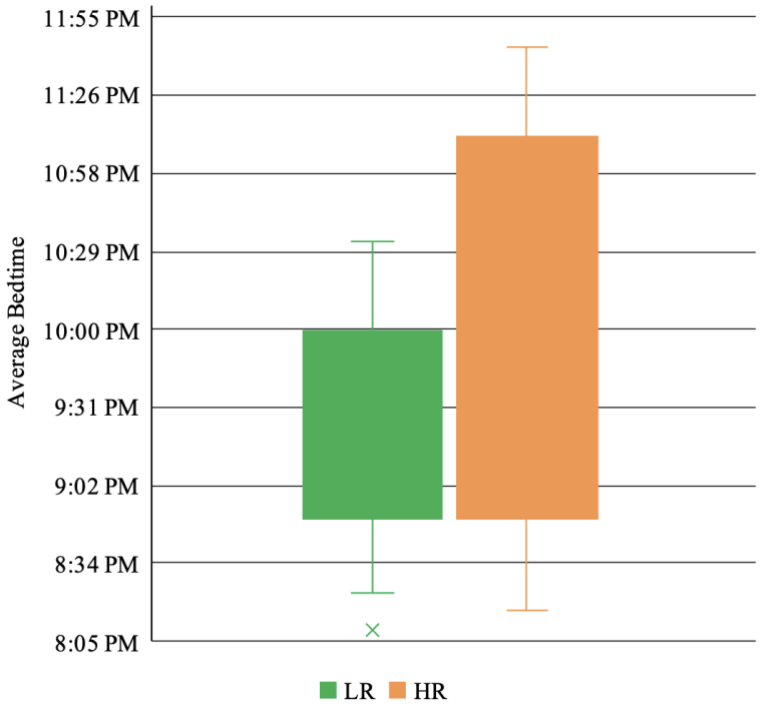


Figure 7.1. *Average bedtime for children at LR and HR of myopia as measured objectively (Actiwatch) for 28 children who participated in the 2-week Summer studies.*

Average wake-up times for all children was 7:06AM as measured with the Actiwatch. Wake times for all children measured with the PICNIC questionnaire showed differences between school days (6:48AM) and non-school (7:30AM) days. No statistically significant differences in wake times were noted between children at HR and LR for myopia, except for non-schools days measured by the PICNIC questionnaire which found that children at HR for myopia wake up later (HR: Daily Surveys 7:03AM, Actiwatch 7:17AM, PICNIC questionnaire 6:48AM school days, 8:12AM non-school days; LR: Daily Surveys 7:18AM, Actiwatch 6:58AM, PICNIC questionnaire 6:47AM school days, 6:54AM non-school days) (Actiwatch: ($H(29,1)=0.01$, $p=0.91$); PICNIC questionnaire school days: ($H(30,1)=0.03$, $p=0.86$), non-school days: ($H(31,1)=10.12$, $p=0.001$) (Figure 7.2.).

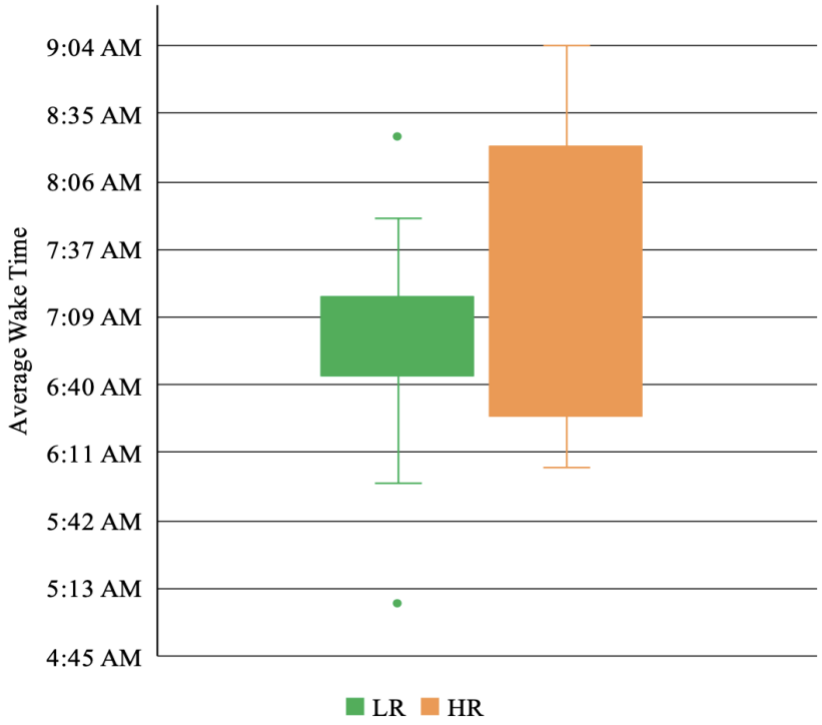


Figure 7.2. *Average wake time for children at HR and LR of myopia as measured objectively (Actiwatch) for 28 children who participated in the 2-week Summer studies.*

A non-statistically significant trend was noted toward longer total hours of sleep per night in children at LR for myopia compared to those at HR with all methods (Daily surveys: LR 10:04 hours, HR 9:42 hours; Actiwatch: LR 8:24 hours, HR 8:17 hours, $H(30,1)=0.06$, $p=0.80$; PICNIC questionnaire school nights: LR 10:13 hours, HR 9:34 hours, $H(31,1)=0.02$, $p=0.97$). However, the results from the PICNIC questionnaire on non-school nights show that children at HR for myopia slept significantly longer those nights (10:40 hours) compared to children at LR (9:59 hours) ($H(31,1)=5.25$, $p=0.02$) (Figure 7.3.).

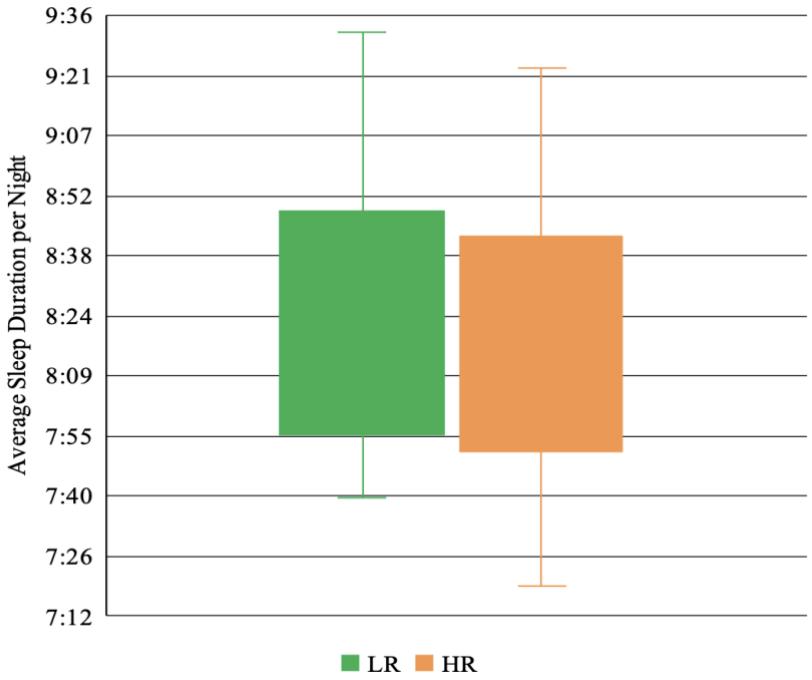


Figure 7.3. *Average hours of sleep duration per night for children at HR and LR of myopia as measured objectively (Actiwatch) for 28 children who participated in the 2-week Summer studies.*

Only one subject who has become myopic was part of Summer 2 trial (the other 3 were part of Summer Trial 1). Therefore, the Daily surveys' subjective reports could not be included in analysis for myopic subjects as these questions were only asked during Summer Trial 2. The objective Actiwatch data was also not used to compare sleep patterns between those in the LR group and those that developed myopia due to lack of data collected for the myopic subjects. The Actiwatch occasionally does not report sleep data due to measurement errors and this was the case for two (S065, S066) of the four myopic subjects. Subjective sleep data from the PICNIC questionnaire show similar wake up times (Myopia: 6:33AM; LR: 6:47AM), bedtimes (Myopia: 8:30PM; LR: 8:34PM), and sleep duration (Myopia:

10:03; LR: 10:13) in children with myopia compared to those at LR for myopia on school nights. However, on non-school nights children with myopia tend to go to bed later (Myopia: 9:37PM; LR: 8:55PM) and wake up later (Myopia: 7:45AM; LR: 6:54AM), with no differences in sleep duration (Myopia: 10:07; LR: 9:59). We lacked sufficient power to conclude on the significance of these results.

7.4. Discussion

Although trends were noted toward children at HR for myopia having later bedtimes and shorter sleep durations than those at LR when using an objective method, these findings did not reach statistical significance. The only differences noted when using the PICNIC follow-up questionnaire, which asks parents to report what they recall the children's behaviors the week before the visit, was that children at HR subjects slept significantly longer on non-school nights, with no differences on school nights. The difference arises from children at HR for myopia waking up later in the mornings when they don't have school. This could impact myopia development as exposure to light in the morning is necessary to maintain normal circadian rhythms (Blume et al. 2019). It has been shown that altering circadian rhythms can induce myopia in animal models using chick models (Nickla 2013). We could not determine a causal effect of sleep patterns on myopia development due to methodological limitations (there was a large number of "off-wrist" time in most children, which may have been more frequent while the child was asleep) and a lack of statistical power as too few children who have so far developed myopia within this sub-group of children from the PICNIC study. The current results add to previous literature showing inconsistent results on sleep patterns related to myopia development in children (Ostrin et al. 2020;

Mirhajianmoghadam et al. 2021; Bhandari et al. 2022).

When comparing the objective and subjective measurement methods, prior to removing the outliers, the Actiwatch shows later bedtimes (23 minutes on average) and later wake times (12 minutes on average) compared to the PICNIC subjective questionnaires. Although the Actiwatch has been validated for sleep measurements in adults (Pigeon et al. 2018), the inconsistency noted between the two methods in the current studies brings into question the accuracy of how these devices measure sleep using an accelerometer and inactivity to qualify as sleep. Because the Actiwatch uses activity to calculate sleep, these devices may find a later bedtime and shorter sleep duration when subjects move in their sleep, or when the devices move around the very small wrists these children have. It is also reasonable to assume that parents do not know precisely when their child falls asleep, reporting the time that they put them to bed, but that they may have stayed up later. There seems to be a similar combination of overestimation by the parents and underestimation by the devices with sleep patterns as that we found for the outdoor time findings (Chapter 4). The Actiwatch seems to be giving unrealistic bedtimes for many of these young children, and that was the reason for removing two of them (S132 and S065) from the analysis, as there were many more "off-wrist" minutes noted in these subjects (Appendix XI). This may indicate that although the watch continues recording when "off-wrist" time is detected, the sleep data collected is unreliable. We believe the mislabeled of "off-wrist" times may be due to our subjects being children and having smaller wrists, although the company that creates the Actiwatch devices claims that they are intended to be used for both children and adults.

We were unable to use sleep data from the Activity Log 1 (Appendix II) due to many parents listing ranges such as “bedtime 11 to 12 PM”, or “wake time 6:00 or 6:30”, or “around 7AM”. Again, this indicates that an open-response questionnaire is not ideal for subjective measures and a forced choice would be better for questions involving time. Although the responses to Activity Log 2 (Appendix III) did provide specific times, this data was discarded as the majority of parents did not complete the log in all three instances it was dispensed to them (at day 0, 7 and 14 of their child's Summer Trial).

8. NEAR WORK AND MYOPIA

8.1. Introduction

Near work has been thought to be associated with myopia for hundreds of years, as discussed in the Introduction chapter. Many studies have consistently shown a significant correlation between myopia development and progression and the amount of near work both in children and adults (Dutheil et al. 2023). Although we know this correlation exists, causation has yet to be determined.

Only one study has evaluated near work data before and after myopia development. When looking at children 5 years before they became myopic through 5 years after myopia development, they found no difference in near work amounts between pre- and post-myopic subjects (Jones-Jordan et al. 2012). However, this study was retrospective, using data from the CLEERE Study. The near work measures were from a subjective questionnaire delivered only once a year asking parents to report an average for the entire school year "how many hours per week (outside of regular school hours) would you estimate this child: studies or reads for school assignments; reads for fun (pleasure); watches TV; and uses a computer/plays videogames." This method of measure is limited by poor recall, averaging over a long period of time, lack of repeated measures and only including time outside of school. More research using prospective studies before myopia develops are needed to determine if there is causation. In addition, this previous study was conducted from 1989 to 2009, and it is important that we continue to investigate this relationship in the modern context of increased near-work demands and the use of electronics as technology continues

to develop. This study will be the first to prospectively investigate the effects of near work on myopia development in an entirely pre-myopic group of children.

8.2. Methods

Subjective measures of near work were obtained using the PICNIC follow-up visit questionnaires from the Summer 2-week Trials. A weekly average of minutes of near work for school days and non-school days was reported by the parents (Appendix I), whereas the typical near work distance was measured in the lab during the PICNIC study visits. We did not obtain objective measures of near work for this group of subjects as we had no available devices to measure viewing distances at the time of these studies.

Statistical analyses of near work were assessed using SPSS. Tukey's Hinges test was used to evaluate for outliers within the 75 percentiles. Shapiro-Wilk tests were used to evaluate for normal distribution ($p<0.05$). The minutes of near work as well as viewing distances between the HR and LR subjects were compared with Independent-Samples Kruskal-Wallis tests. Raw data on sleep patterns for each participant at day is shown in Appendix VII.

8.3. Results

Tukey's Hinges test indicated that there are no outliers within the 75 percentiles. Shapiro-Wilk tests indicated the majority of the data sets are not normally distributed ($p<0.05$). A trend was noted towards reported longer times doing near work activities on school days for young children at HR for myopia (91.07±70.22mins) compared to those at LR (58.76±23.55mins; $H(1)=3.27$, $p=0.07$) (Figure 8.1.).

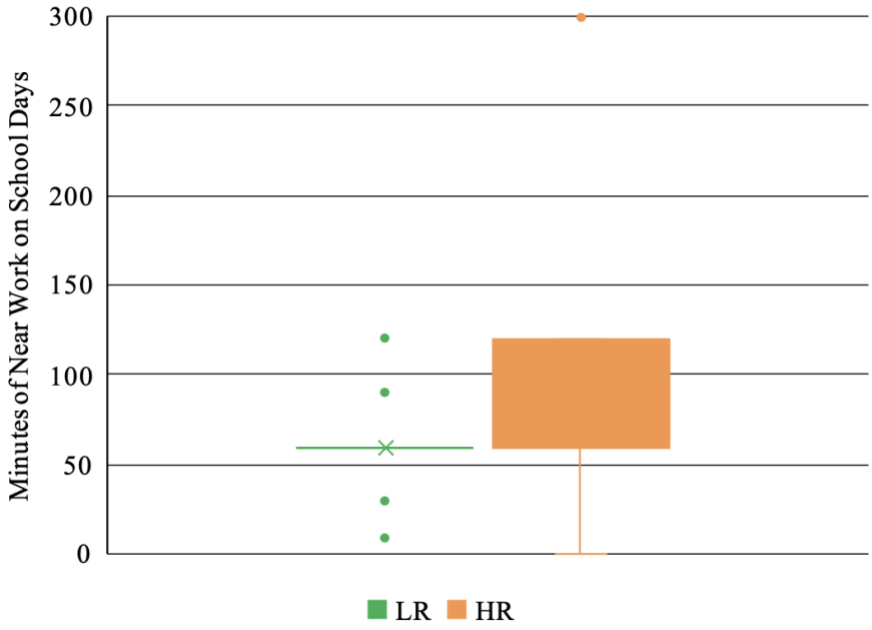


Figure 8.1. *Average minutes of near work on school days for children at HR and LR of myopia reported on the PICNIC Questionnaire (Appendix I) for the week prior to visit for the 31 children who participated in the 2-week Summer studies.*

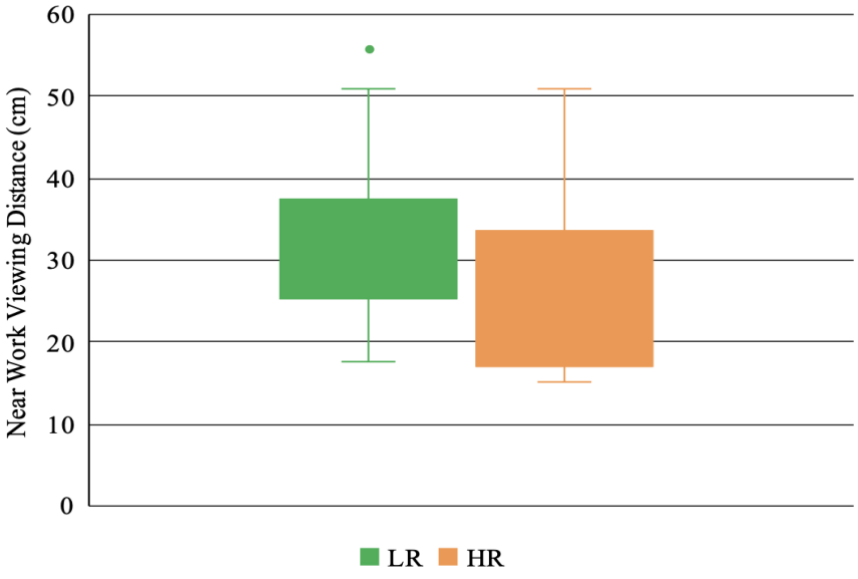


Figure 8.2. *Average near work viewing distance for children at HR and LR of myopia reported by the parents on the PICNIC Questionnaire (Appendix I) for the 31 children who participated in the 2-week Summer studies.*

No differences were noted for non-school days. A similar trend was noted for closer viewing distances in children at HR (27.40±10.27cm) compared to those at LR (33.17±11.44cm), with no significance (Figure 8.2.).

8.4. Discussion

The trends found by the PICNIC follow up questionnaire toward children at HR showing reporting longer near work activities on school days and closer viewing distances than children at LR are consistent with the hypothesis that near work is a risk factor for myopia development. Previous studies (Dutheil et al. 2023) have also shown myopia risk with shorter working distances and increased near work but this is the first study to prospectively investigate these effects in an entirely pre-myopic group of children.

A significant limitation in this study is that the data were obtained from surveys answered by parents who are not with their children during the entire day. Devices that measure viewing distances objectively in real time have recently been developed and are the future in behavioral metrics for myopia research (Zhang et al. 2022). The ClouClip was the only one of these devices available at the time of this study and it was decided that a glasses mounted option would not be a good option for these emmetropic subjects because wearing glasses could alter their typical behaviors. In addition, we only had access to one such device. Other devices have been developed since then, including the Vivior that we used along with the ClouClip in the validity test in adults (see Chapter 9). The ClouClip has been used in several studies with both adults (Bhandari and Ostrin 2020) and children (Wen et al. 2019, 2020, 2021; Zhang et al. 2023) with or without myopia. The Vivior has been used in several studies

involving presbyopic patients as that is the population it was initially designed for (Pajic et al. 2020; Ribeiro et al. 2022). Our group and others have also recently started to use this device in myopia research (Mrochen et al. 2020; Sarkar et al. 2024). No studies to date have measured viewing distances longitudinally in children before and after myopia development.

In addition to the need for a longitudinal study with objective measures of near work time and viewing distances, a more in-depth investigation is needed to determine if the association of near work and myopia is affected by the type of media (physical vs. digital), as well as the effect of the specific viewing distances. The results reported in this chapter were measured using the PICNIC follow-up questionnaire, which only asked about total near work per day, which averaged over seven days, and did not investigate the specifics of the subjects near activities. We attempted to measure these specifics with Activity Log 1 (Appendix II) but were unable to elicit sufficient information due to the parents' vague responses. For example, one parent responded to the near work activities at school by listing “school work” for seven hours not taking into account that a child would not be doing continuous near work for that long. We had planned to calculate diopter hours for each day in a manner similar to Formula 8.1. taken from a study done by Bhandari et al in 2022 (Bhandari et al. 2022).

$$\begin{aligned}&\text{Subjective diopter hours}\\&= \left[3 \times (\text{hours reading print} + \text{hours drawing,painting,writing} + \text{hours using handheld devices})\right]\\&+ \left[1.5 \times (\text{hours using computers} + \text{hours playing board games or cards})\right].\end{aligned}$$

Formula 8.1. *Diopter Hours calculation method.*

Given that almost all the parents combined their answers to include both distance and near work activities, for example “iPad and TV - 30 min”, and they did not indicate how much time was spent on each, we were not able to perform the planned analysis. Many parents listed activities such as “video games” or “Nintendo”, without an indication on whether the activities were done on a TV (further viewing distance) or handheld device. One parent responded to the question regarding near work activities at school and drew an arrow to the examples given, writing “all of them.” Similar issues persisted with the responses to the Activity Log 2 (Appendix III) despite the changes made to improve it from Activity Log 1 (Appendix II). These results indicate the limitations of using an open-response style questionnaire for subjective measures and that questions should be worded in a way that separates near work from intermediate and distance when asking about the use of electronics. Although the Activity logs were not useful in collecting subjective data about near work, when we asked parents, “Would you consider/have you made changes to encourage more time outdoors and less near work since using the questionnaire?”, one parent stated, “Yes, I find myself regularly making sure they are a healthy distance from the screen when using it.” Another parent said they encouraged their child to watch TV instead of using the iPad. One other stated that as an alternative to screen time they were trying to have their child “play with a ball inside, have him help me cook and go out to do grocery shopping.” One parent left comments next to their responses of screen time for pleasure in the log such as “a lot!” and “too long!”. These findings are encouraging in that asking parents to report their children near work behaviors subjectively motivates them to improve their habits related to myopia risk.

9. DEVICE COMPARISON

9.1. Introduction

The Actiwatch was used for objective testing of the visual environment in the children participating in the PICNIC study because it had been used in previous studies measuring outdoor time in relation to myopia (Read et al. 2014, 2015; Ostrin 2017; Ostrin et al. 2018) and it did not require these non-myopic subjects to wear glasses. When evaluating the data from children wearing the Actiwatch, the objective outdoor time measured with the Actiwatch was lower than that reported subjectively by the parents, in agreement with results from previous studies. However, after further evaluation of the raw data with light exposure measured every 30 seconds by the Actiwatch, it became clear that there were many times when children were outdoors but the Actiwatch was not measuring amounts of light over 1000 lux, hence not classifying the time as outdoors. An example of these gaps can be seen in the poster presented at Academy 2022 (Appendix IX) in the Transitions Data Sample from a random subject. That data sample is over a 26-minute period, and it is unlikely that the child transitioned from indoors to outdoors at 13 different times within that time frame. Many findings similar to these occurred for all subjects. Because of these gaps in data, we decided to calculate “transitions” to show potential errors in these objective measures. As described in Chapter 4, the number of transitions found are not feasible in many instances, indicating that the Actiwatch likely underestimates the time spent outdoors. In an attempt to assess the accuracy of the Actiwatch in estimating time outdoors, another set of trials were conducted comparing the Actiwatch with other devices that have been used in previous studies (HOBO pendant, Clouclip) or have recently become available (Vivior) to measure

outdoor time using exposure to light levels (see Chapter 1 for a description of each device). A Validation study comparing light levels with a gold standard light meter was also conducted.

9.2. Methods

Three Comparison Trials were conducted on young adult subjects (lab members) based on the devices that were available at the time. Comparison Trial 1 included only the Actiwatch and HOBO pendant (simultaneously) as the Clouclip devices were backordered at the time of the Academy 2022 presentation (Appendix IX) deadline. Trial 2 was completed when the Clouclip devices arrived, which were then compared with the Actiwatch and HOBO pendant. Both Trial 1 and 2 included three participants due to the number of devices available. Subjects wore the three devices simultaneously. A few months later, we had access to a new device, the Vivior. Trial 3 included one subject who simultaneously wore the Vivior as well as the other three devices (Actiwatch, HOBO pendant, Clouclip). Since both the Vivior and the Clouclip are designed to attach to the right side of the patient's glasses frames, the Vivior (one available) was used on the right side and two Clouclips were used for this comparison to determine the best mounting position for comparison studies. One Clouclip was attached to the Vivior and another one attached to the left side of the frames placed upside down (see Chapter 3.2.3 and Figure 3.1).

In addition to the objective measures obtained at these three device comparison trials, a careful and detailed subjective recording of the time spent outdoors and the number of transitions from an outside to an indoor environment were obtained each day using an

activity diary. The three young adults working in the lab who participated in Trial 1 and Trial 2 studies were the two lab coordinators (S01 and S02) and the MS student (S03). The MS student was the only subject for Trial 3. All three subjects had generally normal systemic and ocular health. The refractive errors of the three subjects were: S01 OD -3.00 -0.75x175, OS -3.25 -0.50x178; S03 OD -2.50 -1.00x180, OS +0.75 -1.75x180. S02 is a functional emmetrope, but wears a 4D base out prism to control an esophoria from breaking down.

The objective recordings of minutes of time spent outdoors each day were obtained from each device used in each trial as described in Chapter 3 and Chapter 4. The number of "transitions" from indoor to outdoor for each day was calculated as described in Chapter 3.2. for each of the devices worn during the three trials. Both the minutes of outdoor time and the number of transitions for each day that were subjectively recorded were also calculated. The subjectively reported time outdoors was recorded in two different ways for Trial 2 and Trial 3, with and without considering time in a vehicle as outdoors time. This was done because the objective devices may or may not measure this as time outdoors. In Trial 3 the objective viewing distances were also obtained from the ClouClip and Vivior devices.

Results of the number of transitions for Trial 1 during seven days with the three methods (Diary, Actiwatch and HOBO pendant), and for Trial 2 during four days with the four methods (Diary, Actiwatch, HOBO pendant and ClouClip) were assessed using SPSS. Tukey's Hinges test was used to evaluate for outliers within the 75 percentiles. Shapiro-Wilk tests were used to evaluate for normal distribution ($p<0.05$). Related Samples Friedman's

Two-Way Analysis of Variance by Ranks tests were used to compare the time spent outdoors and number of transitions provided by each method in the same population.

Lastly, a Validity Test was performed as described in Chapter 3.2.4. In brief, light levels were measured over the course of five minutes for seven different conditions using the four test devices (Actiwatch, HOBO pendant, Clouclip and Vivior) as well as two light meters (iPhone application Lux Light Meter Pro and the Dr. Meter LX1330B light meter). The seven conditions tested included indoors with natural light, indoors with full illumination, facing a computer screen, indoors next to a window, outdoors under direct sun, outdoors under a shade, and outdoors in a car driver's seat. An average of all measures taken by each of the four test devices and an average of three measures manually taken with the two light meters were used in the analyses. For both the Comparison Trials and Validity test the Actiwatch and HOBO pendant captured data every 30 seconds. The Clouclip measured every 5 seconds and the Vivior every 1 minute.

9.3. Results

Outliers that fell outside the 75 percentiles were present as determined by the Tukey's Hinges tests and removed. Shapiro-Wilk tests indicated the majority of the data sets are normally distributed ($p<0.05$). During comparison Trial 1, the Actiwatch provided the lowest amounts of time spent outdoors (daily average 31.69±17.55mins), followed by the Subjective diaries (daily average 45.90±8.67mins) and the HOBO pendant device (daily average 66.83±25.68mins) (Figure 9.1.). These results are similar to those found in the children enrolled in PICNIC, as described in Chapter 4.

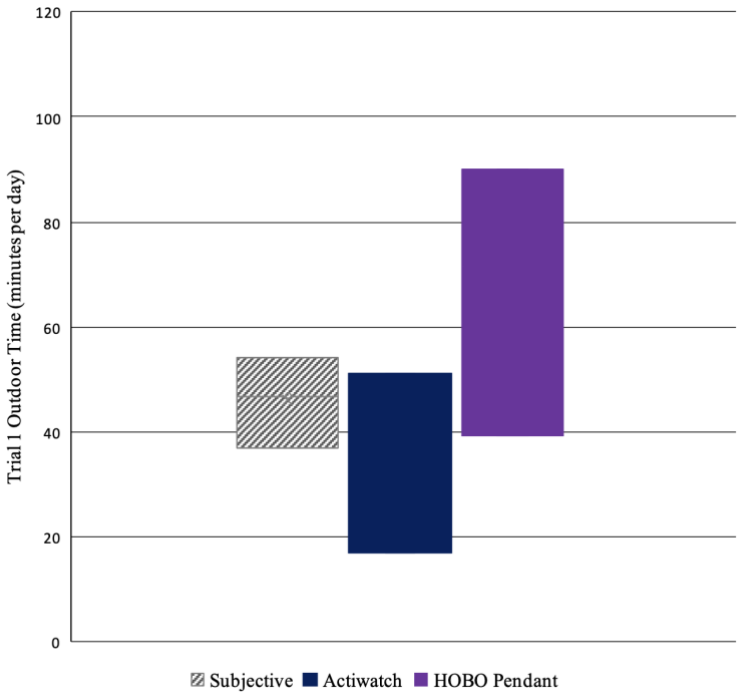


Figure 9.1. *Seven-day average* ***minutes of time outdoors*** *for the three adult subjects who participated in device comparison Trial 1 as measured by subjective (Activity Diary) and objective measures (Actiwatch and HOBO Pendant).*

It is important to note that the HOBO pendant, an objective metric, provided longer times outdoors than the subjective measures in this study. Given the nature of the study, with three subjects wearing two devices, there was insufficient power to find statistically significant differences (Related Samples Friedman ‘s Two-Way Analysis of Variance by Ranks: $F(3,2)=4.667$, $p=0.097$). Nevertheless, these results provide some support for the hypothesis that the Actiwatch may underestimate the time spent outdoors. To provide information on the variability of the measures, the daily measures for Trial 1 are provided in Table 9.1.

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Average
Subjective	12	14	22	8	216	18	32	**46**
Actiwatch	8	19	27	9	113	20	27	**32**
HOBO Pendant	54	41	39	16	215	54	49	**67**
CoV	1.03	0.58	0.30	0.40	0.33	0.66	0.32	**0.37**

Table 9.1. *Average daily minutes of time outdoors for the three adult subjects who participated in device comparison Trial 1 as measured by subjective (Activity Diary) and objective measures (Actiwatch and HOBO Pendant) with covariance (CoV) between measurement methods.*

On the other hand, the Actiwatch provided the largest number of transitions from indoors to outdoors (17±10 times per day in average), followed by the HOBO pendant (15±5 times per day in average) and the Subjective diaries (4±2 times per day in average) (Figure 9.2.). To provide information on the variability of the measures, the daily number of transitions measures for Trial 1 are shown in Table 9.2.

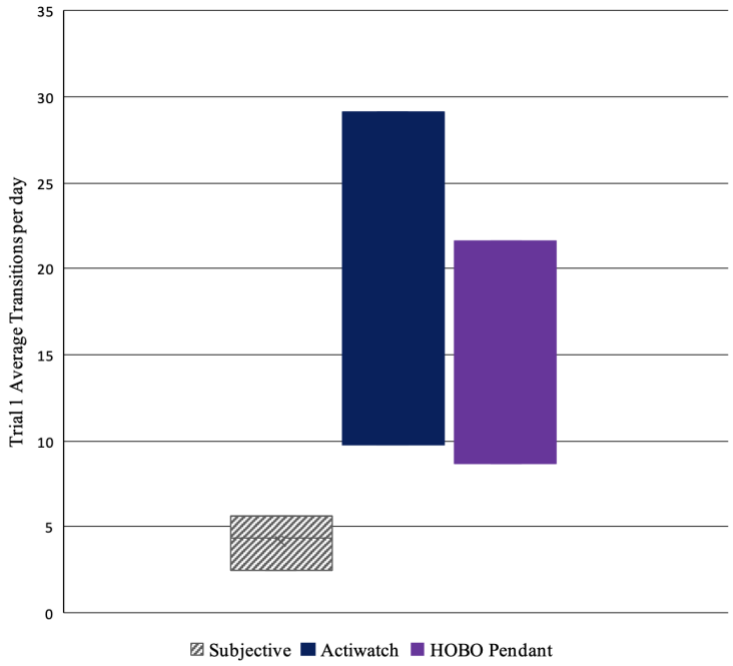


Figure 9.2. *Seven-day average* ***transitions*** *between inside and outside for the three adult subjects who participated in device comparison Trial 1 as measured by subjective (Activity Diary) and objective measures (Actiwatch and HOBO Pendant.*

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Average
Subjective	6	2	4	3	4	6	4	**4**
Actiwatch	8	14	16	7	49	9	18	**17**
HOBO Pendant	12	11	10	9	38	14	14	**15**
CoV	0.35	0.69	0.60	0.48	0.77	0.42	0.60	**0.58**

Table 9.2. *Average daily transitions inside to outside for the three subjects who participated in device comparison Trial 1, measured by subjective (Activity Diary) and objective measures (Actiwatch and HOBO) with covariance (CoV) between measurement methods.*

Results of time outdoors in comparison Trial 2 somewhat differed from those in Trial 1 in that very little difference was noted across all methods (Daily average for Subjective diary no car 29.75±27.27mins; Actiwatch 49.54±41.72mins; HOBO pendant 39.79±23.88mins; Clouclip 48.50±18.50mins) ($F(3,2)=1.800$, $p=0.615$) (Figure 9.3.). Objective measures were more similar across devices for this Trial 2 to those in Trial 1, and they were similar to the subjective measures when the time in the car was not considered as time outdoors.

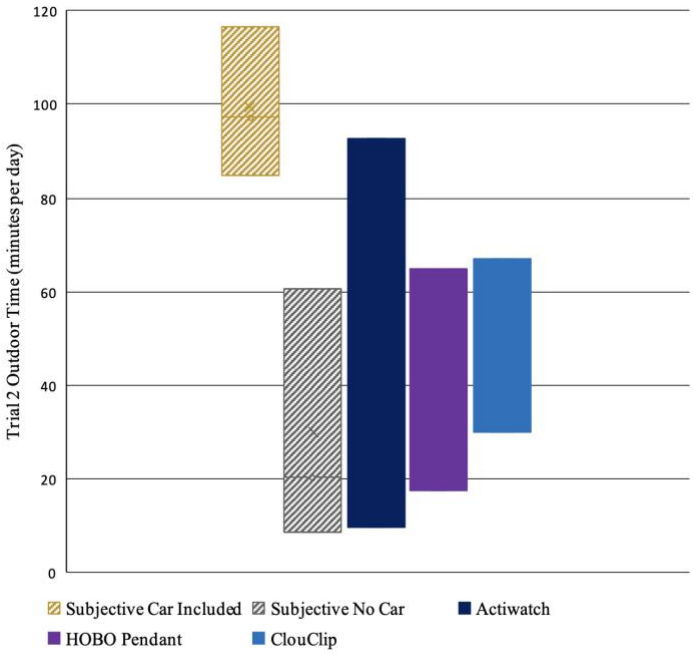


Figure 9.3. *Four-day average* ***minutes of time outdoors*** *for the three adult subjects who participated in device comparison Trial 2 as measured by subjective (Activity Diary both including and excluding time in a vehicle as outdoors) and objective measures (Actiwatch, HOBO pendant, Clouclip).*

When subjective measures included the time spent in a car as outdoor time, these values were much higher than the objective measures (daily average diary with car considered outdoors 99.58±15.88mins). These results indicate that time spent in the car should not be considered time outdoors if comparable results are to be found. However, this is contradicted by findings from the Validity tests, as shown below. To provide information on the variability of the measures, the daily measures for Trial 2 are shown in Table 9.3.

	Day 1	Day 2	Day 3	Day 4	Average
Subjective Car Included	67	71	144	116	**100**
Subjective No Car	15	9	30	65	**30**
Actiwatch	26	53	12	107	**50**
HOBO Pendant	33	57	13	56	**40**
ClouClip	33	45	16	101	**49**
CoV	0.56	0.49	1.32	0.30	**0.50**

Table 9.3. *Average minutes of time outdoors each day for the three adult subjects who participated in device comparison Trial 2 as measured by subjective (Activity Diary both including and excluding time in a vehicle as outdoors) and objective measures (Actiwatch, HOBO pendant, Clouclip) with covariance (CoV) between measurement methods.*

The number of transitions in Trial 2 were also similar to those noted in Trial 1, with the Actiwatch showing again the largest number of transitions between indoors and outdoors (40±32 times per day in average), followed by the HOBO pendant (14±4 times per day in average) and the Clouclip (5±1 times per day in average). The Clouclip was the closest to subjective measures (4±2 times per day on average) of number of transitions (Figure 9.4.). To provide information on the variability of the measures, the daily number of transitions measures for Trial 2 are shown in Table 9.4. Results on the number of transitions are realistic by all methods except for the Actiwatch.

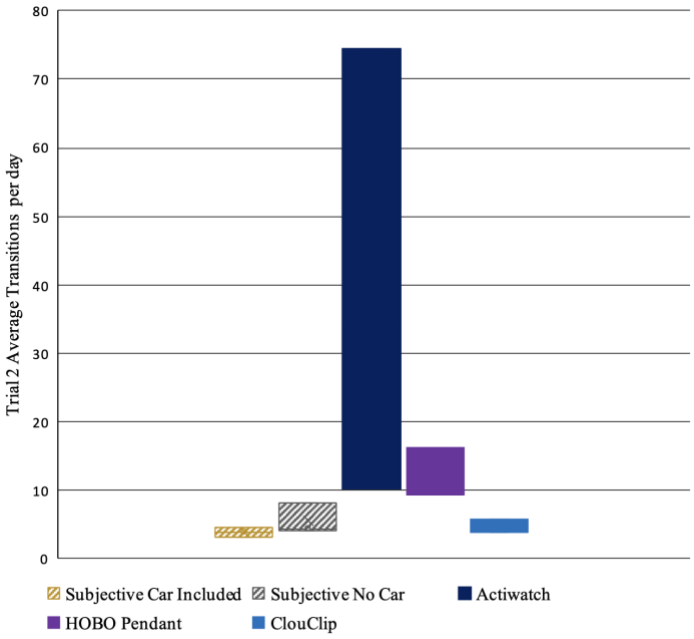


Figure 9.4. *Four-day average* ***transitions*** *between inside and outside for the three adult subjects who participated in device comparison Trial 2 as measured by subjective (Activity Diary both including and excluding time in a vehicle as outdoors) and objective measures (Actiwatch, HOBO Pendant, Clouclip).*

	Day 1	Day 2	Day 3	Day 4	Average
Subjective Car Included	4	3	4	5	**4**
Subjective No Car	5	5	5	7	**6**
Actiwatch	23	39	12	85	**40**
HOBO Pendant	13	14	12	15	**14**
ClouClip	2	5	6	6	**5**
CoV	0.92	1.14	0.50	1.46	**1.12**

Table 9.4. *Average transitions inside to outside each day for the three subjects who participated in device comparison Trial 2, measured by subjective (Activity Diary both including and excluding time in a vehicle as outdoors) and objective measures (Actiwatch, HOBO, Clouclip) with covariance (CoV) between measurement methods.*

Trial 3 also showed somewhat different results compared to Trial 1 and Trial 2, with the Actiwatch reporting the largest time spent outdoors (daily average 122.00±95.83mins) and similar values found compared to the other three devices (HOBO daily average 89.50±43.08mins; ClouClip daily average 78.50±31.97mins; Vivior daily average

71.75±22.07mins) as well as with the subjective measures (with no car time included, daily average 98.25±73.11mins) (Table 9.5.). When the subjective measures include the time spent in a vehicle as outdoors time, this is again larger than all the objective devices (daily average diary with car considered outdoors 117.00±69.22mins) except the Actiwatch. Note that data for the Clouclip that was placed on the left side of the glasses frame (upside down) is not available due to a technical error. Clouclip data for Trial 3 is from the device attached to the right side of the glasses alongside the Vivior.

	Day 1	Day 2	Day 3	Day 4	Average
Subjective Car Included	136	205	80	47	**117**
Subjective No Car	68	205	80	40	**98**
Actiwatch	50	222	186	31	**122**
HOBO Pendant	69	153	78	59	**90**
ClouClip	76	120	76	42	**79**
Vivior	68	88	89	42	**72**
CoV	0.38	0.33	0.44	0.21	**0.21**

Table 9.5. *Daily minutes of time outdoors for one adult subject who participated in device comparison Trial 3 as measured by subjective (Activity Diary both including and excluding time in a vehicle as outdoors) and objective measures (Actiwatch, HOBO Pendant, Vivior, Clouclip) with covariance (CoV) between measurement methods.*

Transitions for Trial 3 were similar to those in Trial 2, with the Actiwatch giving the largest number of transitions (65±44 times per day in average) followed by the HOBO pendant (14±8 times per day in average), the Vivior (11±3 times per day in average), and Clouclip (9±3 times per day in average) devices, and these three devices giving similar values to the subjective measures (6±2 times per day in average) (Table 9.6.).

	Day 1	Day 2	Day 3	Day 4	Average
Subjective Car Included	9	5	4	7	**6**
Subjective No Car	8	5	4	6	**6**
Actiwatch	41	103	100	14	**65**
HOBO Pendant	25	12	6	11	**14**
ClouClip	12	11	5	7	**9**
Vivior	14	12	7	9	**11**
CoV	0.70	1.56	1.84	0.34	**1.26**

Table 9.6. *Daily transitions from inside to outside for one adult subject who participated in device comparison Trial 3 as measured by subjective (Activity Diary both including and excluding time in a vehicle as outdoors) and objective measures (Actiwatch, HOBO Pendant, Vivior, Clouclip) with covariance (CoV) between measurement methods.*

In terms of viewing distance, only assessed in comparison Trial 3, the average minutes of near viewing (≤ 40cm) measured by the ClouClip (daily average 427.50±89.99mins) was higher than measured with the Vivior (daily average 141.25±62.06mins) (Table 9.7.). The Vivior measured more minutes of intermediate (between 40 and 200 cm) (daily average 262.25±111.47mins) and far viewing (>200cm) (daily average 217.50±47.82mins) than the ClouClip (intermediate average 151.50±77.36mins, far average 158.25±109.20mins).

		ClouClip	Vivior	CoV
Minutes of Near (≤40cm)	Day 1	315	57	0.98
	Day 2	450	206	0.53
	Day 3	532	145	0.81
	Day 4	413	157	0.64
	Average	**427.5**	**141.3**	**0.71**
Minutes of Intermediate (>40cm, ≤200cm)	Day 1	221	297	0.21
	Day 2	178	274	0.30
	Day 3	166	371	0.54
	Day 4	41	107	0.63
	Average	**151.5**	**262.3**	**0.38**
Minutes of Distance (>200cm)	Day 1	314	250	0.16
	Day 2	153	148	0.02
	Day 3	92	248	0.65
	Day 4	74	224	0.71
	Average	**158.3**	**217.5**	**0.22**

Table 9.7. *Daily minutes of near, intermediate and distance viewing for one adult subject who participated in device comparison Trial 3 as measured by the Vivior and Clouclip devices with covariance (CoV) between measurement methods.*

Results for the Validity Test indicate that for conditions indoors next to a window, outdoors under the direct sun, or in the car and outdoors under a shade, the Dr. Meter and HOBO measured the highest lux compared to the other devices. For these conditions, all devices measured >1,000 lux except the Vivior, which only captured 927.8 lux outside in the shade, and the Light Meter app next to a window (343.7 lux). For the other conditions (inside natural light, inside full illumination, computer screen), all devices measured <1,000 lux, except the HOBO for inside natural light (1097.9 lux) (Table 9.8. and Figure 9.5.).

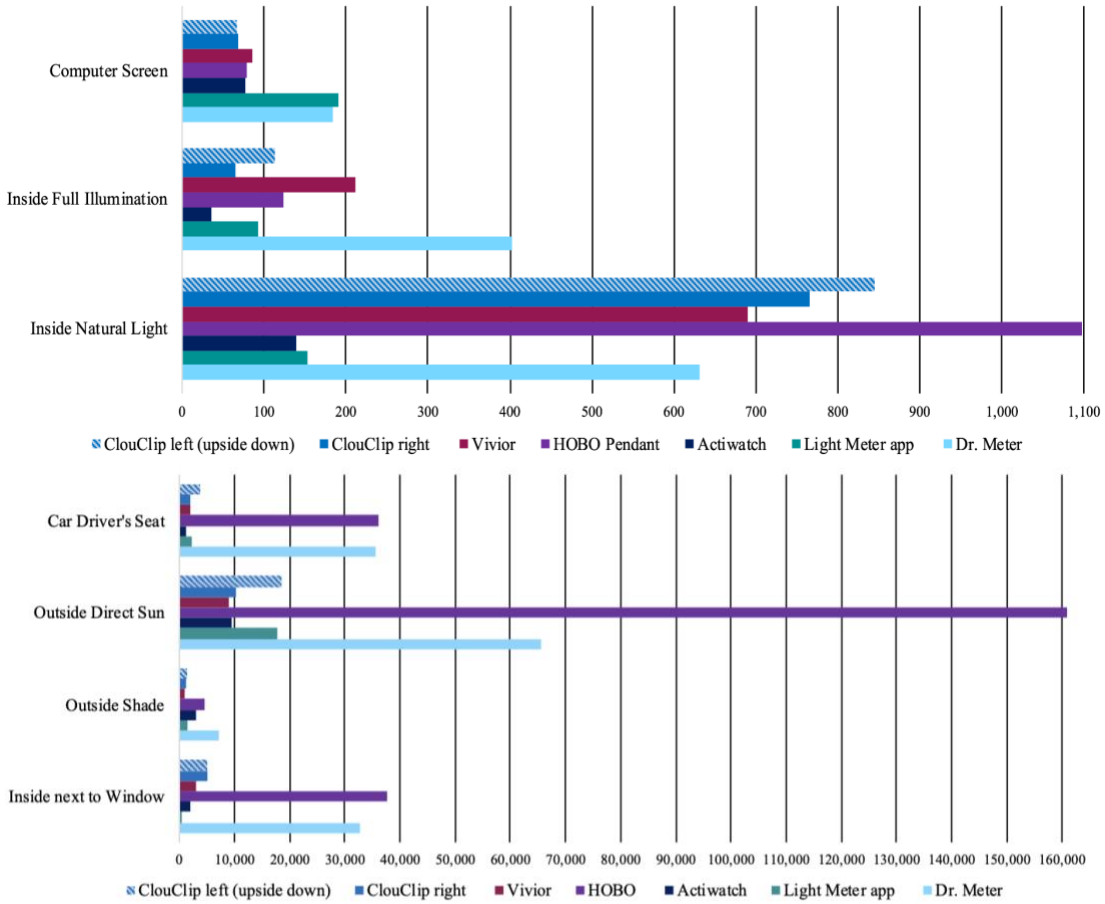


Figure 9.5. *Amount of light (in lux) measured by objective devices (Dr. Meter, Light Meter App, Actiwatch, HOBO Pendant, Vivior, ClouClip right side of glasses, ClouClip left side of glasses) over the course of 5 minutes under the seven different lighting conditions.*

	Inside Natural Light		Inside Full Illumination		Computer Screen		Inside next to Window		Outside Shade		Outside Direct Sun		Car Driver's Seat	
ClouClip left (upside down)	844.58	± 459.81	112.67	± 28.20	67.62	± 27.78	5061.78	± 1740.79	1423.40	± 906.42	18493.00	± 4597.10	3880.52	± 2260.85
ClouClip right	766.02	± 183.13	65.85	± 13.35	68.07	± 19.96	5142.45	± 2217.72	1134.52	± 134.85	10124.90	± 2225.84	2077.32	± 256.88
Vivior	690.39	± 409.99	211.95	± 2.72	84.86	± 23.58	3066.69	± 1164.16	927.77	± 111.69	9033.78	± 2870.45	2025.00	± 592.24
HOBO Pendant	1097.92	± 1097.92	123.80	± 15.45	78.58	± 43.07	37676.01	± 15732.65	4632.81	± 599.06	160925.50	± 34641.88	36029.13	± 14421.32
Actiwatch	139.64	± 94.42	36.40	± 148.46	77.60	± 41.21	2031.70	± 1803.04	2945.53	± 678.67	9529.79	± 3387.89	1109.52	± 673.06
Light Meter app	152.67	± 19.35	92.00	± 13.86	191.33	± 10.69	343.67	± 13.65	1412.67	± 101.91	17782.67	± 705.16	2284.00	± 403.72
Dr. Meter	630.67	± 13.20	402.00	± 0.00	184.67	± 11.02	32700.00	± 3407.35	7043.33	± 141.89	65433.33	± 12050.03	35600.00	± 6286.49
CoV		0.57		0.83		0.51		1.29		0.82		1.35		1.38

Table 9.8. *Average ± standard deviation light levels (lux) measured by objective devices (Dr. Meter, Light Meter App, Actiwatch, HOBO Pendant, Vivior, ClouClip right side of glasses, ClouClip left side of glasses) over five minutes for seven different lighting conditions with covariance (CoV) between measurement methods.*

9.4. Discussion

Unlike the trials on children from the PICNIC study, where the subjective data was provided by parents about their children, these adult comparison trials with three members of the research lab team reported subjective information about themselves. This was done by asking them to keep a log in real-time of every instance they went from an indoor environment to an outdoor environment and vice versa. Therefore, the time spent outdoors and the number of transitions captured by these detailed subjective diaries in the adult trials is a highly reliable measure. We consider subjective measures to be the gold standard, and we compared the recorded objective measures in Trials 1, 2, and 3.

The number of transitions was used as a measure of reliability because an unrealistically high number of transitions may indicate gaps where outdoor time is being wrongly recorded as indoors (due to lower light levels being recorded). Actiwatch always had the highest number of transitions in all three comparison trials. This finding supports the previous concerns that the Actiwatch is not a reliable measure of outdoor time as it may provide lower light levels than the subject is exposed to. However, when assessing the minutes of outdoor

time measured objectively and subjectively in the comparison trials, it becomes clear that the Actiwatch also overestimates in some instances and it is not simply an underestimation issue, as we had previously hypothesized based on the studies with children (Chapter 4). The minutes of outdoor time varied greatly among each comparison trial in this small sample of young adults. Note that the "off-wrist" time problem was not a significant issue with the adult subjects, and there were no reports of removing the watch among the adult subjects that participated in these studies. In Trial 1, the Actiwatch underestimated the time spent outdoors compared to the subjective diaries, as expected. However, in both Trial 2 and Trial 3, the Actiwatch reported higher times than the diaries, which we used as the gold standard, indicating an overestimation of time outdoors by the Actiwatch. In both of these trials, very few differences were noted across all objective and subjective (not including car as outdoors) methods, except for the Actiwatch results in Trial 3, which appear to be much higher than all other methods. When comparing the raw data provided by the watch to the activity diary in Trial 3, several instances were noted when the watch recorded >1,000 lux and the subject was studying using a computer screen. Their computer was facing a wall on the opposite side of the room to the only window. This is clearly an error in Actiwatch, but surprisingly, it is overestimating rather than underestimating, which was the original concern. Why the overestimation errors were more evident in Trial 3 than in the other trials remains unclear, but it may be due to increased time doing near work, studying, and time spent indoors in their apartment.

The combination of errors of overestimation and underestimation seen in all devices compared to the Subjective diaries (except for the Vivior which always underestimated)

brings into question the accuracy of all the objective measures used in these studies. Further evaluation studies are needed to determine the best method for future myopia research. The Philips Respironics company has discontinued the Actiwatch and will no longer be an available option. The added benefit of viewing distance measures that glasses mounted options such as the Vivior or Clouclip offer make them appealing options. Several other light exposure measuring devices are currently being investigated, a new one, the MyLyt, is already available (Dhakal et al. 2023b).

A previous study comparing HOBO pendants worn on the wrist and chest to glasses mounted ClouClip found significant variations in light exposure among the wrist, chest and eye position (Wen et al. 2023). The results from this study Trial 1 showing that the HOBO pendant overestimated time outdoors compared to the Actiwatch could be due to the pendant being worn around the neck and the watch on the wrist, which may allow more exposure to sunlight (e.g., through a car window). Because of this, the diary instructions for Trial 2 and Trial 3 were modified to specify the recording of every time the subjects entered or exited a vehicle so the data could be analyzed with and without including time in the car as time spent outdoors. It appears that the objective measures more closely match subjective diaries when the time spent in a vehicle is not included, as outdoors. However, due to the inaccuracies found with objective measures, final conclusions cannot be made. The time in a vehicle was included as part of the Validity test and all the devices reported >1,000 lux in this setting, indicating that time in a car may or may not be considered outdoors when using objective measures. Future studies using these objective measures of outdoor time should consider

these findings in their study design and data interpretation. More accurate objective measures of light exposure are needed for future studies of time spent outdoors in children.

In comparison Trial 3, the average minutes of near viewing (≤ 40cm) measured by the two glasses-mounted devices seems to indicate that the ClouClip reports more time spent in near work activities than the Vivior, and that the ClouClip reports less time intermediate and distance viewing. As seen in the vague responses by the PICNIC parents regarding near work, obtaining accurate subjective viewing distance measures is challenging. A new survey, the UH Near survey (Gajjar and Ostrin 2023) that has been recently developed may improve the results of subjective measures. However, when the three adult subjects that participated were consulted, they reported that trying to do a similar real-time log of near work would be almost impossible as the daily tasks are too dynamic. There is a clear need to obtain accurate, objective viewing distance measures in future myopia research. The ClouClip has recently been validated for near work measures in children and adults (Bhandari and Ostrin 2020; Wen et al. 2021), and a recent abstract submitted to ARVO 2024 reports validation of the Vivior with good correlation between the Vivior and ClouClip when compared to each other as well as with physically measured distances (Sarkar et al. 2024). In future myopia studies, more validation studies using both devices while children perform different tasks will be needed to determine the best option to measure viewing distances. Given that both devices are designed to be mounted on the right side of glasses frames, it was questioned whether flipping one device to be worn on the left side of the frame or attaching the two devices together on the right side of the frame would be the best approach when comparing the devices. This was tested in comparison Trial 3. However, due to a technical error all data

from the device that was worn on the left side (upside down) was lost. The effect of flipping the device was reported in the Validity Test.

For the Validity Test on light exposure, the Dr. Meter light meter was considered the gold standard with which the other devices were compared. The HOBO pendant results most closely matched the results by Dr. Meter for all outdoor conditions, as well as for indoor conditions next to a window and in a car. Although the HOBO pendant did overestimate in most of these conditions, the differences were small. For measuring time outdoors, overestimation is preferable to underestimation as 1,000 lux is the cut-off used to be considered outdoors in myopia research. Because of the wide access to smartphones, measures with the Light Meter app were also included in this validation, hypothesizing that it would provide similar results to the standard light meter make it possible to use it for future research or clinical use. However, the results from the app were only close to the Dr. Meter light meter when used next to a computer screen, indicating that the Light Meter app is not a useful technique for validating light exposure.

It is worth noting that all devices except the smartphone app measured light levels greater than 1,000 lux when placed indoors next to a window. This should be taken into account when interpreting future studies using such devices. As expected, the Actiwatch significantly underestimated light exposure for all conditions compared to the Dr. Meter light meter. For inside natural light and full illumination, the Vivior matched the Dr. Meter more closely than the ClouClip when it was either used in its regular position or upside down. Interestingly the ClouClip that was upside down on the left side of the frames more closely matched the Dr.

Meter light meter than either of the devices worn correctly on the right side of the frame when light was measured next to the window, in the car or for both outdoor conditions. This may be due to the beveled edge of the ClouClip, which causes the light sensor to face at an upward angle of 10 degrees when it is upside down. However, it is unclear how using the ClouClip in this incorrect position would affect the near work measures and needs further investigation.

Another limitation of these glasses mounted devices is that they are not ideal for a population of young children before they become myopic and need optical correction. We were able to use these glasses mounted devices in our comparison trials because our three adult subjects were all glasses wearers. For our PICNIC subjects having them wear glasses frames with clear or no lenses would very likely have caused changes in their typical behaviors. It is important that we continue to study myopia development in children longitudinally before and after they become myopic. Although the glasses mounted devices are the only options currently available that measure both light exposure and viewing distances, a device that could do this without wearing glasses frames would be better. It has been proven that the mounting position of these devices makes a difference in light exposure measures (Wen et al. 2023). The optimal device for myopia research would be small and attach to the subject's head without glasses, measuring light exposure and viewing distances.

10. GENERAL CONCLUSIONS

These studies present the first reports of objective measures on time spent outdoors, exposure to different wavelengths, activity levels, and sleep patterns in young children with functional emmetropia. The main result of these studies is that children at High Risk (HR) for myopia and those that have already developed myopia spent significantly less time outdoors than those at Low Risk (LR) for myopia. These findings support the hypothesis that time outdoors is protective of myopia. There is a significant correlation between the time children spend outdoors and their refractive error, but not with axial length (AXL) since the optical components of the eye are still changing at these young ages. Similar to findings from previous studies, the average time per day spent outdoors measured objectively with the Actiwatch was significantly shorter than parents' subjective responses. It appears that this difference is partially due to parents overestimating the amount of time their child spends outdoors, as previously thought. However, the unrealistic number of transitions between indoors and outdoors provided by the Actiwatch suggests that in some instances the watch actually underestimates the time spent outdoors. Indeed, several comparison tests using young adult lab members indicated that the Actiwatch, and perhaps the other objective methods evaluated, may give inaccurate estimations of time spent outdoors. The results show that it is not simply parents overestimating outdoor time which has led to the lack of correlation between subjective and objective measures in previous studies, but also errors in the Actiwatch objective measures. The results of the Validity tests supported this hypothesis as they showed that the Actiwatch significantly underestimated light exposure for all conditions compared to a standard light meter, with variable results for the other three

devices. The results from our studies in children have one significant limitation that is the large amount of time the Actiwatch reported “off-wrist” time for most children. Put together, our results highlight the importance of conducting thorough validity studies before using new devices in myopia research regarding light exposure and viewing distances.

There were no differences in activity levels between children at HR and LR for myopia, although a trend toward shorter times spent on light and rigorous activity levels in the HR and myopic groups compared to the LR group was noted. In contrast, there was a significant difference in the total amount of time spent outdoors between the two groups, with children at HR for myopia, and those that have developed myopia, spending less time outdoors. These results indicate that the protective effect of outdoor time is independent of the increased activity levels associated with being outdoors. Reduced activity may be related to myopia development, but it does not appear to be a major contributor.

The children participating in these studies were exposed to larger amounts of red light than blue light. Children at HR for myopia were exposed to lower amounts of all wavelengths (blue, green and red light) compared to children at LR for myopia, with the largest difference between risk groups being in red light exposure. These findings may support recent studies suggesting that red light exposure may be beneficial for myopia (Jiang et al. 2022; Tian et al. 2022; Chen et al. 2023; Dong et al. 2023).

The sleep pattern results were inconclusive due to a lack of power and unrealistic sleep times provided by the Actiwatch. The later wake up times noted in children at HR for myopia during non-school days may be of interest, but further studies are needed to reach significant

conclusions on whether sleep patterns may be associated with myopia development. Although the Actiwatch has been validated for sleep measurements (Pigeon et al. 2018), the unrealistic bed and wake times noted for several of the subjects participating in this study and the inconsistencies between subjective and objective measures put into question their accuracy. The small wrists of the participants may have caused larger errors with the used of these devices. There seems to be a similar combination of overestimation by the parents and underestimation by the devices with sleep patterns as that found for outdoor time.

The near work measures were limited to the subjective PICNIC questionnaire, which asks parents to average for the week prior to their visit. The trend noted toward children at HR reporting longer near work activities on school days and closer viewing distances than children at LR will need to be confirmed with objective measures in future studies. Further studies are also needed to assess the causative role of near work in myopia development. The comparison trials support the use of the ClouClip or Vivior devices to assess viewing distances, although differences between the two indicate that further assessment of these devices is necessary.

The subjective activity log measures used in these studies were not able to provide quantifiable data on outdoor time, near work, or sleep patterns due to the vague responses provided by the parents. Because of this, the study Aim 3 of creating a questionnaire to be used in myopia research was unsuccessful. The hypothesis that questionnaires may be useful as a clinical tool to help parents evaluate their child's adaptable environmental behaviors was also not reliably tested. However, the feedback provided by parents about the surveys was

encouraging as they indicated that such measures could help parents become more aware of their child's behaviors and actively pursue changes to promote more outdoor time and reduce near work.

The poor retention rate of the Winter 90-day trial and the difficulties with families completing the Activity logs indicate that conducting a long-term study with children in this age group is difficult. Cloud-based objective data collection could be helpful in future studies to monitor compliance in real time. If multiple responses are needed from subjective questionnaires, automated reminders and incentives for completion may improve response rates.

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APPENDIX I - PICNIC Questionnaire

On average, how many hours PER DAY did your child spend outside during this week's school days (Mon - Fri) during DAYLIGHT HOURS (before sunset)?
If your child attends an after-school sports or other youth program, how many hours or minutes PER DAY on average did he or she spend outside DURING DAYLIGHT HOURS (before sunset) as part of the program(s) during this week's school days?
Please describe the program(s) from Question #2, how often your child attends that /those programs(s) and how long each event lasts?
On average, how many hours PER DAY did your child spend during this week's school days doing homework and /or reading for pleasure?
How many hours on average, PER DAY, did your child spend during this week's school days playing computer games, using a smartphone/tablet or doing other near work such as puzzles, drawing or building with Legos, either at home or while attending an after-school or other youth program?
How many hours did your child spend outdoors DURING DAYLIGHT HOURS (before sunset) during the last weekend (Saturday and Sunday combined)? Include walks, biking, sports, reading or using technology, eating outside, etc.
How many hours did your child spend during last weekend (Saturday and Sunday combined) on near work? Include working or playing on a computer, reading, homework, drawing, using a smartphone/tablet, puzzles and Lego, and other similar activities.
At what distance (in inches) does your child typically hold a book while reading and doing homework and a tablet/laptop/computer when playing or working on the device?
Based on your answers to the previous questions, how many times (frequency) PER DAY on average does your child go outside DURING DAYLIGHT HOURS (before sunset). The average would include both weekdays and weekends.
On average, at what time does your child go to sleep before a school day (Sunday-Thursday)?
On average, at what time does your child go to sleep before a day on a weekend or holiday (Friday and Saturday)?
On average, how many hours PER DAY did your child spend outside during this week's school days (Mon - Fri) during DAYLIGHT HOURS (before sunset)?
If your child attends an after-school sports or other youth program, how many hours or minutes PER DAY on average did he or she spend outside DURING DAYLIGHT HOURS (before sunset) as part of the program(s) during this week's school days?
Please describe the program(s) from Question #2, how often your child attends that /those programs(s) and how long each event lasts?
On average, how many hours PER DAY did your child spend during this week's school days doing homework and /or reading for pleasure?

On average, how many hours PER DAY did your child spend outside during this week's school days (Mon - Fri) during DAYLIGHT HOURS (before sunset)?
If your child attends an after-school sports or other youth program, how many hours or minutes PER DAY on average did he or she spend outside DURING DAYLIGHT HOURS (before sunset) as part of the program(s) during this week's school days?
Please describe the program(s) from Question #2, how often your child attends that /those programs(s) and how long each event lasts?
On average, how many hours PER DAY did your child spend during this week's school days doing homework and /or reading for pleasure?
How many hours on average, PER DAY, did your child spend during this week's school days playing computer games, using a smart phone/tablet or doing other near work such as puzzles, drawing or building with Legos, either at home or while attending an after-school or other youth program?

Parents are educated that time outdoors includes any activity, any time they are outside a building.

APPENDIX II - Activity Log 1

This questionnaire has two sections: one for SCHOOL days and one for NON-SCHOOL days (holidays and weekends).

Next to each section record how many days out of 7 your child had/did not have school.

(If the entire 7 days was a school holiday you can record 0/7 school days and leave the rest of the school section blank)

Please answer each question with the average PER DAY over the last 7 days.

****ONLY include outdoor activities during daylight hours.****

For questions about travel if more than one mode of transportation was used, please list times for each separately.

For screen time don't forget to include: video games, using phone/tablet, taking devices to bed with them, etc.

Examples of other near work: puzzles, drawing, Legos etc.

Examples of outdoor activities: walks, biking, scootering, sports, reading outside, using technology outside, eating outside, gardening, going to the park, playing in the yard etc.

If any of these questions do not pertain to your family's unique schedule or there is something you would like to add/clarify please feel free to leave additional notes or text/call with any questions you have.

School Days (__ / 7)			
MORNING			
What time do you wake up? ____			
Outdoor activities before school?	Yes No	What:	How long: minutes
Screen time before school?	Yes No	What:	How long: minutes
Reading or other near work activities before school?	Yes No	What:	How long: minutes
How do you travel to school?	School bus Car Public transportation Walk Bike		

How long does it take you to travel to school (in the morning)?	minutes			
Screen time, reading or other near work while you are traveling to school? (in car, bus train etc.)	Yes No	What:		How long: minutes
SCHOOL				
How long is the school day (total)?	hours			
How long is your lunch break?	minutes			
Do you have recess?	Yes No	If Yes, how many:		How long (total): minutes
What do you <u>usually</u> do at recess?				Inside Outside
Do you go outside at any other times during the school day?	Yes No			How long: minutes
Do you use a tablet/computer or other electronic device at school?	Yes No	What:		How long: minutes
Do you read books at school?	Yes No			How long: minutes
Do you do any other near work activity at school (worksheets, drawing, games puzzles, Legos...)	Yes No	What:		How long: minutes
AFTER SCHOOL				
Do you do any indoor extracurricular activities? (if yes please list)	Yes No	What:	Days per week:	How long: minutes
		What:	Days per week:	How long: minutes
		What:	Days per week:	How long: minutes
		What:	Days per week:	How long: minutes
		What:	Days per week:	How long: minutes
Do you do any outdoor extracurricular activities? (if yes please list, for the time note only time during daylight hours)	Yes No	What:	Days per week:	How long: minutes
		What:	Days per week:	How long: minutes

		What:	Days per week:	How long: minutes
		What:	Days per week:	How long: minutes
		What:	Days per week:	How long: minutes
Any other outdoor activities after school? (playing, walking, gardening...)	Yes No	What:		How long: minutes
How do you travel to your activities and/or back home?	School bus Car Public transportation Walk Bike			
How long does it take you to travel to your activities and/or back home?	minutes			
Screen time, reading or other near work while you are traveling? (in car, bus, train etc.)	Yes No	What:		How long: minutes
Do you have homework?	Yes No	Electronic Reading Writing/worksheets Other ( )		How long: minutes
Do you read for pleasure after school?	Yes No			How long: minutes
Screen time for pleasure after school?	Yes No	What:		How long: minutes
Any other near work activities after school?	Yes No	What:		How long: minutes
What time do you go to bed on school nights?				

Non-School Days (__ / 7)				
What time do you wake up?				
Did you go anywhere or stay home?	Traveled Stayed home			
If you left home, how did you get to your destination?	School bus Car Public transportation Walk Bike Stayed Home			
How long did it take you to travel?	minutes			
Any screen time, reading or other near work while you are traveling? (in car, bus, train etc.)	Yes No	What:		How long: minutes
	Yes No	What:	Days per week:	How long: minutes

Do you have any indoor extracurricular activities on non-school days? (if yes please list)		What:	Days per week:	How long: minutes
		What:	Days per week:	How long: minutes
		What:	Days per week:	How long: minutes
		What:	Days per week:	How long: minutes
Do you have any outdoor extracurricular activities on non-school days? (if yes please list)	Yes No	What:	Days per week:	How long: minutes
		What:	Days per week:	How long: minutes
		What:	Days per week:	How long: minutes
		What:	Days per week:	How long: minutes
		What:	Days per week:	How long: minutes
Any other outdoor activities at home or somewhere else? (exercise, playing, walking, gardening etc.)	Yes No	What:		How long: minutes
Do you have homework on non-school days?	Yes No	Electronic Reading Writing/Worksheets Other ( )		How long: minutes
Do you read for pleasure on non-school days?	Yes No			How long: minutes
Any screen time pleasure on non-school days?	Yes No	What:		How long: minutes
Any other near work activities at home or somewhere else?	Yes No	What:		How long: minutes
What time do you go to bed when you don't have school the next day?				

APPENDIX III - Activity Log 2

Activity Log

This questionnaire has two sections: one for SCHOOL days and one for NON-SCHOOL days (holidays and weekends).

ONLY include outdoor activities during daylight hours.

At the beginning of each section, you will be asked how many days out of the past 7 days your child had or did not have school. (If the entire 7 days was a holiday you can record 0/7 school days and skip the rest of the school section questions)

If any of the questions do not pertain to your family's schedule or there is something you would like to add or clarify please do so in the additional comments section at the end.

Other notes:
- Extracurricular activities are regularly scheduled events such as sports practices, music lessons, art classes, etc.
- Other or for pleasure activities include unscheduled things done at home or somewhere else such as playing outside, gardening, coloring, and board games.
- Examples of outdoor activities: walks, biking, scootering, reading outside, using technology outside, eating outside, gardening, going to the park, playing in the yard, etc.
- For screen time, please do not forget to include: video games, phone, tablet, electronic reading devices, TV, taking devices to bed with them, etc.
- Examples of other near work: puzzles, drawing, Legos, etc.

1. Email: _____
2. What is your subject ID: _____

School Days

3. How many days did you have school this week?

0 1 2 3 4 5 6 7

4. What time do you wake up on school days? average for the week: _____
   (Example: 8:30 AM)
5. Outdoor activities BEFORE school
   (Include anything longer than 10 min (you do not need to count walking from the house to the car but if you walk or bike to get to school please include)

	yes	No	Non school day
Monday	☐	☐	☐
Tuesday	☐	☐	☐
Wednesday	☐	☐	☐
Thursday	☐	☐	☐
Friday	☐	☐	☐
Saturday	☐	☐	☐
Sunday	☐	☐	☐

6. For each day you have done an outdoor activity BEFORE school list what the activity was and how long it took: _____
   (ex. Monday: 10 min bike ride, Wednesday: 25 min breakfast outside)

7. Screen time BEFORE school?

	yes	No	Non school day
Monday	☐	☐	☐
Tuesday	☐	☐	☐
Wednesday	☐	☐	☐
Thursday	☐	☐	☐
Friday	☐	☐	☐
Saturday	☐	☐	☐
Sunday	☐	☐	☐

8. For each day you have had screen time BEFORE school list what the activity was and how long it took: _____ (ex. iPad 10 min Mon-Fri)

9. Reading or other near work activities BEFORE school?

	yes	No	Non school day
Monday	◯	◯	◯
Tuesday	◯	◯	◯
Wednesday	◯	◯	◯
Thursday	◯	◯	◯
Friday	◯	◯	◯
Saturday	◯	◯	◯
Sunday	◯	◯	◯

10. For each day you read/did near work BEFORE school list what the activity was and how long it took: _____ (ex. Monday: 20 min legos, Tuesday: 15 min reading)

11. Screen time, reading, or other near work while you are traveling to school? (ex. using iPad/tablet while in car, bus train, etc.)

    ◯ yes

    ◯ no

12. If you have screen time, read or do other near work while you travel to school list what the activity was and for how long: _____

13. What time does school start? _____ (Example: 8:30 AM)
14. What time does school end? _____ (Example: 8:30 AM)
15. Do you have recess?

    ◯ Yes, only 1 break

    ◯ Yes, more than 1 break

    ◯ No

16. How long is each recess break? _____
17. List what you did at recess each day: _____ (make sure to specify inside or outside, ex. Mon-Thur: played on playground, Fri: colored)
18. Do you go outside at any other times during the school day?

    ◯ yes

    ◯ no

19. If you went outside at any other times during the school day list what you did and for how long: _____
20. Did you use a tablet/computer or other electronic device at school?

	yes	No	Non school day
Monday	☐	☐	☐
Tuesday	☐	☐	☐
Wednesday	☐	☐	☐
Thursday	☐	☐	☐
Friday	☐	☐	☐
Saturday	☐	☐	☐
Sunday	☐	☐	☐

21. If you used an electronic device during school list what the activity was and how long it took: _____ (ex. 1 hour computer class Mon, Wed, Fri, used tablet 2 hours Tuesday)
22. Did you read books at school?

	yes	No	Non school day
Monday	☐	☐	☐
Tuesday	☐	☐	☐
Wednesday	☐	☐	☐
Thursday	☐	☐	☐
Friday	☐	☐	☐
Saturday	☐	☐	☐
Sunday	☐	☐	☐

23. If you read at school this week list the days and for how long each day:
_____
24. Did you do any other near work activity at school (worksheets, drawing, games, puzzles, Legos...)

	yes	No	Non school day
Monday	☐	☐	☐
Tuesday	☐	☐	☐
Wednesday	☐	☐	☐
Thursday	☐	☐	☐
Friday	☐	☐	☐
Saturday	☐	☐	☐
Sunday	☐	☐	☐

25. If you did other near work activity at school list what the activity was and for how long each day: _____ (Ex. Mon: art class 1 hour Tuesday: 1 hour games, 2 hours math worksheets)

26. Screen time, reading or other near work while you are traveling home/to activities after school? (ex. using iPad while in car, bus train etc.)

- ◯ yes
- ◯ no

27. If you had screen time, read or did other near work while you travel after school list what the activity was and for how long: _____

28. Did you have any outdoor extracurricular activities this week?

	yes	No	Non school day
Monday	◯	◯	◯
Tuesday	◯	◯	◯
Wednesday	◯	◯	◯
Thursday	◯	◯	◯
Friday	◯	◯	◯
Saturday	◯	◯	◯
Sunday	◯	◯	◯

29. For each day you had outdoor extracurricular activities list what the activity was and how long it took: _____ (ex. Tue: 2 hour soccer game)

30. Other outdoor activities after school (Include anything longer than 10 min (you do not need to count walking from the school to the car but if you walk or bike to travel after school please include)

	yes	No	Non school day
Monday	◯	◯	◯
Tuesday	◯	◯	◯
Wednesday	◯	◯	◯
Thursday	◯	◯	◯
Friday	◯	◯	◯
Saturday	◯	◯	◯
Sunday	◯	◯	◯

31. For each day you did other outdoor activities after school list what the activity was and how long it took: _____ (ex biked 20 min home from school everyday, played outside Mon and Wed)

32. Did you have any indoor extracurricular activities this week?

	yes	No	Non school day
Monday	☐	☐	☐
Tuesday	☐	☐	☐
Wednesday	☐	☐	☐
Thursday	☐	☐	☐
Friday	☐	☐	☐
Saturday	☐	☐	☐
Sunday	☐	☐	☐

33. For each day you had indoor extracurricular activities list what the activity was and how long it took: _____ (ex. Mon: 1.5 hour piano lesson, Wed/Fri: 2 hour karate class)

34. Homework on electronic devices: _____ (average time per night)

35. Homework reading/writing/worksheets/other non-electronic near work: _____ (average time per night)

36. Reading for pleasure/other near work activities after school

	yes	No	Non school day
Monday	☐	☐	☐
Tuesday	☐	☐	☐
Wednesday	☐	☐	☐
Thursday	☐	☐	☐
Friday	☐	☐	☐
Saturday	☐	☐	☐
Sunday	☐	☐	☐

37. For each day you read/did near work after school list what the activity was and how long it took: _____

38. Screen time for pleasure after school

	yes	No	Non school day
Monday	◯	◯	◯
Tuesday	◯	◯	◯
Wednesday	◯	◯	◯
Thursday	◯	◯	◯
Friday	◯	◯	◯
Saturday	◯	◯	◯
Sunday	◯	◯	◯

39. For each day you had screen time after school list what the activity was and how long it took: _____

40. What time do you go to bed on school nights? _____ (Example: 8:30 AM) average for the week
41. Additional Comments for School Days

Non-School Days (holidays and weekends)

42. How many days did you not have school this week?

0	1	2	3	4	5	6	7
◯	◯	◯	◯	◯	◯	◯	◯

43. What time do you wake up? _____ (Example: 8:30 AM) average for all non-school days this week

44. Did you go anywhere?

	stayed home all day	left home	school day
Monday	◯	◯	◯
Tuesday	◯	◯	◯
Wednesday	◯	◯	◯
Thursday	◯	◯	◯
Friday	◯	◯	◯
Saturday	◯	◯	◯
Sunday	◯	◯	◯

45. Screen time, reading or other near work while you are traveling? (ex. using iPad while in car, bus train etc.)

- ◯ yes
- ◯ no

46. If you had screen time, read or did other near work while you traveled list what the activity was and for how long: _____

47. Indoor extracurricular activities on non-school days this week

	stayed home all day	left home	school day
Monday	◯	◯	◯
Tuesday	◯	◯	◯
Wednesday	◯	◯	◯
Thursday	◯	◯	◯
Friday	◯	◯	◯
Saturday	◯	◯	◯
Sunday	◯	◯	◯

48. For each day you had indoor extracurricular activities list what the activity was and how long it took: _____

49. Outdoor extracurricular activities on non-school days this week

	stayed home all day	left home	school day
Monday	◯	◯	◯
Tuesday	◯	◯	◯
Wednesday	◯	◯	◯
Thursday	◯	◯	◯
Friday	◯	◯	◯
Saturday	◯	◯	◯
Sunday	◯	◯	◯

50. For each day you had an outdoor extracurricular activities list what the activity was and how long it took: _____

51. Any other outdoor activities not already listed (ex. playing in the yard, going to the playground, bike ride etc.)

	stayed home all day	left home	school day
Monday	☐	☐	☐
Tuesday	☐	☐	☐
Wednesday	☐	☐	☐
Thursday	☐	☐	☐
Friday	☐	☐	☐
Saturday	☐	☐	☐
Sunday	☐	☐	☐

52. For each day you did any other outdoor activities list what the activity was and how long it took: _____

53. Homework on non-school days

	reading/writing/worksheets/other near work	on electronic devices
yes	☐	☐
no	☐	☐

54. Time spent doing homework on non-school days: _____ (list average electronic and non-electronic time per day)

55. Reading for pleasure/other near work on non-school days

	stayed home all day	left home	school day
Monday	☐	☐	☐
Tuesday	☐	☐	☐
Wednesday	☐	☐	☐
Thursday	☐	☐	☐
Friday	☐	☐	☐
Saturday	☐	☐	☐
Sunday	☐	☐	☐

56. For each day you read/did near work list what the activity was and how long it took: _____

57. Screen time for pleasure on non-school days

	stayed home all day	left home	school day
Monday	☐	☐	☐
Tuesday	☐	☐	☐
Wednesday	☐	☐	☐
Thursday	☐	☐	☐
Friday	☐	☐	☐
Saturday	☐	☐	☐
Sunday	☐	☐	☐

58. For each day you had screen time list what the activity was and how long it took: _____
59. What time do you go to bed when you don't have school the next day? _____ (Example: 8:30 AM) average for the week
60. Additional Comments for Non-School Days: _____

APPENDIX IV - Raw Data - Time Outdoors

Minutes per day of outdoor time measured objectively by the Actiwatch (>1,000 lux of light) and subjectively reported by the parents with Daily surveys for each of the 31 subjects who participated in Summer Trials. Green text indicates children in the Low Risk (LR) of myopia group and orange indicates High Risk (HR). SE OD is the spherical equivalent of the right eye (M) measured with cycloplegic open-field autorefraction. AXL OD is the axial length of the right eye measured by the Lenstar 900 Biometer. Age, SE OD and AXL OD are from the PICNIC follow up visit at which each child was given the Actiwatch.

Objective Minutes of Outdoor Time (>1,000 lux) per Day

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Actiwatch Time Outdoors (minutes per day)														SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S001	Low	Male	8.4	1.28	22.85	180.5	249.5	24.0	206.5	70.5	89.5	30.5	23.0	453.5	78.5	82.5	95.5	110.5	6.5	119.56	121.50	0.98
S005	Low	Female	10.0	1.31	23.20	16.5	107.0	2.0	18.5	140.5	126.0	312.5	154.0	33.0	4.5	181.0	335.0	366.5	408.0	143.75	157.50	0.91
S006	Low	Female	8.2	1.05	23.13	208.5	334.5	159.5	342.0	216.0	52.5	67.0	66.5	8.5	7.0	3.5	107.5	131.5	165.5	111.87	133.57	0.84
S020	Low	Male	10.5	1.36	23.63	115.5	173.0	142.5	20.5	4.0	34.5	141.5	97.0	142.0	160.0	89.0	23.0	193.0	112.0	61.38	103.39	0.59
S024	Low	Male	8.3	1.98	22.52	15.5	58.5	239.5	18.0	158.5	122.5	32.5	23.0	29.0	41.5	15.0	91.0	109.0	71.0	65.68	73.18	0.90
S042	Low	Male	8.7	0.78	22.80	89.0	66.0	188.5	49.0	82.0	87.0	122.5	79.0	150.0	10.5	56.5	112.0	50.5	N/A	46.76	87.88	0.53
S044	Low	Female	6.5	1.70	21.02	1.0	5.5	22.5	140.5	89.5	53.5	85.0	26.5	93.0	228.0	41.5	58.5	71.0	136.5	61.65	75.18	0.82
S056	Low	Female	9.3	1.73	22.52	183.5	206.0	153.0	1.5	60.5	275.5	30.5	104.5	168.0	40.5	19.5	55.0	118.5	59.5	81.42	105.43	0.77
S057	Low	Female	9.3	1.35	23.20	37.5	248.0	370.0	241.5	255.5	215.0	260.0	195.5	240.0	63.0	6.0	416.0	402.0	187.5	125.19	224.11	0.56
S059	Low	Male	7.3	1.93	22.73	165.5	247.5	82.0	133.0	138.0	87.5	59.0	213.0	228.5	111.5	74.5	16.5	51.5	10.0	75.87	115.57	0.66
S061	Low	Female	8.8	1.36	23.28	34.0	235.5	137.5	90.5	58.5	117.0	128.5	377.5	199.0	131.5	102.0	135.5	52.0	129.5	87.41	137.75	0.63
S062	Low	Male	6.8	1.88	22.72	8.5	223.5	173.0	6.0	53.0	145.5	176.0	325.0	111.5	48.5	94.0	91.0	111.0	7.5	91.10	112.43	0.81
S064	Low	Male	6.5	1.10	23.11	256.0	300.5	200.5	2.5	19.5	103.0	36.0	9.0	40.0	341.0	0.5	132.0	14.5	11.0	121.06	104.71	1.16
S114	Low	Female	9.3	1.47	21.47	191.0	17.5	109.0	271.5	207.0	180.0	142.0	51.5	116.0	28.0	106.0	40.5	26.5	36.0	80.38	108.75	0.74
S115	Low	Female	8.9	1.29	22.06	117.5	94.5	124.5	50.5	177.5	109.5	204.0	170.5	59.5	79.5	367.5	356.0	291.5	324.0	111.16	180.46	0.62
S122	Low	Female	7.7	1.40	21.95	12.5	1.5	3.0	1.5	180.0	0.0	22.5	10.0	55.0	35.0	4.5	3.0	0.0	12.5	47.48	24.36	1.95
S132	Low	Male	9.6	1.14	24.02	0.0	54.5	105.5	75.5	153.5	170.5	125.0	8.5	61.5	82.0	15.0	24.5	118.0	95.0	53.85	77.79	0.69
S009	High	Male	8.1	0.61	22.69	51.5	118.0	39.5	41.0	47.5	139.0	93.0	108.5	122.5	111.0	53.0	42.5	9.5	42.0	40.68	72.75	0.56
S018	High	Female	7.8	1.23	23.89	87.0	4.0	5.5	3.0	5.0	42.0	55.0	5.5	16.0	29.0	8.0	127.0	26.5	0.0	37.47	29.54	1.27
S021	High	Female	8.9	0.73	21.75	82.5	107.0	138.5	59.5	95.0	129.5	183.5	242.5	71.5	138.0	49.0	2.0	14.0	28.0	67.05	95.75	0.70
S028	High	Male	8.7	1.43	23.66	74.5	48.0	188.0	110.5	28.0	26.0	66.0	52.0	47.0	185.5	12.0	11.0	3.5	52.0	58.94	64.57	0.91
S029	High	Female	8.2	0.65	22.62	1.5	9.5	113.0	134.0	97.5	83.5	105.5	8.5	57.0	54.0	100.0	55.5	117.5	33.5	44.20	69.32	0.64
S049	High	Male	8.7	0.67	23.91	0.5	1.0	1.5	62.0	15.0	44.0	52.0	10.0	96.0	2.0	54.5	178.0	145.0	167.5	63.66	59.21	1.08
S050	High	Female	8.9	0.66	23.48	12.0	110.5	219.0	26.5	71.5	200.0	220.0	28.0	15.5	18.5	51.0	35.5	29.5	47.5	77.85	77.50	1.00
S054	High	Female	7.7	0.43	22.56	3.0	1.5	140.0	1.5	100.0	19.5	5.0	95.0	1.5	8.0	5.0	5.5	13.0	3.0	46.27	28.68	1.61
S058	High	Male	9.4	-0.12	22.85	34.0	51.0	25.0	42.5	79.5	38.0	29.0	33.5	28.0	23.0	47.5	20.0	40.0	0.0	18.11	35.07	0.52
S060	High	Female	6.5	1.03	23.19	6.0	5.0	1.5	23.5	13.0	37.5	2.0	73.0	26.0	7.0	0.5	65.0	6.5	2.0	23.81	19.18	1.24
S065	High	Male	6.8	0.28	23.44	135.5	103.5	76.5	161.0	74.5	109.5	119.5	0.0	107.5	183.5	158.5	145.0	16.5	24.5	56.70	101.11	0.56
S066	High	Female	8.1	0.19	22.27	41.0	28.5	0.5	42.5	56.0	35.0	38.5	0.0	0.0	0.0	62.0	33.5	0.0	0.0	23.16	24.11	0.96
S069	High	Male	7.3	0.30	23.11	18.0	11.0	31.5	55.5	127.0	139.0	89.0	28.5	154.0	135.0	54.5	21.5	60.0	N/A	51.58	71.12	0.73
S072	High	Male	7.1	1.06	22.90	N/A	112.5	126.5	78.0	91.0	15.5	5.0	147.0	78.5	101.5	118.5	7.5	39.5	127.0	48.87	80.62	0.61
All Subject Average			**8.26**	**1.07**	**22.86**	**72.65**	**107.55**	**107.84**	**80.97**	**95.63**	**97.65**	**98.00**	**89.23**	**97.06**	**80.21**	**65.56**	**91.68**	**88.34**	**79.28**	**69.16**	**89.42**	**0.86**
All Subject Std			**1.06**	**0.54**	**0.71**	**75.08**	**100.80**	**88.27**	**86.60**	**65.62**	**65.79**	**78.29**	**97.56**	**93.20**	**79.15**	**73.11**	**104.55**	**102.58**	**98.65**	**32.06**	**46.85**	**0.33**
All Subject CoV			**0.13**	**0.50**	**0.03**	**1.03**	**0.94**	**0.82**	**1.07**	**0.69**	**0.67**	**0.80**	**1.09**	**0.96**	**0.99**	**1.12**	**1.14**	**1.16**	**1.24**	**0.46**	**0.52**	**0.38**
LR Average			8.47	1.42	22.72	96.03	154.29	131.56	98.18	121.41	115.82	116.18	113.76	128.71	87.68	74.03	123.09	130.44	110.75	87.39	114.33	0.83
LR SD			1.18	0.33	0.76	86.87	109.47	93.57	107.58	73.13	67.97	85.02	111.84	109.78	88.03	90.56	124.88	118.43	116.92	29.95	45.38	0.33
LR CoV			0.14	0.23	0.03	0.90	0.71	0.71	1.10	0.60	0.59	0.73	0.98	0.85	1.00	1.22	1.01	0.91	1.06	0.34	0.40	0.40
HR Average			7.99	0.65	23.02	42.08	50.79	79.04	60.07	64.32	75.57	75.93	59.43	58.64	71.14	55.29	53.54	37.21	40.54	47.03	59.18	0.88
HR SD			0.87	0.43	0.63	42.11	48.69	74.66	46.97	37.82	57.84	65.52	69.46	48.07	68.98	45.11	56.35	43.46	51.69	17.48	27.13	0.33
HR CoV			0.11	0.65	0.03	1.00	0.96	0.94	0.78	0.59	0.77	0.86	1.17	0.82	0.97	0.82	1.05	1.17	1.28	0.37	0.46	0.37

Subjective Minutes of Outdoor Time per Day

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Subjective Time Outdoors While Wearing Actiwatch (minutes per day)													SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S001	Low	Male	8.4	1.28	22.85	210.0	300.0	90.0	180.0	150.0	165.0	195.0	30.0	510.0	240.0	120.0	120.0	120.0	60.0	119.26	177.86	0.67
S005	Low	Female	10.0	1.31	23.20	60.0	180.0	0.0	450.0	495.0	450.0	480.0	450.0	90.0	30.0	330.0	450.0	510.0	510.0	200.52	320.36	0.63
S006	Low	Female	8.2	1.05	23.13	420.0	435.0	300.0	600.0	480.0	180.0	60.0	60.0	30.0	15.0	15.0	270.0	270.0	210.0	191.68	238.93	0.80
S020	Low	Male	10.5	1.36	23.63	30.0	120.0	90.0	30.0	150.0	45.0	180.0	180.0	240.0	300.0	45.0	45.0	180.0	180.0	85.38	129.64	0.66
S024	Low	Male	8.3	1.98	22.52	60.0	75.0	480.0	90.0	330.0	300.0	150.0	180.0	90.0	120.0	60.0	165.0	300.0	120.0	125.77	180.00	0.70
S042	Low	Male	8.7	0.78	22.80	300.0	210.0	315.0	150.0	180.0	360.0	360.0	300.0	240.0	0.0	0.0	180.0	210.0	210.0	113.11	215.36	0.53
S044	Low	Female	6.5	1.70	21.02	60.0	30.0	120.0	360.0	180.0	270.0	810.0	915.0	600.0	480.0	60.0	150.0	150.0	270.0	283.03	318.21	0.89
S056	Low	Female	9.3	1.73	22.52	660.0	540.0	600.0	540.0	480.0	600.0	480.0	480.0	600.0	600.0	480.0	240.0	360.0	240.0	131.41	492.86	0.27
S057	Low	Female	9.3	1.35	23.20	90.0	240.0	300.0	240.0	360.0	300.0	300.0	240.0	210.0	240.0	60.0	360.0	300.0	240.0	86.81	248.57	0.35
S059	Low	Male	7.3	1.93	22.73	240.0	330.0	180.0	180.0	150.0	360.0	135.0	480.0	390.0	225.0	210.0	90.0	120.0	90.0	119.98	227.14	0.53
S061	Low	Female	8.8	1.36	23.28	240.0	300.0	360.0	120.0	180.0	240.0	240.0	360.0	240.0	240.0	240.0	180.0	240.0	120.0	72.40	235.71	0.31
S062	Low	Male	6.8	1.88	22.72	240.0	300.0	360.0	120.0	180.0	240.0	240.0	360.0	240.0	240.0	240.0	180.0	240.0	120.0	72.40	235.71	0.31
S064	Low	Male	6.5	1.10	23.11	540.0	480.0	420.0	570.0	630.0	630.0	420.0	N/A	240.0	570.0	0.0	360.0	270.0	300.0	182.46	432.50	0.42
S114	Low	Female	9.3	1.47	21.47	180.0	300.0	180.0	180.0	420.0	540.0	480.0	240.0	180.0	60.0	240.0	540.0	540.0	540.0	172.54	330.00	0.52
S115	Low	Female	8.9	1.29	22.06	150.0	240.0	300.0	90.0	540.0	270.0	300.0	240.0	300.0	270.0	900.0	480.0	360.0	450.0	199.56	349.29	0.57
S122	Low	Female	7.7	1.40	21.95	240.0	120.0	180.0	180.0	240.0	180.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	45.17	190.00	0.24
S132	Low	Male	9.6	1.14	24.02	30.0	15.0	210.0	120.0	150.0	240.0	150.0	150.0	90.0	60.0	60.0	120.0	150.0	240.0	71.76	127.50	0.56
S009	High	Male	8.1	0.61	22.69	210.0	180.0	45.0	150.0	120.0	195.0	45.0	180.0	120.0	120.0	120.0	300.0	30.0	120.0	72.82	138.21	0.53
S018	High	Female	7.8	1.23	23.89	60.0	150.0	60.0	120.0	240.0	90.0	120.0	60.0	60.0	120.0	90.0	300.0	90.0	30.0	74.59	113.57	0.66
S021	High	Female	8.9	0.73	21.75	240.0	120.0	180.0	210.0	270.0	240.0	240.0	180.0	0.0	120.0	180.0	0.0	120.0	240.0	86.24	167.14	0.52
S028	High	Male	8.7	1.43	23.66	210.0	135.0	300.0	210.0	120.0	75.0	150.0	N/A	150.0	360.0	180.0	105.0	120.0	2.0	93.15	162.85	0.57
S029	High	Female	8.2	0.65	22.62	120.0	30.0	120.0	120.0	60.0	120.0	180.0	240.0	300.0	120.0	60.0	60.0	N/A	60.0	77.91	122.31	0.64
S049	High	Male	8.7	0.67	23.91	0.0	0.0	240.0	240.0	60.0	180.0	180.0	60.0	300.0	180.0	360.0	360.0	420.0	480.0	153.62	218.57	0.70
S050	High	Female	8.9	0.66	23.48	N/A	30.0	120.0	15.0	135.0	255.0	N/A	N/A	120.0	15.0	N/A	120.0	60.0	60.0	73.42	93.00	0.79
S054	High	Female	7.7	0.43	22.56	45.0	0.0	120.0	15.0	120.0	60.0	30.0	90.0	15.0	30.0	0.0	60.0	60.0	30.0	39.55	48.21	0.82
S058	High	Male	9.4	-0.12	22.85	90.0	210.0	150.0	120.0	150.0	120.0	75.0	120.0	N/A	N/A	N/A	N/A	N/A	N/A	41.61	129.38	0.32
S060	High	Female	6.5	1.03	23.19	60.0	45.0	15.0	60.0	15.0	45.0	30.0	60.0	30.0	45.0	75.0	30.0	30.0	15.0	19.16	39.64	0.48
S065	High	Male	6.8	0.28	23.44	210.0	150.0	180.0	120.0	180.0	180.0	240.0	180.0	420.0	300.0	180.0	180.0	180.0	300.0	77.93	214.29	0.36
S066	High	Female	8.1	0.19	22.27	30.0	120.0	0.0	60.0	120.0	0.0	60.0	60.0	180.0	45.0	15.0	0.0	0.0	0.0	56.26	49.29	1.14
S069	High	Male	7.3	0.30	23.11	120.0	120.0	720.0	300.0	180.0	150.0	15.0	60.0	360.0	180.0	60.0	0.0	90.0	N/A	192.14	181.15	1.06
S072	High	Male	7.1	1.06	22.90	120.0	300.0	240.0	150.0	120.0	0.0	180.0	240.0	360.0	120.0	0.0	180.0	210.0	180.0	100.14	171.43	0.58
All Subject Average			8.26	1.07	22.86	175.50	187.26	225.00	196.45	231.77	228.39	225.00	229.44	230.89	187.76	156.43	193.97	204.64	193.46	110.70	203.18	0.58
All Subject Std			1.06	0.54	0.71	152.11	141.08	169.09	155.81	156.69	161.45	177.30	190.73	168.39	160.49	189.97	148.43	140.96	155.33	60.26	105.70	0.22
All Subject CoV			0.13	0.50	0.03	0.87	0.75	0.75	0.79	0.68	0.71	0.79	0.83	0.73	0.85	1.21	0.77	0.69	0.80	0.54	0.52	0.37
LR Average			8.47	1.42	22.72	220.59	247.94	263.82	247.06	311.47	315.88	311.25	311.00	270.00	230.63	191.25	245.63	270.00	243.75	133.72	261.74	0.53
LR SD			1.18	0.33	0.76	179.67	150.48	154.89	183.87	165.30	159.41	188.98	217.70	181.42	188.14	232.67	149.39	125.38	144.86	62.73	100.39	0.19
LR CoV			0.14	0.23	0.03	0.81	0.61	0.59	0.74	0.53	0.50	0.61	0.70	0.67	0.82	1.22	0.61	0.46	0.59	0.47	0.38	0.36
HR Average			7.99	0.65	23.02	116.54	113.57	177.86	135.00	135.00	122.14	118.85	127.50	185.77	135.00	110.00	130.38	117.50	126.42	82.75	132.07	0.66
HR SD			0.87	0.43	0.63	78.94	86.01	179.12	83.62	68.11	81.92	81.12	72.50	145.89	101.92	103.20	124.81	113.31	148.40	44.73	58.71	0.24
HR CoV			0.11	0.65	0.03	0.68	0.76	1.01	0.62	0.50	0.67	0.68	0.57	0.79	0.75	0.94	0.96	0.96	1.17	0.54	0.44	0.36

APPENDIX V - Raw Data - Daily Exposure to Different Wavelengths

Average exposure per day to blue, green and red light measured objectively by the Actiwatch for each of the 31 subjects who participated in Summer Trials. Exposure is reported as irradiance in microwatts per square centimeter ($\mu W/cm^2$). Green text indicates children in the Low Risk (LR) of myopia group and orange indicates High Risk (HR). SE OD is the spherical equivalent of the right eye (M) measured with cycloplegic open-field autorefraction. AXL OD is the axial length of the right eye measured by the Lenstar 900 Biometer. Age, SE OD and AXL OD are from the PICNIC follow up visit at which each child was given the Actiwatch.

Average Daily Blue Light Exposure (μW/cm^2)

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Actiwatch Blue Light average exposure per day (uW/cm2)														SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S001	Low	Male	8.4	1.28	22.85	49.00	330.00	58.90	298.00	76.20	256.00	55.20	38.30	398.00	146.00	164.00	177.00	240.00	28.00	121.87	165.33	0.74
S005	Low	Female	10.0	1.31	23.20	49.60	216.00	28.60	58.10	274.00	257.00	621.00	295.00	74.50	15.80	278.00	904.00	869.00	753.00	318.17	335.26	0.95
S006	Low	Female	8.2	1.05	23.13	469.00	346.00	488.00	217.00	147.00	101.00	167.00	197.00	14.20	27.60	28.10	308.00	278.00	96.90	154.99	206.06	0.75
S020	Low	Male	10.5	1.36	23.63	170.00	192.00	295.00	55.40	36.90	62.70	115.00	124.00	279.00	303.00	34.50	47.40	86.60	64.00	98.39	133.25	0.74
S024	Low	Male	8.3	1.98	22.52	35.80	171.00	602.00	45.80	330.00	192.00	67.20	79.80	72.00	128.00	45.20	165.00	161.00	159.00	149.58	160.99	0.93
S042	Low	Male	8.7	0.78	22.80	155.00	90.80	450.00	51.80	211.00	145.00	213.00	92.20	216.00	25.90	114.00	176.00	91.80	N/A	107.56	156.35	0.69
S044	Low	Female	6.5	1.70	21.02	16.30	21.20	39.60	277.00	190.00	112.00	195.00	64.20	209.00	422.00	112.00	102.00	146.00	321.00	119.14	159.09	0.75
S056	Low	Female	9.3	1.73	22.52	271.00	310.00	309.00	10.60	182.00	234.00	54.20	193.00	266.00	77.00	40.80	84.50	174.00	102.00	103.35	164.86	0.63
S057	Low	Female	9.3	1.35	23.20	64.10	617.00	1,040.00	713.00	805.00	416.00		218.00	542.00	108.00	21.90		783.00	694.00	333.30	501.83	0.66
S059	Low	Male	7.3	1.93	22.73	163.00	450.00	90.60	112.00	177.00	85.20	49.60	161.00	187.00	93.50	58.00	16.10	51.40	9.96	110.72	121.74	0.91
S061	Low	Female	8.8	1.36	23.28	115.00	368.00	219.00	169.00	111.00	247.00	252.00		333.00	423.00	180.00	365.00	98.60	307.00	107.94	245.20	0.44
S062	Low	Male	6.8	1.88	22.72	42.80	352.00	258.00	29.80	99.20	294.00	296.00	627.00	174.00	38.90	152.00	161.00	271.00	37.20	164.69	202.35	0.81
S064	Low	Male	6.5	1.10	23.11		436.00	379.00	20.60	55.80	162.00	74.10	35.00	67.30	321.00	3.10	347.00	45.10	30.70	158.28	152.05	1.04
S114	Low	Female	9.3	1.47	21.47	229.00	20.20	189.00	372.00	462.00	268.00	195.00	102.00	152.00	95.20	131.00	75.30	58.50	62.10	126.37	172.24	0.73
S115	Low	Female	8.9	1.29	22.06	97.10	125.00	168.00	77.50	293.00	49.40	298.00	218.00	47.10	77.90	322.00	369.00	383.00	391.00	131.34	208.29	0.63
S122	Low	Female	7.7	1.40	21.95	25.50	12.30	5.96	4.99	30.30	0.03	32.30	19.60	26.20	71.40	9.15	9.83	2.61	22.90	18.35	19.50	0.94
S132	Low	Male	9.6	1.14	24.02	0.57	31.30	245.00	117.00	185.00	396.00	194.00	60.20	132.00	126.00	26.60	55.20	199.00	196.00	106.80	139.56	0.77
S009	High	Male	8.1	0.61	22.69	82.20	177.00	66.00	66.60	57.00	186.00	64.20	113.00	187.00	127.00	55.60	52.00	6.78	53.70	56.72	92.43	0.61
S018	High	Female	7.8	1.23	23.89	133.00	24.60	18.20	19.70	23.00	76.40	112.00	24.80	34.40	77.30	25.60	168.00	77.50	9.52	53.28	60.29	0.88
S021	High	Female	8.9	0.73	21.75	141.00	89.20	206.00	123.00	252.00	170.00	340.00	607.00	48.00	131.00	122.00	10.10	37.20	48.00	155.43	166.04	0.94
S028	High	Male	8.7	1.43	23.66	85.60	85.90	219.00	161.00	55.00	41.10	86.80	63.20	68.90	208.00	15.30	28.20	21.60	70.00	64.88	86.40	0.75
S029	High	Female	8.2	0.65	22.62	9.63	27.70	120.00	104.00	81.10	70.90	74.50	24.60	84.70	52.20	34.00	39.50	86.30	49.30	32.45	61.32	0.53
S049	High	Male	8.7	0.67	23.91	2.39	6.81	13.40	137.00	40.40	71.30	137.00	17.50	204.00	19.10	104.00			240.00	81.48	82.74	0.98
S050	High	Female	8.9	0.66	23.48	35.80	270.00	477.00	41.30	162.00	398.00	317.00	47.70	42.00	51.70	142.00	64.50	47.20	74.90	149.55	155.08	0.96
S054	High	Female	7.7	0.43	22.56	5.62	3.70	293.00	4.09	149.00	40.20	16.70	137.00	5.35	10.50	4.42	14.10	16.70	6.29	84.94	50.48	1.68
S058	High	Male	9.4	-0.12	22.85	61.80	71.00	25.60	28.80	61.40	53.70	42.30	48.10	8.42	7.13	84.20	11.90	8.76	2.67	27.08	36.84	0.74
S060	High	Female	6.5	1.03	23.19	15.20	10.40	3.61	56.50	29.40	76.50	7.40	190.00	50.60	20.00	13.50	5.34	19.30	4.70	49.57	35.89	1.38
S065	High	Male	6.8	0.28	23.44	244.00	221.00	176.00	349.00	138.00	215.00	192.00	21.10	225.00		278.00		41.30	47.50	100.52	178.99	0.56
S066	High	Female	8.1	0.19	22.27	59.10	53.70	3.10	57.30	92.30	39.40	30.70	0.00	0.26	0.00	102.00	36.40	23.10	2.76	34.07	35.72	0.95
S069	High	Male	7.3	0.30	23.11	39.30	22.70	28.90	67.90	159.00	121.00	102.00	36.60	136.00	106.00	60.20	24.10	54.50	N/A	46.05	73.71	0.62
S072	High	Male	7.1	1.06	22.90	172.00	210.00	131.00	186.00	30.40	14.40	239.00	111.00	154.00	196.00	18.60	68.20	169.00	194.00	75.05	135.26	0.55
All Subject Average			8.26	1.07	22.86	101.31	172.98	214.40	130.06	161.14	156.49	154.67	131.86	143.16	116.87	89.67	139.45	151.60	140.62	111.03	145.00	0.82
All Subject Std			1.06	0.54	0.71	102.44	162.36	224.43	147.65	157.69	116.81	131.25	151.57	126.50	115.06	85.07	187.90	206.51	192.38	71.30	96.41	0.25
All Subject CoV			0.13	0.50	0.03	1.01	0.94	1.05	1.14	0.98	0.75	0.85	1.15	0.88	0.98	0.95	1.35	1.36	1.37	0.64	0.66	0.30
LR Average			8.47	1.42	22.72	122.05	240.52	286.22	154.68	215.61	192.78	179.91	157.14	187.61	147.07	101.20	210.15	231.68	204.67	142.99	190.82	0.77
LR SD			1.18	0.33	0.76	121.84	178.98	258.69	181.33	189.61	118.37	147.72	148.87	143.14	134.05	94.31	222.05	245.16	234.34	76.30	102.33	0.15
LR CoV			0.14	0.23	0.03	1.00	0.74	0.90	1.17	0.88	0.61	0.82	0.95	0.76	0.91	0.93	1.06	1.06	1.14	0.53	0.54	0.19
HR Average			7.99	0.65	23.02	77.62	90.98	127.20	100.16	95.00	112.42	125.83	102.97	89.19	77.38	75.67	45.20	46.86	61.80	72.22	89.37	0.87
HR SD			0.87	0.43	0.63	71.75	90.56	137.61	89.90	67.38	102.12	107.56	154.88	77.41	71.10	73.27	49.62	44.28	74.24	40.08	49.83	0.33
HR CoV			0.11	0.65	0.03	0.92	1.00	1.08	0.90	0.71	0.91	0.85	1.50	0.87	0.92	0.97	1.10	0.94	1.20	0.55	0.56	0.38

Average Daily Green Light Exposure (μW/cm^2)

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Actiwatch Green Light average exposure per day (uW/cm2)														SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S001	Low	Male	8.4	1.28	22.85	90.30	531.00	115.00	534.00	158.00	464.00	98.20	73.10	786.00	281.00	282.00	311.00	401.00	52.20	220.86	298.34	0.74
S005	Low	Female	10.0	1.31	23.20	92.00	378.00	48.50	97.60	469.00	435.00	1,010.00	449.00	124.00	27.90	466.00	1,490.00		1,240.00	474.85	486.69	0.98
S006	Low	Female	8.2	1.05	23.13	930.00	686.00	934.00	440.00	269.00	162.00	286.00	353.00	33.60	51.20	50.40	543.00	468.00	155.00	303.52	382.94	0.79
S020	Low	Male	10.5	1.36	23.63	322.00	447.00	584.00	111.00	62.60	133.00	268.00	261.00	447.00	513.00	107.00	92.30	184.00	140.00	173.60	262.28	0.66
S024	Low	Male	8.3	1.98	22.52	68.50	285.00	1,060.00	77.90	527.00	410.00	132.00	142.00	124.00	220.00	85.90	341.00	353.00	259.00	261.06	291.81	0.89
S042	Low	Male	8.7	0.78	22.80	219.00	127.00	813.00	116.00	381.00	234.00	348.00	187.00	381.00	38.70	171.00	290.00	174.00	N/A	194.37	267.67	0.73
S044	Low	Female	6.5	1.70	21.02	85.40	51.40	107.00	516.00	357.00	198.00	332.00	106.00	366.00	674.00	189.00	222.00	284.00	565.00	191.28	289.49	0.66
S056	Low	Female	9.3	1.73	22.52	410.00	499.00	446.00	23.10	274.00	397.00	86.60	315.00	400.00	120.00	61.70	127.00	255.00	149.00	159.45	254.53	0.63
S057	Low	Female	9.3	1.35	23.20	118.00	1,070.00	1,570.00	1,170.00	1,290.00	644.00		433.00	984.00	172.00	33.80			1,130.00	528.02	783.16	0.67
S059	Low	Male	7.3	1.93	22.73	418.00	1,050.00	207.00	245.00	408.00	185.00	108.00	440.00	532.00	224.00	150.00	29.30	110.00	18.70	268.85	294.64	0.91
S061	Low	Female	8.8	1.36	23.28	178.00	579.00	385.00	270.00	171.00	430.00	407.00	1,290.00	580.00	726.00	275.00	673.00	154.00	482.00	299.82	471.43	0.64
S062	Low	Male	6.8	1.88	22.72	65.30	547.00	413.00	48.50	150.00	484.00	489.00	1,120.00	278.00	104.00	236.00	280.00	427.00	57.30	285.18	335.65	0.85
S064	Low	Male	6.5	1.10	23.11	1,190.00	899.00	578.00	43.00	98.20	276.00	153.00	73.50	134.00	702.00	6.41	550.00	60.50	55.00	375.84	344.19	1.09
S114	Low	Female	9.3	1.47	21.47	407.00	53.70	374.00	662.00	858.00	614.00	323.00	206.00	248.00	147.00	270.00	164.00	115.00	108.00	237.91	324.98	0.73
S115	Low	Female	8.9	1.29	22.06	231.00	260.00	421.00	161.00	579.00	105.00	763.00	533.00	116.00	207.00	855.00	1,000.00	947.00	992.00	343.38	512.14	0.67
S122	Low	Female	7.7	1.40	21.95	38.10	17.80	17.80	15.60	43.20	0.06	73.80	30.50	47.60	102.00	17.10	16.40	4.32	36.70	27.72	32.93	0.84
S132	Low	Male	9.6	1.14	24.02	0.35	94.70	431.00	213.00	322.00	673.00	351.00	76.90	262.00	316.00	48.60	116.00	352.00	314.00	180.17	255.04	0.71
S009	High	Male	8.1	0.61	22.69	130.00	293.00	104.00	128.00	115.00	306.00	107.00	240.00	302.00	246.00	95.30	89.20	13.00	84.20	95.84	160.91	0.60
S018	High	Female	7.8	1.23	23.89	205.00	40.80	28.80	35.30	56.00	131.00	180.00	40.60	52.90	130.00	43.80	320.00	123.00	11.50	87.55	99.91	0.88
S021	High	Female	8.9	0.73	21.75	300.00	182.00	417.00	250.00	464.00	360.00	690.00		136.00	278.00	250.00	36.60	105.00	124.00	176.47	276.35	0.64
S028	High	Male	8.7	1.43	23.66	155.00	144.00	568.00	265.00	113.00	69.30	157.00	127.00	113.00	481.00	30.40	48.00	35.70	119.00	161.38	173.24	0.93
S029	High	Female	8.2	0.65	22.62	19.60	47.50	203.00	203.00	160.00	135.00	168.00	46.50	141.00	88.00	62.10	79.50	182.00	101.00	61.50	116.87	0.53
S049	High	Male	8.7	0.67	23.91	4.82	12.50	23.20	244.00	69.60	154.00	231.00	36.20	351.00	32.60	161.00		416.00		140.00	144.66	0.97
S050	High	Female	8.9	0.66	23.48	59.20	430.00	910.00	76.20	268.00	713.00	553.00	83.10	92.80	114.00	239.00	116.00	158.00	131.00	268.74	281.66	0.95
S054	High	Female	7.7	0.43	22.56	17.00	7.50	449.00	8.64	232.00	64.60	29.90	208.00	9.80	18.60	10.30	23.40	26.30	9.66	129.29	79.82	1.62
S058	High	Male	9.4	-0.12	22.85	108.00	116.00	42.30	47.20	105.00	90.70	74.70	77.40	20.50	30.20	135.00	20.80	18.90	4.47	42.61	63.66	0.67
S060	High	Female	6.5	1.03	23.19	33.10	18.70	6.66	117.00	51.60	137.00	12.00	315.00	84.30	32.40	21.70	6.69	33.60	8.52	83.55	62.73	1.33
S065	High	Male	6.8	0.28	23.44	411.00	389.00	300.00	563.00	260.00	369.00	384.00	34.10	409.00		484.00		85.60	90.10	166.96	314.90	0.53
S066	High	Female	8.1	0.19	22.27	87.10	86.90	6.63	86.80	135.00	57.90	49.00	0.00	0.59	0.01	151.00	53.50	40.90	4.67	50.23	54.29	0.93
S069	High	Male	7.3	0.30	23.11	67.90	42.60	80.50	148.00	321.00	262.00	190.00	70.40	331.00	236.00	128.00	46.70	118.00	N/A	101.86	157.08	0.65
S072	High	Male	7.1	1.06	22.90	265.00	386.00	234.00	305.00	49.50	27.40	392.00	203.00	266.00	305.00	30.30	105.00	317.00	318.00	126.95	228.80	0.55
All Subject Average			8.26	1.07	22.86	216.96	315.23	383.14	232.93	284.41	281.32	281.54	252.34	263.00	220.59	166.03	256.80	205.58	241.43	200.61	261.37	0.81
All Subject Std			1.06	0.54	0.71	261.82	304.73	368.32	247.19	265.42	202.94	234.51	297.97	231.32	207.48	177.80	336.96	200.78	341.32	121.14	159.80	0.24
All Subject CoV			0.13	0.50	0.03	1.21	0.97	0.96	1.06	0.93	0.72	0.83	1.18	0.88	0.94	1.07	1.31	0.98	1.41	0.60	0.61	0.29
LR Average			8.47	1.42	22.72	286.06	445.62	500.25	279.04	377.47	343.77	326.79	358.18	343.72	272.11	194.41	390.31	285.92	359.62	266.23	346.35	0.78
LR SD			1.18	0.33	0.76	324.36	338.95	405.70	304.04	315.56	200.68	256.38	355.55	263.27	235.93	210.05	393.60	230.49	411.08	120.12	157.12	0.13
LR CoV			0.14	0.23	0.03	1.13	0.76	0.81	1.09	0.84	0.58	0.78	0.99	0.77	0.87	1.08	1.01	0.81	1.14	0.45	0.45	0.17
HR Average			7.99	0.65	23.02	133.05	156.89	240.94	176.94	171.41	205.49	229.83	113.95	164.99	153.22	131.56	78.78	119.50	83.84	120.92	158.19	0.84
HR SD			0.87	0.43	0.63	121.98	153.83	266.03	145.19	122.22	184.89	203.57	96.94	138.97	145.41	127.75	83.33	119.10	90.06	60.34	87.40	0.32
HR CoV			0.11	0.65	0.03	0.92	0.98	1.10	0.82	0.71	0.90	0.89	0.85	0.84	0.95	0.97	1.06	1.00	1.07	0.50	0.55	0.38

Average Daily Red Light Exposure (μW/cm^2)

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Actiwatch Red Light average exposure per day (uW/cm2)														SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S001	Low	Male	8.4	1.28	22.85	115.00	587.00	104.00	681.00	205.00	559.00	106.00	83.30	1,510.00	389.00	434.00	392.00	455.00	48.80	381.52	404.94	0.94
S005	Low	Female	10.0	1.31	23.20	82.40	350.00	53.00	96.00	453.00	524.00	1,290.00	586.00	127.00	28.50	448.00	1,710.00	1,640.00	1,800.00	660.43	656.28	1.01
S006	Low	Female	8.2	1.05	23.13	1,260.00	881.00	1,090.00	689.00	415.00	193.00	275.00	456.00	26.10	51.90	53.20	522.00	799.00	232.00	396.82	495.94	0.80
S020	Low	Male	10.5	1.36	23.63	773.00	778.00	1,210.00	97.10	57.10	102.00	290.00	349.00	567.00	539.00	55.80	80.30	355.00	171.00	347.64	387.45	0.90
S024	Low	Male	8.3	1.98	22.52	78.50	361.00	1,340.00	78.10	655.00	888.00	175.00	216.00	115.00	294.00	79.20	421.00	587.00	290.00	364.02	398.41	0.91
S042	Low	Male	8.7	0.78	22.80	341.00	182.00	1,760.00	131.00	431.00	305.00	671.00	289.00	692.00	52.20	275.00	493.00	346.00	N/A	433.66	459.09	0.94
S044	Low	Female	6.5	1.70	21.02	22.90	29.40	59.60	521.00	315.00	281.00	348.00	135.00	422.00	851.00	185.00	140.00	223.00	565.00	235.25	292.71	0.80
S056	Low	Female	9.3	1.73	22.52	659.00	860.00	931.00	45.20	452.00	599.00	126.00	462.00	632.00	229.00	105.00	200.00	401.00	226.00	282.91	423.37	0.67
S057	Low	Female	9.3	1.35	23.20	147.00	1,680.00	1,890.00	1,610.00	1,550.00	959.00	2,400.00	792.00	2,000.00	247.00	40.10	3,340.00		1,410.00	949.57	1,389.62	0.68
S059	Low	Male	7.3	1.93	22.73	768.00	1,900.00	514.00	406.00	624.00	279.00	145.00	879.00	1,570.00	477.00	237.00	41.60	183.00	34.90	557.21	575.61	0.97
S061	Low	Female	8.8	1.36	23.28	200.00	722.00	656.00	286.00	241.00	743.00	747.00	2,420.00	956.00	1,200.00	320.00	1,210.00	212.00	545.00	591.49	747.00	0.79
S062	Low	Male	6.8	1.88	22.72	75.10	648.00	597.00	53.10	190.00	905.00	838.00	2,190.00	334.00	148.00	260.00	330.00	662.00	63.40	560.95	520.97	1.08
S064	Low	Male	6.5	1.10	23.11	1,640.00	1,280.00	775.00	81.40	211.00	521.00	278.00	177.00	252.00	1,290.00	5.50	665.00	127.00	105.00	528.94	529.14	1.00
S114	Low	Female	9.3	1.47	21.47	886.00	89.80	515.00	1,500.00		1,100.00	479.00	457.00	331.00	189.00	332.00	425.00	270.00	163.00	408.36	518.22	0.79
S115	Low	Female	8.9	1.29	22.06	340.00	645.00	605.00	279.00	800.00	155.00	1,200.00	927.00	259.00	382.00		2,030.00	1,590.00	1,560.00	599.21	828.62	0.72
S122	Low	Female	7.7	1.40	21.95	55.40	24.10	11.50	10.20	47.00	0.05	95.50	44.40	62.90	150.00	22.10	22.60	6.74	57.30	40.58	43.56	0.93
S132	Low	Male	9.6	1.14	24.02	0.57	47.70	471.00	279.00	370.00	1,100.00	347.00	89.30	214.00	283.00	77.80	108.00	503.00	391.00	279.76	305.81	0.91
S009	High	Male	8.1	0.61	22.69	179.00	430.00	127.00	199.00	206.00	545.00	118.00	399.00	444.00	511.00	171.00	107.00	12.60	102.00	174.15	253.61	0.69
S018	High	Female	7.8	1.23	23.89	288.00	50.90	38.20	37.70	63.30	337.00	231.00	56.50	80.90	138.00	55.90		151.00	39.10	102.71	120.58	0.85
S021	High	Female	8.9	0.73	21.75	300.00	155.00	364.00	177.00	442.00	282.00	714.00	1,130.00	67.80	187.00	274.00	11.40	69.90	94.30	299.57	304.89	0.98
S028	High	Male	8.7	1.43	23.66	259.00	253.00	842.00	360.00	148.00	84.50	259.00	255.00	201.00	1,100.00	30.40	60.40	48.60	176.00	322.41	298.35	1.08
S029	High	Female	8.2	0.65	22.62	23.20	47.20	220.00	251.00	169.00	153.00	158.00	50.00	158.00	91.60	60.40	63.20	229.00	120.00	74.24	128.11	0.58
S049	High	Male	8.7	0.67	23.91	3.76	10.90	24.20	276.00	69.60	207.00	214.00	58.80	320.00	29.40	178.00	588.00			172.67	165.06	1.05
S050	High	Female	8.9	0.66	23.48	69.10	680.00	1,080.00	55.80	300.00	767.00	554.00	89.40	66.40	94.80	277.00	106.00	84.70	121.00	328.68	310.37	1.06
S054	High	Female	7.7	0.43	22.56	11.60	7.10	727.00	9.21	441.00	78.60	40.40	359.00	10.40	23.00	9.18	26.00	35.30	12.00	220.83	127.84	1.73
S058	High	Male	9.4	-0.12	22.85	190.00	199.00	47.60	57.70	165.00	134.00	122.00	91.90	15.60	13.90	162.00	22.10	15.90	5.21	71.84	88.71	0.81
S060	High	Female	6.5	1.03	23.19	26.00	18.00	6.06	176.00	44.50	151.00	14.50	357.00	116.00	34.10	23.10	9.09	30.50	7.97	98.94	72.42	1.37
S065	High	Male	6.8	0.28	23.44	555.00	357.00	288.00	553.00	203.00	395.00	347.00	42.40	295.00		491.00	588.00	58.90	78.20	190.77	327.04	0.58
S066	High	Female	8.1	0.19	22.27	154.00	140.00	7.08	141.00	237.00	101.00	68.80	0.01	0.72	0.08	269.00	80.40	40.30	5.76	89.48	88.94	1.01
S069	High	Male	7.3	0.30	23.11	106.00	57.70	161.00	219.00	412.00	449.00	283.00	90.10	489.00	394.00	224.00	61.20	198.00	N/A	151.41	241.85	0.63
S072	High	Male	7.1	1.06	22.90	297.00	692.00	440.00	345.00	49.10	24.10	551.00	300.00	372.00	335.00	30.80	108.00			211.67	295.33	0.72
All Subject Average			8.26	1.07	22.86	319.53	456.86	550.14	312.92	332.19	416.81	435.01	446.16	409.90	325.08	172.88	465.38	333.37	312.00	326.70	380.64	0.90
All Subject Std			1.06	0.54	0.71	391.28	487.52	523.14	380.51	300.61	327.59	484.83	574.91	487.12	354.88	141.70	732.75	419.32	486.61	210.02	273.67	0.23
All Subject CoV			0.13	0.50	0.03	1.22	1.07	0.95	1.22	0.90	0.79	1.11	1.29	1.19	1.09	0.82	1.57	1.26	1.56	0.64	0.72	0.26
LR Average			8.47	1.42	22.72	437.87	650.88	740.12	402.54	438.51	541.94	577.09	620.71	592.35	400.04	183.11	713.56	522.48	478.90	448.14	528.04	0.87
LR SD			1.18	0.33	0.76	484.33	558.42	569.75	484.33	362.78	357.52	597.33	691.65	586.48	378.27	148.39	889.77	472.93	578.97	203.74	285.86	0.12
LR CoV			0.14	0.23	0.03	1.11	0.86	0.77	1.20	0.83	0.66	1.04	1.11	0.99	0.95	0.81	1.25	0.91	1.21	0.45	0.54	0.14
HR Average			7.99	0.65	23.02	175.83	221.27	319.44	204.10	210.68	264.87	262.48	234.22	188.34	227.07	161.20	140.83	81.23	69.23	179.24	201.65	0.94
HR SD			0.87	0.43	0.63	155.08	236.00	357.08	148.87	141.13	212.12	211.74	292.85	166.91	308.55	138.24	201.50	72.22	58.74	89.44	96.70	0.32
HR CoV			0.11	0.65	0.03	0.88	1.07	1.12	0.73	0.67	0.80	0.81	1.25	0.89	1.36	0.86	1.43	0.89	0.85	0.50	0.48	0.34

APPENDIX VI - Raw Data - Activity Levels

Minutes per day of light (>320 cpm), moderate (>1048 cpm), and rigorous (>1624 cpm) activity measured objectively by the Actiwatch for each of the 31 subjects who participated in Summer trials. Green text indicates children in the Low Risk (LR) of myopia group and orange indicates High Risk (HR). SE OD is the spherical equivalent of the right eye (M) measured with cycloplegic open-field autorefraction. AXL OD is the axial length of the right eye measured by the Lenstar 900 Biometer. Age, SE OD and AXL OD are from the PICNIC follow up visit at which each child was given the Actiwatch.

Minutes of Light (>320 cpm) Activity per Day

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Actiwatch Minutes of Light Activity														SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S001	Low	Male	8.4	1.28	22.85	162.5	128.0	192.5	210.5	203.5	238.5	237.5	249.5	124.5	162.5	247.0	261.0	208.5	230.0	44.63	204.00	0.22
S005	Low	Female	10.0	1.31	23.20	213.0	231.0	96.0	165.0	185.0	182.5	213.0	153.0	124.5	168.0	268.0	278.0	219.5	222.5	51.09	194.21	0.26
S006	Low	Female	8.2	1.05	23.13	239.0	138.0	182.5	120.5	127.0	140.5	121.5	128.0	101.5	271.5	109.0	318.5	209.5	182.5	66.62	170.68	0.39
S020	Low	Male	10.5	1.36	23.63	234.0	290.0	328.0	174.5	207.0	212.0	161.5	208.5	141.0	118.0	190.5	213.5	137.5	161.0	58.11	198.36	0.29
S024	Low	Male	8.3	1.98	22.52	257.0	250.0	232.5	277.0	302.5	202.5	299.0	261.0	241.5	313.5	291.0	246.0	246.5	322.5	34.52	267.32	0.13
S042	Low	Male	8.7	0.78	22.80	216.5	259.0	235.0	237.0	256.5	289.0	273.5	223.5	220.5	305.5	303.0	367.5	251.5	N/A	43.07	264.46	0.16
S044	Low	Female	6.5	1.70	21.02	297.0	289.0	321.0	343.0	315.5	294.5	398.0	334.5	335.0	373.0	240.5	309.5	322.0	364.0	39.38	324.04	0.12
S056	Low	Female	9.3	1.73	22.52	403.5	480.5	212.0	127.0	88.0	158.0	211.5	215.0	342.0	242.5	152.5	160.5	223.5	194.5	109.03	229.36	0.48
S057	Low	Female	9.3	1.35	23.20	210.0	240.0	128.0	277.5	233.5	173.0	228.0	138.0	249.5	125.5	125.0	314.5	207.5	137.0	62.09	199.07	0.31
S059	Low	Male	7.3	1.93	22.73	370.0	382.0	326.5	335.0	278.0	343.5	250.0	391.5	330.5	313.5	260.5	221.0	306.5	242.0	53.71	310.75	0.17
S061	Low	Female	8.8	1.36	23.28	253.5	304.0	261.0	155.0	197.0	269.0	235.5	333.5	293.5	264.0	273.0	281.5	169.5	268.5	50.01	253.46	0.20
S062	Low	Male	6.8	1.88	22.72	332.0	351.0	290.5	242.0	306.0	331.0	279.5	344.5	328.0	296.5	229.0	180.5	282.0	259.0	48.85	289.39	0.17
S064	Low	Male	6.5	1.10	23.11	369.5	273.5	175.0	228.5	285.0	211.5	200.0	250.0	334.0	212.0	288.0	226.0	305.0	420.5	69.73	269.89	0.26
S114	Low	Female	9.3	1.47	21.47	28.0	76.0	288.0	209.0	92.0	174.0	97.0	205.0	120.5	157.0	154.5	141.5	161.5	215.5	66.83	151.39	0.44
S115	Low	Female	8.9	1.29	22.06	242.5	272.0	237.0	273.5	387.0	181.5	297.0	271.0	0.0	317.5	373.0	351.5	320.0	61.5	110.86	256.07	0.43
S122	Low	Female	7.7	1.40	21.95	275.5	211.0	246.0	230.0	190.0	15.0	276.5	167.0	199.5	227.5	174.0	260.0	226.0	226.0	65.27	208.86	0.31
S132	Low	Male	9.6	1.14	24.02	0.0	185.5	265.0	218.0	245.0	250.5	171.5	148.0	225.5	195.0	163.0	226.0	233.5	293.0	70.88	201.39	0.35
S009	High	Male	8.1	0.61	22.69	273.5	268.5	237.5	236.0	226.0	260.5	237.0	193.5	250.5	289.0	242.5	188.0	162.5	242.0	34.84	236.21	0.15
S018	High	Female	7.8	1.23	23.89	109.5	189.5	156.0	158.0	144.0	146.5	134.0	124.5	123.5	122.0	94.0	187.5	126.5	0.0	46.04	129.68	0.36
S021	High	Female	8.9	0.73	21.75	220.5	259.0	290.0	194.5	307.5	360.0	337.5	340.0	257.5	298.0	158.5	193.5	207.0	208.5	63.88	259.43	0.25
S028	High	Male	8.7	1.43	23.66	363.0	285.0	388.0	237.5	288.5	335.5	252.0	303.0	299.0	316.0	117.0	328.0	274.0	214.0	67.45	285.61	0.24
S029	High	Female	8.2	0.65	22.62	170.5	146.0	200.0	157.5	177.0	223.5	149.5	285.0	193.5	208.0	145.0	183.0	210.0	143.5	39.29	185.14	0.21
S049	High	Male	8.7	0.67	23.91	142.0	112.5	170.0	176.0	166.0	195.5	161.0	172.0	243.0	153.5	274.0	345.0	335.5	334.5	78.75	212.89	0.37
S050	High	Female	8.9	0.66	23.48	211.0	329.0	206.0	272.5	233.0	273.5	340.5	201.0	285.5	203.0	87.0	260.5	263.5	116.5	71.47	234.46	0.30
S054	High	Female	7.7	0.43	22.58	104.0	83.0	163.5	130.5	170.0	156.5	227.5	316.0	59.0	151.0	75.0	176.5	170.0	48.5	71.33	145.07	0.49
S058	High	Male	9.4	-0.12	22.85	251.5	175.0	270.0	211.0	203.5	161.0	251.0	235.5	117.0	82.0	239.5	191.5	69.5	13.5	78.57	176.54	0.45
S060	High	Female	6.5	1.03	23.19	312.0	268.0	191.0	341.5	329.0	336.0	256.5	239.0	292.5	87.5	0.5	0.0	264.5	287.5	117.08	228.96	0.51
S065	High	Male	6.8	0.28	23.44	247.0	271.5	160.0	77.0	165.0	247.0	0.0	167.5	1.5	84.5	160.5	217.0	151.0	123.5	84.87	148.07	0.57
S066	High	Female	8.1	0.19	22.27	263.0	266.0	83.0	335.0	288.0	154.0	229.5	0.0	0.0	0.0	211.0	151.0	0.0	0.0	125.74	141.46	0.89
S069	High	Male	7.3	0.30	23.11	359.0	223.5	134.5	210.0	363.0	304.0	272.0	269.0	251.0	273.0	172.5	188.0	344.5	N/A	72.09	258.77	0.28
S072	High	Male	7.1	1.06	22.90	321.5	310.0	326.5	300.5	202.0	274.0	307.5	262.5	325.0	286.0	228.5	289.0	317.0	317.0	37.60	280.50	0.13
All Subject Average			**8.26**	**1.07**	**22.86**	**240.37**	**243.45**	**225.56**	**221.31**	**231.00**	**228.84**	**229.23**	**230.00**	**206.77**	**213.11**	**195.06**	**233.98**	**223.40**	**201.69**	**65.60**	**223.40**	**0.32**
All Subject Std			**1.06**	**0.54**	**0.71**	**96.39**	**87.67**	**73.75**	**69.16**	**75.04**	**77.13**	**79.61**	**82.68**	**105.97**	**90.60**	**81.17**	**76.69**	**79.45**	**108.82**	**24.10**	**52.70**	**0.16**
All Subject CoV			**0.13**	**0.50**	**0.03**	**0.40**	**0.36**	**0.33**	**0.31**	**0.32**	**0.34**	**0.35**	**0.36**	**0.51**	**0.43**	**0.42**	**0.33**	**0.36**	**0.54**	**0.37**	**0.24**	**0.51**
LR Average			8.47	1.42	22.72	241.38	256.50	236.26	224.88	229.32	215.68	232.38	236.56	218.32	238.41	225.97	256.29	237.06	237.50	61.45	234.87	0.28
LR SD			1.18	0.33	0.76	107.41	97.16	66.82	64.42	81.01	79.48	72.23	79.20	102.76	75.90	72.36	64.12	55.40	87.16	21.26	49.22	0.11
LR CoV			0.14	0.23	0.03	0.44	0.38	0.28	0.29	0.35	0.37	0.31	0.33	0.47	0.32	0.32	0.25	0.23	0.37	0.35	0.21	0.41
HR Average			7.99	0.65	23.02	239.14	227.61	212.57	216.96	233.04	244.82	225.39	222.04	192.75	182.39	157.54	206.89	206.82	157.62	70.64	209.49	0.37
HR SD			0.87	0.43	0.63	85.09	74.99	82.00	76.78	70.05	73.83	80.42	89.07	111.95	100.00	77.42	84.08	101.24	119.67	27.10	55.20	0.20
HR CoV			0.11	0.65	0.03	0.36	0.33	0.39	0.35	0.30	0.30	0.40	0.40	0.58	0.55	0.49	0.41	0.49	0.76	0.38	0.26	0.54

Minutes of Moderate (>1048 cpm) Activity per Day

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Actiwatch Minutes of Moderate Activity														SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S001	Low	Male	8.4	1.28	22.85	11.5	14.5	22.5	15.0	35.5	28.0	35.5	52.5	16.5	32.0	56.0	40.0	38.5	0.0	16.02	28.43	0.56
S005	Low	Female	10.0	1.31	23.20	8.0	8.5	1.5	5.5	3.0	6.5	4.0	3.0	3.0	4.0	18.5	15.0	9.0	12.0	5.01	7.25	0.69
S006	Low	Female	8.2	1.05	23.13	8.0	8.0	11.0	21.0	10.0	4.5	4.5	4.0	3.0	8.5	0.5	26.0	11.5	7.5	6.92	9.14	0.76
S020	Low	Male	10.5	1.36	23.63	7.0	13.0	13.5	13.0	3.5	15.0	16.0	11.0	17.0	2.0	3.5	12.5	25.0	10.5	6.16	11.61	0.53
S024	Low	Male	8.3	1.98	22.52	6.0	14.0	9.5	17.0	32.0	18.0	18.0	11.0	5.0	43.0	9.0	12.5	22.5	35.5	11.47	18.07	0.63
S042	Low	Male	8.7	0.78	22.80	34.5	27.0	18.0	20.5	15.0	37.0	0.0	8.0	24.0	29.0	61.0	49.0	36.0	N/A	16.44	27.62	0.60
S044	Low	Female	6.5	1.70	21.02	27.0	34.0	19.5	27.0	11.5	17.0	27.0	19.5	34.0	37.5	12.5	26.0	53.0	44.5	11.91	27.86	0.43
S056	Low	Female	9.3	1.73	22.52	9.5	35.0	3.5	39.5	0.5	2.0	9.5	3.0	9.5	9.0	5.0	4.0	5.0	5.0	11.94	10.00	1.19
S057	Low	Female	9.3	1.35	23.20	4.5	7.5	4.5	17.0	6.5	3.5	7.0	5.0	2.0	2.0	0.5	25.5	3.0	10.5	6.75	7.07	0.95
S059	Low	Male	7.3	1.93	22.73	86.0	61.5	43.0	88.0	52.5	50.0	50.0	69.0	77.5	55.0	69.5	25.5	45.5	36.0	18.43	57.79	0.32
S061	Low	Female	8.8	1.36	23.28	5.0	10.0	6.0	9.5	1.0	2.0	5.0	8.5	12.0	4.5	2.5	3.0	2.0	4.5	3.40	5.39	0.63
S062	Low	Male	6.8	1.88	22.72	31.5	54.5	51.5	21.5	18.5	40.0	40.5	54.5	48.0	29.5	59.5	4.5	12.0	6.0	18.87	33.71	0.56
S064	Low	Male	6.5	1.10	23.11	14.5	8.5	4.5	5.0	16.0	20.5	1.5	7.0	12.0	16.0	6.5	6.5	12.0	19.0	5.87	10.68	0.55
S114	Low	Female	9.3	1.47	21.47	1.0	4.0	12.0	21.0	3.0	18.5	3.0	11.0	5.5	3.0	4.0	4.0	9.5	12.5	6.23	8.00	0.78
S115	Low	Female	8.9	1.29	22.06	2.0	10.0	23.0	4.0	55.0	15.0	68.0	37.5	13.5	16.0	30.0	30.0	20.0	37.5	18.89	25.82	0.73
S122	Low	Female	7.7	1.40	21.95	8.0	11.0	6.0	5.0	6.0	0.0	16.5	13.5	7.5	10.5	7.0	11.0	19.0	10.5	4.88	9.39	0.52
S132	Low	Male	9.6	1.14	24.02	0.0	3.5	13.5	12.5	21.0	19.5	1.5	10.0	13.5	8.0	9.5	43.0	14.0	21.5	10.79	13.64	0.79
S009	High	Male	8.1	0.61	22.69	31.5	77.5	15.0	32.5	12.0	28.5	13.0	42.0	37.5	33.5	15.5	22.0	26.5	19.5	16.87	29.04	0.58
S018	High	Female	7.8	1.23	23.89	10.5	27.5	10.5	9.0	5.0	16.0	5.5	5.5	8.5	13.0	1.0	7.5	14.5	0.0	6.94	9.57	0.72
S021	High	Female	8.9	0.73	21.75	6.5	7.5	29.5	4.5	8.5	16.0	19.0	15.0	11.5	19.0	5.0	5.5	6.5	8.0	7.25	11.57	0.63
S028	High	Male	8.7	1.43	23.66	44.0	30.0	25.5	30.5	40.5	26.5	63.0	54.0	69.0	61.5	13.0	32.5	53.0	43.0	16.51	41.86	0.39
S029	High	Female	8.2	0.65	22.62	21.0	16.0	49.0	10.5	10.0	27.5	22.5	25.5	29.5	38.5	16.5	13.0	16.0	3.0	12.14	21.32	0.57
S049	High	Male	8.7	0.67	23.91	12.0	4.0	16.0	8.0	8.0	46.0	47.0	27.5	84.0	25.5	37.5	64.0	47.5	51.5	23.84	34.18	0.70
S050	High	Female	8.9	0.66	23.48	3.5	5.0	3.0	7.0	2.5	5.0	4.5	21.5	9.5	8.5	1.0	3.5	1.5	18.0	6.08	6.71	0.90
S054	High	Female	7.7	0.43	22.56	3.0	1.5	22.0	1.5	6.5	2.0	8.0	14.0	0.0	3.0	0.5	8.5	0.0	1.0	6.33	5.11	1.24
S058	High	Male	9.4	-0.12	22.85	20.5	5.0	48.0	14.5	28.5	8.0	22.0	27.5	9.0	1.0	20.5	27.5	3.5	0.0	13.55	16.82	0.81
S060	High	Female	6.5	1.03	23.19	7.0	2.0	3.5	4.5	8.5	7.5	10.5	8.5	11.0	2.5	0.0	0.0	8.5	5.0	3.67	5.64	0.65
S065	High	Male	6.8	0.28	23.44	22.5	17.0	8.5	11.5	24.5	24.5	0.0	7.0	0.5	0.0	14.5	9.5	6.5	5.5	8.65	10.86	0.80
S066	High	Female	8.1	0.19	22.27	11.5	18.0	2.0	31.0	14.5	15.0	14.5	0.0	0.0	0.0	10.0	13.5	0.0	0.0	9.37	9.29	1.01
S069	High	Male	7.3	0.30	23.11	9.0	9.0	10.0	9.5	22.0	15.5	17.5	6.0	29.5	36.0	5.5	5.5	26.5	N/A	10.10	15.50	0.65
S072	High	Male	7.1	1.06	22.90	51.5	32.0	25.5	66.0	7.0	16.0	74.0	77.5	28.5	29.0	23.5	50.5	79.0	48.5	23.81	43.46	0.55
All Subject Average			8.26	1.07	22.86	16.71	18.60	17.13	18.79	15.76	17.77	20.27	21.27	20.37	18.73	16.74	19.39	20.23	16.41	11.13	18.46	0.69
All Subject Std			1.06	0.54	0.71	18.20	18.34	14.31	18.48	14.49	13.06	20.81	20.86	22.28	17.16	19.74	16.43	19.18	16.27	5.82	13.31	0.21
All Subject CoV			0.13	0.50	0.03	1.09	0.99	0.84	0.98	0.92	0.73	1.03	0.98	1.09	0.92	1.18	0.85	0.95	0.99	0.52	0.72	0.30
LR Average			8.47	1.42	22.72	15.53	19.09	15.47	20.12	17.09	17.47	18.09	19.29	17.85	18.21	20.88	19.88	19.85	17.06	10.59	18.32	0.66
LR SD			1.18	0.33	0.76	20.87	17.42	13.74	19.74	17.15	14.48	19.78	20.67	19.46	16.34	24.41	14.67	15.16	13.85	5.43	13.72	0.20
LR CoV			0.14	0.23	0.03	1.34	0.91	0.89	0.98	1.00	0.83	1.09	1.07	1.09	0.90	1.17	0.74	0.76	0.81	0.51	0.75	0.31
HR Average			7.99	0.65	23.02	18.14	18.00	19.14	17.18	14.14	18.14	22.93	23.68	23.43	19.36	11.71	18.79	20.68	15.62	11.79	18.64	0.73
HR SD			0.87	0.43	0.63	14.99	20.06	15.24	17.44	10.82	11.64	22.46	21.61	25.70	18.70	10.77	18.90	23.80	19.40	6.40	13.30	0.21
HR CoV			0.11	0.65	0.03	0.83	1.11	0.80	1.01	0.76	0.64	0.98	0.91	1.10	0.97	0.92	1.01	1.15	1.24	0.54	0.71	0.29

Minutes of Rigorous (>1624 cpm) Activity per Day

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Actiwatch Minutes of Rigorous Activity														SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S001	Low	Male	8.4	1.28	22.85	5.0	4.5	6.0	3.5	5.5	6.5	12.5	9.5	5.0	2.0	12.0	22.0	15.5	15.5	5.78	8.93	0.65
S005	Low	Female	10.0	1.31	23.20	0.0	1.0	0.0	0.0	0.5	0.0	0.5	0.0	0.0	0.0	4.5	1.0	1.5	0.5	1.20	0.68	1.77
S006	Low	Female	8.2	1.05	23.13	0.0	0.5	2.5	1.5	0.0	5.5	16.0	0.5	0.0	1.5	0.0	4.5	0.5	0.5	4.28	2.39	1.79
S020	Low	Male	10.5	1.36	23.63	2.5	1.0	2.0	2.0	1.0	2.5	5.0	1.0	3.0	0.0	0.5	2.0	3.0	2.5	1.27	2.00	0.64
S024	Low	Male	8.3	1.98	22.52	0.0	8.5	1.0	4.5	13.5	3.5	6.5	1.0	5.5	19.5	3.5	1.0	3.5	9.5	5.47	5.79	0.95
S042	Low	Male	8.7	0.78	22.80	5.5	5.5	1.5	2.5	4.5	5.0	4.0	1.0	1.0	4.0	7.0	4.5	6.0	N/A	1.95	4.00	0.49
S044	Low	Female	6.5	1.70	21.02	3.5	7.0	4.0	12.5	5.5	1.0	5.0	1.0	10.0	4.5	3.5	8.0	12.0	7.0	3.62	6.04	0.60
S056	Low	Female	9.3	1.73	22.52	0.0	6.0	0.0	11.0	0.0	0.0	0.0	1.0	0.0	0.5	0.0	0.0	0.5	0.0	3.20	1.36	2.35
S057	Low	Female	9.3	1.35	23.20	0.5	1.0	1.0	1.5	0.5	4.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	1.08	0.64	1.68
S059	Low	Male	7.3	1.93	22.73	10.0	7.0	12.0	18.0	6.5	5.5	19.5	9.0	5.5	7.0	18.0	9.0	5.5	8.5	4.94	10.07	0.49
S061	Low	Female	8.8	1.36	23.28	0.0	1.0	0.5	1.0	0.0	0.0	0.5	1.0	0.5	0.0	0.0	0.0	0.5	0.0	0.41	0.36	1.16
S062	Low	Male	6.8	1.88	22.72	3.0	5.5	4.0	7.0	2.0	5.0	7.0	8.5	7.5	2.5	10.0	1.0	0.0	1.5	3.08	4.61	0.67
S064	Low	Male	6.5	1.10	23.11	2.0	3.0	1.5	2.0	1.0	1.5	0.0	1.5	0.5	3.0	0.0	0.5	1.0	3.5	1.11	1.50	0.74
S114	Low	Female	9.3	1.47	21.47	0.0	0.0	0.0	6.0	0.0	0.5	0.5	0.0	2.5	0.0	0.5	0.0	2.0	6.0	2.15	1.29	1.67
S115	Low	Female	8.9	1.29	22.06	0.0	1.0	3.0	0.0	4.5	0.5	3.0	0.5	1.0	1.5	5.5	3.0	1.0	281.5	74.75	21.86	3.42
S122	Low	Female	7.7	1.40	21.95	0.0	0.0	2.0	0.0	1.0	0.0	3.0	9.0	0.5	1.0	0.5	0.0	0.0	1.0	2.39	1.29	1.86
S132	Low	Male	9.6	1.14	24.02	0.0	1.0	2.5	3.0	3.5	2.5	0.5	3.0	1.0	0.0	1.0	5.0	1.0	1.0	1.48	1.79	0.83
S009	High	Male	8.1	0.61	22.69	12.5	17.0	4.0	8.0	4.0	3.0	6.5	16.0	22.5	13.0	3.0	13.5	6.0	10.5	6.02	9.96	0.60
S018	High	Female	7.8	1.23	23.89	3.5	17.0	1.0	0.0	0.0	3.5	1.0	2.5	2.0	2.0	0.0	4.5	3.5	0.0	4.34	2.89	1.50
S021	High	Female	8.9	0.73	21.75	2.0	0.0	7.0	0.5	0.5	1.5	3.5	2.0	1.5	2.5	0.0	1.0	0.0	0.0	1.90	1.57	1.21
S028	High	Male	8.7	1.43	23.66	7.0	7.0	4.0	9.5	3.0	6.5	9.0	19.0	9.5	11.5	0.0	3.0	12.0	2.0	4.96	7.36	0.67
S029	High	Female	8.2	0.65	22.62	0.5	2.0	11.0	1.0	0.5	2.0	1.5	12.5	5.5	8.0	6.5	2.0	0.5	1.0	4.10	3.89	1.05
S049	High	Male	8.7	0.67	23.91	0.0	0.0	2.5	0.6	1.0	4.5	8.5	1.0	13.5	4.0	6.0	18.5	8.5	8.5	5.54	5.50	1.01
S050	High	Female	8.9	0.66	23.48	0.5	1.0	0.0	0.5	0.5	0.5	0.0	4.5	0.5	1.0	0.5	0.0	0.0	24.5	6.45	2.43	2.66
S054	High	Female	7.7	0.43	22.56	0.0	0.0	1.5	0.0	1.0	0.0	1.0	0.5	0.0	0.0	0.0	2.0	2.0	0.5	0.76	0.61	1.26
S058	High	Male	9.4	-0.12	22.85	4.5	1.0	9.0	3.5	6.0	2.5	4.5	0.5	0.5	0.0	4.0	6.5	0.5	0.0	2.83	3.07	0.92
S060	High	Female	6.5	1.03	23.19	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.5	0.0	0.0	3.0	0.5	0.83	0.43	1.93
S065	High	Male	6.8	0.28	23.44	5.0	1.0	0.0	3.0	2.5	2.0	0.0	0.0	0.0	0.0	2.5	1.0	2.0	0.0	1.54	1.36	1.13
S066	High	Female	8.1	0.19	22.27	2.5	3.0	0.0	3.0	3.5	2.0	0.5	0.0	0.0	0.0	2.0	1.0	0.0	0.0	1.36	1.25	1.08
S069	High	Male	7.3	0.30	23.11	0.5	1.0	1.5	0.0	3.0	0.0	3.5	1.0	10.0	11.5	0.5	2.5	2.0	N/A	3.69	2.85	1.30
S072	High	Male	7.1	1.06	22.90	12.0	5.0	2.0	18.5	0.5	2.0	18.5	19.0	8.0	7.5	7.0	7.5	11.0	4.0	6.28	8.75	0.72
All Subject Average			8.26	1.07	22.86	2.66	3.50	2.81	4.00	2.47	2.37	4.56	4.06	3.81	3.50	3.18	4.03	3.37	13.45	5.44	4.08	1.25
All Subject Std			1.06	0.54	0.71	3.58	4.44	3.18	5.10	2.88	2.09	5.51	5.77	5.14	4.80	4.26	5.41	4.23	51.86	13.00	4.42	0.69
All Subject CoV			0.13	0.50	0.03	1.35	1.27	1.13	1.27	1.17	0.88	1.21	1.42	1.35	1.37	1.34	1.34	1.25	3.86	2.39	1.08	0.55
LR Average			8.47	1.42	22.72	1.88	3.15	2.56	4.47	2.91	2.56	4.91	2.79	2.56	2.76	3.91	3.65	3.15	21.16	6.95	4.39	1.28
LR SD			1.18	0.33	0.76	2.81	2.89	2.93	5.05	3.55	2.32	5.91	3.62	3.06	4.75	5.21	5.51	4.43	69.57	17.55	5.36	0.81
LR CoV			0.14	0.23	0.03	1.50	0.92	1.14	1.13	1.22	0.91	1.20	1.30	1.19	1.72	1.33	1.51	1.41	3.29	2.53	1.22	0.63
HR Average			7.99	0.65	23.02	3.61	3.93	3.11	3.43	1.93	2.14	4.14	5.61	5.32	4.39	2.29	4.50	3.64	3.96	3.61	3.71	1.22
HR SD			0.87	0.43	0.63	4.26	5.90	3.55	5.29	1.76	1.84	5.16	7.48	6.70	4.89	2.63	5.45	4.13	7.07	2.08	3.05	0.54
HR CoV			0.11	0.65	0.03	1.18	1.50	1.14	1.54	0.91	0.86	1.25	1.33	1.26	1.11	1.15	1.21	1.13	1.79	0.57	0.82	0.44

APPENDIX VII - Raw Data - Sleep Patterns

Bed time, wake up time and total sleep duration per night measured objectively by the Actiwatch and subjectively reported by the parents with Daily surveys. Bedtime before school days and non-school days, wake up time on school days and non-school days and total sleep duration before school days and non-school days reported subjectively as an average for the week prior to the visit by the parents with the PICNIC questionnaire for each of the 31 subjects who participated in Summer Trials. Green text indicates children in the Low Risk (LR) of myopia group and orange indicates High Risk (HR). Pink highlighted cells indicate data that was removed due to measurement errors and outliers. SE OD is the spherical equivalent of the right eye (M) measured with cycloplegic open-field autorefraction. AXL OD is the axial length of the right eye measured by the Lenstar 900 Biometer. Age, SE OD and AXL OD are from the PICNIC follow up visit at which each child was given the Actiwatch.

Objective Bedtime per Day

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Actiwatch Bedtime														SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S001	Low	Male	8.4	1.28	22.85	22.82	21.89	21.3	21.89	22.74	22.43	22.63	23.21	22.83	19.16	21.58	21.84	21.88	21.82	0.99	22.00	0.05
S005	Low	Female	10.0	1.31	23.20	20.21	20.51	22.41	19.64	19.93	19.83	19.99	20.08	20.72	20.73	21.08	20.32	20.31	20.43	0.69	20.44	0.03
S006	Low	Female	8.2	1.05	23.13	20.66	21.98	21.13	21.74	21.56	22.53	20.94	20.54	21.73	20.89	21.93	25.64	23.79	23.94	1.46	22.07	0.07
S020	Low	Male	10.5	1.36	23.63	21.69	21.77	21.62	21.73	21.26	20.1	21.53	21.9	18.92	22.74	21.32	21.57	21.02	22.24	0.93	21.39	0.04
S024	Low	Male	8.3	1.98	22.52	20.36	20.87	20.95	21.56	20.1	20.68	18.77	20.72	20.65	20.37	19.32	20.36	20.67	20.17	0.69	20.40	0.03
S042	Low	Male	8.7	0.78	22.80	20.98	21.76	21.73	20.46	21.03	19.58	20.79	20.93	20.49	20.67	21.73	21.12	21.12	N/A	0.60	20.95	0.03
S044	Low	Female	6.5	1.70	21.02	20.78	20.06	21.16	19.45	20.81	22.42	21.83	19.83	18.82	21.94	18.63	22.67	21.4	21.64	1.29	20.82	0.06
S056	Low	Female	9.3	1.73	22.52	22.6	21.94	23.23	21.23	21.51	21.18	21.14	21.48	21.06	21.6	22.1	21.54	21.17	20.96	0.65	21.62	0.03
S057	Low	Female	9.3	1.35	23.20	22.78	20.63	22.13	22.36	22.21	22.51	22.18	21.68	23.51	22.58	22.88	21.43	22.63	22.31	0.69	22.27	0.03
S059	Low	Male	7.3	1.93	22.73	21.54	21.08	20.88	20.58	20.99	20.94	20.32	21.2	21.9	20.68	20.93	21.09	20.98	21.37	0.40	21.03	0.02
S061	Low	Female	8.8	1.36	23.28	20.92	20.57	20.31	20.15	20.3	19.78	20.28	20.54	21.8	20.5	20.48	20.27	23.92	24.93	1.51	21.05	0.07
S062	Low	Male	6.8	1.88	22.72	20.99	20.78	20.87	21.33	21.23	19.84	20.81	20.64	21.84	21.12	20.37	20.91	20.8	20.67	0.46	20.87	0.02
S064	Low	Male	6.5	1.10	23.11	22.98	22.25	22.53	22.26	22.08	22.13	21.85	22.25	23.32	22.9	22.27	23.44	22.62	22.89	0.48	22.56	0.02
S114	Low	Female	9.3	1.47	21.47	20.69	N/A	21.9	22.1	21.56	22.98	21.04	22.28	23	21.93	21.63	21.7	20.32	21.09	0.80	21.71	0.04
S115	Low	Female	8.9	1.29	22.06	21.85	21.46	21.87	22.3	22.28	22.92	21.77	21.29	20.84	21.1	21.3	21.49	21.21	19.22	0.86	21.49	0.04
S122	Low	Female	7.7	1.40	21.95	21.08	21.88	20.17	21.95	21.11	N/A	22.18	23.57	23.97	21.69	22.23	22.6	22.18	21.46	1.01	22.01	0.05
S132	Low	Male	9.6	1.14	24.02	N/A	N/A	21.3	22.1	20.61	1.07	22.94	21.2	21.45	21.23	21.71	21.4	22.82	21.51			
S009	High	Male	8.1	0.61	22.69	21.52	21.25	21.45	21.53	23.26	21.24	20.49	21.29	19.96	20.72	21.01	22.53	21.76	20.5	0.84	21.32	0.04
S018	High	Female	7.8	1.23	23.89	17.38	20.88	21.49	21.56	22	21.41	21.48	21.54	17.55	21.12	21.79	21.88	20.61	N/A	1.54	20.82	0.07
S021	High	Female	8.9	0.73	21.75	22.51	22.73	22.73	23.21	22.21	23.38	18.74	22.97	24.18	24.1	24.12	23.84	22.45	23.19	1.36	22.88	0.06
S028	High	Male	8.7	1.43	23.66	22.69	21.29	20.75	20.61	20.73	20.55	21.04	21.15	21.1	21.46	23.17	N/A	20.84	20.98	0.79	21.26	0.04
S029	High	Female	8.2	0.65	22.62	20.73	21.34	21.28	20.66	21.16	20.68	20.71	20.6	20.38	18.67	20.4	21.15	20.89	20.25	0.66	20.64	0.03
S049	High	Male	8.7	0.67	23.91	23.23	22.8	23.02	23.48	23.7	23.43	22.76	23.53	23.45	24.47	23.34	22.49	23.77	22.66	0.52	23.30	0.02
S050	High	Female	8.9	0.66	23.48	23.3	23.28	22.13	16.69	22.63	23.07	22.49	31.56	25.58	24.97	23.78	22.93	23.09	22.56	2.08	23.43	0.09
S054	High	Female	7.7	0.43	22.56	24.68	26.38	19.63	25.58	23.13	23.44	25.19	26.41	23.39	25.8	27.68	24.83	25.58	25.58			
S058	High	Male	9.4	-0.12	22.85	21.43	23.88	22.92	23.2	20.88	20.57	21.31	21.03	22.66	22.02	19.52	20.67	21.94	20.66	1.21	21.62	0.06
S060	High	Female	6.5	1.03	23.19	22.53	21.28	21.49	20.52	21.04	20.81	20.43	20.98	22.07	20.42	N/A	N/A	N/A	21.33	0.67	21.17	0.03
S065	High	Male	6.8	0.28	23.44	22.01	20.63	18.14	17.08	N/A	20.93	21.75	22.43	N/A	35.67	22.38	14.36	22.13	20.34			
S066	High	Female	8.1	0.19	22.27	22.98	24.64	26.57	25.1	22.37	22.23	24.55	N/A	N/A	N/A	N/A	21.47	N/A	N/A	1.74	23.74	0.07
S069	High	Male	7.3	0.30	23.11	21.2	21.08	22.87	21.38	21.26	20.73	20.49	20.5	20.06	20.59	20.39	20.58	20.58	21.08	0.68	20.91	0.03
S072	High	Male	7.1	1.06	22.80	20.43	20.32	20.38	20.54	19.69	20.63	19.79	19.58	21.26	20.34	19.63	19.78	20.7	20.88	0.52	20.28	0.03
All Subject Average			**8.26**	**1.07**	**22.86**	**21.65**	**21.77**	**21.62**	**21.42**	**21.51**	**20.80**	**21.36**	**21.90**	**21.67**	**22.07**	**21.68**	**21.58**	**21.83**	**21.67**	**0.93**	**21.57**	**0.04**
All Subject Std			**1.06**	**0.54**	**0.71**	**1.35**	**1.39**	**1.42**	**1.82**	**1.00**	**3.92**	**1.40**	**2.28**	**1.78**	**3.02**	**1.75**	**1.93**	**1.29**	**1.45**	**0.43**	**0.93**	**0.02**
All Subject CoV			**0.13**	**0.50**	**0.03**	**0.06**	**0.06**	**0.07**	**0.09**	**0.05**	**0.19**	**0.07**	**0.10**	**0.08**	**0.14**	**0.08**	**0.09**	**0.06**	**0.07**	**0.46**	**0.04**	**0.44**
LR Average			8.47	1.42	22.72	21.43	21.30	21.50	21.34	21.25	20.06	21.23	21.37	21.58	21.28	21.26	21.73	21.70	21.67	0.84	21.42	0.04
LR SD			1.18	0.33	0.76	0.92	0.68	0.80	0.94	0.78	5.21	1.05	1.03	1.47	0.96	1.08	1.31	1.12	1.41	0.34	0.65	0.02
LR CoV			0.14	0.23	0.03	0.04	0.03	0.04	0.04	0.04	0.26	0.05	0.05	0.07	0.05	0.05	0.06	0.05	0.07	0.40	0.03	0.40
HR Average			7.99	0.65	23.02	21.90	22.27	21.78	21.51	21.85	21.65	21.52	22.58	21.80	23.10	22.27	21.38	22.03	21.67	1.05	21.78	0.05
HR SD			0.87	0.43	0.63	1.73	1.76	1.95	2.56	1.17	1.19	1.76	3.21	2.20	4.34	2.34	2.63	1.53	1.57	0.52	1.21	0.02
HR CoV			0.11	0.65	0.03	0.08	0.08	0.09	0.12	0.05	0.05	0.08	0.14	0.10	0.19	0.11	0.12	0.07	0.07	0.50	0.06	0.46

Objective Wake Time per Day

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Actiwatch Wake Time														SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S001	Low	Male	8.4	1.28	22.85	7.71	7.76	8.97	7.14	6.98	7.55	8.05	8.40	7.98	10.64	7.20	7.24	7.19	7.08	0.98	7.85	0.13
S005	Low	Female	10.0	1.31	23.20	5.62	4.93	5.89	5.55	5.04	5.18	5.03	4.23	5.36	5.85	5.52	5.40	3.20	4.84	0.71	5.12	0.14
S006	Low	Female	8.2	1.05	23.13	6.34	6.60	7.48	6.75	7.61	4.81	6.41	6.98	7.06	6.56	6.74	9.86	9.21	9.18	1.35	7.26	0.19
S020	Low	Male	10.5	1.36	23.63	6.46	7.29	6.81	6.11	7.20	6.73	6.57	7.37	6.88	8.35	6.83	6.01	6.37	7.35	0.61	6.88	0.09
S024	Low	Male	8.3	1.98	22.52	6.50	5.97	5.50	6.36	6.41	6.28	5.87	5.53	5.68	5.68	5.99	5.37	6.22	6.29	0.38	5.98	0.06
S042	Low	Male	8.7	0.78	22.80	6.69	4.72	8.16	7.10	7.63	6.95	6.98	6.88	7.09	7.13	6.68	6.35	7.22	N/A	0.79	6.89	0.11
S044	Low	Female	6.5	1.70	21.02	6.50	7.18	3.73	6.04	6.49	5.87	6.61	6.82	4.28	5.24	5.38	6.81	6.73	7.03	1.05	6.05	0.17
S056	Low	Female	9.3	1.73	22.52	6.07	6.44	7.78	6.23	7.34	7.20	7.28	7.06	6.27	11.98	7.01	6.25	7.18	6.68	1.47	7.20	0.20
S057	Low	Female	9.3	1.35	23.20	7.34	5.98	6.83	6.98	7.38	6.91	7.88	6.78	7.76	7.11	6.77	6.98	7.52	7.56	0.49	7.13	0.07
S059	Low	Male	7.3	1.93	22.73	6.08	6.59	6.10	6.19	7.61	7.18	6.95	6.60	6.63	6.85	7.28	6.95	6.58	6.23	0.46	6.70	0.07
S061	Low	Female	8.8	1.36	23.28	7.17	6.83	6.42	7.12	6.14	6.79	7.39	6.71	7.54	7.53	7.78	3.01	6.37	9.46	1.38	6.88	0.20
S062	Low	Male	6.8	1.88	22.72	7.17	6.90	6.94	8.35	6.33	7.43	6.92	6.71	7.93	7.62	8.36	6.52	7.63	7.51	0.64	7.31	0.09
S064	Low	Male	6.5	1.10	23.11	8.24	8.59	8.81	7.72	7.74	7.88	7.67	7.87	8.77	8.79	9.33	7.78	10.00	8.79	0.70	8.43	0.08
S114	Low	Female	9.3	1.47	21.47	7.55	N/A	7.08	7.38	8.08	7.68	9.21	7.56	7.78	8.08	9.47	6.98	7.24	7.29	0.76	7.80	0.10
S115	Low	Female	8.9	1.29	22.06	6.89	7.08	7.40	7.67	6.08	6.90	6.63	7.08	6.89	8.00	7.29	7.80	6.73	7.36	0.51	7.13	0.07
S122	Low	Female	7.7	1.40	21.95	6.18	6.70	7.18	6.82	6.58	N/A	8.26	8.39	7.94	8.83	3.17	7.43	7.39	7.58	1.41	7.11	0.20
S132	Low	Male	9.6	1.14	24.02	N/A	N/A	7.18	6.58	7.03	8.71	7.59	15.98	7.58	6.96	6.56	6.83	8.03	7.59			
S009	High	Male	8.1	0.61	22.69	6.03	7.05	7.22	6.66	8.54	6.33	6.09	6.28	6.34	6.21	5.98	7.97	6.28	6.21	0.77	6.66	0.12
S018	High	Female	7.8	1.23	23.89	7.66	5.91	6.10	7.03	6.59	6.35	5.35	6.21	7.53	7.33	9.31	8.82	7.26	N/A	1.14	7.03	0.16
S021	High	Female	8.9	0.73	21.75	6.24	7.31	7.03	7.19	7.32	7.25	8.64	9.23	9.17	10.78	11.02	10.41	9.83	6.55	1.64	8.43	0.19
S028	High	Male	8.7	1.43	23.66	4.96	6.64	5.75	5.82	5.74	6.14	5.79	6.62	6.48	6.50	6.23	N/A	6.63	6.94	0.54	6.17	0.09
S029	High	Female	8.2	0.65	22.62	6.90	6.03	7.35	7.15	6.96	6.98	6.96	7.05	7.31	7.70	7.38	7.38	7.30	6.98	0.38	7.10	0.05
S049	High	Male	8.7	0.67	23.91	10.38	9.93	9.83	9.76	9.88	7.46	9.76	9.52	9.53	11.09	7.48	7.50	7.36	7.53	1.30	9.07	0.14
S050	High	Female	8.9	0.66	23.48	7.63	8.88	7.59	4.91	5.08	8.88	8.07	17.57	12.68	8.82	8.66	10.62	9.08	5.09	2.22	8.15	0.27
S054	High	Female	7.7	0.43	22.56	13.03	11.25	11.32	12.31	8.62	11.34	9.73	8.34	12.64	15.10	9.72	10.91	11.95	12.93			
S058	High	Male	9.4	-0.12	22.85	5.86	6.76	8.49	7.33	5.83	6.50	5.40	5.52	5.87	6.83	6.24	6.18	7.25	5.55	0.87	6.40	0.14
S060	High	Female	6.5	1.03	23.19	8.38	7.22	7.58	7.09	6.22	6.02	5.69	6.47	5.81	6.08	N/A	N/A	N/A	6.04	0.85	6.60	0.13
S065	High	Male	6.8	0.28	23.44	7.78	6.78	8.76	8.27	N/A	7.90	7.98	7.86	N/A	17.43	8.07	9.76	8.38	5.53			
S066	High	Female	8.1	0.19	22.27	7.08	10.91	13.18	10.08	7.28	7.02	7.18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.45	8.96	0.27
S069	High	Male	7.3	0.30	23.11	6.84	7.07	6.04	7.03	6.81	7.48	6.94	6.48	7.18	6.40	6.87	6.62	6.50	6.41	0.38	6.76	0.06
S072	High	Male	7.1	1.06	22.90	6.42	6.03	7.83	6.35	6.43	6.01	3.51	6.89	5.25	5.91	6.80	5.93	5.87	6.07	0.96	6.09	0.16
All Subject Average			**8.26**	**1.07**	**22.86**	**7.12**	**7.15**	**7.49**	**7.20**	**6.97**	**7.06**	**7.04**	**7.70**	**7.42**	**8.25**	**7.28**	**7.35**	**7.40**	**7.13**	**0.97**	**7.11**	**0.13**
All Subject Std			**1.06**	**0.54**	**0.71**	**1.51**	**1.51**	**1.76**	**1.43**	**1.03**	**1.21**	**1.37**	**2.70**	**1.86**	**2.76**	**1.56**	**1.76**	**1.57**	**1.58**	**0.53**	**0.92**	**0.06**
All Subject CoV			**0.13**	**0.50**	**0.03**	**0.21**	**0.21**	**0.23**	**0.20**	**0.15**	**0.17**	**0.20**	**0.35**	**0.25**	**0.34**	**0.21**	**0.24**	**0.21**	**0.22**	**0.54**	**0.13**	**0.46**
LR Average			8.47	1.42	22.72	6.78	6.64	6.96	6.83	6.92	6.88	7.14	7.47	7.02	7.72	6.90	6.68	7.11	7.36	0.86	6.98	0.12
LR SD			1.18	0.33	0.76	0.70	0.99	1.25	0.72	0.78	0.98	0.97	2.40	1.12	1.71	1.48	1.40	1.41	1.14	0.37	0.79	0.05
LR CoV			0.14	0.23	0.03	0.10	0.15	0.18	0.11	0.11	0.14	0.14	0.32	0.16	0.22	0.21	0.21	0.20	0.15	0.43	0.11	0.43
HR Average			7.99	0.65	23.02	7.51	7.70	8.15	7.64	7.02	7.26	6.94	8.00	7.98	8.94	7.81	8.37	7.81	6.82	1.13	7.29	0.15
HR SD			0.87	0.43	0.63	2.05	1.80	2.09	1.91	1.33	1.43	1.78	3.12	2.53	3.70	1.58	1.83	1.74	2.04	0.67	1.08	0.07
HR CoV			0.11	0.65	0.03	0.27	0.23	0.26	0.25	0.19	0.20	0.26	0.39	0.32	0.41	0.20	0.22	0.22	0.30	0.60	0.15	0.48

Objective Sleep Duration per Day

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Actiwatch Sleep Duration														SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S001	Low	Male	8.4	1.28	22.85	8.28	8.87	9.03	8.07	7.55	8.51	7.90	8.39	8.41	14.70	8.60	8.74	8.22	8.31	1.73	8.83	0.20
S005	Low	Female	10.0	1.31	23.20	8.14	7.29	6.71	8.75	7.98	8.70	7.83	7.58	6.88	8.08	7.38	8.42	6.01	7.58	0.78	7.67	0.10
S006	Low	Female	8.2	1.05	23.13	8.49	7.62	9.28	7.09	9.21	6.01	8.48	8.84	8.11	8.83	8.34	7.68	8.58	7.93	0.88	8.18	0.11
S020	Low	Male	10.5	1.36	23.63	7.71	7.15	7.39	6.78	8.84	10.44	7.68	8.71	10.37	8.39	8.31	6.39	7.97	7.68	1.19	8.13	0.15
S024	Low	Male	8.3	1.98	22.52	8.91	8.15	8.08	8.10	8.61	8.47	9.52	6.98	8.08	8.68	10.23	8.19	8.22	9.48	0.80	8.55	0.09
S042	Low	Male	8.7	0.78	22.80	8.50	6.63	9.03	9.38	9.72	11.35	9.23	8.92	9.38	9.58	8.00	6.93	8.73	N/A	1.22	8.88	0.14
S044	Low	Female	6.5	1.70	21.02	8.23	9.98	5.21	9.01	8.51	6.78	7.38	9.93	8.53	6.92	9.94	7.17	8.11	8.32	1.37	8.14	0.17
S056	Low	Female	9.3	1.73	22.52	6.71	8.09	8.04	8.34	9.24	9.16	9.34	8.35	8.09	12.34	8.13	8.23	9.63	9.01	1.27	8.76	0.15
S057	Low	Female	9.3	1.35	23.20	7.32	8.28	7.64	7.41	8.42	7.06	8.73	8.32	7.51	7.34	7.04	8.24	8.33	8.36	0.58	7.86	0.07
S059	Low	Male	7.3	1.93	22.73	7.77	8.33	8.43	8.35	9.51	8.80	9.58	8.16	7.00	9.38	8.82	8.71	8.68	8.15	0.69	8.55	0.08
S061	Low	Female	8.8	1.36	23.28	9.08	9.33	8.68	9.58	8.63	9.41	9.63	8.73	8.98	10.03	9.92	4.83	6.07	7.87	1.48	8.63	0.17
S062	Low	Male	6.8	1.88	22.72	9.26	8.26	7.94	10.28	8.05	10.58	9.16	8.92	8.78	8.44	10.87	8.08	9.85	9.02	0.96	9.11	0.11
S064	Low	Male	6.5	1.10	23.11	7.87	7.98	8.63	7.98	7.10	8.92	8.25	8.27	7.10	8.93	9.56	7.34	10.05	8.68	0.87	8.33	0.10
S114	Low	Female	9.3	1.47	21.47	10.84	N/A	7.94	8.52	9.69	8.44	11.93	8.52	8.27	9.97	10.62	9.16	10.71	9.26	1.22	9.53	0.13
S115	Low	Female	8.9	1.29	22.06	6.58	7.78	7.58	7.72	5.89	6.70	7.19	8.01	8.07	8.64	8.15	8.57	6.88	10.74	1.17	7.75	0.15
S122	Low	Female	7.7	1.40	21.95	7.16	7.51	9.70	7.73	7.32	N/A	8.75	7.79	6.99	9.37	4.21	7.58	8.03	8.30	1.34	7.73	0.17
S132	Low	Male	9.6	1.14	24.02	N/A	N/A	7.66	7.61	10.08	7.18	7.35	18.29	8.80	8.62	8.23	8.67	7.94	9.10			
S009	High	Male	8.1	0.61	22.69	7.60	7.11	7.91	7.28	8.19	7.83	7.01	7.59	9.12	8.02	7.41	8.55	7.34	8.18	0.59	7.80	0.08
S018	High	Female	7.8	1.23	23.89	13.71	8.04	7.47	8.28	7.30	8.00	7.02	7.90	13.10	9.78	10.88	10.52	10.13	N/A	2.19	9.39	0.23
S021	High	Female	8.9	0.73	21.75	7.80	7.59	7.52	9.23	6.90	7.65	7.11	7.36	8.35	7.14	12.58	9.27	7.93	9.34	1.49	8.27	0.18
S028	High	Male	8.7	1.43	23.66	5.62	8.19	8.28	8.12	7.73	8.50	8.18	8.58	8.59	8.25	17.55	N/A	8.91	9.03	0.88	8.17	0.11
S029	High	Female	8.2	0.65	22.62	9.13	7.78	8.84	8.95	8.52	8.73	8.63	8.41	9.22	12.86	9.62	8.88	9.24	8.82	1.16	9.12	0.13
S049	High	Male	8.7	0.67	23.91	10.03	9.13	8.64	9.15	8.24	6.43	9.71	9.10	9.11	8.88	6.63	8.10	7.15	8.01	1.09	8.45	0.13
S050	High	Female	8.9	0.66	23.48	7.65	9.01	8.83	10.70	5.34	7.18	7.81	9.98	10.30	6.55	8.27	11.66	8.05	5.96	1.85	8.25	0.22
S054	High	Female	7.7	0.43	22.56	10.85	7.33	13.31	9.33	7.62	9.93	6.37	4.91	11.03	12.63	5.13	8.53	8.85	9.13			
S058	High	Male	9.4	-0.12	22.85	7.33	5.41	8.23	6.72	7.24	8.43	5.52	7.11	6.24	7.07	10.26	8.53	7.25	7.21	1.26	7.33	0.17
S060	High	Female	6.5	1.03	23.19	9.52	9.24	9.09	9.55	8.45	8.56	8.61	8.77	7.33	9.30	N/A	N/A	N/A	8.13	0.67	8.78	0.08
S065	High	Male	6.8	0.28	23.44	9.77	10.11	14.40	14.93	N/A	10.24	21.84	8.25	N/A	5.51	7.95	18.56	8.71	7.59			
S066	High	Female	8.1	0.19	22.27	6.95	8.68	8.84	7.15	6.78	7.24	5.70	N/A	N/A	N/A	N/A	7.81	N/A	N/A	1.03	7.39	0.14
S069	High	Male	7.3	0.30	23.11	8.05	7.97	5.80	8.61	8.37	7.65	8.75	8.43	9.48	8.15	8.36	7.19	8.35	7.53	0.86	8.05	0.11
S072	High	Male	7.1	1.06	22.90	8.51	8.42	10.08	7.78	9.43	8.31	6.89	10.09	6.69	8.53	9.63	9.12	8.12	7.91	1.05	8.54	0.12
All Subject Average			8.26	1.07	22.86	8.45	8.11	8.52	8.60	8.15	8.37	8.62	8.64	8.55	9.03	8.99	8.61	8.35	8.38	1.13	8.36	0.13
All Subject Std			1.06	0.54	0.71	1.56	0.98	1.75	1.53	1.12	1.29	2.79	2.07	1.44	1.96	2.39	2.27	1.11	0.90	0.38	0.57	0.04
All Subject CoV			0.13	0.50	0.03	0.18	0.12	0.21	0.18	0.14	0.15	0.32	0.24	0.17	0.22	0.27	0.26	0.13	0.11	0.34	0.07	0.32
LR Average			8.47	1.42	22.72	8.18	8.08	8.06	8.28	8.49	8.53	8.70	8.98	8.20	9.31	8.61	7.82	8.35	8.61	1.10	8.41	0.13
LR SD			1.18	0.33	0.76	1.06	0.85	1.06	0.91	1.09	1.51	1.18	2.48	0.93	1.83	1.59	1.06	1.27	0.81	0.32	0.54	0.04
LR CoV			0.14	0.23	0.03	0.13	0.11	0.13	0.11	0.13	0.18	0.14	0.28	0.11	0.20	0.19	0.14	0.15	0.09	0.29	0.06	0.28
HR Average			7.99	0.65	23.02	8.75	8.14	9.09	8.98	7.70	8.19	8.51	8.19	9.05	8.67	9.52	9.73	8.34	8.07	1.18	8.29	0.14
HR SD			0.87	0.43	0.63	1.99	1.14	2.25	2.02	1.03	1.02	4.02	1.33	1.89	2.14	3.22	3.03	0.89	0.95	0.47	0.62	0.05
HR CoV			0.11	0.65	0.03	0.23	0.14	0.25	0.22	0.13	0.12	0.47	0.16	0.21	0.25	0.34	0.31	0.11	0.12	0.40	0.08	0.37

Subjective Daily Sleep Patterns



Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Subjective Daily Survey Bedtime														SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S020	Low	Male	10.5	1.36	23.63	8.50	9.00	9.25	9.75	9.50	9.50	8.92	9.25	9.00	9.00	9.25	8.58	8.75	9.25	0.36	9.11	0.04
S042	Low	Male	8.7	0.78	22.80	10.50	9.50	10.75	11.25	10.88	10.47	10.00	10.50	11.00	10.75	12.25	10.00	10.00	9.83	0.70	10.55	0.07
S114	Low	Female	9.3	1.47	21.47	11.00	11.75	10.75	10.75	10.75	9.75	11.00	10.17	10.50	10.00	12.00	11.00	11.00	11.00	0.61	10.82	0.06
S115	Low	Female	8.9	1.29	22.06	9.50	9.75	9.75	10.25	9.00	10.00	9.50	10.00	9.75	11.00	10.00	10.25	9.75	10.25	0.47	9.91	0.05
S122	Low	Female	7.7	1.40	21.95	10.00	10.50	10.50	11.00	9.00	12.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.00	10.50	0.10
S132	Low	Male	9.6	1.14	24.02	8.50	10.50	10.50	10.00	10.50	8.00	9.50	9.50	10.00	9.50	9.00	9.50	9.50	9.00	0.75	9.54	0.08
S028	High	Male	8.7	1.43	23.66	10.25	9.75	10.00	9.00	10.50	9.25	8.50	N/A	9.75	9.50	7.00	9.75	9.50	9.50	0.84	9.48	0.09
S029	High	Female	8.2	0.65	22.62	11.00	10.00	9.75	11.00	11.00	10.50	10.75	10.25	11.50	10.25	10.75	10.50	N/A	10.75	0.47	10.62	0.04
S050	High	Female	8.9	0.66	23.48	N/A	9.00	8.50	N/A	6.50	6.00	N/A	10.50	13.00	9.00	N/A	11.00	12.00	6.50	2.52	9.06	0.28
S058	High	Male	9.4	-0.12	22.85	9.25	8.00	9.25	9.25	9.25	10.08	9.25	9.25	N/A	N/A	N/A	N/A	N/A	N/A	0.56	9.20	0.06
S066	High	Female	8.1	0.19	22.27	N/A	N/A	10.50	11.00	9.83	9.00	9.25	9.25	N/A	11.50	9.25	9.25	11.50	9.75	0.95	10.01	0.10
All Subject Average			8.90	0.93	22.80	9.83	9.78	9.95	10.33	9.70	9.50	9.74	9.85	10.56	10.06	9.94	9.98	10.25	9.54	0.84	9.89	0.09
All Subject Std			0.78	0.54	0.82	0.96	1.02	0.73	0.80	1.30	1.54	0.71	0.54	1.26	0.89	1.72	0.81	1.13	1.32	0.59	0.65	0.07
All Subject CoV			0.09	0.58	0.04	0.10	0.10	0.07	0.08	0.13	0.16	0.07	0.05	0.12	0.09	0.17	0.08	0.11	0.14	0.71	0.07	0.77
LR Average			9.11	1.24	22.66	9.67	10.17	10.25	10.50	9.94	9.95	9.78	9.88	10.05	10.05	10.50	9.87	9.80	9.87	0.65	10.07	0.06
LR SD			0.91	0.25	1.01	1.03	0.97	0.61	0.59	0.87	1.31	0.78	0.51	0.76	0.84	1.53	0.90	0.82	0.80	0.23	0.66	0.02
LR CoV			0.10	0.20	0.04	0.11	0.10	0.06	0.06	0.09	0.13	0.08	0.05	0.08	0.08	0.15	0.09	0.08	0.08	0.35	0.07	0.33
HR Average			8.64	0.56	22.98	10.17	9.19	9.60	10.06	9.42	8.97	9.69	9.81	11.42	10.06	9.00	10.13	11.00	9.13	1.07	9.67	0.11
HR SD			0.56	0.59	0.58	0.88	0.90	0.76	1.09	1.76	1.77	0.72	0.66	1.63	1.09	1.89	0.78	1.32	1.83	0.83	0.64	0.09
HR CoV			0.07	1.04	0.03	0.09	0.10	0.08	0.11	0.19	0.20	0.07	0.07	0.14	0.11	0.21	0.08	0.12	0.20	0.78	0.07	0.83

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Subjective Daily Survey Wake Time														SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S020	Low	Male	10.5	1.36	23.63	6.50	7.00	7.00	6.75	7.00	6.75	6.67	7.00	6.75	8.00	6.75	6.33	6.25	7.25	0.43	6.86	0.06
S042	Low	Male	8.7	0.78	22.80	7.00	6.75	8.25	7.50	7.67	7.25	7.00	6.75	7.50	7.25	7.25	7.00	7.25	6.67	0.42	7.22	0.06
S114	Low	Female	9.3	1.47	21.47	7.50	8.25	7.25	8.25	8.25	8.25	8.00	7.67	8.00	8.00	9.50	7.50	7.50	7.50	0.56	7.96	0.07
S115	Low	Female	8.9	1.29	22.06	7.25	7.25	7.50	8.00	7.00	8.00	7.00	7.25	7.00	8.00	7.50	7.50	6.75	7.50	0.40	7.39	0.05
S122	Low	Female	7.7	1.40	21.95	7.00	7.00	7.00	7.00	7.00	8.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.41	7.17	0.06
S132	Low	Male	9.6	1.14	24.02	9.50	7.50	7.50	7.00	7.00	8.00	7.50	7.00	7.00	6.50	6.50	7.00	7.00	6.50	0.78	7.25	0.11
S028	High	Male	8.7	1.43	23.66	6.75	6.75	6.50	6.00	6.75	5.75	6.00	N/A	6.50	6.50	6.00	6.00	6.25	6.25	0.34	6.31	0.05
S029	High	Female	8.2	0.65	22.62	7.50	6.50	7.00	7.50	7.50	7.50	7.50	7.00	8.25	7.50	7.75	7.50	N/A	7.50	0.41	7.42	0.06
S050	High	Female	8.9	0.66	23.48	N/A	8.00	5.00	N/A	5.00	5.00	N/A	7.00	12.00	7.00	N/A	9.00	10.00	5.00	2.60	7.33	0.35
S058	High	Male	9.4	-0.12	22.85	5.75	6.50	7.75	5.75	5.75	6.25	5.75	5.75	N/A	N/A	N/A	N/A	N/A	N/A	0.71	6.16	0.11
S066	High	Female	8.1	0.19	22.27	7.00	9.00	9.00	9.00	7.33	7.00	7.25	7.25	9.50	9.50	7.25	7.25	10.00	7.25	1.13	8.11	0.14
All Subject Average			8.90	0.93	22.80	7.18	7.32	7.25	7.28	6.93	7.07	6.96	6.96	8.06	7.58	7.31	7.23	7.63	6.82	0.74	7.20	0.10
All Subject Std			0.78	0.54	0.82	0.97	0.80	1.01	1.00	0.89	1.05	0.73	0.52	1.74	0.94	1.05	0.85	1.53	0.83	0.66	0.59	0.09
All Subject CoV			0.09	0.58	0.04	0.13	0.11	0.14	0.14	0.13	0.15	0.10	0.08	0.22	0.12	0.14	0.12	0.20	0.12	0.88	0.08	0.86
LR Average			9.11	1.24	22.66	7.46	7.29	7.42	7.42	7.32	7.71	7.23	7.13	7.25	7.55	7.50	7.07	6.95	7.08	0.50	7.31	0.07
LR SD			0.91	0.25	1.01	1.05	0.53	0.47	0.61	0.53	0.58	0.52	0.35	0.50	0.67	1.19	0.48	0.48	0.47	0.15	0.36	0.02
LR CoV			0.10	0.20	0.04	0.14	0.07	0.06	0.08	0.07	0.08	0.07	0.05	0.07	0.09	0.16	0.07	0.07	0.07	0.30	0.05	0.29
HR Average			8.64	0.56	22.98	6.75	7.35	7.05	7.06	6.47	6.30	6.63	6.75	9.06	7.63	7.00	7.44	8.75	6.50	1.04	7.07	0.14
HR SD			0.56	0.59	0.58	0.74	1.11	1.48	1.51	1.07	0.99	0.88	0.68	2.31	1.31	0.90	1.23	2.17	1.14	0.93	0.82	0.12
HR CoV			0.07	1.04	0.03	0.11	0.15	0.21	0.21	0.17	0.16	0.13	0.10	0.26	0.17	0.13	0.17	0.25	0.17	0.89	0.12	0.86

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Subjective Daily Survey Sleep Duration														SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S020	Low	Male	10.5	1.36	23.63	8.50	9.00	9.25	9.75	9.50	9.50	8.92	9.25	9.00	9.00	9.25	8.58	8.75	9.25	0.36	9.11	0.04
S042	Low	Male	8.7	0.78	22.80	10.50	9.50	10.75	11.25	10.88	10.47	10.00	10.50	11.00	10.75	12.25	10.00	10.00	9.83	0.70	10.55	0.07
S114	Low	Female	9.3	1.47	21.47	11.00	11.75	10.75	10.75	10.75	9.75	11.00	10.17	10.50	10.00	12.00	11.00	11.00	11.00	0.61	10.82	0.06
S115	Low	Female	8.9	1.29	22.06	9.50	9.75	9.75	10.25	9.00	10.00	9.50	10.00	9.75	11.00	10.00	10.25	9.75	10.25	0.47	9.91	0.05
S122	Low	Female	7.7	1.40	21.95	10.00	10.50	10.50	11.00	9.00	12.00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.00	10.50	0.10
S132	Low	Male	9.6	1.14	24.02	8.50	10.50	10.50	10.00	10.50	8.00	9.50	9.50	10.00	9.50	9.00	9.50	9.00	9.00	0.75	9.54	0.08
S028	High	Male	8.7	1.43	23.66	10.25	9.75	10.00	9.00	10.50	9.25	9.50	N/A	9.75	9.50	7.00	9.75	9.50	9.50	0.84	9.48	0.09
S029	High	Female	8.2	0.65	22.62	11.00	10.00	9.75	11.00	11.00	10.50	10.75	10.25	11.50	10.25	10.75	10.50	N/A	10.75	0.47	10.62	0.04
S050	High	Female	8.9	0.66	23.48	N/A	9.00	8.50	N/A	6.50	6.00	N/A	10.50	13.00	9.00	N/A	11.00	12.00	6.50	2.52	9.06	0.28
S058	High	Male	9.4	-0.12	22.85	9.25	8.00	9.25	9.25	9.25	10.08	9.25	9.25	N/A	N/A	N/A	N/A	N/A	N/A	0.56	9.20	0.06
S066	High	Female	8.1	0.19	22.27	N/A	N/A	10.50	11.00	9.83	9.00	9.25	9.25	N/A	11.50	9.25	9.25	11.50	9.75	0.95	10.01	0.10
All Subject Average			8.90	0.93	22.80	9.83	9.78	9.95	10.33	9.70	9.50	9.74	9.85	10.56	10.06	9.94	9.98	10.25	9.54	0.84	9.89	0.09
All Subject Std			0.78	0.54	0.82	0.96	1.02	0.73	0.80	1.30	1.54	0.71	0.54	1.26	0.89	1.72	0.81	1.13	1.32	0.59	0.65	0.07
All Subject CoV			0.09	0.58	0.04	0.10	0.10	0.07	0.08	0.13	0.16	0.07	0.05	0.12	0.09	0.17	0.08	0.11	0.14	0.71	0.07	0.77
LR Average			9.11	1.24	22.66	9.67	10.17	10.25	10.50	9.94	9.95	9.78	9.88	10.05	10.05	10.50	9.87	9.80	9.87	0.65	10.07	0.06
LR SD			0.91	0.25	1.01	1.03	0.97	0.61	0.59	0.87	1.31	0.78	0.51	0.76	0.84	1.53	0.90	0.82	0.80	0.23	0.66	0.02
LR CoV			0.10	0.20	0.04	0.11	0.10	0.06	0.06	0.09	0.13	0.08	0.05	0.08	0.08	0.15	0.09	0.08	0.08	0.35	0.07	0.33
HR Average			8.64	0.56	22.98	10.17	9.19	9.60	10.06	9.42	8.97	9.69	9.81	11.42	10.06	9.00	10.13	11.00	9.13	1.07	9.67	0.11
HR SD			0.56	0.59	0.58	0.88	0.90	0.76	1.09	1.76	1.77	0.72	0.66	1.63	1.09	1.89	0.78	1.32	1.83	0.83	0.64	0.09
HR CoV			0.07	1.04	0.03	0.09	0.10	0.08	0.11	0.19	0.20	0.07	0.07	0.14	0.11	0.21	0.08	0.12	0.20	0.78	0.07	0.83

Subjective Weekly Average Sleep Patterns

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Subjective PICNIC Questionnaire Average for the Week Prior to Visit						
						Bed Time Before School Day	Bed Time Before Non-School Days	Wake Up School Day	Wake Up Non-School Day	Sleep Duration Before School Day	Sleep Duration Before Non-School Day
S001	Low	Male	8.4	1.28	22.85	21.00	21.50	7.00	7.00	10.00	9.50
S005	Low	Female	10.0	1.31	23.20	20.50	20.50	6.00	6.00	9.50	9.50
S006	Low	Female	8.2	1.05	23.13	20.50	20.50	6.00	6.00	9.50	9.50
S020	Low	Male	10.5	1.36	23.63	20.00	21.00	6.25	7.00	10.25	10.00
S024	Low	Male	8.3	1.98	22.52	21.00	21.50	6.50	6.50	9.50	9.00
S042	Low	Male	8.7	0.78	22.80	20.00	20.50	6.00	6.00	10.00	9.50
S044	Low	Female	6.5	1.70	21.02	20.00	20.00	7.00	7.00	11.00	11.00
S056	Low	Female	9.3	1.73	22.52	20.00	20.50	7.00	7.00	11.00	10.50
S057	Low	Female	9.3	1.35	23.20	20.50	21.25	7.75	8.00	11.25	10.75
S059	Low	Male	7.3	1.93	22.73	21.00	21.50	6.75	7.00	9.75	9.50
S061	Low	Female	8.8	1.36	23.28	20.50	20.50	6.75	6.75	10.25	10.25
S062	Low	Male	6.8	1.88	22.72	19.50	20.00	6.50	7.00	11.00	11.00
S064	Low	Male	6.5	1.10	23.11	20.00	20.50	7.00	7.50	11.00	11.00
S114	Low	Female	9.3	1.47	21.47	21.75	22.50	8.00	8.25	10.25	9.75
S115	Low	Female	8.9	1.29	22.06	20.50	20.50	7.00	7.00	10.50	10.50
S122	Low	Female	7.7	1.40	21.95	21.50	21.50	7.50	7.00	10.00	9.50
S132	Low	Male	9.6	1.14	24.02	21.50	21.50	6.50	6.50	9.00	9.00
S009	High	Male	8.1	0.61	22.69	20.50	22.00	7.00	8.00	10.50	10.00
S018	High	Female	7.8	1.23	23.89	21.00	21.00	6.50	7.00	9.50	10.00
S021	High	Female	8.9	0.73	21.75	21.50	22.50	5.50	8.50	8.00	10.00
S028	High	Male	8.7	1.43	23.66	21.00	21.50	10.00	10.00	3.00	12.50
S029	High	Female	8.2	0.65	22.62	22.00	23.50	7.50	11.00	9.50	11.50
S049	High	Male	8.7	0.87	23.91	19.50	20.00	6.50	7.50	11.00	11.50
S050	High	Female	8.9	0.66	23.48	22.00	22.00	8.00	8.00	10.00	10.00
S054	High	Female	7.7	0.43	22.56	20.00	20.50	7.00	7.00	11.00	10.50
S058	High	Male	9.4	-0.12	22.85	20.00	20.00	6.50	7.00	10.50	11.00
S060	High	Female	6.5	1.03	23.19	20.00	21.00	7.75	8.00	11.75	11.00
S065	High	Male	6.8	0.28	23.44	20.50	20.50	7.00	7.00	10.50	10.50
S068	High	Female	8.1	0.19	22.27	20.50	22.00	6.50	9.00	10.00	11.00
S069	High	Male	7.3	0.30	23.11	20.50	22.00	5.75	7.00	9.25	9.00
S072	High	Male	7.1	1.06	22.90	21.50	23.00	7.00	10.00	9.50	11.00
All Subject Average			**8.26**	**1.07**	**22.86**	**20.65**	**21.20**	**6.90**	**7.50**	**9.93**	**10.30**
All Subject Std			**1.06**	**0.54**	**0.71**	**0.70**	**0.92**	**0.85**	**1.18**	**1.50**	**0.84**
All Subject CoV			**0.13**	**0.50**	**0.03**	**0.03**	**0.04**	**0.12**	**0.16**	**0.15**	**0.08**
LR Average			8.47	1.42	22.72	20.57	20.93	6.79	6.91	10.22	9.99
LR SD			1.18	0.33	0.76	0.64	0.67	0.59	0.62	0.66	0.69
LR CoV			0.14	0.23	0.03	0.03	0.03	0.09	0.09	0.06	0.07
HR Average			7.99	0.65	23.02	20.75	21.54	7.04	8.21	9.57	10.68
HR SD			0.87	0.43	0.83	0.78	1.08	1.10	1.33	2.16	0.87
HR CoV			0.11	0.65	0.03	0.04	0.05	0.16	0.16	0.22	0.08

APPENDIX VIII - Raw Data - Near Work

Minutes per day of near work activities reported subjectively as an average for the week prior to the visit by the parents with the PICNIC questionnaire for each of the 31 subjects who participated in Summer Trials. Average near work viewing distance measured in centimeters as part of the PICNIC visit. Green text indicates children in the Low Risk (LR) of myopia group and orange indicates High Risk (HR). SE OD is the spherical equivalent of the right eye (M) measured with cycloplegic open-field autorefraction. AXL OD is the axial length of the right eye measured by the Lenstar 900 Biometer. Age, SE OD and AXL OD are from the PICNIC follow up visit at which each child was given the Actiwatch.

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Average Minutes per Day Spent in Each Activity for the Week Prior to Visit			Nearwork Distance (cm)
						Homework & Reading School Days	Other Nearwork School Days	All Near Work Non-School Days	
S001	Low	Male	8.4	1.28	22.85	60.0	120.0	360.0	50.8
S005	Low	Female	10.0	1.31	23.20	120.0	60.0	60.0	30.5
S006	Low	Female	8.2	1.05	23.13	60.0	120.0	240.0	30.5
S020	Low	Male	10.5	1.36	23.63	60.0	180.0	180.0	27.9
S024	Low	Male	8.3	1.98	22.52	60.0	60.0	120.0	30.5
S042	Low	Male	8.7	0.78	22.80	30.0	180.0	360.0	30.5
S044	Low	Female	6.5	1.70	21.02	60.0	60.0	60.0	25.4
S056	Low	Female	9.3	1.73	22.52	60.0	300.0	300.0	25.4
S057	Low	Female	9.3	1.35	23.20	60.0	120.0	360.0	30.5
S059	Low	Male	7.3	1.93	22.73	30.0	60.0	120.0	30.5
S061	Low	Female	8.8	1.36	23.28	60.0	60.0	120.0	55.9
S062	Low	Male	6.8	1.88	22.72	60.0	60.0	120.0	55.9
S064	Low	Male	6.5	1.10	23.11	9.0	30.0	150.0	17.8
S114	Low	Female	9.3	1.47	21.47	60.0	120.0	600.0	30.5
S115	Low	Female	8.9	1.29	22.06	90.0	60.0	300.0	22.9
S122	Low	Female	7.7	1.40	21.95	60.0	240.0	720.0	24.1
S132	Low	Male	9.6	1.14	24.02	60.0	180.0	360.0	44.5
S009	High	Male	8.1	0.61	22.69	120.0	30.0	120.0	15.2
S018	High	Female	7.8	1.23	23.89	120.0	30.0	180.0	25.4
S021	High	Female	8.9	0.73	21.75	300.0	900.0	480.0	15.2
S028	High	Male	8.7	1.43	23.66	90.0	120.0	300.0	33.0
S029	High	Female	8.2	0.65	22.62	60.0	60.0	240.0	38.1
S049	High	Male	8.7	0.67	23.91	60.0	240.0	240.0	35.6
S050	High	Female	8.9	0.66	23.48	75.0	30.0	120.0	30.5
S054	High	Female	7.7	0.43	22.56	0.0	300.0	120.0	50.8
S058	High	Male	9.4	-0.12	22.85	60.0	30.0	420.0	25.4
S060	High	Female	6.5	1.03	23.19	60.0	15.0	30.0	25.4
S065	High	Male	6.8	0.28	23.44	60.0	120.0	120.0	15.2
S066	High	Female	8.1	0.19	22.27	120.0	120.0	300.0	22.9
S069	High	Male	7.3	0.30	23.11	30.0	30.0	30.0	33.0
S072	High	Male	7.1	1.06	22.90	120.0	60.0	360.0	17.8
All Subject Average			8.26	1.07	22.86	73.35	132.10	244.84	30.56
All Subject Std			1.06	0.54	0.71	51.96	163.33	165.24	11.13
All Subject CoV			0.13	0.50	0.03	0.71	1.24	0.67	0.36
LR Average			8.47	1.42	22.72	58.76	118.24	266.47	33.17
LR SD			1.18	0.33	0.76	23.55	75.35	184.90	11.44
LR CoV			0.14	0.23	0.03	0.40	0.64	0.69	0.34
HR Average			7.99	0.65	23.02	91.07	148.93	218.57	27.40
HR SD			0.87	0.43	0.63	70.22	232.41	139.94	10.27
HR CoV			0.11	0.65	0.03	0.77	1.56	0.64	0.37

APPENDIX IX - American Academy of Optometry Poster 2022

NECO | New England College of Optometry

Objective and Subjective Measures of Time Spent Outdoors in Young Children

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BACKGROUND

PICNIC (Preventing myopia: Investigating Contributing factors to Nearsightedness In Children): N=97 young children with functional emmetropia at baseline are followed for 3 years to compare ocular and visual metrics between those that do and do not develop myopia.

TIME OUTDOORS prevents (or delays) myopia development[1,2,3]

Outdoor Time Assessment Methods

Questionnaires (traditional) vs. Objective Light Exposure (more recent)

Mixed results for correlation between the two methods:

- Dharani et al, 2012: HOBO Pendant vs parent diary → poor correlation[4]
- Alvarez et al, 2013: HOBO Pendant vs subject diary → poor correlation[5]
- Chodick et al, 2008: UVR tracker vs diary → significant correlation but varied on time of day/type of activity[6]
- Ostrin et al, 2015: adults tend to overestimate their own outdoor time parents respond about their kids more closely match objective[7]
- Read et al, 2015: watch vs questionnaire → significantly correlated[8]

PURPOSE

To compare subjective and objective measures of time outdoors in young children during emmetropization.

METHODS

SUBJECTS

- N=20 children (participants of the PICNIC study)
- Study Period: July – September 2021
- Ages: 7.35±1.04 years
- Uncorrected Distance VA: +0.02±0.03 LogMAR
- SE (cycloplegic open-field autorefraction): +1.15±0.53 D
- AXL: 21.82±0.63 mm
- Myopia Risk: N=12 High Risk (HR), N=8 Low Risk (LR)

MEASURES

Time Outdoors and Sleep / Wake Times



Actiwatch Spectrum Plus device (https://www.usa.philips.com/healthcare/solutions)

Objective:

- *Actiwatch Spectrum Plus* (Philips Respironics, USA)
  - Capture data point every 30 sec
  - Color light sensor measurement range: 0-35,000 lux, 380-750 nm
- Worn on wrist continuously for 2 weeks
- Illuminance >1000 lux = cut-off for outside

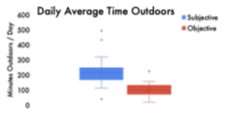
Subjective:

- Nightly questionnaire (text): *"How many hours did your child spend outdoors today (round to nearest 15 mins) during the daytime?"*

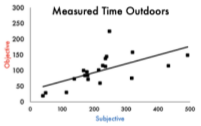
RESULTS

OUTDOOR TIME over 2 WEEKS

Actiwatch gave significantly shorter outdoor times than parent reported time: (t=5.82, p<<0.01)



Good correlation between the two methods: (R=0.62, p<0.01)



TRANSITION INDOORS to OUTDOORS

Actiwatch results indicated that children transitioned from inside to outside 37 times a day on average (range 0 to 149), which is not likely. We therefore questioned whether the differences in time outdoors between the Actiwatch and the Subjective measurements were due to parents overestimating or the Actiwatch underestimating the time children spent outdoors. This prompted an additional study to compare the Actiwatch to another objective measurement device.

ACTIWATCH vs. HOBO COMPARISON STUDY

- *HOBO pendant (64K UA-002-64, Onset Computer Corporation) worn on lanyard is* a broad spectrum light sensor:
  - Capture data point every 30 sec
  - Color light sensor measurement range: 0-320,000 lux, 150–1,200 nm



HOBO Pendant device (https://www.onsetcomp.com/products/data-loggers/ua-002-64)

- N=3 young adult subjects (research team members, 25.85±3.24 years)
- Wore both *Actiwatch and HOBO pendant* continuously for 1 week (October 2022)

Minutes Outdoors per Day:

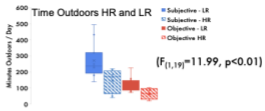
	Subjective	Watches	Hobo
S001	36.86	27.14	71.29
S002	54.14	51.07	90.00
S003	46.71	16.86	39.21

Transitions per Day:

	Subjective	Watches	Hobo
S001	5.57	12.86	15.43
S002	4.29	29.14	21.57
S003	2.43	9.71	8.71

TIME OUTDOORS and MYOPIA RISK

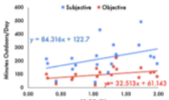
When divided into HR and LR: children at HR spent significantly more time outdoors than those at LR:



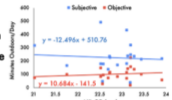
($F_{(1,19)}$=11.99, p<0.01)

TIME OUTDOORS and SE or AXL

Significant correlation between time outdoors and refractive error (SE): (R=0.48, p=0.03)



No correlation of outdoor time with AXL:



SLEEP TIMES and MYOPIA RISK

ActiWatch measured no differences between groups in sleep times (HR: 10.5±1.4 h; LR: 9.7±0.7 h; $F_{(1,19)}$=2.17, p=0.16).

CONCLUSIONS

- Parents estimation of time outdoors is double that of the objective measures.
- Large number of transitions indoors / outdoors indicates times where the watches may not be accurately capturing light levels and underestimating outdoor time.
- A combination of these two errors is likely causing the discrepancy between subjective and objective measures.
- Children at HR for myopia spend less time outdoors, with no differences in sleep duration.
- It is important to educate parents on the protective effects of outdoor time and use a combination of subjective and objective measures of outdoor time to gain a comprehensive understanding of children's myopia related behavior.

Transitions Data Sample

Time	White Light
14:55:00	216.43
14:55:30	1405.33
14:56:00	1287.29
14:56:30	738.46
14:57:00	1170.19
14:57:30	880.1
14:58:00	1307.34
14:58:30	2772.67
14:59:00	1841.65
14:59:30	150.56
15:00:00	0
15:00:30	14.78
15:01:00	922.4
15:01:30	1133.09
15:02:00	418.57
15:02:30	261.39
15:03:00	249.24
15:03:30	1155.2
15:04:00	699.72
15:04:30	2452.59
15:05:00	1488.16
15:05:30	1009.19
15:06:00	485.86
15:06:30	1240.31
15:07:00	665.47
15:07:30	951.06
15:08:00	1190.52
15:08:30	794.79
15:09:00	957.66
15:09:30	4205.02
15:10:00	1131.43
15:10:30	938.09
15:11:00	984.19
15:11:30	1369.89
15:12:00	387.86
15:12:30	676.32
15:13:00	593.96
15:13:30	822.23
15:14:00	1014.4
15:14:30	432.36
15:15:00	615.42
15:15:30	1145.75
15:16:00	1314.05
15:16:30	1734.18
15:17:00	1450.8
15:17:30	493.02
15:18:00	13.66
15:18:30	30.31
15:19:00	12.49
15:19:30	12.93
15:20:00	14.86
15:20:30	965.45
15:21:00	1248.38

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  - NIH T35 (EY 7149-22), PI J. Gwiazda.

APPENDIX X - Boston, MA Weather During Trials

Average temperature in Fahrenheit per day and total precipitation in inches per day reported by Weather Underground for each of the 31 subjects who participated in Summer trials. Green text indicates children in the Low Risk (LR) of myopia group and orange indicates High Risk (HR). SE OD is the spherical equivalent of the right eye (M) measured with cycloplegic open-field autorefraction. AXL OD is the axial length of the right eye measured by the Lenstar 900 Biometer. Age, SE OD and AXL OD are from the PICNIC follow up visit at which each child was given the Actiwatch. Please note that these are the averages for the city of Boston, MA to note weather trends for these trials. We do not have the exact locations information for these subjects during their trials. They may have traveled outside of this area and experienced different weather patterns than shown here.

Average Temperature (°F) in Boston, MA

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Temperature (°F) in Boston While Wearing Actiwatch													SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S001	Low	Male	8.4	1.28	22.85	73.3	71.6	72.0	81.8	77.0	69.1	72.7	72.9	69.3	70.7	74.6	71.9	69.6	67.1	3.68	72.40	0.05
S005	Low	Female	10.0	1.31	23.20	68.6	70.1	72.2	67.4	67.2	69.7	74.3	82.6	73.7	70.3	69.2	79.3	76.5	71.7	4.54	72.34	0.06
S006	Low	Female	8.2	1.05	23.13	80.7	84.8	82.8	85.5	75.0	71.7	76.1	78.8	76.8	75.8	75.8	72.3	71.7	79.3	4.55	77.65	0.06
S020	Low	Male	10.5	1.36	23.63	63.7	67.0	72.9	68.1	63.8	64.8	64.6	66.4	72.4	73.7	69.7	69.4	71.5	65.2	3.53	68.09	0.05
S024	Low	Male	8.3	1.98	22.52	68.6	75.7	68.7	66.7	68.6	67.7	64.8	66.5	72.4	72.9	74.4	67.6	67.9	68.3	3.21	69.34	0.05
S042	Low	Male	8.7	0.78	22.80	65.7	55.9	63.3	63.1	61.3	61.4	68.3	75.4	77.7	72.0	69.4	71.8	72.4	79.1	6.84	68.34	0.10
S044	Low	Female	6.5	1.70	21.02	63.1	58.4	61.4	65.8	77.4	79.3	66.5	68.6	70.1	72.2	67.4	67.2	69.7	74.3	5.83	68.67	0.08
S056	Low	Female	9.3	1.73	22.52	71.7	73.3	71.6	72.0	81.8	77.0	69.1	72.7	72.9	69.3	70.7	74.6	71.9	69.6	3.36	72.73	0.05
S057	Low	Female	9.3	1.35	23.20	74.3	82.6	73.7	70.3	69.2	79.3	76.5	71.7	73.3	71.6	72.0	81.8	77.0	69.1	4.40	74.46	0.06
S059	Low	Male	7.3	1.93	22.73	69.0	74.7	75.2	68.6	75.7	68.7	66.7	68.6	67.7	64.8	66.5	72.4	72.9	74.4	3.67	70.42	0.05
S061	Low	Female	8.8	1.36	23.28	76.8	75.8	75.8	72.3	71.7	79.3	83.9	85.8	81.6	69.3	69.3	79.1	78.4	68.9	5.46	76.29	0.07
S062	Low	Male	6.8	1.88	22.72	76.8	75.8	75.8	72.3	71.7	79.3	83.9	85.8	81.6	69.3	69.3	79.1	78.4	68.9	5.46	76.29	0.07
S064	Low	Male	6.5	1.10	23.11	76.4	81.1	76.2	71.3	70.9	80.7	84.8	82.8	85.5	75.0	71.7	76.1	78.8	76.8	4.78	77.72	0.06
S114	Low	Female	9.3	1.47	21.47	77.6	82.7	80.5	77.3	75.6	80.1	75.8	83.1	80.9	83.4	85.1	86.1	82.5	67.6	4.82	79.88	0.06
S115	Low	Female	8.9	1.29	22.06	82.7	80.5	77.3	75.6	80.1	67.6	70.6	72.2	67.6	71.4	70.0	70.7	70.5	74.0	4.88	73.63	0.07
S122	Low	Female	7.7	1.40	21.95	78.4	77.1	69.4	70.0	72.1	77.2	76.0	70.8	70.2	75.6	79.2	76.0	72.7	63.7	4.35	73.46	0.06
S132	Low	Male	9.6	1.14	24.02	68.1	63.8	64.8	64.6	66.4	72.4	73.7	69.7	69.4	71.5	65.2	63.1	60.4	72.0	4.05	67.51	0.06
S009	High	Male	8.1	0.61	22.69	61.3	61.4	68.3	75.4	77.7	72.0	69.4	71.8	72.4	60.0	64.3	63.0	60.0	57.8	6.44	66.77	0.10
S018	High	Female	7.8	1.23	23.89	65.3	66.1	75.1	65.7	55.9	63.3	63.1	61.3	61.4	68.3	75.4	77.7	72.0	69.4	6.23	67.14	0.09
S021	High	Female	8.9	0.73	21.75	80.7	84.8	82.8	85.5	75.0	71.7	76.1	78.8	76.8	75.8	75.8	72.3	71.7	79.3	4.55	77.65	0.06
S028	High	Male	8.7	1.43	23.66	64.6	66.4	72.4	73.7	69.7	69.4	71.5	65.2	63.1	60.4	72.0	63.7	60.1	62.0	4.67	66.73	0.07
S029	High	Female	8.2	0.65	22.62	58.1	61.4	65.1	65.3	63.0	57.8	54.0	55.4	55.0	53.3	55.2	56.1	61.4	66.7	4.60	59.13	0.08
S049	High	Male	8.7	0.67	23.91	63.1	58.4	61.4	65.8	77.4	79.3	66.5	68.6	70.1	72.2	67.4	67.2	69.7	74.3	5.83	68.67	0.08
S050	High	Female	8.9	0.66	23.48	68.3	75.4	77.7	72.0	69.4	71.8	72.4	79.1	76.3	77.6	76.5	71.6	74.8	70.8	3.37	73.84	0.05
S054	High	Female	7.7	0.43	22.56	71.6	72.0	81.8	77.0	69.1	72.7	72.9	69.3	70.7	74.6	71.9	69.6	67.1	76.4	3.83	72.62	0.05
S058	High	Male	9.4	-0.12	22.85	53.8	58.1	61.4	65.1	65.3	63.0	57.8	54.0	55.4	55.0	53.3	55.2	56.1	61.4	4.24	58.21	0.07
S060	High	Female	6.5	1.03	23.19	69.6	74.3	73.1	75.1	73.4	70.1	69.0	74.7	75.2	68.6	75.7	68.7	68.7	68.6	3.14	71.63	0.04
S065	High	Male	6.8	0.28	23.44	76.4	81.1	76.2	71.3	70.9	80.7	84.8	82.8	85.5	75.0	71.7	76.1	78.8	76.8	4.78	77.72	0.06
S066	High	Female	8.1	0.19	22.27	82.7	80.5	77.3	75.6	80.1	75.8	83.1	80.9	83.4	85.1	86.1	82.5	67.6	70.6	5.41	79.38	0.07
S069	High	Male	7.3	0.30	23.11	83.9	85.8	81.6	69.3	69.3	79.1	78.4	68.9	65.5	67.8	71.8	69.6	74.3	N/A	6.74	74.25	0.09
S072	High	Male	7.1	1.06	22.90	68.3	75.4	77.7	72.0	69.4	71.8	72.4	60.0	64.3	63.0	60.0	57.8	62.2	64.3	6.24	67.04	0.09
All Subject Average			**8.26**	**1.07**	**22.86**	**71.07**	**72.65**	**73.08**	**71.66**	**71.33**	**72.38**	**72.25**	**72.43**	**72.20**	**70.50**	**70.86**	**71.28**	**70.49**	**70.28**	**4.76**	**71.61**	**0.07**
All Subject SD			**1.06**	**0.54**	**0.71**	**7.63**	**8.86**	**6.35**	**5.76**	**5.93**	**6.30**	**7.54**	**8.39**	**7.73**	**6.96**	**6.98**	**7.52**	**6.49**	**5.52**	**1.07**	**5.29**	**0.02**
All Subject CoV			**0.13**	**0.50**	**0.03**	**0.11**	**0.12**	**0.09**	**0.08**	**0.08**	**0.09**	**0.10**	**0.12**	**0.11**	**0.10**	**0.10**	**0.11**	**0.09**	**0.08**	**0.22**	**0.07**	**0.24**
LR Average			8.47	1.42	22.72	72.68	73.58	72.56	71.34	72.09	73.25	73.43	74.96	74.30	72.28	71.74	74.03	73.11	71.18	4.55	72.89	0.06
LR SD			1.18	0.33	0.76	5.93	8.37	5.75	5.96	5.64	6.16	6.51	6.77	5.45	3.94	4.92	5.86	5.18	4.58	0.97	3.80	0.01
LR CoV			0.14	0.23	0.03	0.08	0.11	0.08	0.08	0.08	0.08	0.09	0.09	0.07	0.05	0.07	0.08	0.07	0.06	0.21	0.05	0.22
HR Average			7.99	0.65	23.02	69.12	71.51	73.71	72.06	70.40	71.32	70.81	69.34	69.65	68.34	69.79	67.94	67.32	69.11	5.00	70.06	0.07
HR SD			0.87	0.43	0.63	9.14	9.62	7.19	5.70	6.34	6.54	8.67	9.34	9.40	9.14	8.97	8.14	6.66	6.55	1.16	6.48	0.02
HR CoV			0.11	0.65	0.03	0.13	0.13	0.10	0.08	0.09	0.09	0.12	0.13	0.14	0.13	0.13	0.12	0.10	0.09	0.23	0.09	0.25

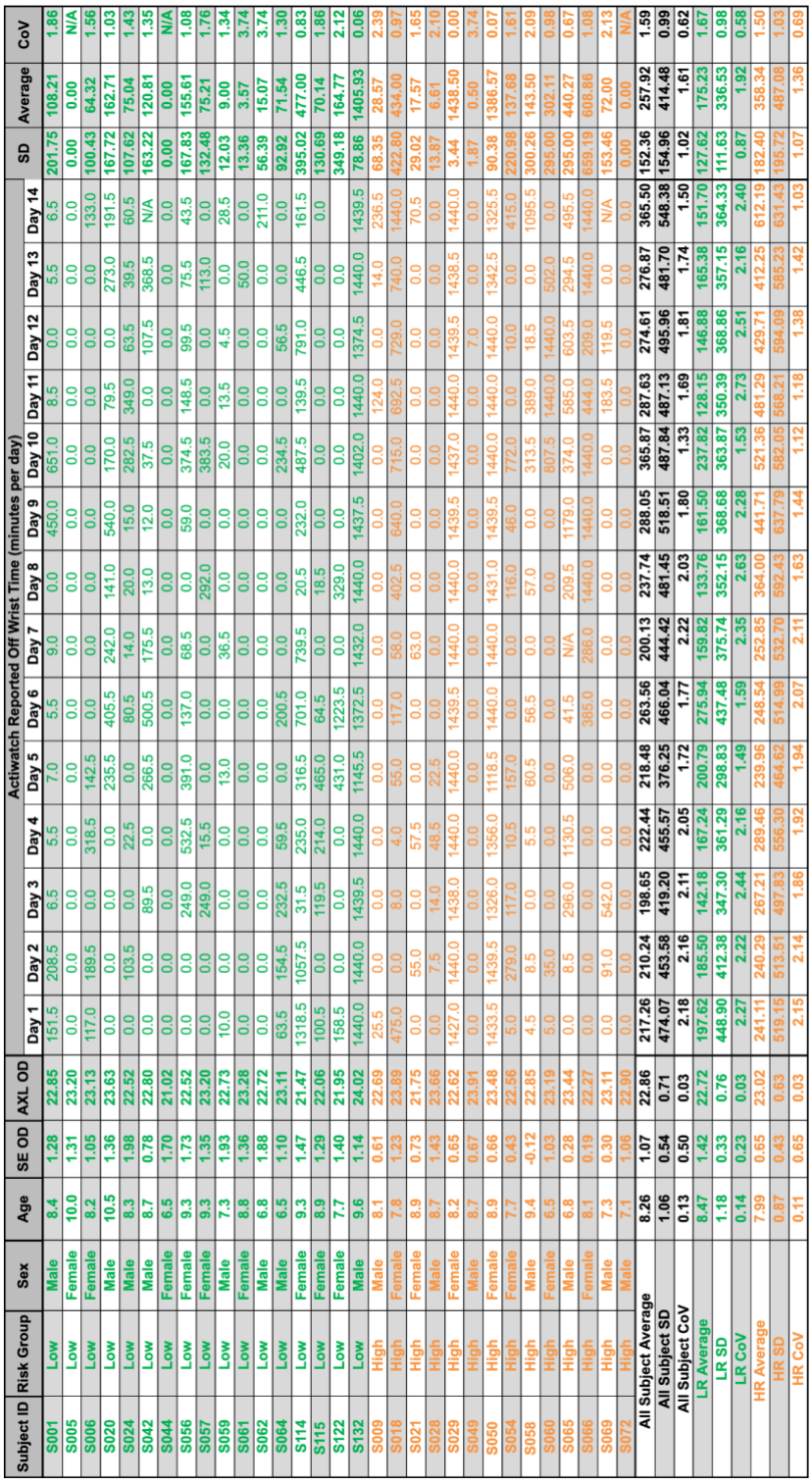
Total Precipitation (inches) in Boston, MA

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Precipitation (inches) in Boston While Wearing Actiwatch														SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S001	Low	Male	8.4	1.28	22.85	0.0	0.0	0.0	0.1	0.0	0.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0	1.3	0.36	0.14	2.49
S005	Low	Female	10.0	1.31	23.20	0.2	2.0	0.0	0.3	1.0	0.0	0.0	0.0	0.0	0.3	0.1	0.0	0.0	N/A	0.58	0.30	1.92
S006	Low	Female	8.2	1.05	23.13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.1	0.7	1.7	0.54	0.26	2.07
S020	Low	Male	10.5	1.36	23.63	0.0	0.0	0.0	0.0	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.20	0.08	2.49
S024	Low	Male	8.3	1.98	22.52	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.18	0.09	2.02
S042	Low	Male	8.7	0.78	22.80	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.18	0.07	2.67
S044	Low	Female	6.5	1.70	21.02	2.9	0.1	2.0	0.0	0.0	0.3	0.2	0.2	2.0	0.0	0.3	1.0	0.0	0.0	0.95	0.64	1.50
S056	Low	Female	9.3	1.73	22.52	0.0	0.0	0.0	0.0	0.1	0.0	0.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.11	0.05	2.24
S057	Low	Female	9.3	1.35	23.20	0.0	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.4	0.13	0.07	1.78
S059	Low	Male	7.3	1.93	22.73	0.0	0.0	0.1	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.11	0.05	2.17
S061	Low	Female	8.8	1.36	23.28	0.0	1.2	0.0	0.1	0.7	1.7	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.53	0.27	1.96
S062	Low	Male	6.8	1.88	22.72	0.0	1.2	0.0	0.1	0.7	1.7	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.53	0.27	1.96
S064	Low	Male	6.5	1.10	23.11	0.7	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.35	0.13	2.64
S114	Low	Female	9.3	1.47	21.47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.04	0.02	1.84
S115	Low	Female	8.9	1.29	22.06	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.04	0.01	2.64
S122	Low	Female	7.7	1.40	21.95	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.3	0.0	0.0	0.17	0.09	1.96
S132	Low	Male	9.6	1.14	24.02	0.0	0.7	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.20	0.08	2.49
S009	High	Male	8.1	0.61	22.69	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.5	1.0	0.32	0.15	2.07
S018	High	Female	7.8	1.23	23.89	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.18	0.07	2.67
S021	High	Female	8.9	0.73	21.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.1	0.7	1.7	0.54	0.26	2.07
S028	High	Male	8.7	1.43	23.66	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.12	0.04	2.81
S029	High	Female	8.2	0.65	22.62	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.1	0.0	0.20	0.09	2.36
S049	High	Male	8.7	0.67	23.91	2.9	0.1	2.0	0.0	0.0	0.3	0.2	0.2	2.0	0.0	0.3	1.0	0.0	0.0	0.95	0.64	1.50
S050	High	Female	8.9	0.66	23.48	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.0	0.17	0.06	2.75
S054	High	Female	7.7	0.43	22.56	0.0	0.0	0.1	0.0	0.4	0.0	0.2	0.0	0.0	0.0	0.0	0.0	1.3	0.7	0.38	0.19	1.99
S058	High	Male	9.4	-0.12	22.85	0.8	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.1	0.27	0.14	1.91
S060	High	Female	6.5	1.03	23.19	0.0	0.1	0.0	0.0	0.2	0.9	0.0	0.0	0.1	0.0	0.0	0.3	0.0	0.0	0.25	0.11	2.26
S065	High	Male	6.8	0.28	23.44	0.7	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.35	0.13	2.64
S066	High	Female	8.1	0.19	22.27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.04	0.02	1.84
S069	High	Male	7.3	0.30	23.11	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	4.2	0.0	0.0	0.0	0.1	N/A	1.17	0.34	3.41
S072	High	Male	7.1	1.06	22.90	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.5	1.0	0.0	0.0	0.32	0.15	2.07
All Subject Average			8.26	1.07	22.86	0.26	0.18	0.16	0.06	0.27	0.20	0.06	0.03	0.29	0.10	0.08	0.15	0.18	0.27	0.34	0.16	2.23
All Subject SD			1.06	0.54	0.71	0.73	0.46	0.49	0.11	0.37	0.44	0.14	0.09	0.88	0.30	0.16	0.31	0.32	0.52	0.28	0.15	0.42
All Subject CoV			0.13	0.50	0.03	2.80	2.56	3.12	2.02	1.39	2.18	2.42	2.99	3.02	3.08	2.14	2.09	1.79	1.94	0.82	0.95	0.19
LR Average			8.47	1.42	22.72	0.22	0.32	0.16	0.08	0.27	0.30	0.04	0.04	0.15	0.10	0.08	0.09	0.09	0.22	0.31	0.15	2.17
LR SD			1.18	0.33	0.76	0.70	0.59	0.48	0.14	0.40	0.54	0.11	0.11	0.49	0.29	0.17	0.24	0.21	0.52	0.25	0.16	0.35
LR CoV			0.14	0.23	0.03	3.19	1.85	3.04	1.68	1.50	1.82	2.85	2.54	3.29	2.82	1.99	2.62	2.43	2.31	0.80	1.00	0.16
HR Average			7.99	0.65	23.02	0.31	0.01	0.16	0.02	0.27	0.09	0.09	0.01	0.47	0.09	0.06	0.22	0.30	0.32	0.38	0.17	2.31
HR SD			0.87	0.43	0.63	0.78	0.02	0.52	0.06	0.35	0.25	0.18	0.04	1.21	0.31	0.16	0.38	0.40	0.53	0.32	0.16	0.50
HR CoV			0.11	0.65	0.03	2.52	2.37	3.33	2.47	1.31	2.86	2.08	3.74	2.57	3.58	2.46	1.72	1.37	1.68	0.84	0.92	0.22

APPENDIX XI - Off-Wrist Time

Minutes of time reported as “off-wrist” by the Actiwatch and minutes of time added to outdoor time to compensate for parent reported watch removal for each of the 31 subjects who participated in Summer Trials. Green text indicates children in the Low Risk (LR) of myopia group and orange indicates High Risk (HR). SE OD is the spherical equivalent of the right eye (M) measured with cycloplegic open-field autorefraction. AXL OD is the axial length of the right eye measured by the Lenstar 900 Biometer. Age, SE OD and AXL OD are from the PICNIC follow up visit at which each child was given the Actiwatch. Actiwatch reported “off-wrist” times do not necessarily indicate time that the watch was not on the subject's wrist but rather the time that the sensor on the device indicated that it was removed.

Reported Minutes Per Day Reported as Off-Wrist



Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Actiwatch Reported Off Wrist Time (minutes per day)													SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S001	Low	Male	8.4	1.28	22.85	151.5	208.5	6.5	5.5	7.0	5.5	9.0	0.0	450.0	651.0	8.5	0.0	5.5	6.5	201.75	108.21	1.86
S005	Low	Female	10.0	1.31	23.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	N/A
S006	Low	Female	8.2	1.05	23.13	117.0	189.5	0.0	318.5	142.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	133.0	100.43	64.32	1.56
S020	Low	Male	10.5	1.36	23.63	0.0	0.0	0.0	0.0	235.5	405.5	242.0	141.0	540.0	170.0	79.5	0.0	273.0	191.5	167.72	162.71	1.03
S024	Low	Male	8.3	1.98	22.52	0.0	103.5	0.0	22.5	0.0	80.5	14.0	20.0	15.0	282.5	349.0	63.5	39.5	60.5	107.62	75.04	1.43
S042	Low	Male	8.7	0.78	22.80	0.0	0.0	89.5	0.0	266.5	500.5	175.5	13.0	12.0	37.5	0.0	107.5	368.5	N/A	163.22	120.81	1.35
S044	Low	Female	6.5	1.70	21.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	N/A
S056	Low	Female	9.3	1.73	22.52	0.0	0.0	249.0	532.5	391.0	137.0	68.5	0.0	59.0	374.5	148.5	99.5	75.5	43.5	167.83	155.61	1.08
S057	Low	Female	9.3	1.35	23.20	0.0	0.0	249.0	15.5	0.0	0.0	0.0	292.0	0.0	383.5	0.0	0.0	113.0	0.0	132.48	75.21	1.76
S059	Low	Male	7.3	1.93	22.73	10.0	0.0	0.0	0.0	13.0	0.0	36.5	0.0	0.0	20.0	13.5	4.5	0.0	28.5	12.03	9.00	1.34
S061	Low	Female	8.8	1.36	23.28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	0.0	13.36	3.57	3.74
S062	Low	Male	6.8	1.88	22.72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	211.0	56.39	15.07	3.74
S064	Low	Male	6.5	1.10	23.11	63.5	154.5	232.5	59.5	0.0	200.5	0.0	0.0	0.0	234.5	0.0	56.5	0.0	0.0	92.92	71.54	1.30
S114	Low	Female	9.3	1.47	21.47	1318.5	1057.5	31.5	235.0	316.5	701.0	739.5	20.5	232.0	487.5	139.5	791.0	446.5	161.5	395.02	477.00	0.83
S115	Low	Female	8.9	1.29	22.06	100.5	0.0	119.5	214.0	465.0	64.5	0.0	18.5	0.0	0.0	0.0	0.0	0.0	0.0	130.69	70.14	1.86
S122	Low	Female	7.7	1.40	21.95	158.5	0.0	0.0	0.0	431.0	1223.5	0.0	329.0	0.0	0.0	0.0	0.0	0.0		349.18	164.77	2.12
S132	Low	Male	9.6	1.14	24.02	1440.0	1440.0	1439.5	1440.0	1145.5	1372.5	1432.0	1440.0	1437.5	1402.0	1440.0	1374.5	1440.0	1439.5	78.86	1405.93	0.06
S009	High	Male	8.1	0.61	22.69	25.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	124.0	0.0	14.0	236.5	68.35	28.57	2.39
S018	High	Female	7.8	1.23	23.89	475.0	0.0	8.0	4.0	55.0	117.0	58.0	402.5	640.0	715.0	692.5	729.0	740.0	1440.0	422.80	434.00	0.97
S021	High	Female	8.9	0.73	21.75	0.0	55.0	0.0	57.5	0.0	0.0	63.0	0.0	0.0	0.0	0.0	0.0	0.0	70.5	29.02	17.57	1.65
S028	High	Male	8.7	1.43	23.66	0.0	7.5	14.0	48.5	22.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.87	6.61	2.10
S029	High	Female	8.2	0.65	22.62	1427.0	1440.0	1438.0	1440.0	1440.0	1439.5	1440.0	1440.0	1439.5	1437.0	1440.0	1439.5	1438.5	1440.0	3.44	1438.50	0.00
S049	High	Male	8.7	0.67	23.91	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.0	0.0	1.87	0.50	3.74
S050	High	Female	8.9	0.66	23.48	1433.5	1439.5	1326.0	1356.0	1118.5	1440.0	1440.0	1431.0	1439.5	1440.0	1440.0	1440.0	1342.5	1325.5	90.38	1386.57	0.07
S054	High	Female	7.7	0.43	22.56	5.0	279.0	117.0	10.5	157.0	0.0	0.0	116.0	46.0	772.0	0.0	10.0	0.0	415.0	220.98	137.68	1.61
S058	High	Male	9.4	-0.12	22.85	4.5	8.5	0.0	5.5	60.5	56.5	0.0	57.0	0.0	313.5	389.0	18.5	0.0	1095.5	300.26	143.50	2.09
S060	High	Female	6.5	1.03	23.19	5.0	35.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	807.5	1440.0	1440.0	502.0	0.0	295.00	302.11	0.98
S065	High	Male	6.8	0.28	23.44	0.0	8.5	296.0	1130.5	506.0	41.5	N/A	209.5	1179.0	374.0	585.0	603.5	294.5	495.5	295.00	440.27	0.67
S066	High	Female	8.1	0.19	22.27	0.0	0.0	0.0	0.0	0.0	385.0	286.0	1440.0	1440.0	1440.0	444.0	209.0	1440.0	1440.0	659.19	608.86	1.08
S069	High	Male	7.3	0.30	23.11	0.0	91.0	542.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	183.5	119.5	0.0	N/A	153.46	72.00	2.13
S072	High	Male	7.1	1.06	22.90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	N/A
All Subject Average			8.26	1.07	22.86	217.26	210.24	198.65	222.44	218.48	263.56	200.13	237.74	288.05	365.87	287.63	274.61	276.87	365.50	152.36	257.92	1.59
All Subject SD			1.06	0.54	0.71	474.07	453.58	419.20	455.57	376.25	466.04	444.42	481.45	518.51	487.84	487.13	495.96	481.70	548.38	154.96	414.48	0.99
All Subject CoV			0.13	0.50	0.03	2.18	2.16	2.11	2.05	1.72	1.77	2.22	2.03	1.80	1.33	1.69	1.81	1.74	1.50	1.02	1.61	0.62
LR Average			8.47	1.42	22.72	197.62	185.50	142.18	167.24	200.79	275.94	159.82	133.76	161.50	237.82	128.15	146.88	165.38	151.70	127.62	175.23	1.67
LR SD			1.18	0.33	0.76	448.90	412.38	347.30	361.29	298.83	437.48	375.74	352.15	368.68	363.87	350.39	368.86	357.15	364.33	111.63	336.53	0.98
LR CoV			0.14	0.23	0.03	2.27	2.22	2.44	2.16	1.49	1.59	2.35	2.63	2.28	1.53	2.73	2.51	2.16	2.40	0.87	1.92	0.58
HR Average			7.99	0.65	23.02	241.11	240.29	267.21	289.46	239.96	248.54	252.85	364.00	441.71	521.36	481.29	429.71	412.25	612.19	182.40	358.34	1.50
HR SD			0.87	0.43	0.63	519.15	513.51	497.83	556.30	464.62	514.99	532.70	592.43	637.79	582.05	568.21	594.09	585.23	631.43	195.72	487.08	1.03
HR CoV			0.11	0.65	0.03	2.15	2.14	1.86	1.92	1.94	2.07	2.11	1.63	1.44	1.12	1.18	1.38	1.42	1.03	1.07	1.36	0.69

Minutes of Time Manually Added to Objective Outdoor Time

Subject ID	Risk Group	Sex	Age	SE OD	AXL OD	Minutes Added for Parent Reported Off Wrist Time														SD	Average	CoV
						Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14			
S001	Low	Male	8.4	1.28	22.85	151.5	195.00	0.00	0.0	0.00	0.00	0.0	0.00	169.00	0.0	0.00	0.00	0.00	0.0	73.67	36.82	2.00
S005	Low	Female	10.0	1.31	23.20	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S006	Low	Female	8.2	1.05	23.13	0.0	165.00	0.00	294.0	140.50	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	133.0	93.14	52.32	1.78
S020	Low	Male	10.5	1.36	23.63	0.0	0.00	0.00	0.0	0.00	0.00	89.0	14.40	0.00	57.5	79.00	0.00	145.00	76.5	47.51	32.96	1.44
S024	Low	Male	8.3	1.98	22.52	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S042	Low	Male	8.7	0.78	22.80	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S044	Low	Female	6.5	1.70	21.02	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S056	Low	Female	9.3	1.73	22.52	0.0	0.00	0.00	0.0	0.00	147.50	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	39.42	10.54	3.74
S057	Low	Female	9.3	1.35	23.20	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S059	Low	Male	7.3	1.93	22.73	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S061	Low	Female	8.8	1.36	23.28	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S062	Low	Male	6.8	1.88	22.72	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S064	Low	Male	6.5	1.10	23.11	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S114	Low	Female	9.3	1.47	21.47	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S115	Low	Female	8.9	1.29	22.06	0.0	0.00	0.00	0.0	0.00	64.50	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	17.24	4.61	3.74
S122	Low	Female	7.7	1.40	21.95	0.0	0.00	0.00	0.0	162.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	43.30	11.57	3.74
S132	Low	Male	9.6	1.14	24.02	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S009	High	Male	8.1	0.61	22.69	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S018	High	Female	7.8	1.23	23.89	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S021	High	Female	8.9	0.73	21.75	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S028	High	Male	8.7	1.43	23.66	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S029	High	Female	8.2	0.65	22.62	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S049	High	Male	8.7	0.67	23.91	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S050	High	Female	8.9	0.66	23.48	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S054	High	Female	7.7	0.43	22.56	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S058	High	Male	9.4	-0.12	22.85	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S060	High	Female	6.5	1.03	23.19	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S065	High	Male	6.8	0.28	23.44	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S066	High	Female	8.1	0.19	22.27	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S069	High	Male	7.3	0.30	23.11	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
S072	High	Male	7.1	1.06	22.90	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.00	N/A
All Subject Average			8.26	1.07	22.86	4.89	11.61	0.00	9.48	9.76	6.84	2.87	0.46	5.45	1.85	2.55	0.00	4.68	6.76	10.14	4.80	2.74
All Subject SD			1.06	0.54	0.71	27.21	45.12	0.00	52.80	37.87	28.56	15.98	2.59	30.35	10.33	14.19	0.00	26.04	27.16	23.73	12.56	1.11
All Subject CoV			0.13	0.50	0.03	5.57	3.89	N/A	5.57	3.88	4.18	5.57	5.57	5.57	5.57	5.57	N/A	5.57	4.02	2.34	2.62	0.41
LR Average			8.47	1.42	22.72	8.91	21.18	0.00	17.29	17.79	12.47	5.24	0.85	9.94	3.38	4.65	0.00	8.53	12.32	18.49	8.75	2.74
LR SD			1.18	0.33	0.76	36.74	60.01	0.00	71.31	50.37	38.14	21.59	3.49	40.99	13.95	19.16	0.00	35.17	36.19	29.87	16.09	1.11
LR CoV			0.14	0.23	0.03	4.12	2.83	N/A	4.12	2.83	3.06	4.12	4.12	4.12	4.12	4.12	N/A	4.12	2.94	1.62	1.84	0.41
HR Average			7.99	0.65	23.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N/A
HR SD			0.87	0.43	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N/A
HR CoV			0.11	0.65	0.03	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A