Academic Performance of Oyler School Students after Receiving Spectacle Correction

A Thesis

Presented in Partial Fulfillment of the Requirements for the Degree Master of Science in the Graduate School of The Ohio State University

By

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Abstract

Oyler School is located in one of the lowest socioeconomic areas in Cincinnati, Ohio. The OneSight Vision Center was established in 2012 to provide much needed eye care to children in Cincinnati. The purpose of this research study is to analyze the academic success of this group of inner-city students before and after receiving spectacle correction. In addition, the compliance rate of spectacle wear and a comparison of the IEP students to the non-IEP students from the Cincinnati school district are included.

Eye examination records for 2,333 students were provided from 81 different schools in Cincinnati, which were all examined at the OneSight Vision Center during the 2012-2013 and 2013-2014 academic years.

Analysis of the various eye examination components was conducted, and the data showed that many children from the clinic sample had myopia (37.2%), hyperopia (7.7%), and astigmatism (36.9%). In addition, many children exhibited phorias greater than 5^\(^\Delta\) (0.9%), strabismus (2.7%), convergence insufficiency (0.8%), and accommodative insufficiency (3.0%).

All of the Oyler School students who received spectacles increased their average GPA by 0.14 points (p=0.17) two quarters after receiving spectacle correction. Myopes saw an increase in average GPA by 0.08 (p=0.50), hyperopes saw the greatest increase in GPA by 0.37 (p=0.34), and astigmats increased by 0.13 (p=0.45). Although none of these
increases were statistically significant, a 0.37 increase in GPA two quarters after receiving vision correction is very meaningful. All groups of refractive error saw an increase in math and reading GPA scores, but not writing; however none of the changes were statistically significant. Large variability in GPA change and small sample sizes resulted in poor power (generally less than 20%) to detect statistically significant changes in our GPA scores.

Only 28.9% of children who received glasses during the 2012-2013 school year wore their glasses to their 2013-2014 vision examination. The majority reported losing (53.1%) or breaking (34.6%) glasses. Non-compliant students had less refractive error ($p=0.003$) and were younger ($p=0.05$).

When comparing the IEP student population to the non-IEP students from the overall OneSight Vision Center clinic population, 15.8% of IEP students had binocular visual acuity 20/40 or worse at near compared to 11.8% of the non-IEP students ($X^2$, $p<=0.02$). When comparing strabismus prevalence at near, 5.2% of IEP students had strabismus at near compared to 2.8% of the non-IEP students ($X^2$, $p<0.05$). IEP students also had higher prevalence of NPC $\geq 6$ cm with 28.6% IEP students compared to 21.3% non-IEP students ($X^2$, $p<0.01$). However, the prevalence of refractive errors and binocular vision conditions were not statistically significantly different between IEP and non-IEP students.

It is important for children to have a comprehensive eye examination because a large population of children suffer from various vision conditions that can negatively affect the learning process. Some of these negative effects can be reversed.
with vision correction, which can improve a child’s academic performance. This is especially true for hyperopic children, who are often missed by current vision screening standards. Even if a child receives vision correction, careful attention must be paid to compliance with regard to the wear of vision correction because many children discontinue spectacle wear over the course of a year, primarily due to loss or breakage of the spectacles.
Dedication

This document is dedicated to my family and fiancé for always believing in me.
Acknowledgments

I would like to thank Dr. Jeff Walline for being my advisor and guiding me through the master’s program over the last three years. You are such a great optometrist and I admire your dedication to optometric research. I’m lucky to have been able to work with you and you have taught me many things and were always there to answer my questions. Thank you for encouraging me to present my research at the American Academy of Optometry meeting the past two years, which were great experiences. Lastly, thank you for allowing me to work on a research topic that I am passionate about and I hope our research together can prove to be a benefit to the optometric world.

I would also like to thank Oyler School, the OneSight Vision Center and specifically Dr. Terri Gossard, Dr. Laura Theimann, and Cari Van Pelt. Thank you for partnering with OSU Optometry and providing the eye examination records for the OneSight Center and the Oyler School students’ grades. I especially want to thank each of you for working hard each day to provide these children the eye care that they deserve.

Lastly, thank you to Dr. Toole and Dr. Gossard for taking the time to be on my thesis committee.
Vita

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Fields of Study

Major Field: Vision Science
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Chapter 1: Introduction

1.1 OneSight Vision Center at Oyler School

Oyler School is located in Lower Price Hill, Cincinnati, Ohio. Lower Price Hill is one of the lowest socioeconomic areas in Cincinnati plagued with drug addiction, poverty, and lack of education. In response to the increasing demand for a public school system in the area, in the late 1990’s, the Ohio Supreme Court voted and approved the funding to build numerous schools around Ohio. This was the start of Oyler School, which opened in 2006.

With the opening of Oyler School, children now had access to education, but there was still an overwhelming need for health services, vision care included. OneSight is an independent nonprofit organization that provides vision care to underserved populations all over the world. They recognized Cincinnati’s need, and started the process of opening the OneSight Vision Center located directly in Oyler School, with additional help from the Ohio Optometric Association and the Cincinnati Eye Institute. OneSight’s goal is to not only meet the need for health care, but to provide a sustainable center with long-lasting effects. The OneSight Vision Center opened in 2012.

With onsite optometrists, technicians and staff, the vision center provides vision care and eye wear to targeted students within Cincinnati Public Schools (CPS). CPS has an enrollement of 33,000 children. Approximately 3,000 students were examined during OneSight Vision Center’s first year of operation during the 2012-2013 academic year.
These school-based programs have proven to be successful in other areas as well. In New York City, 265 first and second graders from eight public schools participated in a study to assess the effectiveness of a school-based program. The program was called *A Vision for Success* and it provided children with a complete optometric eye examination and two pairs of eyeglasses, one of which was to remain at school while their teachers encouraged them to wear their glasses. Initially, all students were given a mandated vision screening. Those in the intervention group who had failed the screening were then referred to the *A Vision for Success* program. Those in the control group who failed the screening were given a letter to advise the parents to take their child to an optometrist, which is standard practice. At the start of the study, 22% of the children in the intervention group were already wearing glasses versus 19% in the control group (p>0.10). At follow-up, after receiving a professional optometric examination, 25% of the intervention group worse eyeglasses, while the control group stayed at 19% (p<0.001). This study showed that school-based vision programs are more successful at providing children who need vision correction with eyeglasses than the standard referral letter home to the parents after a failed school vision screening. With an extra pair of glasses located at school at all times and teachers encouraging the students to wear their glasses, compliance rates increased (Ethan, 2010).

As shown by the previous study, refractive error and binocular vision conditions can affect children at an early age. The etiologies and prevalence of the various disorders will be discussed in the next section, followed by a look into how these disorders can affect a child’s academic performance.
1.2 Refractive Error

Refractive error, also known as ametropia, can affect academic performance especially when uncorrected. Refractive error occurs when the secondary far point of the eye is not on the retina. Factors that affect the location of the far point are the focal power of the eye (determined primarily by corneal curvature and lens power), and length of the eye. There are three main types of refractive error: myopia, hyperopia, and astigmatism. When the secondary far point of the eye is on the retina, there is no refractive error and this is known as emmetropia.

1.2.1 Myopia

Myopia, also known as nearsightedness, is a refractive error that results in decreased visual acuity while looking in the distance. Myopia can be axial meaning that the eye is too long relative to the power of the eye; therefore, light entering the eye focuses in front of the retina. There is also refractive myopia. Light entering the eye focuses in front of the retina because the power of the eye is too high relative to the length of the eye.

1.2.1a Myopia Etiology

Over the years, there have been different ideas on what causes myopia, including genetic and environmental factors. One main theory that causes myopia is extensive near work. Saw performed a study on the association between near work and myopia in
children 7 to 9 years old in Singapore. After adjusting for a variety of other factors such as genetics, socioeconomic status, and light exposure, her results showed that the children who read more than two books per week were three times more likely to have -3.00 D or more of myopia compared to subjects who read fewer than two books per week on average (95% confidence interval (CI): 1.80-5.18). Within the group that read more than two books per week, the children who read more than two hours per day (odds ratio (OR) = 1.50) were no more likely to have higher amounts of myopia than children who read fewer than two hours per day (OR=1.04). Saw still concluded that there is a higher chance of myopia among children that perform more reading. This association wasn’t as strong among older myopic subjects (Saw, 2002).

Another study evaluating the effects of near work was performed by You et al. on a sample of 4,814 students from first to fourth grade. A survey was given to the parents that asked questions about near work behaviors and some personal variables such as demographics and medical history. The results showed that as grade level increased, the amount of near work behaviors during school increased with less breaks during these intervals of near work. After one year, axial length increased by +0.32 ± 0.35 mm (p=0.004) and the spherical equivalent increased by -0.51 ± 0.51 D (p=0.02). Sixteen percent of the children were myopic after one year (OR=0.90, CI: 0.84-0.96). This was after controlling for confounding data such as parental myopia, age, gender, height, and daily outdoor time. Therefore the amount of near work is independent of hereditary factors when affecting myopia progression (You, 2016).
This hot topic of outdoor time reducing the onset of myopia at early ages has been heavily studied recently. Morgan and his colleagues did a recent study that analyzed this association. They picked twelve elementary schools and monitored the children’s uncorrected visual acuity and the children were divided into two groups. The intervention group were given 45 extra minutes of outdoor time each day. In the beginning, the prevalence of myopia was not different among the two groups of children at the various schools. The children were followed over three years and the intervention group had 30.4% incidence of myopia while the control group at 39.5% (p<0.001) by the end of the three-year period. Increase in axial length was seen less in the intervention group but this analysis was not significant. Therefore, increased time outdoors does decrease the onset of myopia, but it may be due to some other cause rather than increase in axial length (Morgan, 2014).

Another main theory on myopia development is genetics. There have been a few twin studies performed to further evaluate the genetic link of myopia. Hammond et al. examined the refractive error of 226 identical twins and 280 fraternal twins from the ages of 49 to 79 years. Among the subjects, 26% were myopic which was defined as -0.50 D or more myopic. When treating refractive error as a continuous spectrum from myopia into hyperopia, the heritability was 84% to 86% (CI: 81-89%). When myopia is treated as a binary trait, the heritability for myopia alone was 90%. The results were similar between both types of twins, so even though fraternal twins only share half their genes and with the heritability of myopia still so high among fraternal twins, this shows that genetic effects have a major role in myopia development (Hammond, 2001).
Around the same time, Mutti and his colleagues assessed the association between myopia and various factors including genetics, near work, playing sports, and school achievement. Overall, they found that children who were myopic were more likely to have myopic parents, to spend more time studying and reading, spend less time playing sports, and to have higher academic achievement (assessed by the Iowa Tests of Basic Skills (ITBS)) than emmetropic children (Chi-square ($X^2$) and Wilcoxon rank-sum tests, all $p<0.024$). Multivariate logistic regression models exhibited no significant interactions between parental myopia, near work, sports, and school achievement, indicating that each acts independently on myopia. When just comparing the number of myopic parents to near work, school achievement, and time playing sports, number of myopic parents had a stronger effect on myopia incidence than the other factors. Parents that are not myopic only have a 6.3% chance of having a child that is myopic, but if one parent is myopic then that chance goes up to 18.2% and goes up even more to 32.9% if both parents are myopic. These associations between myopic parents and the development of myopic children were all significant ($p=0.001$), which shows that genetics plays a big role in the development of myopia (Mutti, 2002).

Overall, the strongest environmental component associated with myopia onset appears to be time spent outdoors, but genetics appears to play an even stronger role than environment.
1.2.1b Myopia Prevalence

Through numerous studies, myopia has proven to be one of the most prevalent ametropias among people. In a study done by Zhao et al., it was shown that the prevalence of myopia was 16.2% in children between the ages of 5 and 15 in Shunyi District, China. Myopia was defined as -0.50 spherical equivalent (SE) diopters or less in either eye. The prevalence of myopia among the 5 year olds was close to 0%, but increased to 36.7% in males and 55% in females for the 15 year old children (Zhao, 2000).

In an earlier but important study, Sperduto analyzed data from the 1971 to 1972 National Health and Nutrition Examination Survey (NHANES) on the prevalence of myopia of 12 through 54 year olds in the United States. The results stated that the prevalence of myopia when assessing right eyes was 25%. Myopia was determined by using an algorithm that took in consideration the measurements from lensometry, pinhole visual acuity or presenting visual acuity of 20/40 or worse. Males and African Americans had lower prevalence rates compared to females and Whites (p<0.05 for gender, p<0.01 for race). It was also found that families with higher income and education had higher occurrence of myopia (Sperduto, 1983).

Then the prevalence rate of myopia was examined for 1999-2004 in the United States and compared to the original data using the NHANES. The right eye was assessed for those over the age of 12 years old. The prevalence of myopia, which was defined as the spherical equivalent of -1.00 D or more myopic, was 41.6%. This was a 16.6% increase from the data evaluated from 1971-1972 (p<0.001). Myopia was found to be
more common in females between the ages of 20 and 39 (p<0.001) and more common in non-Hispanic Whites than the other races (p<0.001). The prevalence rate of myopia increased from the first cohort to the second cohort for both black and white subjects (p<0.001 and p<0.001 respectively), but myopia was still more prevalent among white individuals overall. Myopia was found to be less prevalent in those over the age of 60 compared to other refractive errors (Vitale, 2008).

Myopia prevalence is the not the same among all countries. Another study in Northeastern Iran studied the prevalence rates of refractive errors in children between 6 and 17 years old. The prevalence here is much less than the United States at only 4.3% (CI: 3.3-5.3). Myopia was defined as the spherical equivalent of -0.50 D or more myopic (Rezvan, 2011).

Additionally, another study showed the prevalence of myopia in children in Hong Kong with a mean age of 9.3 years. The study found myopia as the most prevalent refractive error at 36.7% when myopia was defined as -0.50 D or more myopic. Children older than eleven years old were more likely to be myopic compared to children younger than seven years old (OR=14.81, CI=14.17-15.48) (Fan, 2004).

Overall prevalence studies have shown that Asian countries tend to have the highest rates of myopia followed by western countries including the United States. Middle East countries have the lowest rates of myopia (Table 1). Definitions of myopia and age of the samples may vary from study-to-study making it difficult to compare the various studies, but overall, myopia is a very common refractive error throughout the world, with an estimated one billion cases of myopia expected by 2050 (Holden, 2016).
<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Location</th>
<th>Sample Size</th>
<th>Age</th>
<th>Myopia Definition</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zhao et al.</td>
<td>2000</td>
<td>China</td>
<td>5884</td>
<td>5-15</td>
<td>≤ -0.50 D</td>
<td>Overall: 16.2% 5 year olds: 0.0% 15 year old: 36.7-55.5%</td>
</tr>
<tr>
<td>Sperduto et al.</td>
<td>1971-1972</td>
<td>USA</td>
<td>4436</td>
<td>12-54</td>
<td>&lt; 0 D</td>
<td>Overall: 25% Less for Males* and African Americans* More for higher education and higher income</td>
</tr>
<tr>
<td>Vitale et al.</td>
<td>1999-2004</td>
<td>USA</td>
<td>8339</td>
<td>&gt; 12</td>
<td>≤ -1.00 D</td>
<td>Overall: 41.6% More in females^ and Whites^</td>
</tr>
<tr>
<td>Rezvan et al</td>
<td>2011</td>
<td>Iran</td>
<td>2020</td>
<td>6-17</td>
<td>≤ -0.50 D</td>
<td>Overall: 4.3%</td>
</tr>
<tr>
<td>Fan et al.</td>
<td>2004</td>
<td>Hong Kong</td>
<td>7560</td>
<td>5-16</td>
<td>≤ -0.50 D</td>
<td>Overall: 36.7% More in &lt;11 year olds</td>
</tr>
</tbody>
</table>

*(p≤0.05), ^*(p≤0.001)

Table 1: Summary of myopia prevalence population-based studies in the literature

1.2.2 Hyperopia

Hyperopia, also known as farsightedness, is a refractive error that can result in decreased visual acuity at near depending on the severity of the refractive error and several other related factors. Axial hyperopia is when the eye is too short relative to the power of the eye; therefore, light entering the eye focuses behind the retina where the secondary far point is. Refractive hyperopia is when the power of the eye is low relative to the length of the eye. Entering light focuses behind the retina due to insufficient convergence.
1.2.2a Hyperopia Etiology

Most infants are born hyperopic, but most undergo emmetropization- a natural process to correct their refractive error. A study done by Mutti and his colleagues examined the process of emmetropization. When studying 222 infants at three months of age and then at nine months of age, they saw that the mean spherical equivalent refractive error decreased from $+2.16 \pm 1.30 \text{ D}$ to $+1.36 \pm 1.06 \text{ D}$ ($p<0.0001$). As refractive error decreased, axial length increased, the crystalline lens thinned and flattened, and corneal power and lens power decreased. The decrease in hyperopia was due to the elongation of the eye which resulted in the reduction of the lenticular and cornea power (Mutti, 2005).

1.2.2b Hyperopia Prevalence

A study done in Poland analyzed the prevalence of hyperopia in a large sample of Polish schoolchildren between the ages of 6 to 18 years old. Hyperopia was defined as a spherical equivalent (SE) of $+1.00 \text{ D}$ or more hyperopic, and all refractive measurements were performed with a cycloplegic agent. These authors found that 13.1% of the children were hyperopic which was similar to the amount of myopes (13.3%). A negative correlation was found between hyperopia and age ($p<0.001$), therefore hyperopia is more common in younger children (Czepita, 2007).

In another country, researchers looked at the prevalence of hyperopia in Australian schoolchildren ages 6 and 12 years old. Their measurements also involved a cycloplegic refractive measurement. They defined moderate hyperopia as a spherical equivalent of $+2.00 \text{ D}$ or more hyperopic. They found that 13.2% of the 6 year olds had
moderate hyperopia and 5% of the 12 year olds had moderate hyperopia, which shows that hyperopia decreases with age. The results also showed that hyperopia was more common in Caucasian children (15.7% for 6 year old, 6.8% for 12 year olds) compared to other ethnic groups. Lastly, the results showed that female six year olds were more likely to be hyperopic (p=0.005), but there was no significant difference between gender among the twelve year olds (Ip, 2008).

An additional study which was part of the Multi-Ethnic Pediatric Eye Disease Study (MEPEDS) looked at the association between the prevalence of hyperopia and age, gender and ethnicity. Hyperopia was defined as a spherical equivalent of +2.00 D or more hyperopic. In non-Hispanic White children, the prevalence rate of hyperopia was 25.65% which was higher than the myopia and astigmatism prevalence rates (1.20% and 6.33% respectively). In Asian children, the prevalence rate of hyperopia was 13.47% which was higher than myopia and astigmatism prevalence rates (3.98% and 8.29% respectively). Their study also showed that hyperopia was more common in girls than boys (p=0.0002) and hyperopia did not significantly lower with age (p=0.31) (Wen, 2013).

Though most children are born as hyperopes, the overall main trend seen in hyperopia prevalence studies is that hyperopia decreases with age. An additional common finding among studies is that hyperopia is more likely to be seen in Caucasian children compared to other ethnicities (Table 2). Definitions of hyperopia and age of the samples may vary from study-to-study making it difficult to compare the various studies, but overall, hyperopia is a very common refractive error throughout the world.
<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Location</th>
<th>Sample Size</th>
<th>Age</th>
<th>Hyperopia Definition</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Czepita et al.</td>
<td>2007</td>
<td>Poland</td>
<td>4422</td>
<td>6-18</td>
<td>≥ +1.00 D</td>
<td>Overall: 13.1% Less for older children^</td>
</tr>
<tr>
<td>Ip et al.</td>
<td>2008</td>
<td>Australia</td>
<td>4118</td>
<td>6 &amp; 12</td>
<td>≥ +2.00 D</td>
<td>6 year olds: 13.2% 12 year olds: 5% More for Whites (6.8%-15.7%) More among females (6 year olds)*</td>
</tr>
<tr>
<td>Wen et al</td>
<td>2013</td>
<td>USA</td>
<td>3008</td>
<td>6-72 mo</td>
<td>≥ +2.00 D</td>
<td>Whites: 25.65% Asians: 13.4% Higher among females^</td>
</tr>
</tbody>
</table>

*(p≤0.05), ^*(p≤0.001)

Table 2: Summary of hyperopia prevalence population-based studies in the literature

1.2.3 Astigmatism

Astigmatism is another type of refractive error where the principal meridians have different powers and therefore have different locations for their secondary far points. If the meridians are 90° apart, it is known as regular astigmatism and if they’re not 90° apart, it is called irregular astigmatism.

1.2.3a Astigmatism Etiology

A cross-sectional study was performed on a sample from the Multi-Ethnic Pediatric Eye Disease and Baltimore Pediatric Eye Disease Study. This study was designed to evaluate the risk factors for astigmatism in preschool children by a univariate
The results confirmed that children with -1.00 D or more of myopia were 4.6 times more likely to have astigmatism (CI: 3.56-5.96) and children with +2.00 D or more of hyperopia were 1.6 times more likely to have astigmatism (CI: 1.39-1.94) when compared to children without refractive error. Age was also evaluated and it was found that children between 6 and 12 months old were three times more likely to have astigmatism than 5 to 6 year old children (CI: 2.26-3.73). The next association evaluated was ethnicity. Hispanic and African American children were 2.4 and 1.5 times more likely respectively (when compared to non-Hispanic Caucasian children), which shows that race isn’t a huge risk factor for astigmatism but still shows an increased likelihood. The last association that was analyzed was whether maternal smoking during pregnancy was a risk factor for astigmatism. This factor showed a 1.5 increase in likelihood of astigmatism in children (CI: 1.14-1.87) if the mother smoked. Though some of the increase in likeliness of astigmatism can be considered low, these are all risk factors that lead to an increased prevalence of astigmatism in preschool children (McKean-Cowdin, 2011).

1.2.3b Astigmatism Prevalence

In Iran, a study was performed to analyze the characteristics of astigmatism in schoolchildren. Random sampling from 460 schools provided 5,544 subjects for the study. Cycloplegic refraction was performed on children in elementary school and junior high school, and non-cycloplegic refraction was performed on high school children. These authors defined astigmatism as cylinder power -0.75 DC or more. The overall
prevalence of astigmatism was 13.47% and there were no significant relationships with age or gender. Overall, 45.76%, 48.14%, and 6.09% had with-the-rule, against-the-rule, and oblique astigmatism respectively. A correlation between increase in age and decrease in prevalence of with-the-rule astigmatism and an increase in against-the-rule astigmatism was found (p<0.001). They found that myopes had 8.81 increased risk for astigmatism and hyperopia only had a 3.81 increased risk for astigmatism. For the subjects’ refractive errors, with-the-rule astigmatism group had an average of +1.93 D for the spherical component or the refractive error, against-the-rule astigmatism subjects had an average of +1.37 for the spherical component, and oblique astigmatism subjects had an average of +0.88 D for the spherical component (p<0.001). Therefore, with-the-rule astigmatism subjects tend to have higher refractive error. This study compared to others had higher overall prevalence of astigmatism (Fotouhi, 2011).

The large multi-country Refractive Error Study in Children (RESC) was performed to evaluate the prevalence of astigmatism. The study included 46,260 children, all of which received cycloplegic autorefraction. The researchers defined astigmatism as cylinder power -0.75 DC or more in the right eye. The overall astigmatism prevalence was 13.3% (CI: 12.5-14.0%), but there were differences among the ethnicities (p<0.001). Hispanic children (27.0%) had the highest prevalence of astigmatism followed by Chinese children (17.2%) then Malay children (12.2%). The lowest rates of astigmatism were found in Indian children (8.22%), Nepali children (3.32%) and African children (8.81%). Their study also showed that higher astigmatism rates was associated with younger children (OR=0.98, p=0.001) and female children (OR=1.11, p=0.003). Though
this study did not include Caucasian children, this wide-spread analysis provides good insight on how astigmatism prevalence can vary across the world (Wang, 2014).

In some children such as Hispanics and Chinese children, astigmatism is just as prevalent as other refractive errors of myopia and astigmatism. However, astigmatism is not that common in some countries such as Africa and Nepal. Similar to hyperopia, the trend of decreasing astigmatism is seen with increased age; however older children with astigmatism tend to have against-the-rule astigmatism rather than with-the-rule astigmatism (Table 3).

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Location</th>
<th>Sample Size</th>
<th>Age</th>
<th>Astigmatism Definition</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fotouhi et al.</td>
<td>2011</td>
<td>Iran</td>
<td>5544</td>
<td>6-20</td>
<td>$\geq -0.75 \text{ DC}$</td>
<td>Overall: 13.4%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>WTR: 45.76%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>ATR: 48/14%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Oblique: 6.09%</td>
</tr>
<tr>
<td>Wang et al.</td>
<td>2014</td>
<td>China</td>
<td>46260</td>
<td>30+</td>
<td>$\geq -0.75 \text{ DC}$</td>
<td>Overall: 13.3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hispanic: 27.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Chinese: 17.2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Malay: 12.2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>African: 8.81%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Indian: 8.22%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nepali: 3.32%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Higher in younger children$^\wedge$</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Higher among females*$^*$</td>
</tr>
</tbody>
</table>

*(p≤0.05), $^\wedge$(p≤0.001)

Table 3: Summary of astigmatism prevalence population-based studies in the literature
1.3 Binocular Vision

Binocular vision, the act of using both eyes together, is important because it allows us to better perceive depth with stereoacuity. It is even more important that both eyes are lined up perfectly so that the object we’re viewing is lined up with both foveas. If one eye is even slightly misaligned, then the images aren’t hitting both foveas, so the signal relaying from our retinas to the brain will be misinterpreted resulting in diplopia. This double vision and strain on the eyes, can result in suppression and asthenopia, which can lead to trouble with near activities such as school work. It is also important that both eyes are focusing the correct amount and developing at the appropriate rate to prevent blurry vision. Some binocular issues that can occur are phorias, strabismus, amblyopia, and accommodation issues.

1.3.1 Phoria

Phorias are latent deviations of the eyes in their fusion-free position. If the eye turns inward when the eye is covered, then it is labeled as an esophoria and an outward turn is an exophoria. There are also vertical phorias where an eye can turn up (hyperphoria) or down (hypophoria) in its fusion-free position. If there is no turn, whether horizontal or vertical, then it is classified as orthophoria. Phorias are most often measured by performing cover test, but can also be measured by prism dissociation such as the Von Graefe test or by dissimilar objects done by the Maddox rod. These techniques break fusion of the eyes to eliminate fusional vergence.
1.3.1a Phoria Prevalence

The prevalence of phoria development in children was studied by Walline et al. via a cross sectional study and longitudinal study by using data from the Orinda Longitudinal Study of Myopia (OLSM). Cover test results were measured three years from the baseline measurement. The results showed that the majority of children (97%) had orthophoria at distance and there was no significant change with an increase in age. When near phorias were measured, 31.8% of the children were exophoric and 6.7% were esophoric. With an increase in age, the prevalence of exophorias decreased by 10.8% and esophorias increased by 5.5%, and these associations between the prevalence of phorias and age were found to be significant (p<0.0001). In conclusion of this study, children are more likely to be exophoric, but become more esophoric as they get older (Walline, 1998).

1.3.2 Vergence Dysfunction

When one has too high of a phoria at either distance or near, they have a vergence dysfunction. The most common vergence dysfunction is convergence insufficiency (CI), which is when one has a high exophoria at near compared to distance. Another common vergence dysfunction is when one has a high esophoria at near compared to distance, which is known as convergence excess (CE). High phorias can also occur at distance. When there is a high exophoria at distance compared to near, it is called divergence excess (DE) and when there is a high esophoria at distance compared to near, it is called divergence insufficiency (DI). The near vergence dysfunctions can be more symptomatic
due to the amount of near work students perform at school. They can cause strain on the eyes when performing near work such as reading and writing and can lead to symptoms of diplopia, eyestrain, headaches, or blurry vision.

1.3.2a Near Vergence Dysfunction Prevalence

Rouse et al. researched the frequency of convergence insufficiency among fifth and sixth graders that ranged from 9 to 13 years old. The children were labeled with a CI if they had a 4 prism diopter (pd) or greater exophoria at near compared to distance, insufficient fusional convergence and a receded nearpoint of convergence. Out of the 684 students that were screened, 453 students had sufficient CI measurement data and it was found that 8.4% were classified as a low suspect CI (≥4pd exophoria at near with one clinical sign), 8.8% were classified as a high suspect CI (≥4pd exophoria at near with two clinical signs), and 4.2% were classified as a definite CI (≥4pd exophoria at near with three clinical signs). The results showed that there was no difference between gender on the prevalence of CI (p=0.95). Asian-Pacific subjects had the highest percentage of low suspect CI, but Black subjects had the highest percentage of definite CI (p<0.0005). In conclusion, it was determined that the prevalence of CI is high among this age group with 13% of children having a significant CI (high suspect CI plus definite CI) (Rouse, 1999).

Although it was conducted many years ago and contained a few flaws, there is a historical population-based study that looked at the prevalence of CI in children and this was performed by Letourneau et al. He initiated two different studies. First he had a sample of 735 elementary school children between the ages of 7 to 14 years old. He
found that 8.3% had a CI which was defined as a near point convergence (NPC) of greater than 10 cm. Then, he performed the same study with a larger population size. After screening 2,054 students between the ages of 6 and 13 years old, he found that 8.3% had a CI with the same definition. A difference with his second study was that he then performed cover test on these students with a receded NPC and found that 2.3% had an additional clinical sign of a higher exophoria at near than distance (Letourneau, 1988).

A more recent study in South Korea, investigated the prevalence of general binocular dysfunctions among rural schoolchildren by performing comprehensive eye examinations on 589 children between 8 and 13 years old. They found that 10.3% of the students had convergence insufficiency and only 1.9% had convergence excess. To be classified as a CI, the student must have exophoria at near greater than 6 pd, reduced positive fusional vergence (PFV), and NPC of greater than or equal to 10 cm. They must also have either a low AC/A ratio, binocular accommodative facility with +2.00 D (of ≤2.5 cpm) or negative relative accommodation (NRA) ≤1.50 D. To be classified with CE, the student must have an esophoria at near greater than 2 pd, a reduced negative fusional vergence (NFV) at near, and either a high AC/A ratio, reduced binocular accommodative facility or a positive relative accommodation (PRA) less than or equal to 1.25 D. Their study showed that vergence dysfunctions are frequent in children and convergence insufficiency is the most prevalent (Jang, 2015).

A study in South Africa looked at the prevalence of near vision anomalies in children between 13 and 19 years old. The study included 65 children. They found that 3.2% had a receded NPC, 16% were classified as a low suspect CI, none had high suspect
CI, and 1.6% had definite CI. They also found that 3.2% had CE. A low suspect CI was defined as only having an exophoria at near (greater than or equal to 4 pd) greater than distance. A high suspect CI was defined as having the same definition as a low suspect but also included either a reduced PFV at near or an NPC greater than or equal to 7 cm break or greater than or equal to 10 cm recovery. A definite CI was defined as a low suspect CI plus both of the additional clinical signs. A CE was defined as having an esophoria at near greater than or equal to 2 pd, a reduced NFV at near, and MEM (≥0.75D). Their study showed that vergence dysfunctions are dominant in their small population and warrants the next step of conducting the same study on a larger scale (Wajuihian, 2016).

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Location</th>
<th>Sample Size</th>
<th>Age</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rouse et al.</td>
<td>1999</td>
<td>USA</td>
<td>684</td>
<td>9-13</td>
<td>8.4% low suspect CI 8.8% high suspect CI 4.2% definite CI 1.6% definite CI 3.2% CE</td>
</tr>
<tr>
<td>Letourneau &amp; Ducic</td>
<td>1988</td>
<td>?</td>
<td>735 2054</td>
<td>7-14 6-13</td>
<td>8.3% CI 10.6% CE</td>
</tr>
<tr>
<td>Jang &amp; Park</td>
<td>2015</td>
<td>South Korea</td>
<td>589</td>
<td>8-13</td>
<td>10.3% CI 1.9% CE</td>
</tr>
<tr>
<td>Wajuihian &amp; Hansraj</td>
<td>2016</td>
<td>South Africa</td>
<td>65</td>
<td>13-19</td>
<td>3.2% receded NPC 16.0% low suspect CI 0% high suspect CI 1.6% definite CI 3.2% CE</td>
</tr>
</tbody>
</table>

*(p≤0.05), ^(p≤0.001)  

Table 4: Summary of near vergence dysfunction prevalence population-based studies in the literature
1.3.3 Strabismus

Strabismus, also known as heterotropia, is a manifest deviation of the eyes when both eyes are open, unlike phorias which are latent deviations when the eyes are not fused. In strabismus, one eye is directed towards the object of regard and therefore the image falls on the fovea, while the strabismic eye does not point towards the object of regard and the object of regard does not line up with the fovea. A strabismus can be classified by its frequency: constant or intermittent; laterality: right eye, left eye, or alternating; and direction: eso (pointing in), exo (pointing out), hyper (pointing up), or hypo (pointing down). In strabismus, the extraocular muscles (EOM) play a critical role and have become the focus of many studies to determine the etiology and possible treatments for strabismus.

1.3.3a Strabismus Prevalence

Various studies have looked at the prevalence of strabismus among children. Cherfan et al. collaborated on a study that looked at the prevalence rates of strabismus of children under 19 years old in Olmsted County, Minnesota from 1985 to 1994. They found that out of 627 children, 1.9% had horizontal strabismus, which was diagnosed at a mean age of 52 months. During a mean follow up period of 10.4 years, more children were diagnosed with strabismus giving a total of 7.9% with strabismus. The most common types of strabismus were accommodative esotropia (27.9%) and intermittent exotropia (16.9%). Of the subjects with strabismus, 60.1% has esotropia and 30.3% had exotropia. (Cherfan, 2014).
The Baltimore Pediatric Eye Disease Study found the prevalence of amblyopia, strabismus, and refractive error in children between the ages of 6 and 71 months in four different ethnic groups: African American, Asian American, Hispanics/Latinos and non-Hispanic White. A paper in 2009 reported on the prevalence rates of amblyopia and strabismus in only White and African American children from this study. Manifest strabismus was found in 3.3% of White and 2.1% of African American children (RR=1.61 CI=0.97-2.66). Esotropia and exotropia were equally found among the children. All but one case was over the age of 11 months and the highest rates were found in those between the ages of 60 to 71 months. Amblyopia was found in 1.8% White and 0.8% African American children. Overall, they saw that strabismus and amblyopia were more commonly seen in White children than African American children (Friedman, 2009). While these two studies show that the prevalence of strabismus can be considered relatively low, these studies show that the rates of strabismus and amblyopia are higher than non-Western countries.

In Japan, Matsuo and Matsuo looked at strabismus and amblyopia rates in elementary school children. Visual acuity testing was performed by the school teachers and visual exams were performed by school ophthalmologists. All information was sent to the authors to be analyzed. They received information on 86,531 children. Of these children, 1.28% had strabismus and 0.14% had amblyopia. Of the students with strabismus, 0.69% had exotropia and 0.28% had esotropia. The most common types of strabismus and amblyopia were intermittent exotropia (0.12%), accommodative esotropia (0.02%), anisometropia amblyopia (0.03%), and ametropic amblyopia (0.01%). Of the
children, 0.28% were classified as having an unknown type of strabismus and 0.09% with an unknown type of amblyopia. The authors reported that the prevalence rates of strabismus and amblyopia are found to be lower than Western countries (Matsuo, 2005).

There are certain health risks that increase the prevalence of developing strabismus. A study looked at the prevalence rates of strabismus among children with Retinopathy of Prematurity (ROP) in the Early Treatment for Retinopathy of Prematurity (ETROP) randomized trial. They examined 401 children with the first evaluation at 9 months old and then intended to examine them again at 6 years old, but only a total of 341 were examined at 6 years also. The prevalence of strabismus of the 9 month olds was 30.0% and this increased to 42.2% in the 6 year olds. The overall prevalence rate of strabismus in all children from birth to 6 years was 59.4%. Seventy-seven strabismic children (74.8%) who were examined when they were 9 months old, were also examined at 6 years of age and were found to still be strabismic. VanderVeen, et al. concluded that most children with a history of ROP develop strabismus during the first six years of life showing that strabismus is a common side effect of ROP (VanderVeen, 2011).

A study performed in Australia described the prevalence and associated factors found in strabismic patients. Their subjects included 1,739 six year olds. Forty-eight children (2.8%) were diagnosed with strabismus. Of those with strabismus, 54% had esotropia, 29% had exotropia, and 15% had microstrabismus (less than 10 prism diopters). When analyzing the associations found among the strabismic children, prematurity was found to increase the risk for strabismus by five times (OR=5.0, CI=1.8-14.1). Visual impairment was more common in those with strabismus (22.9%, p<0.0001).
Strabismus was also found to be highly correlated with hyperopia, astigmatism, anisometropia, and amblyopia (p<0.0001) (Robaei, 2006). These risk factors are consistent with other comparable studies.

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Location</th>
<th>Sample Size</th>
<th>Age</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cherfan et al.</td>
<td>1985-1994</td>
<td>USA</td>
<td>627</td>
<td>&lt;19</td>
<td>1.9% to 79% in 10.4 years Accommodative ET: 27.9% Intermittent XT: 16.9%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60.1% ET, 30.3% XT</td>
</tr>
<tr>
<td>Friedman et al.</td>
<td>2009</td>
<td>USA</td>
<td>2546</td>
<td>6-71 mo</td>
<td>White: 3.3% African American: 2.1% (RR=1.61)</td>
</tr>
<tr>
<td>Matsuo &amp; Matsuo</td>
<td>2005</td>
<td>Japan</td>
<td>86531</td>
<td>6-12</td>
<td>Overall: 1.28% 0.69% XT, 0.28% ET Intermittent XT: 0.12% Accommodative ET: 0.02%</td>
</tr>
<tr>
<td>Robaei et al</td>
<td>2006</td>
<td>Australia</td>
<td>1739</td>
<td>6</td>
<td>Overall: 2.8% 52% ET, 29% XT 15% microstrabismus More seen with prematurity More in hyperopia, astigmatism, anisometropia, amblyopia^</td>
</tr>
</tbody>
</table>

*(p≤0.05), ^(p≤0.001)*

Table 5: Summary of strabismus prevalence population-based studies in the literature

1.3.4 Amblyopia

Amblyopia is a unilateral or bilateral condition in which the best corrected visual acuity is reduced in the absence of any obvious structural anomalies or ocular pathologies. The types of amblyopia are refractive, strabismic, or deprivation. Refractive amblyopia occurs from having either bilateral high refractive error or high amounts of
anisometropia. Strabismic amblyopia occurs from having a constant, unilateral strabismus. Lastly, deprivation amblyopia occurs from unilateral or bilateral occlusion of vision which can be due to many etiologies such as congenital cataracts, significant ptosis blocking the visual axis, or a significant corneal dystrophy. It is important to diagnose amblyopia at an early age because it is easier to treat and is more likely to result in complete resolution. Amblyopia can cause visual eyestrain and blurry vision for children which can affect their performance in school.

1.3.4a Amblyopia Prevalence

The Multi-Ethnic Pediatric Eye Disease Study (MEPeds) was a large population-based study on preschool children of various ethnicities in California. For this particular study, they evaluated the prevalence of amblyopia and strabismus in Asian and non-Hispanic White preschool children and also the risk factors for these conditions. Pertaining to the prevalence rates of amblyopia, their results showed that amblyopia was detected in 1.81% of Asian and non-Hispanic White children. The prevalence of amblyopia increased as age increased among the non-Hispanic White children (p=0.01), but no significant correlation was found for the Asian children (p=0.30). Their results showed that amblyopia can be found in children as little as 6 months and is shown to increase from 6 to 72 months. They hope that this knowledge of amblyopia rates can better prepare clinicians when examining children (Mckean-Cowdin, 2013).

Another study evaluated the same question but in Singaporean Chinese children. Their large study of 3,009 children ranged from 6 to 72 months. They defined unilateral
amblyopia as a 2-line difference between the eyes with a visual acuity worse than 20/30 in the worse eye, along with anisometropia of ≥1.00 D for hyperopia, ≥3.00 D for myopia or ≥1.50 D for astigmatism, strabismus, or a past or present visual axis deprivation. Bilateral amblyopia was defined as both eyes having a visual acuity of worse than 20/50 if younger than 48 months or worse than 20/40 if older than 48 months along with hyperopia greater than 4.00 D, myopia greater than -6.00 D or astigmatism greater than 2.50 D or if they had or have a bilateral visual axis deprivation. Their results showed that the prevalence of amblyopia was 1.19% (95% CI, 0.73-1.83). There was no difference between age (p=0.37) or gender (p=0.22). Unilateral amblyopia was more common than bilateral amblyopia by twice as much. Refractive amblyopia was the diagnosis 85% of the time and strabismic amblyopia was only seen 15% of the time (Chia, 2010).

Another group of researchers did a similar study two years later focusing on Australian preschool children as part of the Sydney Pediatric Eye Disease Study. Their study also had a large population size of 2,461 children between the ages of 6 and 72 months. Their definition of amblyopia was the same as the previous study. Their study concluded that 1.9% had amblyopia or suspected amblyopia. Their study showed that the rates of amblyopia among this age group are comparable to previous studies (Pai, 2012).

An even more recent study as part of the Vision in Preschoolers (VIP) study began a project to find the prevalence rates of vision disorders by racial and ethnic groups among children in Head Start. Head Start is a federal program that provides education to children from birth to 5 years old from low income families. Their study looked at 4,040 children between the ages of 3 and 5 years old from five different Head Start programs all
over the United States. They found that the prevalence of amblyopia was similar among the Asian, Hispanic, non-Hispanic White, African American and American Indian children (p=0.07). The prevalence rates specifically were 3.27% African American children, 3.48% American Indian children, 2.98% Asian children, 5.04% Hispanic children and 5.44% non-Hispanic White children. Their results had slightly higher prevalence rates of amblyopia compared to similar studies, and showed the prevalence of amblyopia is not significantly different between ethnicities (Ying, 2014).

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Location</th>
<th>Sample Size</th>
<th>Age</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>McKean-Cowdin et al.</td>
<td>2013</td>
<td>USA</td>
<td>9172</td>
<td>30-72 mo</td>
<td>Asian &amp; White: 1.81% More in increased age* for Whites</td>
</tr>
<tr>
<td>Chia et al.</td>
<td>2010</td>
<td>China</td>
<td>3009</td>
<td>6-72 mo</td>
<td>Overall: 1.19% No difference with age/gender Refractive: 85% Strabismic: 15%</td>
</tr>
<tr>
<td>Pai et al.</td>
<td>2012</td>
<td>Australia</td>
<td>2461</td>
<td>6-72 mo</td>
<td>Overall: 1.9%</td>
</tr>
<tr>
<td>Ying et al.</td>
<td>2014</td>
<td>USA</td>
<td>4040</td>
<td>3-5</td>
<td>Same for Asian, Hispanic, Whites, African Americans, Indian 3.27-5.44%*</td>
</tr>
</tbody>
</table>

*(p≤0.05), ^*(p≤0.001)

Table 6: Summary of amblyopia prevalence population-based studies in the literature

1.4 Accommodation

Accommodation is the ability for our eyes to adjust and change our focus from viewing at distance to viewing at near; and these functions involve the ciliary body and crystalline lens. The ability to accommodate is determined by age. As we grow older, our
ability to focus decreases. A common accommodative dysfunction is accommodative insufficiency (AI) meaning one is unable to accommodate an appropriate amount based on their age. In comparison, there is accommodative excess, which is when one accommodates too much needed for the target that is being viewed. These dysfunctions can cause eyestrain and blurry vision for children who are performing tasks at near such as reading and writing for school.

1.4a Accommodative Dysfunction Prevalence

The same study performed by Jang and Park that looked at prevalence of vergence dysfunctions among children in South Korea, also looked at prevalence of accommodative dysfunctions. As stated before, their study included 589 children between the ages of 8 and 13 years old. Compared to 13.2% of the students that had a vergence dysfunction, 9% had an accommodative dysfunction. They found that 5.3% students had accommodative insufficiency and 1.2% had accommodative excess. Accommodative insufficiency was defined as an amplitude of accommodative 2.00 D below age expected minimum amplitudes, monocular accommodative facility less than or equal to 4.5 cycles per minute (cpm), and either binocular accommodative facility less than or equal to 2.5 cpm or a PRA of less than or equal to 1.25 D. Accommodative excess was defined as variable visual acuity variable objective and subjective refractions, and either monocular facility (≤4.5 cpm) or binocular accommodative facility (≤2.5 cpm) or a PRA ≤1.50 D. Though not as high prevalence rate as vergence dysfunctions, accommodative
dysfunctions are still frequent in this population and AI is more common than AE (Jang, 2015).

Another study that did dual analysis of vergence and accommodative dysfunctions was by Wajuihian and Hansraj. They looked at near vision anomalies in children between the ages of 13 and 19 years old in South Africa. Of the subjects, 1.6% had accommodative insufficiency and no subjects were classified with accommodative excess. They defined accommodative insufficiency as having an amplitude of accommodation at least 2.00 D below minimum age expected value, MEM findings greater than +0.75 D, and both monocular accommodative facility with -2.00 D flippers less than 6 cpm and less than 3 cpm binocularly. They defined accommodative excess as having a low MEM (<0.25D), difficulty clearing 2.00 D with monocular accommodative facility (<6cpm) and reduced binocular accommodative facility with 2.00 D (<3cpm), even though no students in their study met these requirements. The prevalence rates of accommodative issues were found to be lower than vergence dysfunctions and both overall were low for this population compared to other populations (Wajuihian, 2016).

Though we tend to often separate accommodative disorders from vergence disorders, in fact these often coexist. Marran et al. investigated this coexistence in elementary school children between fourth and sixth grade. The study included 299 children who were tested for CI and AI which included completing the CISS-V15 symptom survey to assess how frequently these children have symptoms that have been known to occur from having CI. Out of the 299 students, 170 fell into the categories of interest: normal binocular vision (NBV), CI only, AI only and CI and AI combined. Their
study found that 60.0% had NBV, 25.9% had CI only, 8.2% had AI only and 5.9% had CI with AI. Even though the prevalence of CI was greater than AI in this population, it shows that it is still common to have both at the same time. Another interesting result from the study was the results of the symptom survey. The children with AI only (p=0.006) or CI with AI (p=0.001) had greater symptoms scores than the children with NBV or CI only and there was no difference between scores among the NBV or CI only subjects (p=0.54) (Marran, 2006).

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Location</th>
<th>Sample Size</th>
<th>Age</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jang &amp; Park</td>
<td>2015</td>
<td>South Korea</td>
<td>589</td>
<td>8-13</td>
<td>Overall: 9% 5.2% AI 1.2% AE</td>
</tr>
<tr>
<td>Wajuihian &amp; Hansraj</td>
<td>2016</td>
<td>South Africa</td>
<td>65</td>
<td>13-19</td>
<td>1.6% AI 0% AE</td>
</tr>
<tr>
<td>Marran et al.</td>
<td>2006</td>
<td>USA</td>
<td>299</td>
<td>4th, 5th, 6th grade, avg age: 11.5±0.63</td>
<td>60% NBV 25.9% CI only 8.2% AI only 5.9% CI+ AI CI+AI had greater symptoms^</td>
</tr>
</tbody>
</table>

*(p≤0.05), ^(p≤0.001)

Table 7: Summary of accommodative dysfunction prevalence population-based studies in the literature

1.5 Vision and Academic Success

Mitchell Scheiman and Michal Rouse created a textbook addressing the management of learning related vision problems. In their textbook, they address different visual aspects and how they have an impact on reading and other school subjects.
Learning how to read is a major process that can be impacted by ocular ability. When students are learning how to read, they need to be able to carefully study a line of words to be able to assess the order of the letters to recognize the word or be able to sound it out if it is a word that they do not recognize. At this stage of learning how to read, students need accurate oculomotor control to be able to study the word. They also need to be able to use visual perception and visual memory to recall words that they have learned as they are reading. Reading at this stage normally doesn’t extend for long periods of time and the print size is often large and spaced out; therefore, accommodation and fatigue aren’t large factors in success (Scheiman, 2006).

Scheiman and Rouse state “As students become older, learning to read progresses to reading to learn.” At this educational milestone, the text size starts to become smaller and the amount of reading increases. The emphasis at this stage is less on analyzing the words individually, but rather on comprehension and speed. Now accommodation and binocular vision can start to have an increased role in school, along with the ability of oculomotor control to be able to stay on track while reading. Students that often have omissions, substitutions or careless errors may have inaccurate oculomotor control and this can lead to poor comprehension. One way students might overcome poor oculomotor control is decreasing their reading rate to avoid missing words. Students with poor accommodation might now start to experience fatigue over time, asthenopia, and headaches, so they might compensate for this by the avoidance of reading. Those with binocular vision issues who now start to notice the double vision
while reading, might start to develop suppression as an adaptation to the diplopia (Scheiman, 2006).

Vision problems can affect more than just reading. Math can be affected because a student needs to be able to have visual spatial ability to be able to appreciate written numbers as actual quantities and in advanced courses, such as trigonometry and geometry, be able to appreciate spatial relationships. Having good oculomotor control is important for math also, by being able to read numbers in rows or columns (Scheiman, 2006).

Spelling can be affected by vision problems, especially lack of oculomotor control, for similar reasons. When learning how to spell a word, a student must be able to carefully study the individual letters in the correct order to be able to memorize how to spell the word. Being able to sound an unknown word out to be able to spell it requires good visual perception (Scheiman, 2006).

Writing is another subject that can be affected by vision problems, in particular eye-hand coordination in younger students who learn to write by copying letters and words. If a student experiences poor binocular vision and oculomotor control, it can cause their writing skills to be delayed (Scheiman, 2006). Individual research studies have been performed to show the impact that visual problems can have on school performance.
1.5.1 Myopia and Learning

The different types of vision anomalies each have their own symptoms that may cause challenges in a child’s academic performance. The American Optometric Association has stated that 80% of the learning process is dependent on vision (AOA, 2017). The main symptom of myopia is the decreased ability to see clearly at distance. International educational performance, for reading, math, and science, and the association of myopia was studied by Morgan and Rose by identifying 65 areas with high and low myopia prevalence by obtaining data through the Organization for Economic Cooperation and Development (OECD) and the Program in Secondary Assessment (PISA). PISA found that high myopia prevalence in Asia is associated with high ranks in educational performance. However, other areas that also had high performance rates were located in areas that had low myopia prevalence, including Australia and areas in North America and the United Kingdom. The authors also reported that areas with high prevalence rates and high educational performance also had high levels of school tutoring whereas the areas of low myopia prevalence did not. The authors proposed that tutoring was the cause of the high educational performance and the extra near work activity was a factor in the high myopia prevalence, which falls back on the theory that extensive near work is an etiology of myopia (Morgan, 2013).

An earlier study done in 2007 evaluated the relationship between school grades and myopia in 740 children from Singapore that were between 10 to 12 years old. They saw that children with average exam scores in the 75th percentile were 2.5 times more likely to be myopic (SE ≤ -0.50 D) compared to the children in the 25th percentile once
the data were adjusted for various cofounders (CI=1.4-4.5). This trend was consistent throughout the ranking for English language scores (p=0.001), native language scores (p<0.0001), and math scores (p=0.055), with math being non-significant. This study concluded that myopia is associated with higher academic performance (Saw, 2007).

A study conducted by Akrami and his colleagues looked at various types of refractive error and the association with intelligence in children. One hundred thirty-seven students’ school performance was assessed by teacher-based evaluations. Myopia was defined as more than -0.50 D of myopia, hyperopia as +0.50 D or greater hyperopia and astigmatism as -1.00 DC or more of cylinder. The study resulted in a significant difference (p≤0.05) between the average school scores of those with both myopia and astigmatism compared to the students with no refractive error. Other types of refractive error including those with just myopia were not significantly different, which contradicts most studies on myopia and academic performance. They deduced that the contradiction may have come from their sample sizes. They had few number of students with just myopia and hyperopia, but rather larger percentages of those with ametropia compounded with astigmatism compared to most other studies. However, there was still an association with myopic astigmats with higher school scores (Akrami, 2012).

Another study performed in Asia looked at vision status and how it affected academic achievement among children in Malaysia. Around 1,103 children from seven different public schools were included in the trial. Students were grouped into the low academic achievement or average/above-average academic achievement groups based on their standardized school performance in primary language and math. Twelve percent in
the low academic group compared to 4% in the average/above-average group had visual acuities 20/40 or worse (p=0.001) and 7% in the low academic group had an esophoria or exophoria of more than 5.0 prism diopters, any type of strabismus, and/or a hyperphoria of more than 2.0 prism diopters compared to the 1% in the average/above-average group (p<0.001). The low academic group had significantly lower scores in the execution tests of the Gardner Reversal frequency test, which assesses visual-spatial skills compared to the higher academic group (p≤0.043), and had lower scores on word sentence copying tasks (p≤0.001). The study concluded that students with poorer academic performance presented with poorer distance visual acuity and they were more likely to exhibit binocular vision abnormalities. (Chen, 2011). Overall, the study reinforced the idea that vision greatly influences learning.
<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Location</th>
<th>Sample Size</th>
<th>Age</th>
<th>Test</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morgan &amp; Rose</td>
<td>2013</td>
<td>65 countries</td>
<td>15</td>
<td>PISA</td>
<td>Asia=higher performance &amp; high myopic rates Increase in tutoring causes artificially high performance in low myopic areas</td>
<td></td>
</tr>
<tr>
<td>Saw et al.</td>
<td>2007</td>
<td>Singapore</td>
<td>740</td>
<td>10-12</td>
<td>Exam Scores</td>
<td>75th percentile = 2.5x myopic Same for English language, native language, math (p=0.055)</td>
</tr>
<tr>
<td>Chen et al.</td>
<td>2011</td>
<td>Asia</td>
<td>1103</td>
<td>2nd grade</td>
<td>Gardener Reversal Freq. Test, sentence copying</td>
<td>Decreased distance VA &amp; low academic achievement, Strabismus/high phoria &amp; low academic group\</td>
</tr>
</tbody>
</table>

*(p≤0.05), ^(p≤0.001)*

Table 8: Summary of myopia and learning from population-based studies in the literature

1.5.2 Hyperopia and Learning

Hyperopia can have a greater impact on school ability, because its symptoms include blurry vision at near and asthenopia due to constant accommodative demands to overcome the blurry vision. This can lead to strain on the child’s academic performance since it is known that a student’s day at school involves mostly near work with the tasks of reading and writing and the increase of technology in the classroom such as computers and tablets. Williams looked into this issue with hyperopia and educational success in children. The study included 1,298 children at 8 years old which were screened for hyperopia and the National Foundation for Education Research (NFER) and Standardized
Assessment Test (SAT) test scores were compared between the students which were grouped based on their refractive error. The NFER focuses on reading and writing based on the child’s age level and the SAT focuses on a variety of subjects. One hundred five children were diagnosed with hyperopia. For the NFER, children with more than +1.25 D of hyperopia (mean score=99.3, CI=93.0-105.6) and those with more than +3.00 D of hyperopia (mean score=98.4, CI=93.0-103.8) scored lower on the test than those that were not referred for hyperopia (mean score=103.6, CI=99.7-107.4). The SATs followed the same trend where the children with hyperopia scored significantly lower than those that did not have hyperopia. When analyzing SAT scores, the children were divided into non-referred group, hyperopia less than +3.00 D group, and hyperopia greater than +3.00 D group. The hyperopes with +3.00 D or more, only 79.5% of the children received a Core Subject Indicator (CSI) of level 2 which is the pass rate, while the hyperopes that were less than +3.00 D and the non-referred group had similar pass rates of 86.7% and 85.9% respectively (both p<0.05) (Williams, 2004).

Shankar and her colleagues performed an additional study on literacy of children aged 4 to 7 years with uncorrected hyperopia versus those that were emmetropic. Hyperopia was defined as greater than or equal to +2.00 D and emmetropes were defined as +1.50 D or less. Their literacy was assessed by three standard tests, which included letter/word reading skills, receptive vocabulary, and phonological awareness. Hyperopes performed worse on letter and word recognition ability (p=0.049) and on receptive vocabulary (p=0.004), but there was no difference found on phonological awareness ability. The study looked at whether these differences in literacy skill were due more to
family demographics, developmental levels and/or the amount spent on literacy at home, but no significant differences in these categories were found between the two groups of children. The study concluded that uncorrected hyperopia has an impact on a child’s literacy ability and were not due to other underlying factors (Shankar, 2007).

Van Rijn performed a recent study that questioned whether spectacles could improve reading speed in children with hyperopia from the ages of 9 and 10 years. Hyperopic subjects received one of three refractive error corrections (no correction, +0.50 D OU, and full correction). Myopic children were included as an additional control group. The children’s reading speed was assessed before receiving correction and about six months after receiving correction by doing one-minute tests (testing real words) and the Klepel test (reading non-real words). At the initial visit, the myopic children read 11% faster on the one-minute tests (p=0.005), but not significantly higher on the Klepel test than each of the hyperopic groups. On the subsequent visit, the hyperopes that received full correction increased their test score for the one-minute test by 13% more than the +0.50 D OU and no correction hyperopic groups (p=0.019 and p= 0.012 respectively). Correction of myopes did not have a significant impact on the test scores. The study concluded that correcting hyperopia would help increase the reading speed of real words, but not nonsense words, since it is believed that hyperopia affects word recognition, not decoding of new words (van Rijn, 2014).

A classic paper by Rosner and Rosner determined the relationship between moderate hyperopia and academic achievement by determining the minimal amount of hyperopia that affects school performance. They recruited 782 children from first to fifth
grade and they used the Iowa Test of Basic Skills, which is a standardized test to quantify academic achievement in these children. In the subcategory of high performers, 33% were myopic and 13% were hyperopic. In the subcategory of low performers, 10% were myopic and 14% were hyperopic. Emmetrope children were found to be in the middle range, slightly closer to the high scorer group. The hyperopes in the low score group, were found to have hyperopia that exceeded +1.25 D (p=0.014) (Rosner, 1997).
<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Location</th>
<th>Sample Size</th>
<th>Age</th>
<th>Test</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Williams et al.</td>
<td>2004</td>
<td>Wales</td>
<td>1298</td>
<td>8</td>
<td>NFER SAT</td>
<td>&gt; +1.25 D: mean 99.3 NFER &lt; +3.00 D: mean: 98.4 NFER No hyperopia: mean: 103.6 NFER &gt; +3.00 D: 79.5% CSI2 SAT &lt; +3.00 D ore none: 85.9-86.7% CSI2 SAT</td>
</tr>
<tr>
<td>Shankar et al.</td>
<td>2007</td>
<td>Canada</td>
<td>41</td>
<td>4-7</td>
<td>Literacy</td>
<td>Worse on letter/word recognition* and receptive vocab*</td>
</tr>
<tr>
<td>Van Rijn et al.</td>
<td>2014</td>
<td>The Netherlands</td>
<td>1007</td>
<td>9-10</td>
<td>Klepel test, 1 min reading test</td>
<td>Myopia: 11% faster on 1-min test* Corrected hyperopes: 13% faster than other hyperopes*</td>
</tr>
<tr>
<td>Rosner &amp; Rosner</td>
<td>1997</td>
<td>?</td>
<td>782</td>
<td>1&lt;sup&gt;st&lt;/sup&gt;-5&lt;sup&gt;th&lt;/sup&gt; grade</td>
<td>Iowa Test of Basic Skills</td>
<td>High performers: 33% myopic, 13% hyperopic Low performers: 10% myopic, 14% hyperopic</td>
</tr>
</tbody>
</table>

*(p≤0.05), ^(p≤0.001)*

Table 9: Summary of hyperopia and learning from population-based studies in the literature

### 1.5.3 Astigmatism and Learning

Another type of refractive error, astigmatism, can affect learning by causing distorted, blurry vision, which can sometimes be seen as double vision. Wills performed one of the few studies on astigmatic refractive error and its effects on reading.
performance. She used 30 subjects that were visually normal and created five groups: fully corrected, induced -1.00 D and -2.00 D of cylinder at both 90 degrees and 180 degrees. Reading and eye movements fluency were tested using Discrete Reading Rate (DRR), Developmental Eye Movement test (DEM) and recording eye movements with the Visagraph (III) while reading. Wills found that distance and near acuity were decreased in all of the simulated astigmatic groups (p<0.001) compared to the fully corrected group. Reading speed via the DRR was reduced by 10% for the -2.00 DC against-the-rule (ATR) group. When using smaller text, it was reduced up to 24% for the -1.00 DC ATR group and the -2.00 DC ATR and with-the-rule (WTR) groups (p<0.05). During the DEM, completion rates were decreased for the -2.00 DC ATR and WTR groups (p<0.05). However, there was no significant difference in eye movements tracked by the Visagraph between the different subgroups of simulated astigmatism. This study showed that uncorrected astigmatism could cause learning complications by reducing reading fluency, especially for ATR astigmatism (Wills, 2012).

1.5.4 Accommodative and Vergence Dysfunctions and Learning

Children with accommodative and vergence issues are especially vulnerable to hindered learning due to strain on their visual system while doing near work, which takes up the majority of a day at school. Shin and colleagues investigated these visual dysfunctions and how they affected academic achievement in children. Eighty-two children that scored 20 or more symptoms on the College of Optometrists in Vision Development Quality of Life (COVD-QOL) were further evaluated and diagnosed with a
non-strabismic accommodative (n=29) or vergence dysfunction (n=28), or a combination of the two (n=25). Various school subjects such as reading, math, social science, and science were evaluated for these children from the school’s standardized achievement test. The children with accommodative dysfunctions had significantly lower test scores overall (p<0.001), but not when comparing science performance alone. For children with vergence dysfunctions, reading scores were significantly lower (p<0.05). Those that had both conditions had lower test scores (p<0.001), but not specifically in science. All eighty-two children with accommodative and vergence dysfunction had significantly lower test scores than those that did not have accommodative or vergence dysfunctions (p<0.001). This study suggests the importance of having a child’s accommodative and vergence ranges checked before entering school rather than just a refractive error screening. The study also pondered an additional question for the future of whether or not treatment of these accommodative and vergence issues would help improve academic achievement for these children (Shin, 2009).

Rouse et al. evaluated academic behaviors in children with symptomatic convergence insufficiency by using the academic behavior survey (ABS). The survey consists of six questions that asks the parents about their concerns about their child’s school performance and their perception of how often the child experiences problems while doing schoolwork. The higher the ABS score, the more problem behaviors the child has during schoolwork. The survey was given to the parents of 212 children who had symptomatic CI and 49 normal binocular vision (NBV) children all of whom were between the ages of 9 and 17 years. The CI children were further divided into two groups
based on whether their parents reported that the child had ADHD. Their results showed
that the children with symptomatic CI and ADHD scored significantly higher on the ABS
than the children with CIs without ADHD \(p=0.001\) and the NBV children \(p<0.0001\).
The children with CI and no ADHD scored significantly higher on the ABS than the
NBV children \(p=0.036\). Since the children with ADHD also had higher scores on the
ABS, they advised that children with ADHD be screened for vergence dysfunctions to
allow proper vision therapy if needed (Rouse, 2009).

A few years later, Borsting continued his study by seeing if the treatment of
symptomatic convergence insufficiency had an effect on the ABS score. The ABS was
given to the parents of 218 children with symptomatic CI before they started CI therapy
as part of the Convergence Insufficiency Therapy Trial (CITT). The CITT divided the
children into four different therapy groups (1) home-based pencil push-ups, (2) home-
based computer vergence/accommodative therapy and pencil push-ups, (3) office-based
vergence/accommodative therapy with home reinforcement and (4) office-based placebo
therapy with home reinforcement. After twelve weeks of therapy, the subjects were
categorized as “successful,” “improved,” or “non-responsive” to the therapy by using the
symptom score from the CISS survey, NPC values and positive fusional vergence values.
The ABS was then re-administered. The ABS score was found to be significantly lower
for the children who were successful or improved after treatment compared to those who
were non-responders \(p=0.0002\) and \(p=0.043\). Therefore, parents who report more
problems with schoolwork for their children and therefore have higher ABS scores, might
benefit from CI therapy and their ABS score will reduce if they are successful or have improvement after their treatment (Borsting, 2012).

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Location</th>
<th>Sample Size</th>
<th>Age</th>
<th>Test</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shin et al.</td>
<td>2009</td>
<td>South Korea</td>
<td>82</td>
<td>9-13</td>
<td>School subjects</td>
<td>Accommodative scored lower(^) overall Verge scored lower* Combination scored lower(^)</td>
</tr>
<tr>
<td>Rouse et al.</td>
<td>2009</td>
<td>USA</td>
<td>261</td>
<td>9-17</td>
<td>ABS</td>
<td>CI + ADHD scored higher(^) than others CI only scored higher than NBV*</td>
</tr>
<tr>
<td>Borsting et al.</td>
<td>2012</td>
<td>USA</td>
<td>218</td>
<td>9-17</td>
<td>ABS</td>
<td>ABS was lower in the successful and improved VT groups*</td>
</tr>
</tbody>
</table>

*(p \leq 0.05), ^*(p \leq 0.001)

Table 10: Summary of accommodative and vergence dysfunctions and learning from population-based studies in the literature

1.5.5 Strabismus and Learning

Understanding the etiology and prevalence of strabismus in children is important, because this ocular deviation can lead to poor visual outcomes, which can affect their life both physically and emotionally. A study done by Reed et al. looked at parents’ observations of the academic and nonacademic performance of children with strabismus. Parents of 137 strabismic children between the ages of 6 and 16 years old participated in the study. Over half the children were diagnosed with strabismus before six years old. Of the 137 children, 90 had esotropia and 37 had exotropia. Eighty-two children (59.9%) had
strabismus surgery before entering elementary school, but 33 of these children had residual strabismus of more than ten prism diopters. The parents were asked about their child’s academic developmental skills such as the learning to read process, language abilities, and math abilities, and they were also asked about nonacademic activities such as the presence of headaches and eyestrain. Parents mostly based their opinions on the child’s academic performance by their own observations, parent-teacher conferences, and the child’s report cards. Thirty-eight percent of parents with strabismic children reported their child had reading difficulties and 22% of the parents in the control group did the same. These results were found to be statistically non-significant; however, the opinion that the children with strabismus had a harder time with the learning to read process was statistically significant (p=0.028). No correlation was found between reading difficulties and high hyperopia, poor visual acuity, poor stereo acuity, early onset strabismus, or suppression. Almost half of the children with strabismus (49%) were found to have at least one academic difficulty other than reading (p<0.025). Nonacademic difficulty, such as catching balls, headaches, and eyestrain was experienced by 47% of the children with strabismus (p<0.005) (Reed, 2004). Strabismus can indeed affect a child’s academic and nonacademic performance, which is why it is important to detect and treat as early as possible.

1.6 Correction of Vision Anomalies

We now know that various types of visual anomalies can affect school performance, but detection of these anomalies is difficult unless children have their eyes
examined regularly. One major issue is the lack of follow up after failed school vision screenings. Kimel performed an investigation on children from kindergarten to fifth grade who failed their school vision screening to find contributing factors to the non-compliance on follow up examination. These children attended Rockford Public Schools in Illinois. Kimel discovered through interviews with the children’s parents that the cost of eye care was a contributing factor with 31% ranking money concerns as the major issue. No insurance coverage was also a major concern for 11% of the parents. Concerning logistical barriers, 22% claimed appointment problems kept them from following up and 16% weren’t able to plan ahead to schedule an appointment. For the social/family barriers to following up with eye examinations, the major issues were that all adults in the family work (45%), unspecific family issues (34%), and having a large family (29%). In the perceptual barrier category, 38% did not believe the results of the failed school vision screening and an equal proportion did not think eye care was a priority. Factors that improved compliance with follow up examinations were if the parent wore glasses, the parent had at least a high school diploma, the family’s income was above 200% of the federal poverty level, and if the family had a car and phone. Kimel concluded that there are barriers to compliance that aren’t as obvious to the public, but needs to be addressed to help improve compliance of follow up examinations (Kimel, 2006).

Once the child does receive proper eye care, the next major issue is compliance of wearing their glasses. A study performed by Gogate et al. studied the spectacle compliance among children in India. Over two thousand children were given glasses and
out of those children, about one thousand were re-assessed the next year. The results were that only 29.5% were wearing their glasses at the time of the second examination. Of the 70.5% not wearing their glasses, 68.5% reported that their glasses were at home and 29.4% reported not having their glasses at all. There was a positive correlation between compliance of spectacle wear and the magnitude of refractive error (p<0.0001), father’s education (p=0.016), and females (p=0.029). There was a negative correlation between spectacle wear compliance and the visual acuity of the better eye (p<0.0001) and the area of where they lived (p<0.0001). Of those that were myopic, 44% were wearing their glasses at the time of re-examination. Separate positive associations within the myopic subgroup were increasing refractive error (p<0.0001), worsening visual acuity (p<0.0001) and higher academic success (p<0.0001) (Gogate, 2013).

Horwood published a study on the compliance of first time spectacle wear in children younger than eight years old in the United Kingdom. One hundred thirty-three children were surveyed, and the average compliance was 79.5%. Sixty percent of the subjects were hyperopic, 16% were myopic, and 52% had astigmatism. The factors that influenced compliance of spectacle wear were not the effect glasses had on vision, but rather their friends’ opinions about the glasses Negative comments on glasses weren’t seen until the children were older, starting at age 5, but they were reported to come from non-friends rather than friends. Even though this study showed that spectacle wear compliance was good among these children, an important part of the study showed that the major influence of compliance comes from the opinions of others on one’s glasses. Because the negative comments on glasses starts around age 5 years, it was suggested
that prescribing correction even earlier in life would help compliance, because at earlier ages, they would be exposed to more positive comments (Horwood, 1998).

A third study on spectacle wear compliance was performed on children in Mexico where financial issues were completely removed from the situation by providing free glasses. Four hundred ninety-three children from 5 to 18 years of age were given glasses and then evaluated 18 months later. The majority of the children given glasses were myopic (74.5%). At the time of evaluation, only 13.4% wore their glasses. Thirty-four percent of the children had their glasses with them, but were not wearing them. The results showed that the compliant children were more likely to be younger (OR=1.19), myopic (OR=3.97), or live in rural areas (OR=10.6). The older children listed the main reason for non-compliance as their appearance while wearing their glasses (Castanon, 2006). This study showed that non-compliance with spectacle wear is more a concern of attitude towards wearing glasses, not influenced as much by financial concerns of purchasing the glasses.

Another issue that arises with children is the attitude towards wearing glasses and the worry of being stereotyped and made fun of by peers. A study performed by Horwood investigated common visual defects and peer victimization in children. He looked at wearing glasses, having strabismus, and wearing an eye patch and the effect these had on a child’s social acceptance. Around 6,536 children from the Avon Longitudinal Study of Parents and Children (ALSPAC) were given an eye examination when they were 7.5 years old and then evaluated one year later. After one year of wearing their correction, those who wore glasses and those with a history of eye patching were 35-37% more
likely to be bullied either physically or verbally. For those wearing glasses, the bullying rate was found to be frequent (OR=1.35) versus only occasionally (OR=1.26). No correlation with bullying was found for gender or strabismus (Horwood, 2005). This study showed opinions of peers and being bullied can play a role in a child’s self-esteem and spectacle wear compliance. The authors concluded that prescribing refractive error correction at an earlier age could decrease negative comments and bullying.

Walline led a study that compared the self-perception in kids wearing contact lenses compared to those wearing glasses for three years. The subjects were children eight to eleven years old and myopic. They used the Self-Perception Profile for Children Global Self-Worth scale to record overall global self-worth, but also evaluated self-perceptions in specific areas: physical appearance, athletic competence, scholastic competence, behavioral conduct, and social acceptance. The results showed that global self-worth was the same between those wearing glasses and those wearing contact lenses (CI -0.004 to +0.117), but physical appearance (CI +0.07 to +0.22), athletic competence (CI +0.01 to +0.15), and social acceptance (CI +0.03 to +0.17) were higher for the contact lens wearers than spectacle wearers (Walline, 2009). Contact lens wear also provides non-visual benefits for young children.

Focus groups conducted in China evaluated the attitudes about wearing glasses of students from age 14 to 18 years with at least -0.50 D or more of myopia, as well as the attitudes of their parents and teachers. All three groups felt that treating early myopia was harmful to the eyes. In addition, both the students and parents were often unsure of the magnitude of the child’s prescription and were unsure if the child should be wearing
correction. The study found that when parents didn’t purchase glasses, it was typically due to “being too busy” rather than financial reasons. Children ranked “inconvenience” as the primary reason for non-compliance. When surveyed what would help make wearing glasses more accepted, “accuracy of lens power” was the first answer. This study showed that education about refractive error and its correction could help improve compliance rates on spectacle wear (Li, 2010).

Following the last study, the See Well to Learn Well Study determined whether an educational program on wearing spectacles would help improve compliance on spectacle wear. The educational program consisted of a lecture, video, and classroom demonstration promoting spectacle wear. The results showed that 25.7% of the children who received the educational program bought glasses that were recommended to them and 34% who did not receive an educational program bought glasses but the difference was not significant. They found that females, bad visual acuity, and high refractive error were significantly related to spectacle purchase (p=0.02, p<0.001, and p=0.001 respectively) (Congdon, 2011). This study found that their educational program failed to promote spectacle purchase, but perhaps it should have been directed towards the children’s parents who decide the family’s purchases and not to just the children. Once the family purchases the spectacles, an educational program for the children should then help promote spectacle wear compliance.
1.7 Special Population of Students

An Individual Education Program (IEP) is specifically designed for those with special educational needs by a child’s teachers, parents, and school administrators. The IEP includes the child’s current school performance and the individual special education services needed to help the child reach their academic, social, and/or behavioral goals.

In 1990, the Individuals with Disabilities Education Act (IDEA), was created to ensure students with learning disabilities would receive an education that meets their individual needs. In 2003, the Ohio Revised Code 3323.19 declared that within three months of the initial referral for an IEP, the child is required to have a comprehensive eye examination by an optometrist or ophthalmologist unless they have had an eye exam within the past nine months. However, the code also states that no child shall be denied receiving special educational services whether they have had an eye exam or not; therefore, compliance with the Ohio Revised Code is not mandatory.

1.7a IEP Prevalence

Walline and Carder compared the prevalence rates of visual problems of children with IEPs to population-based samples from the literature. Two hundred fifty-five children had IEPs and the average spherical equivalent refractive error in the right eye was $+0.54 \pm 2.21$ D. Compared to population-based studies published in the peer-reviewed literature, the children with IEPs had higher prevalence rates of myopia (9 of 13 studies), hyperopia (10 of 13 studies), astigmatism (6 of 9 studies), anisometropia (3 of 4 studies), and strabismus (6 of 6 studies). The data showed that the entering distance
visual acuity of the children with IEPs with visual correction being worn at the start of the examination (n=510) was 20/40 or worse for 23.7% of eyes. After refraction (n=430), the number of IEP students with 20/40 or worse visual acuity went down to 11.6%. This shows that reduced visual acuity can be corrected with a proper eye examination. Their study showed that IEP students have higher prevalence rates of refractive error than the general population (Walline, 2012). This population of students is an important cohort that needs to carefully be screened for visual anomalies that may hinder their academic performance.

In conclusion, refractive error and binocular vision conditions are prevalent among children entering school. As seen in the literature, refractive errors such as hyperopia and astigmatism, and binocular vision conditions such as convergence insufficiency, accommodative insufficiency, and strabismus can make learning challenging and have been seen to cause poorer academic performance. These conditions cause eyestrain, blurry vision, and diplopia putting these children at a disadvantage compared to their emmetrope, myope and/or normal binocular vision classmates.

1.8 Purpose of Study

The purpose of this study is to determine whether a group of inner-city children improves academic performance after receiving spectacle correction. In addition, the compliance rate of spectacle wear and a comparison of the IEP children to the non-IEP children from the Cincinnati school district will be included.
Chapter 2: Methods

2.1 IRB Approval

The study was approved through The Ohio State University Biomedical Sciences Institutional Review Board with a waiver of consent.

2.2 Data Collection

Data were collected from October 2012 to May 2013 and from August 2013 to May 2014 during two academic school years by the means of a comprehensive eye exam completed by a single doctor during the 2012-2013 school year and two different doctors during the 2013-2014 school year; therefore while conventional standards of eye care were met, testing procedures were not performed in a standardized manner. These examinations were performed at the OneSight Vision Center at Oyler School. All data were recorded on paper clinic charts. A technician recorded the patients’ demographic information including student ID number, school name or code, grade level, age, gender, and ethnicity. The date of the exam and if known, the date of their last eye examination were recorded. The technician recorded the patients’ chief complaint and whether the patient currently wore glasses or had worn glasses in the past but may have lost, broken, or grown out of their old pair. Non-cycloplegic autorefraction, color vision testing and stereoacuity testing were then performed, followed by unaided and aided (when
applicable) Snellen visual acuities taken at both distance and near. The optometrist then finished the comprehensive examination. Non-cycloplegic retinoscopy and non-cycloplegic manifest refractive errors were first measured and cycloplegic retinoscopy and cycloplegic manifest refractive errors were measured according to the discretion of the optometrist. Cover test at distance and near, near point of convergence (NPC), negative relative accommodation (NRA) and positive relative accommodation (PRA) were also measured. All patients’ eyes were dilated, unless medical issues or a hostile reaction made it unreasonably safe. The type of mydriatic eye drop and any abnormal findings were recorded. A final prescription was determined by the optometrist and if necessary, any ophthalmology or vision therapy referrals were noted. All paper charts were copied, de-identified, and delivered to The Ohio State University College of Optometry for data extraction and entry.

2.3 Data Entry

The paper charts were numbered for future reference. All data were entered into an Excel spreadsheet. The paper chart number and the patient’s ID number, school name or code, date of examination, years since last eye examination, grade, and age were entered. Gender was entered numerically with females assigned as 1, males assigned as 2, and 0 was entered for those that were unrecorded on the charts. Individual Education Program (IEP) status and Language Education Program (LEP) status were entered binary with 1 assigned to positive IEP and LEP patients and 0 assigned to non-IEP and non-LEP patients separately. Whether the patient wore correction at the time of the examination
was marked as “1” meaning yes and “0” meaning no. If the student was not wearing
correction at the time of the examination, he or she was asked if vision correction had
been worn before, and it was recorded “1” if they said yes and “0” if they said no. If they
had stated that they had worn correction before, they were asked if they had broken their
glasses or had lost their glasses and it was entered as “1” if they said yes to either of these
questions or “0” if they said no. The denominator of the Snellen fraction for entering
distance visual acuity for each eye and entering binocular near visual acuity were entered.
All numerators for the Snellen fraction for visual acuities were 20 feet. Each component
of the spherocylindrical non-cycloplegic and cycloplegic (if applicable) autorefraction
was entered for each eye. Stereoacuity testing results were entered for local contour and
color vision testing results were entered as the percentage of plates read correctly. Cover
test for distance and near was entered in prism diopters with exo deviations as negative,
eso deviations as positive, orthophoria as “0”, phorias as “P”, and tropias as “T”. NPC
was recorded in centimeters. Each component of the spherocylindrical non cycloplegic
and cycloplegic (if applicable) manifest refractive error was entered for each eye.
Mydriatic drops were entered as “C” for Cyclopentolate, “T” for Tropicamide and “C/T”
for a combination of both. Vision therapy referral was entered binary with “0” for a non-
referral needed and “1” for a referral needed. An additional column was entered for any
additional important notes about the patient which included any diagnoses of
accommodative insufficiency (AI), convergence insufficiency (CI), strabismus (S),
ambyopia (Amb), strabismic amblyopia (S.Amb), accommodative excess (AE), and
accommodative spasm (AS). Each component of the patient’s final prescription for each
eye was entered including any add powers and/or prism. Spherical equivalent (M), J0 and J45 were calculated for each eye for all refractive error data. All data were entered twice. The two entries were compared and differences were corrected after consultation with the data source to ensure no mistakes were made in data transfer. All paper charts were stored securely.

2.4 Academic Scores

At the end of each academic year quarter, grade point average (GPA) was calculated to determine an overall score of academic performance for each subject individually. GPA was calculated by assigning numbers to letter grades: A=4, B=3, C=2, D=1, F=0; then the average was calculated. Oyler School provided grades for each quarter for the 2012-2013, 2013-2014, and 2014-2015 academic years for math, reading, and writing subjects, which were used to calculate GPA for the students.

2.5 Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics Version 22 and Microsoft Excel. We compared continuous variables using Student’s t-test and we compared categorical variables using the Chi-square test.
Chapter 3: Results

3.1 Overall OneSight Vision Center Clinic Population

In the 2013-2014 academic year, 2,333 students were examined with a total of 2,333 comprehensive examinations and 59 follow-up examinations. Only comprehensive examinations were included in the data analysis. The students were from 81 schools in Cincinnati, Ohio. For 838 of the examinations, years since the student’s last exam was recorded and the average was 0.7 years (~8.5 months). For 357 students out of the 838 recorded (42.6%), this was their first vision examination. The majority of the students that were examined were in elementary school, but ranged from preschool to 12th grade (Figure 1). Age was recorded for 2,330 (99.9%) of the exams and the students ranged from 3 to 19 years old with an average ± standard deviation of 10.0 ± 3.5 years. Gender was recorded for 2,328 (99.8%) of the patients, and there were 1,299 (55.7%) females. Whether the child had an IEP or LEP was recorded for all examinations which resulted in 461 (19.8%) students on an IEP and 106 (4.5%) students who were in the LEP program.
At the time of the examination, 190 (8.1%) wore vision correction and 832 (35.7%) reported having worn correction before. Of the 832 students who previously wore correction, 468 (56.3%) reported broken glasses and 267 (32.1%) reported lost glasses. The average entering distance visual acuity (VA) for the right eye was +0.29 ± 0.30 logMAR (20/39.2 Snellen acuity) and +0.28 ± 0.29 logMAR (20/38.3 Snellen acuity) for the left eye. The average entering near binocular VA was +0.09 ± 0.16 logMAR (20/24.5 Snellen acuity).

Stereoacuity was performed on 1,986 (85.1%) of the students and the average local stereopsis was 125 ± 98 seconds of arc. Color testing was performed on 2,188 (93.8%) of the children (including both males and females) and the average percentage of color plates read correctly was 95 ± 17%.

Cover test at near was performed on 2,250 (96.4%) students. Fourteen of the students had strabismus, but the magnitude was not recorded. One student had a
magnitude recorded, but it was not specified whether it was a phoria or tropia. Cover test at distance was performed on 2,233 (95.7%) students. Six of the students had strabismus, but the magnitude was not recorded (Figure 2). Of the people with strabismus at distance, the average amount was $-2.4 \pm 24.4$ prism diopters (range: $-44.0$ to $+44.0^\Delta$). Of the people with strabismus at near, the average amount was $+0.3 \pm 24.1$ prism diopters (range: $-44.0$ to $+44.0^\Delta$). Of the people with distance cover test who did not have strabismus at distance, the average phoria was $-0.1 \pm 1.3$ prism diopters (range: $-20.0$ to $+10.0^\Delta$). The average amount of phoria at near of those without strabismus at near was $-0.6 \pm 2.7$ prism diopters (range: $-25.0$ to $+14.0^\Delta$).

![Figure 2: Prevalence of eye deviations from the overall OneSight Vision Center clinic population](image)

NPC was performed on 2,195 (94.1%) students with an average of $4.1 \pm 3.5$ cm. The proportion of students with a NPC of 6 cm or worse was 22.7%. NRA and PRA were
performed on 465 (19.9%) students and the average results were +2.10 ± 0.74 D and -1.54 ± 1.03 D, respectively.

Cycloplegic/mydriatic drops were instilled in the eyes of 2,304 (98.8%) students. Tropicamide was used for 2,000 (85.7%) of the students, cyclopentolate was used for 285 (12.2%), and a combination of the two was used for 19 (0.8%) of the students. Non-cycloplegic autorefraction was performed on 2,331 (99.9%) and cycloplegic autorefraction on 2,289 (98.1%) of the students. Non-cycloplegic manifest refraction was performed on all students and cycloplegic refraction was performed on 295 students (12.6%). According to the prescribing optometrist, 1,666 (71.4%) children warranted a prescription for glasses. Out of those given prescriptions, 86 (5.2%) included an add power (range: +1.00 to +3.50) and 30 (1.8%) were prescribed prism. The average spherical equivalent (SE) for the final prescription for the right eye was -0.33 ± 1.98 D (range: +10.38 to -13.25 D) and -0.26 ± 1.99 D (range: +9.88 to -14.00 D) for the left eye. For research purposes, myopia was defined at -0.50 D spherical equivalent (SE) or more myopic, hyperopia was defined as +2.00 D SE or more hyperopic, and astigmatism was defined as cylinder power -0.75 DC or more with the final prescription of the right eye. Out of the all the students, 869 (37.2%) were myopic, 179 (7.7%) were hyperopic, and 860 (36.9%) were astigmatic.

Out of the all the students, 431 (18.5%) had a binocular vision condition, including amblyopia, vergence dysfunction, and/or accommodation dysfunction (Table 11). Six of these students had multiple conditions. Amblyopia was the most common binocular vision condition among the students, but the type of amblyopia was not
specified most of the time. Students who would benefit from vision therapy were referred, which included 22 students (0.9%)

<table>
<thead>
<tr>
<th>Condition</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amblyopia (Unspecified type)</td>
<td>319</td>
<td>13.7%</td>
</tr>
<tr>
<td>Convergence Insufficiency</td>
<td>18</td>
<td>0.8%</td>
</tr>
<tr>
<td>Convergence Excess</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Divergence Insufficiency</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Divergence Excess</td>
<td>10</td>
<td>0.4%</td>
</tr>
<tr>
<td>Accommodative Insufficiency</td>
<td>71</td>
<td>3.0%</td>
</tr>
<tr>
<td>Accommodative Excess</td>
<td>6</td>
<td>0.3%</td>
</tr>
<tr>
<td>Duane's Syndrome</td>
<td>3</td>
<td>0.1%</td>
</tr>
<tr>
<td>Total</td>
<td>482</td>
<td>20.2%</td>
</tr>
</tbody>
</table>

Table 11: Binocular vision conditions from the overall OneSight Vision Center clinic population

3.2 Oyler School Students from OneSight Vision Center Clinic Population

When looking at just the Oyler School students who attended the OneSight Vision Center, 442 students received a comprehensive eye examination during the 2013-2014 school year. Of the 442 Oyler School students, 286 students reported that their last eye examination was an average of 0.85 ± 0.78 years ago (~10.2 months) and 67 (23.0%) answered that this was the first eye examination. The students ranged from preschool to 12th grade. The average age was 10.5 ± 4.0 years. Out of all the students, 219 (49.5%) were female. Eighty-seven students (20.0%) were listed as having an IEP and no students were in the LEP program.
Only 46 (10.4%) students wore refractive error correction to the examination, but 144 (32.6%) claimed to have had correction previously. Of those 144 students, 55 (38.2%) reported that their glasses were broken and 63 (43.8%) reported lost glasses.

Out of the 442 students, 440 (99.5%) had their distance visual acuity recorded. Of those 440 students, 102 (23.2%) were 20/40 or worse in the right eye and 101 (23.0%) were 20/40 or worse in their left eye. The average distance visual acuity in the right eye was +0.16 ± 0.24 logMAR (20/28.8 Snellen acuity) and the average distance visual acuity in the left eye was +0.15 ± 0.23 logMAR (20/28.4 Snellen acuity). Near visual acuity was measured binocularly for 429 (97.1%) students, and 25 (5.8%) had visual acuity 20/40 or worse at near. The average near binocular visual acuity was +0.05 ± 0.12 logMAR (20/22.4 Snellen acuity).

Stereoacuity was measured on 402 (91.0%) students and the average stereopsis was 104 ± 81.5 seconds of arc. Color vision was tested on 411 (93.0%) of the students, and 97.0 ± 13.4% of the plates were read correctly.

Cover test at near was performed on 428 (96.8%) students. Two of the students had strabismus, but the magnitude was not recorded. Cover test at distance was performed on 427 (96.6%) students. One of the students had strabismus, but the magnitude was not recorded (Figure 3). Of the people with strabismus at distance, the average amount was -1.4 ± 21.9 prism diopters (range: -30.0 to +22.5\(^\Delta\)). Of the people with strabismus at near, the average amount was +3.0 ± 22.3 prism diopters (range: -30.0 to +30.0\(^\Delta\)). Of the people with distance cover test who did not have strabismus at distance, the average phoria was -0.2 ± 1.7 prism diopters (range: -18.0 to +6.0\(^\Delta\)). The
average amount of phoria at near of those without strabismus at near was \(-0.5 \pm 2.7\) prism diopters (range: \(-18.0\) to \(+11.0\)).

Figure 3: Prevalence of eye deviations of Oyler School students from the OneSight Vision Center

Near point of convergence was performed on 419 (94.8\%) students and the average was \(3.7 \pm 3.2\) cm. NRA and PRA were performed on 110 (24.9\%) students, and the average results were \(+2.10 \pm 0.65\) D and \(-1.90 \pm 1.10\) D, respectively.

According to the prescribing optometrist, 243 (55.0\%) children warranted a prescription for glasses. Out of those given prescriptions, 17 (7.0\%) included an add power (range: \(+1.00\) to \(+3.00\)) and 9 (3.7\%) were prescribed prism. The average spherical equivalent for the final prescription for the right eye was \(+0.04 \pm 1.72\) D (range: \(+8.50\) to \(-13.25\) D) and \(+0.10 \pm 1.77\) D (range: \(+8.00\) to \(-14.00\) D) for the left eye. For research purposes, myopia was defined at \(-0.50\) D SE or more of myopia, hyperopia was defined as \(+2.00\) D SE or more hyperopic, and astigmatism was defined as cylinder power \(-0.75\)
DC or more with the final prescription of the right eye. Out of the all the students, 99 (22.4%) were myopic, 36 (8.1%) were hyperopic, and 95 (21.5%) had astigmatism (Figure 4).

![Figure 4: Distribution of frequency of spherical equivalent refractive error for Oyler School students from the OneSight Vision Center clinic population](image)

Binocular vision conditions, including amblyopia, vergence dysfunction, and accommodation dysfunction were reported for 61 (13.8%) students. Nearly 8% of the students had amblyopia (Table 12). Out of the 442 students, 16 (3.6%) were referred for vision therapy evaluation.
<table>
<thead>
<tr>
<th>Condition</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amblyopia (Unspecified type)</td>
<td>38</td>
<td>8.6%</td>
</tr>
<tr>
<td>Convergence Insufficiency</td>
<td>2</td>
<td>0.5%</td>
</tr>
<tr>
<td>Convergence Excess</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Divergence Insufficiency</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Divergence Excess</td>
<td>4</td>
<td>0.9%</td>
</tr>
<tr>
<td>Accommodative Insufficiency</td>
<td>16</td>
<td>3.6%</td>
</tr>
<tr>
<td>Accommodative Excess</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>Duane's Syndrome</td>
<td>1</td>
<td>0.2%</td>
</tr>
<tr>
<td>Total</td>
<td>61</td>
<td>13.8%</td>
</tr>
</tbody>
</table>

Table 12: Binocular vision conditions of Oyler School students from OneSight Vision Center

3.3 Compliance Rate of Wearing Spectacle Correction for Oyler School Students

Four hundred one Oyler School students were given comprehensive eye examinations during the 2012-2013 school year and 256 (63.8%) received glasses. Out of these students, 114 (44.5%) returned for an eye examination during the 2013-2014 school year. Only 33 (28.9%) were wearing their glasses at the time of their second eye examination. When the children were asked where their glasses were, 28 (34.6%) reported breaking their glasses and 43 (53.1%) lost them.

Non-compliant students were emmetropic (-0.75 < SE < +1.00 D) 42% of the time compared to 7% with emmetropia for the compliant students ($X^2$, p=0.003) based on the final prescription of the right eye (Figure 5). The non-compliant students were younger than the compliant students (T-test, p=0.05). There were no significant differences between the compliant and non-compliant students for gender, distance or near visual acuities, cover test at distance or near, or amount of astigmatism.

65
3.4 Academic Performance after Receiving Spectacle Correction

Out of the 442 total Oyler students that received an eye examination, school grade point averages (GPAs) were calculated for 238 (53.8%) students. Out of these 238 students, 129 (54.2%) were prescribed eye glasses. The average age of those who were prescribed glasses was 10.7 ± 3.5 years. The average spherical equivalent refractive error was +0.01 ± 2.57 D (range: +8.50 to −13.25 D) for the final prescription of the right eye. Of the students, 69 students (53.5%) were female. Of the students who received spectacles, 55 students had myopia (42.6%), 23 students had hyperopia (17.8%), and 47 students had astigmatism (36.4%).

A school year includes four quarters. Table 13 shows the beginning and end dates for each quarter, as well as the number of students examined. The 42 students who
received eye examinations during the first quarter were eliminated from the data analysis because we did not have GPA scores for these students before they received spectacle correction. Seven additional students were eliminated from the data analysis due to insufficient GPA data. The students from quarters two-four were included in the analysis since we had GPA scores for at least two quarters after their eye examination.

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Range of Dates</th>
<th>Number of Students Examined</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8/26/13-10/17/13</td>
<td>42</td>
</tr>
<tr>
<td>2</td>
<td>10/18/13-12/19/13</td>
<td>31</td>
</tr>
<tr>
<td>3</td>
<td>1/18/14-3/7/14</td>
<td>38</td>
</tr>
<tr>
<td>4</td>
<td>3/10/14-5/2/14</td>
<td>18</td>
</tr>
</tbody>
</table>

Table 13: Date ranges for academic school year quarters and number of Oyler School students examined per quarter

For research purposes, myopia was defined at -0.50 D SE or more myopic, hyperopia was defined as +2.00 D SE or more hyperopic, and astigmatism defined as cylinder power -0.75 DC or more with the final prescription of the right eye. The average GPA for all myopic, hyperopic, and astigmatic was determined for the quarter prior to receiving a spectacle correction and compared to the average GPA of two quarters after receiving a spectacle correction. All groups saw an increase in average GPA after receiving new glasses, with hyperopia having the largest amount of increase and myopes having the smallest amount of increase in average GPA. However, the increase in GPA
was not statistically significant for any of the groups. Figure 6 shows the GPA before and after receiving a glasses prescription by refractive error category.

![Graph showing GPA before and after receiving a spectacle correction](image)

Figure 6: Average GPA for Oyler School students before and after receiving a spectacle correction

The average GPA before and after receiving a prescription was also broken down by subject: math, reading and writing. All groups saw an increase in average GPA for math and reading. Hyperopes saw the most increase in GPA in math and astigmats saw the most increase in GPA in reading (Figure 7).
All groups had a decrease in writing average GPA after receiving spectacle correction (Figure 8)
However, none of the changes in GPA were statistically significant (Table 14).

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Before Rx +/- SD</th>
<th>After Rx +/- SD</th>
<th>Difference in GPA</th>
<th>Paired t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Students</td>
<td>80</td>
<td>1.93 ± 1.05</td>
<td>2.07 ± 0.95</td>
<td>0.14</td>
<td>p=0.17</td>
</tr>
<tr>
<td>Myope Overall</td>
<td>37</td>
<td>2.02 ± 1.09</td>
<td>2.10 ± 0.98</td>
<td>0.08</td>
<td>p=0.50</td>
</tr>
<tr>
<td>Myope Math</td>
<td>36</td>
<td>1.97 ± 1.18</td>
<td>2.10 ± 1.21</td>
<td>0.13</td>
<td>p=0.39</td>
</tr>
<tr>
<td>Myope Reading</td>
<td>36</td>
<td>2.00 ± 1.41</td>
<td>2.13 ± 1.09</td>
<td>0.13</td>
<td>p=0.52</td>
</tr>
<tr>
<td>Myope Writing</td>
<td>11</td>
<td>2.27 ± 0.79</td>
<td>1.95 ± 1.13</td>
<td>-0.32</td>
<td>p=0.19</td>
</tr>
<tr>
<td>Hyperope Overall</td>
<td>9</td>
<td>1.54 ± 1.21</td>
<td>1.91 ± 1.02</td>
<td>0.37</td>
<td>p=0.34</td>
</tr>
<tr>
<td>Hyperope Math</td>
<td>9</td>
<td>1.11 ± 1.27</td>
<td>2.00 ± 1.46</td>
<td>0.89</td>
<td>p=0.12</td>
</tr>
<tr>
<td>Hyperope Reading</td>
<td>9</td>
<td>1.67 ± 1.32</td>
<td>2.00 ± 1.12</td>
<td>0.33</td>
<td>p=0.49</td>
</tr>
<tr>
<td>Hyperope Writing</td>
<td>6</td>
<td>2.17 ± 1.47</td>
<td>2.08 ± 1.32</td>
<td>-0.09</td>
<td>p=0.84</td>
</tr>
<tr>
<td>Astigmat Overall</td>
<td>28</td>
<td>1.71 ± 1.19</td>
<td>1.84 ± 0.94</td>
<td>0.12</td>
<td>p=0.45</td>
</tr>
<tr>
<td>Astigmat Math</td>
<td>27</td>
<td>1.70 ± 1.38</td>
<td>1.83 ± 1.13</td>
<td>0.13</td>
<td>p=0.42</td>
</tr>
<tr>
<td>Astigmat Reading</td>
<td>27</td>
<td>1.59 ± 1.39</td>
<td>1.89 ± 1.06</td>
<td>0.30</td>
<td>p=0.25</td>
</tr>
<tr>
<td>Astigmat Writing</td>
<td>10</td>
<td>2.00 ± 1.05</td>
<td>1.45 ± 0.93</td>
<td>-0.55</td>
<td>p=0.09</td>
</tr>
<tr>
<td>Low Rx Overall</td>
<td>25</td>
<td>1.90 ± 1.01</td>
<td>2.24 ± 0.94</td>
<td>0.34</td>
<td>p=0.10</td>
</tr>
<tr>
<td>Emmetropoe Overall</td>
<td>63</td>
<td>2.46 ± 1.13</td>
<td>2.27 ± 1.09</td>
<td>-0.19</td>
<td>p=0.15</td>
</tr>
</tbody>
</table>

Table 14: Average GPA before and after receiving a spectacle correction for Oyler School students
Large variability in GPA change and small sample sizes resulted in poor power (generally less than 20%) to detect statistically significant changes in our samples given $\alpha = 0.05$ and calculated for standard deviations of 1.0 and 1.2 (Table 15).

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>SD = 1.0</th>
<th>SD = 1.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample</td>
<td>80</td>
<td>0.22</td>
<td>0.18</td>
</tr>
<tr>
<td>Myopes</td>
<td>37</td>
<td>0.10</td>
<td>0.09</td>
</tr>
<tr>
<td>Hyperopes</td>
<td>9</td>
<td>0.19</td>
<td>0.15</td>
</tr>
<tr>
<td>Astigmats</td>
<td>28</td>
<td>0.12</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Table 15: The power to detect the change in overall GPA for the overall sample and each refractive error group ($\alpha = 0.05$)

3.5 IEP Students from the Overall OneSight Vision Center Clinic Population

Out of the 2,333 students from the overall OneSight Vision Center clinic population, 461 (19.8%) had IEPs. The students with IEPs range from preschool to 12th grade and the average age was 11.3 ± 3.3 years compared to the average age of 9.7 ± 3.3 years of the non-IEP students (T-test, $p<0.001$) (Figure 9). For the IEP students, 204 (44.3%) were female and three did not report gender; and for the non-IEP students, 1095 (58.5%) were female and two did not report gender. Out of the IEP students, 5 (1.1%) students also participated in the LEP program compared to 101 (5.4%) students for the non-IEP students ($X^2$, $p=0.000069$).
At the time of the examination, 50 (10.8%) IEP students wore refractive error correction and 140 (7.5%) non-IEP students wore refractive error correction ($X^2$, $p=0.12$). However, 203 (44.0%) IEP students claimed to have had correction at one point. When asked why they weren’t wearing their vision correction, 117 (57.6%) reported that their glasses were broken and 62 (30.5%) reported they had lost their glasses. For the non-IEP students, 629 (33.6%) students claimed to have had correction before at one point and 351 (55.8%) broke them and 205 (32.6%) lost them.

The average distance visual acuity in the right eye for IEP students was $+0.31 \pm 0.31$ logMAR (20/41.0 Snellen acuity) and the average distance visual acuity in the left eye for IEP students was $+0.29 \pm 0.29$ logMAR (20/39.4 Snellen acuity). The average near binocular visual acuity for IEP students was $+0.11 \pm 0.18$ logMAR (20/25.5 Snellen acuity). The average distance visual acuity in the right eye for non-IEP students was
+0.29 ± 0.30 logMAR (20/39.0 Snellen acuity) and the average distance visual acuity in the left eye for non-IEP students was +0.28 ± 0.28 logMAR (20/38.0 Snellen acuity). The average near binocular visual acuity for non-IEP students was +0.08 ± 0.16 logMAR (20/24.3 Snellen acuity). For distance visual acuity in the right eye, 234 (50.8%) IEP students had 20/40 or worse visual acuity and 882 (47.1%) non-IEP students had 20/40 or worse visual acuity in the right eye (X², p=0.16). When comparing distance visual acuity in the left eye, 219 (47.5%) IEP students had 20/40 or worse visual acuity and 848 (45.3%) non-IEP students had 20/40 or worse visual acuity (X², p=0.39). When comparing binocular near visual acuity, 73 (15.8%) IEP students had 20/40 or worse visual acuity and 221 (11.8%) non-IEP students had 20/40 or worse visual acuity (X², p=0.20), which was significantly higher for the IEP students.

Stereoacuity was measured on 375 (81.3%) IEP students and 1,611 (86.1%) non-IEP students. The average stereopsis for IEP students was 129 ± 101 seconds of arc and the average stereoacuity for non-IEP students was 124 ± 98 seconds of arc (T-test, p=0.44). Color vision was performed on 434 (94.1%) IEP students and 1,754 (93.7%) non-IEP students. The average percentage of color plates read correctly was 94 ± 19% correct for IEP students and 95 ± 16% correct for non-IEP students (T-test, p=0.15).

Cover test at near was performed on 440 (95.4%) IEP students and 1,810 (96.7%) non-IEP students. Cover test at distance was performed on 440 (95.4%) IEP students and 1,793 (95.8%). (Figure 10). When comparing the prevalence of strabismus at distance between IEP students (3.3%) and non-IEP students (2.2%), there is no significant difference (X², p=0.33). However, when comparing the prevalence of strabismus at near
between IEP students (5.2%) and non-IEP students (2.7%), there is a significant
difference ($X^2 p<0.05$). The average strabismus at distance for IEP students was $-10.4 \pm 23.5$ prism diopters (range: $-30.0$ to $+35.0\Delta$) and for non-IEP students the average
strabismus at distance was $+0.3 \pm 24.5$ prism diopters (range: $-44.0$ to $+44.0\Delta$) (T-test,
p=0.18). For near, the average strabismus for IEP students was $-5.4 \pm 24.4$ prism diopters
(range: $-30.0$ to $+35.0\Delta$) and for non-IEP students, the average strabismus at near was
$+2.6 \pm 24.1$ prism diopters (range: $-44.0$ to $+44.0\Delta$) (T-test, p=0.24). For the students that
did not have strabismus, the average phoria at distance for IEP students was $-0.1 \pm 1.7$
prism diopters (range: $-18.0$ to $+10.0\Delta$) and for non-IEP students, the average phoria at
distance was $-0.1 \pm 1.3$ prism diopters (range: $-20.0$ to $+10.0\Delta$) (T-test, p=0.94). For near,
the average phoria for IEP students was $-0.7 \pm 3.2$ prism diopters (range: $-20.0$ to $+14.0\Delta$
and for non-IEP students, the average phoria at near was $-0.6 \pm 2.6$ prism diopters (range:
$-25.0$ to $+11.0\Delta$) (T-test, p=0.38).
NPC was performed on 436 (94.6%) IEP students and 1,759 (94.0%) non-IEP students. The average NPC for IEP students was 4.5 ± 4.0 cm and the average NPC for non-IEP students was 4.0 ± 3.4 cm (T-test, p=0.03). For IEP students, 132 (28.6%) IEP students had a NPC of 6 cm or more, which was significantly higher compared to 398 (21.3%) non-IEP students who had a NPC of 6 cm or more (X², p=0.0007). NRA and PRA was performed on 90 (19.5%) IEP students and 375 (20.0%) non-IEP students. The average NRA and PRA results were +2.06 ± 0.72 D and -1.65 ±1.09 D respectively for IEP students and the NRA and PRA results were +2.11 ± 0.74 D and -1.51 ± 1.01 D respectively for non-IEP students (T-test, p=0.59, p=0.28 respectively).

According to the prescribing optometrist, 345 (74.8%) IEP students and 1,321 (70.6%) non-IEP students warranted a prescription for glasses (X², p=0.07). Out of the given prescriptions, 21 (6.1%) IEP students and 65 (4.9%) non-IEP students included an
add power (range: +1.00 to +3.50 D for both group of students) ($X^2$, p=0.27). Out of the
given prescriptions 10 (2.9%) IEP students and 20 (1.5%) non-IEP students were
prescribed prism ($X^2$, p=0.06). The average SE for the final prescription for the right eye
was $-0.33 \pm 2.29$ D (range: $+8.63$ to $-12.25$ D) for IEP students and $-0.32 \pm 1.89$ D
(range: $+10.38$ to $-13.25$ D) for non-IEP students. The average SE for the final
prescription for the left eye was $-0.21 \pm 2.12$ D (range: $+8.88$ to $-11.75$ D) for IEP
students and $-0.27 \pm 1.96$ D (range: $+9.88$ to $-14.00$ D) for non-IEP students. For research
purposes, myopia was defined as $-0.50$ SE or more myopic, hyperopia was defined as
$+2.00$ SE or more hyperopic, and astigmatism was defined as cylinder power $-0.75$ DC or
more with the final prescription of the right eye. There were 171 (37.1%) IEP students
and 698 (37.3%) non-IEP students that were myopes; 41 (8.9%) IEP students and 138
(7.4%) non-IEP students that were hyperopes, and 183 (39.7%) IEP students and 677
(36.2%) non-IEP students that had astigmatism (Figure 11). Refractive error was not
significantly different between IEP and non-IEP students for myopia ($X^2$, p=0.94),
hyperopia ($X^2$, p=0.27), and astigmatism ($X^2$, p=0.16).
Eighty-two (17.8%) IEP students and 347 (18.5%) non-IEP students ($X^2$, $p=0.71$) were reported to have a binocular vision condition including amblyopia, vergence dysfunction and/or accommodation dysfunction (Table 16). One IEP student and four non-IEP students had multiple binocular vision conditions. Amblyopia was the most common binocular vision condition among both groups of students, but the type of amblyopia was not specified most of the time. None of the binocular vision conditions prevalence were significantly different between the groups of students. Students who would benefit from vision therapy were referred, which included, 4 (0.9%) IEP students and 18 (1.0%) non-IEP students ($X^2$, $p=0.85$).
<table>
<thead>
<tr>
<th>Condition</th>
<th>IEP</th>
<th>IEP%</th>
<th>Non-IEP</th>
<th>Non-IEP%</th>
<th>Chi-Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amblyopia (Unspecified Type)</td>
<td>56</td>
<td>12.1%</td>
<td>268</td>
<td>14.3%</td>
<td>p=0.23</td>
</tr>
<tr>
<td>Convergence Insufficiency</td>
<td>6</td>
<td>1.3%</td>
<td>12</td>
<td>0.6%</td>
<td>p=0.15</td>
</tr>
<tr>
<td>Convergence Excess</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
<td>NA</td>
</tr>
<tr>
<td>Divergence Insufficiency</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
<td>NA</td>
</tr>
<tr>
<td>Divergence Excess</td>
<td>2</td>
<td>0.4%</td>
<td>8</td>
<td>0.4%</td>
<td>p=0.98</td>
</tr>
<tr>
<td>Accommodative Insufficiency</td>
<td>16</td>
<td>3.5%</td>
<td>55</td>
<td>2.9%</td>
<td>p=0.55</td>
</tr>
<tr>
<td>Accommodative Excess</td>
<td>2</td>
<td>0.4%</td>
<td>4</td>
<td>0.2%</td>
<td>p=0.11</td>
</tr>
<tr>
<td>Duane's Syndrome</td>
<td>1</td>
<td>0.2%</td>
<td>2</td>
<td>0.1%</td>
<td>p=0.55</td>
</tr>
<tr>
<td>Total</td>
<td>83</td>
<td>18.0%</td>
<td>349</td>
<td>18.6%</td>
<td>p=0.75</td>
</tr>
</tbody>
</table>

Table 16: Binocular vision conditions for IEP and non-IEP students from the overall OneSight Vision Center clinic population
Chapter 4: Discussion

4.1 Overall OneSight Vision Center Clinic Population

This large population of students examined at the OneSight Vision Center in one academic year allows us to compare the prevalence of eye examination components of these children to the known prevalence of children around the world determined by several studies. This clinic allows children to receive the proper eye care that they need and gave 45.0% of the children their first eye examination.

4.1.1 Refractive Error Prevalence

4.1.1a Myopia Prevalence

These data shows that this population of the OneSight Vision Center students are 37.2% myopes. Our result is lower to the results seen in the most recent NHANES study performed in the United States from 1999-2004. Their study showed the overall prevalence rate of myopia to be 41.6% \( (X^2, p<0.00001) \) (Vitale, 2008). The myopia prevalence in Asian countries was seen in Zhao’s study with 36.7% fifteen year old myopic males in China (Zhao, 2000) and Fan’s study with 36.7% myopes in Hong Kong (Fan, 2004). Both of these studies seemed to have similar prevalence of myopic subjects, and there was no significant difference compared to the OneSight Vision Center clinic population \( (X^2, p=0.87 \text{ for both studies}) \). This is surprising since both of these studies had the same definition of myopia as our study, unlike the NHANES study. A reason why our
myopia prevalence is not similar to Zhao’s study is that the prevalence of myopia was reported for 15 year olds, whereas our study had a large range of age from 3 to 19 years old with the average age of 10.0 ± 3.5 years. Also the cohort of students may vary between the studies. The inner-city children of Cincinnati may have underlying risk factors for refractive error, such as poor education and low socioeconomic status that is unlike the risk factors located in Asian countries. In addition, the students examined at the OneSight Vision Center were students that had failed vision screenings or referred by parents and/or teachers for likely visual problems which makes our sample not a truly random sample. The myopia literature-based prevalence studies, though located in specific areas around the world, provided a more random sample of subjects.

4.1.1.b Hyperopia Prevalence

Only 7.7% of the students at the OneSight Vision Center were hyperopic. This is lower than the included studies in our literature search. Czepita had results that showed that 13.2% of 6-18 year old children in Poland were hyperopic, which was significantly higher than our prevalence (X², p<0.00001) (Czepita, 2007). One reason that our prevalence is lower is that we defined hyperopia as +2.00 D SE or greater and Czepita defined hyperopia as +1.00 D SE or greater. The next two studies had the same hyperopia definition as our study but still had higher prevalence of hyperopia in their subjects. The study performed by Ip did show that hyperopia rates decrease with age (13.2% for 6 year olds and 5% of 12 year olds) (Ip, 2008). Though our study did not look at prevalence of hyperopia comparing 6 and 12 year olds specifically, the prevalence of hyperopia for the
overall OneSight Vision Center clinic population is significantly lower compared to the 6 year olds and significantly higher than 12 years olds from Ip’s study \((X^2, p<0.00001)\). This may be explained because it is shown that hyperopia decreases with age and our average age of the OneSight Vision Center clinic population was \(10.0 \pm 3.5\) years, which is between 6 and 12 years old. Therefore since hyperopia decreases with age, it makes sense that our clinic’s prevalence of hyperopia would be lower than the 6 year olds, but higher than the 12 year old from Ip’s study. The MEPEDS study had hyperopia rates ranging from 13.5-25.7% depending on race (Wen, 2013). Race was not indicated on the examination records from the OneSight Vision Center, so we cannot control for race when comparing the prevalence of hyperopia. However, our prevalence of hyperopia was significantly lower when compared to Wen’s range of hyperopia prevalence \((X^2, p<0.00001)\), which may be due to low amount of diversity in urban Cincinnati.

4.1.1c Astigmatism Prevalence

Our literature search included a study of children in Iran that estimated astigmatism prevalence of 13.5% (Fotouhi, 2011). Using the same definition of astigmatism, we found that 36.9% of children had more than -0.75 DC of astigmatism in the final prescription of the right eye, which was significantly higher than Fotouhi’s study \((X^2, p<0.00001)\). As noted before, perhaps the patients in the clinic population were self-selected, so the prevalence of astigmatism was artificially increased because these patients were more likely to require an eye examination. Also Fotouhi’s study consisted of subjects located in Iran, which is demographically different from Cincinnati, Ohio.
Another study by Wang included a large population and reported 13.3% prevalence of astigmatism, which again is significantly lower than our results ($X^2$, $p<0.00001$) (Wang, 2014). Wang’s study evaluated the prevalence of astigmatism among ethnicities, which we are not able to compare since race was not indicated in the examination records from OneSight Vision Center. Another reason that the prevalence of astigmatism may differ between studies is the effect of astigmatism axis, which was not specified in our data nor Fotouhi or Wang’s studies. ATR or oblique astigmatism axis may cause more visual distortion than WTR and would more likely cause visual symptoms enough to warrant a referral to the OneSight Vision Center for the students in Cincinnati. Perhaps the subjects in the literature-based studies had more WTR astigmatism axis.

4.1.2 Binocular Vision

Since we have established that binocular vision conditions can influence a child’s academic performance, it’s important to know how the prevalence of binocular vision problems compares between our clinic population and population-based samples in the literature.

4.1.2a Phoria Prevalence

The Orinda Longitudinal Study of Myopia (OLSM) found that most children are orthophoric at distance. The OLSM also reported at near, 31.8% were exophoric and 6.7% were esophoric. The OLSM found that children become relatively more esophoric with age. In our sample, 95.7% of the patients were orthophoric at distance, compared to
95.6% of the subjects in OLSM ($X^2$, $p=0.85$) (Walline, 1998). At near, only 6.8% of the OneSight Vision Center students were exophoric and 0.8% were esophoric. The prevalence of near cover test results in our sample may have been significantly lower ($X^2$, $p<0.00001$) than the OLSM because measurements of near phorias tend to be more variable. Slight changes in one’s accommodative or convergence will affect the outcome of the phoria measurement. The measurements conducted at the OneSight Vision Center were performed by different doctors therefore that introduces additional variability. It is also unknown if the near cover test was measured before or after obtaining an accurate prescription. Since it was shown that the majority of the students at the OneSight Vision Center needed updated spectacle correction, their accommodation through their habitual visual correction if any would not be accurate and therefore the near phoria measurement would not be accurate. If a student was under-accommodating, the exophoria would appear more exophoric and increase the prevalence of exophoria in the sample. Esophoria prevalence would increase if the student is over-minused in their correction and is forced to increase their accommodation to keep the target clear. This is why it is important to use a consistent accommodative target and measure through the correct refractive error to ensure accurate near cover test results.

4.1.2b Strabismus Prevalence

Approximately 2.7% of the overall OneSight Vision Center clinic population had strabismus at near. The magnitude of strabismus ranged from about $5^\Delta$ to $44^\Delta$ in each type of strabismus. The Baltimore Pediatric Eye Disease Study found 3.3% of Whites and
2.1% of African Americans had strabismus at near (Friedman, 2009). These rates are not significantly lower or higher than our population when comparing either ethnicity ($X^2$, $p=0.15$, $p=0.24$ respectively). Another study by Cherfan reported 1.9% of their subjects had strabismus which included children under the age of 19 years old ($X^2$, $p=0.33$). Their study looked at the different types of strabismus, which was not indicated in our eye examination records from the OneSight Vision Center (Cherfan, 2014). Another study in Japan showed that 1.28% of their large sample size had strabismus, which again was not significantly lower than our population ($X^2$, $p>0.05$) (Matsuo, 2005). However, as mentioned with the phorias, the importance of keeping accommodation and convergence stable when measuring near cover test can eliminate variability in results and since examination measurements were performed by different doctors, it is unknown if these factors were consistent among the students. Also, previous strabismus surgery can affect the prevalence of strabismus in a sample. However, since the vision examination received at the OneSight Vision Center was the first eye examination for many of the Cincinnati children, it is unlikely that they had previous strabismus detection and correction. This is the same for previous hyperopic correction that can correct for esotropia. It is unlikely that this component masked our strabismus prevalence since many children entered the exam not wearing visual correction. The main reason that there is no difference in the prevalence rates of strabismus among our population and the literature-based samples is most likely due to demographic and genetic variables.
4.1.2c Vergence Dysfunction Prevalence

Less than 1% of the overall OneSight Vision Center clinic population had CI and no students had CE. One difficulty in comparing the clinic’s vergence dysfunction prevalence to the evidence seen in numerous literature-based studies is that in the research, the studies divided convergence insufficiency into different categories based on the severity of the CI and these categories of CI were not recorded on the examination records from the OneSight Vision Center and therefore not able to be examined. Rouse and Borsting’s study reported 21.4% of the subjects had CI (Rouse, 1999). Letourneau found 8.3% of his subjects had CI (Letourneau, 1988) and Jang found 10.3% with CI and 1.9% with CE (Jang, 2015). A study in South Africa found 17.6% of subjects had CI and 3.2% had CE (Wajuihian, 2016). All studies found a significantly higher prevalence of CI than our population at the OneSight Vision Center ($X^2$, all $p<0.00001$). Our prevalence of CI and CE are lower than the literature-based studies, because of most likely the definitions of these vergence dysfunctions. Letourneau’s first study only included NPC results and his later study then included NPC and near cover test results. Rouse’s study used the most supportable clinical cutoff values for CI definitions for NPC, cover test results, and vergence ranges. It is unknown what the examiners at the OneSight Vison Center used as their definition of CI, specifically the amount of receded NPC, exophoria at distance versus near, and if the CISS survey was used to evaluate CI symptoms. The OneSight Vision Center optometrists may have used a more conservative definition for vergence dysfunctions; therefore the prevalence rate of these dysfunctions were lower than the literature-based studies.
4.1.2d Accommodative Dysfunction Prevalence

The students examined at the OneSight Vision Center had AI 3% of the time and accommodative excess 0.2% of the time. Jang’s study from South Korea had 5.3% students with AI and 1.2% with AE (Jang, 2015). This study had significantly higher prevalence of AI and AE than our population ($X^2$, p=0.007, p=0.0008 respectively). Wajuihian’s study in South Africa did not have any children with AE but found 1.6% with AI which was not significantly lower than our population ($X^2$, p=0.49) most likely to due to the small sample size of only 65 subjects of Wajuihian’s study (Wajuihian, 2016). Lastly, Marran’s study showed that 8.2% had AI, which was higher than our population ($X^2$, p<0.0001) (Marran, 2006). The differences in prevalence of AI may be due to the same issues found with vergence dysfunctions and that is the fact that these dysfunctions all rely on criteria definitions and these definitions may differ among studies and different examiners. On the examination records given by the OneSight Vision Center, Positive Relative Accommodation (PRA) was the only measurement of accommodation recorded. AI and AE definitions often include amplitude of accommodation, accommodative facility through plus and minus lenses and MEM measurements, which were not performed consistently on the OneSight Vision Center clinic population. Having a more standardized definition of these disorders would allow better comparison of prevalence between studies.
4.2 Oyler School Students from the OneSight Vision Center Clinic Population

We just compared the prevalence rates of refractive error and binocular vision disorders in the overall OneSight Vision Center clinic population to studies found in the literature. Now we can compare the literature specifically to the children that attend Oyler School. Even though it’s a smaller sample size compared to the other population, Oyler School is located directly in the lowest socioeconomic area of Cincinnati and these children have specific demographics compared to the overall population. Therefore, these children have a more specific and more of an array of demographics compared to the overall population which includes children from all over Cincinnati and different neighborhoods. For 23% of the Oyler children, this was their first eye examination.

4.2.1 Refractive Error Prevalence

4.2.1a Myopia Prevalence

Approximately 22.4% of the Oyler students were myopic compared to 36.5% of the overall OneSight Vision Center clinic population, which is significantly lower ($X^2$, p<0.00001). Oyler School students’ myopia prevalence is also significantly lower than the literature-based studies ($X^2$, p<0.0001), which is unlike the overall OneSight Vision Center clinic population which showed no significantly difference when compared to the literature for the majority of the studies. One trend in myopia seen is that prevalence of myopia increases with age. However, this cannot explain the difference seen in the Oyler School students compared to the literature, because the average age of the Oyler School students was 10.5 ± 4.0 years, which is higher than the overall OneSight Vision Center
clinic population of 9.9 ± 3.5 years. Most of the literature-based studies choose subjects that start around the age of 12 to 15 years old and range into adulthood. The difference seen in prevalence may be due to the fact that myopia prevalence is known to be higher in Asian countries and both Fan and Zhao’s study took place in Asia which is a different demographic area than Cincinnati and underlying risk factors may differ between the subjects included in the studies.

4.2.1b Hyperopia Prevalence

The rate of hyperopia among the Oyler School students is the same as the overall population at 8.1%, which is not a significant comparison ($X^2$, $p=0.99$). Therefore as already mentioned in the previous discussion on hyperopia prevalence, this rate of hyperopia is less than what is seen in the past literature-based studies. Czepita’s study in Poland found 13.2% prevalence of hyperopia among his subjects ($p<0.002$), Ip’s study reported 13.2% prevalence of hyperopia for 6 year olds ($p=0.003$) and 5% for 12 year olds ($p=0.008$), and Wen reported 13.5% to 25.7% prevalence of hyperopia depending on race ($p=0.001$ to $p<0.00001$). As mentioned before, the definition of hyperopia varied among our research and Czepita’s study which had a lower definition of hyperopia of $+1.00$ D SE; thus allowing more subjects to fall into the category of hyperopia. As also mentioned previously, it can be explained that the Oyler School students prevalence of hyperopia falls in the middle of Ip’s subjects of 6 and 12 year olds since as age increases, hyperopia decreases and the average age of the Oyler School students was 10.5 ± 4.0 years which falls in the middle of Ip’s age range of subjects. Wen’s study compared
prevalence between different races, which we are not able to do so since race was not indicated on examination records from the OneSight Vision Center.

4.2.1c Astigmatism Prevalence

The rate of astigmatism among the Oyler children was 21.5% which is lower than the overall population which had 37.6% astigmats ($X^2$, $p<0.00001$). Even though the Oyler School students had less astigmatism than overall, it is still higher than the literature search which included a study that resulted in a 13.5% prevalence of astigmatism by Fotouhi ($X^2$, $p<0.00001$) (Fotouhi, 2011) and a study that reported 13.3% prevalence of astigmatism by Wang ($X^2$, $p<0.00001$) (Wang, 2014). Our higher amounts of astigmatism may be due to underlying risk factors and genetics in our population of Oyler School students. Also the axis of astigmatism is a big contributor. Perhaps the Oyler School students have more ATR or oblique astigmatism axis which would cause more visual distortion than WTR and would more likely cause visual symptoms enough to warrant a referral to the OneSight Vision Center. Perhaps the subjects in the literature-based studies had more WTR astigmatism axis and ATR is known to increase as age increases; hence our population average age may be higher than the literature-based studies.
4.2.2 Binocular Vision

4.2.2a Phoria Prevalence

Just as the overall OneSight Vision Center population, the Oyler School students’ results for distance cover test show that the majority of students are orthophoria at distance which this result is also seen in the OLSM ($X^2$, $p=0.73$). For near cover test results, there were 6.5% of the Oyler School students that were exophoric at near and 1.2% that were esophoric at near. This is a much lower prevalence than reported by OLSM which had 31.8% exophoria and 6.7% esophoria ($X^2$, $p<0.00001$) (Walline, 1998). As mentioned previously, if a non-accommodative target was used for near cover test measurements, then the amount of accommodative and convergence fusion will not be accurate and can affect the amount of phoria measured. Additionally, for accommodation to be accurate, a patient must be looking through the correct visual prescription. If the student was undercorrected, which is most likely the case for many of these students, they may be under-accommodating or over-accommodating causing the exophoria or esophoria to decrease.

4.2.2b Strabismus Prevalence

The rates of esotropia and exotropia among the Oyler School students were 1.2% each, which is not significantly different from the overall OneSight Vision Center clinic population of 1.3% for each strabismus type ($X^2$, $p=0.90$). The Baltimore Pediatric Eye Disease Study found 3.3% of Whites and 2.1% of African Americans had strabismus at near (Friedman, 2009). These rates are not significantly different than our population for
either ethnicity ($X^2$, $p=0.36$, $p=0.59$ respectively). Another study by Cherfan reported 1.9% of their subjects had strabismus which included children under the age of 19 ($X^2$, $p=0.52$). Their study looked at the different types of strabismus, which was not indicated in our eye examination records from the OneSight Vision Center (Cherfan, 2014). Another study in Japan showed that 1.28% of their large sample size had strabismus, which again was not statistically different than our population ($X^2$, $p>0.05$) (Matsuo, 2005). However, as mentioned with the phorias, the importance of keeping accommodation and convergence stable when measuring near cover test can eliminate variability in results and since examination measurements were performed by different doctors, it is unknown if these factors were consistent among the students. Also, previous strabismus surgery can affect the prevalence of strabismus in a sample. Since the vision examination received at the OneSight Vision Center was the first eye examination for 23% of the Oyler School students, it is unlikely that they had previous strabismus detection and correction. In addition, this concept is the same for the chance of having previous hyperopic correction that can correct for esotropia. It is unlikely that this component masked our strabismus prevalence since 89.6% of the Oyler School students entered the exam not wearing visual correction. The main reason for differences in the prevalence rates of strabismus among our population and the literature-based samples is most likely due to demographic and genetic variables.
4.2.2c Vergence Dysfunction Prevalence

The prevalence of vergence dysfunction was not significantly lower among the Oyler School students compared to the overall OneSight Vision Center population ($X^2$, $p=0.44$). Only 0.5% of the Oyler School students had CI and no Oyler School students had CE. As mentioned before, one difficulty in comparing the OneSight Vision Center’s vergence dysfunction prevalence to the evidence seen in numerous studies is that in the research, the studies divided convergence insufficiency into different categories based on the severity of the CI and these categories of CI were not recorded and therefore not able to be examined. Rouse and Borsting’s study reported 21.4% of the subjects had CI (Rouse, 1999), Letourneau found 8.3% of his subjects had CI (Letourneau, 1988), and Jang found 10.3% with CI and 1.9% with CE (Jang, 2015). A study in South Africa found 17.6% of subjects had CI and 3.2% had CE (Wajuihian, 2016). All studies found a significantly higher prevalence of CI than our population of Oyler School students ($X^2$, $p<0.00001$). Our prevalence of CI and CE are lower than the literature-based studies, because of most likely the definitions of these vergence dysfunctions. As mentioned previously, Letourneau’s first study only included NPC results and then his later study included NPC and near cover test results. Rouse’s study used the most supportable clinical cutoff values for CI definitions for NPC, cover test results, and vergence ranges. It is unknown what the examiners at the OneSight Vison Center used as their definition of CI, specifically the amount of receded NPC, exotropia at distance versus near, and if the CISS survey was used to evaluate CI symptoms. The OneSight Vision center doctors
may have used a more conservative definition for vergence dysfunctions; therefore the prevalence rate of these dysfunctions were lower than the literature-based studies.

4.2.2d Accommodative Dysfunction Prevalence

The prevalence of accommodative dysfunction was not significantly different between the Oyler School students and the overall OneSight Vision Center clinic population. The Oyler School students had 3.6% with AI and 0% with AE. Jang’s study from South Korea had 5.3% students with AI and 1.2% with AE (Jang, 2015). Unlike the overall OneSight Vision Center which had significantly lower prevalence of AI than Jang’s study, the Oyler School students did not have a significantly lower prevalence of AI than Jang’s study ($X^2$, $p=0.21$). Wajuihian’s study in South Africa did not have any children with AE but found 1.6% with AI which was not significantly different than our population ($X^2$, $p=0.38$) most likely to due to the small sample size of only 65 subjects in Wajuihian’s study (Wajuihian, 2016). Having a higher prevalence rate of a condition is less likely when the sample size is small. Lastly, Marran’s study showed that 8.2% had AI, which was higher than our population ($X^2$, $p<0.006$) (Marran, 2006). The differences in prevalence of AI may be due to the same issue found with vergence dysfunctions and that is the fact that these dysfunctions all rely on criteria definitions and these definitions may differ among studies and different doctors. On the examination records given by the OneSight Vision Center, PRA was the only measurement of accommodation recorded. AI and AE definitions often include amplitude of accommodation, accommodative facility through plus and minus lenses and MEM measurements, which were not performed.
consistently on the OneSight Vision Center clinic population. Having a more standardized definition of these disorders would allow better comparison of prevalence between studies.

4.3 Compliance Rates of Spectacle Wear

When evaluating compliance rates of spectacle wear, we used only Oyler students and saw if the students who were prescribed glasses during the 2012-2013 academic year, were wearing their glasses when they returned to their annual examination the following year. Out of the 256 students who received glasses, 114 (44.5%) returned the following year for an annual vision examination. Out of these, only 28.9% wore their glasses.

Kimel’s study reported that the major contributors to non-compliance with follow-up examinations are finances, scheduling problems, family issues, and poor parental education on the importance of eye care (Kimel, 2006). However, we could not interview the children who failed to return for their eye examination during the second year, so we were not able to assess reasons for non-compliance with follow-up examinations. However, Oyler School is located in the one of the lowest socioeconomic areas of Cincinnati, so it is likely that similar factors would exist in our sample and therefore affect spectacle wear compliance.

Oyler School student spectacle wear compliance was not significantly associated with Gogate’s study which reported 29.5% of students wore their glasses to the second examination ($X^2$, p=0.90). The 28.9% spectacle compliance wear of the Oyler School students was significantly higher than Castanon’s study in Mexico which reported a
13.4% compliance rate ($X^2$, $p=0.00005$). Out of the non-compliant children in Gogate’s study, 29.4% reported no longer having their glasses at all, while 87.7% of the Oyler students claimed that their glasses were broken or lost. His results also showed that compliance was better among students with higher refractive error and females. Our results also showed that students with higher refractive error were more likely to be compliant, but we found no significant difference between gender (Gogate, 2013). Castanon’s study found that compliant children tended to be significantly younger, but our study found that compliant children were older (Castanon, 2006). Younger children generally don’t understand the importance of wearing their spectacle correction, because they don’t foresee that poor vision can hinder their ability to perform successfully in school. Perhaps the reason that the younger children in Castanon’s study were more compliant with spectacle wear is because they had parents that wore glasses and were more likely to reinforce the importance of spectacle wear. Also the level of parent education and the household that a child grows up in can affect a child’s knowledge of proper medical care for themselves. OneSight Vision Center is located in the lowest socioeconomic area in Cincinnati where parent education on importance of comprehensive medical care including dental and vision care is low. Horwood’s study in the UK showed better compliance rates than previously mentioned studies. His study reported 79.5% compliance with spectacle wear and friends’ opinions on glasses had the most effect on spectacle wear which is significantly higher than the Oyler School students ($X^2$, $p<0.00001$) (Horwood, 2005). Perhaps certain countries such as the UK have better perspectives on glasses wear and fashion. Another reason that their study
presented with a higher rate of spectacle wear compliance is because they evaluated compliance of spectacle wear only six weeks after dispensing the glasses. They chose this time period because they felt that the first initial weeks of spectacle wear were the most crucial to form long lasting habits of spectacle wear. Compliance rate of spectacle wear for the Oyler School students were evaluated after an entire year of initially prescribing the glasses, which many circumstances can occur during that time such as losing or breaking the glasses, which was a common trait seen with the Oyler School students. The Oyler School has goals to try to combat non-compliance with spectacle wear by one day providing every child with two pairs of glasses. One pair of glasses will be maintained at the school so teachers can enforce compliance. Obviously this solution is costly and not possible in all situations.

4.4 Academic Performance

The average GPA of all Oyler School students who received a prescription showed an increase in GPA from 1.93 ± 1.05 the quarter before receiving spectacle to 2.07 ± 0.95 two quarters after receiving spectacles; however this increase was not statistically significant (p=0.17).

4.4.1 Myopes and Learning

Myopes saw an increase in their average GPA from 2.02 ± 1.09 before receiving a prescription to 2.10 ± 0.98 after receiving a prescription though not statistically significant (p=0.50). When looking at math, reading and writing individually, myopes
increased their GPA by 0.13 for both math and reading (p=0.39 and p=0.52 respectively), but decreased their writing GPA by 0.32 (p=0.19). Overall, myopes had a higher GPA than hyperopes and astigmats by 0.48 and 0.31, respectively, before receiving correction. That difference in GPA between students with myopia and students with hyperopia and between students with myopia and astigmatism narrowed after receiving vision correction to 0.19 and 0.26, respectively. Morgan and Rose reported that the areas with the highest prevalence of myopia were located in Asia and coincidentally these areas also had the highest educational performance. They concluded that myopes tend to have higher academic performance than patients with other refractive errors, which is the trend seen with the Oyler School students (Morgan, 2013). Saw also found that myopes were 2.5 more likely to be in the 75th percentile for academic performance (Saw, 2007) and Akrami reported myopes have significantly higher school academic scores than students with other refractive errors (Akrami, 2012). Our data also showed that the GPA of myopia children is higher than students with other refractive errors.

Myopes had the least amount of GPA increase after receiving spectacle correction, because these students tend to already be part of the high academic performers, plus myopia is harder to miss in vision screenings and also in the classroom. In the classroom, teachers can often spot nearsighted children, because these children are squinting to see the blackboard across the room. These children are more likely to already have been referred to an optometrist for an eye examination and already have the appropriate glasses, therefore these children should already be achieving their best academic performance unlimited by uncorrected refractive error. These children’s
amount of myopia can increase year to year and therefore an updated prescription can still cause a slight increase in GPA, but not as dramatic as if these children had never worn spectacles before.

4.4.2 Hyperopes and Learning

Students with hyperopia exhibited a greater increase after receiving spectacle correction than children with other refractive errors \( p=0.34 \). Before receiving an eye examination, hyperopes had a lower GPA than myopic and astigmatic students. Hyperopic students’ GPA increased in math and reading, with math showing the greatest increase of 0.89 \( p=0.12 \) followed by reading, which increased by 0.33 \( p=0.49 \). Just like the myopic students, the GPA of hyperopic students decreased by 0.09 for writing \( p=0.84 \). One possible reason that math increased more than reading is that with reading our visual system can tolerate a little more blur but still have comprehension of the text due to context clues of the sentence. However with math, precise visual clarity is important, because our visual system needs to analyze each number individually to be able to perform the correct calculation. Williams and his colleagues looked at NFER and SAT test scores and found that hyperopes with at least +1.25 D refractive error and especially those over +3.00 D scored worse than non-hyperopes on both standardized tests (Williams, 2005). Shankar et al reported that hyperopes perform worse on letter and word recognition \( p=0.049 \) and Van Rijn’s study found that if hyperopes receive the proper correction, they read 13% faster than uncorrected hyperopes \( p=0.012 \).
The Oyler School students saw more benefit from spectacle correction, because hyperopes are more likely to receive a spectacle correction for the first time because hyperopia can be more easily missed than myopia. For instance, hyperopia is often missed in vision screenings or in the classroom, because these children can accommodate for short periods of time to achieve clear vision when needed. However, when these children are forced to use their accommodation all day long with excessive nearwork in the classroom, that’s when headaches and eyestrain occur and can hinder a child’s academic performance. These children often don’t know that the symptoms that they are experiencing are not normal, so they do not know that they should tell their parents or teacher. Instead they start to avoid doing tasks that cause these symptoms for instance avoiding reading or doing their homework and may start to act out in class instead. These behaviors can be mistaken as being an intellectually disabled student and the child may be placed in special classes or labeled as ADHD. Therefore, children with hyperopia that are corrected for the time or are receiving an updated prescription can benefit the most from this correction which is seen in the GPA increase in the Oyler School students.

4.4.3 Astigmatism and Learning

Our data included 28 students that were classified as astigmats, but only nine students had only astigmatism. The remaining 19 students had astigmatism with myopia or hyperopia. Just as students with myopia or hyperopia, students with astigmatism also increased their GPA after receiving spectacle correction, this time by 0.12 points (p=0.45). Wills reported that reading speed was reduced in those with induced against-
the-rule astigmatism and both orientations of astigmatism slowed reading speed for patients with high astigmatism (Wills, 2012). However, the astigmatism was induced in subjects that normally didn’t have astigmatism. Though uncorrected astigmatism can definitely affect academic work, children who have been living with uncorrected astigmatism may more easily adapt rather than subjects experiencing induced visual distortion for the first time. This idea can explain why astigmats didn’t benefit as much as hyperopes after receiving spectacle correction. Additionally, the axis of astigmatism can also affect the amount of visual distortion. One improvement in our research study is that we could divide the astigmatism students by with-the-rule astigmatism, against-the-rule astigmatism or oblique axis to see which students benefited more from spectacle correction. It is presumed that against-the-rule and oblique would benefit more than with-the-rule astigmatism because with with-the-rule axis astigmatism, students can squint and adapt easier than the other types.

Another potential reason that astigmatism and other refractive errors may not have exhibited a statistically significant increase in GPA may have been that the text used in day-to-day school work, may have been larger and easier to see than the smaller text in the standardized tests used in various studies such as Will’s study on astigmatism and William’s study on hyperopia. Smaller text would be harder to differentiate and comprehend with visual distortion compared to larger text.

While none of these changes in GPA were statistically significant, it may be argued that a change in overall GPA from 1.54 to 1.91 just two quarters after receiving spectacle correction is meaningful. Unfortunately, large variability in GPA change and
small sample sizes resulted in poor power (generally less than 20%) to detect statistically significant changes in our samples.

4.5 IEP Students from the Overall OneSight Vision Center Clinic Population

IEP students are a special subgroup of students that tend to have a higher prevalence of vision disorders than non-IEP students.

Walline and Carder showed that IEP children have higher rates of myopia when compared to the literature-based population (9 of 13 studies). The IEP students examined at the OneSight Vision Center were 37.1% myopes which was not significantly higher than the 37.3% of the non-IEP students that were myopes. ($X^2$, $p=0.94$) Walline’s study reported that IEP students had more prevalence of hyperopia for 10 out of 13 studies. The IEP students examined at the OneSight Vision Center were 8.9% hyperopes which was not significantly higher than the 7.4% of the non-IEP students that were hyperopes ($X^2$, $p=0.27$). For astigmatism, Walline’s study reported that IEP students have higher prevalence of astigmatism compared to the literature-based studies for 6 out of 9 studies. The IEP students at the OneSight Vision Center were 39.7% astigmatic which again was not significantly higher than the 36.2% of non-IEP students with astigmatism ($X^2$, $p=0.16$) (Walline, 2012). Additionally, Walline’s study reported that IEP students had higher prevalence of strabismus compared to the literature-based studies for 6 out of 6 studies (Walline, 2012). When comparing the prevalence of strabismus at near with IEP students compared to the non-IEP students, the IEP students did have significantly higher prevalence of strabismus at near ($X^2$, $p<0.05$).
Although the ultimate goal of the clinic was to provide every student with an annual eye examination, The OneSight Vision Center at Oyler School is the only school based vision center for the entire CPS district. Because of this, students who had IEPs, failed vision screenings, or whose parents and/or teachers requested an eye examination were essentially the only students to receive eye examinations at the clinic. This enhanced the prevalence of vision anomalies in the children with and the children without IEPs, so this may explain why the prevalence rates of visual disorders in IEP students were not significantly different than students without IEPs.
Chapter 5: Conclusion

These data may serve as a catalyst to show the importance of comprehensive eye examinations for all children before they enter school. This early exposure to eye care is important because refractive error and various vision disorders of binocular vision are prevalent among children, especially these inner city children in the Cincinnati Public School District. Correction of these vision conditions can have a positive impact on academic performance especially for hyperopic children.

We also showed that these children are not compliant with spectacle wear, especially if they have low refractive error or are young. We must try to improve compliance with spectacle correction because glasses can only help with academic success if student wear them.

Unfortunately, our data should not be used to examine differences in vision conditions between IEP and non-IEP students. A previous study found that children with IEPs have significantly more vision anomalies than population-based samples, but in our sample, the IEP and non-IEP students had similar amounts of vision anomalies. We believe this is because the students without IEPs that were examined were referred because they failed vision screenings or because the teacher or parent requested the vision examination. This artificially inflated the number of people in the non-IEP group with vision anomalies, which is often the case in a clinic population.
In conclusion, children continue to need an advocate to show the public the importance of obtaining proper eye care to help them succeed in school and optometrists must continue to educate the world.
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