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Research Article

The Correlation between Accommodative Lag and Refractive Error in Minors Under 18

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Abstract

Background: This study evaluates the correlation between accommodative lag and refractive error in minors under the age of 18 in order to determine if the amount of refractive error and type of refractive error (myopia, hyperopia, astigmatism) play a role in the magnitude of accommodative lag.

Methods: The population sample consisted of minors under the age of 18 who are patients at the Ferris State University Eye Center at the Michigan College of Optometry. The data collected included a lag of accommodation via Nott Retinoscopy at 40 cm, objective (auto-refraction or retinoscopy) and subjective refractive error, patient age, gender, and parental consent for research.

Results: Myopic, emmetropic, and hyperopic children primarily had lags of accommodation that fell within the normal range. Hyperopes who did not have a normal lag of accommodation were more likely to have a higher lag of accommodation rather than a lead. Myopes however, had an equal tendency for a higher lag or lead of accommodation.

Conclusions: The majority of myopic, emmetropic, and hyperopic children all had accommodative lags that fell within the normal range of +0.50 to +0.75 diopters.

Introduction

Ocular accommodation is the means by which the refractive state of the eye is adjusted to bring a near image into focus on the retina [1]. An individual's accommodative response can be measured by a variety of different methods including amplitude of accommodation, facility of accommodation, and lag of accommodation. All three methods comprise a thorough evaluation of the strength, flexibility, and accuracy of the accommodative system. Accommodative lag is an error in the accuracy of the accommodative system, although the term "error" is often a misnomer since a certain amount of error is normal and beneficial. When the accommodative response is less than the demand this is considered the accommodative lag [2]. When the accommodative response is more than the demand this is considered a lead of accommodation [2]. Both lag of accommodation and lead of accommodation are inaccuracies of the focusing system and may be beneficial or detrimental to certain patient presentations depending on other visual factors [1]. This study focuses on the correlation between refractive error and accommodative lag in patients under the age of 18.

Many studies have demonstrated the association between a lag of accommodation and myopia progression [2-7]. Myopia progression often results from retinal blur or defocus [7,8]. Hyperopic defocus seen with a high accommodative lag may contribute to myopia progression in children [7,8]. Hyperopic defocus occurs when the conjugate image of the object falls behind the retina leading to retinal blur [4,7,8]. Retinal blur is a stimulus for eye growth resulting in axial elongation in order to clear the blur and place the conjugate image on the retina [4,7,8]. This elongation of the eye and increase in axial length, results in an increase in myopic refractive error [5,7,8]. The opposite is true for myopic defocus [8]. Myopic defocus is when the conjugate image of the object falls in front of the retina [8]. Myopic defocus inhibits eye growth and axial elongation [8]. Many studies have evaluated the effect of plus lenses in the form of a bifocal or progressive addition lens on axial length and myopic progression [4,5,7]. These studies have demonstrated that creating a myopic defocus by bringing the conjugate image in front of the retina limits axial elongation and myopia progression [4,7].

Accommodative lag is measured using dynamic retinoscopy [9]. Dynamic retinoscopy quantifies accommodative lag by determining the refractive state of an accommodating eye [9]. There are three commonly used methods used for determining the lag of accommodation: Nott Retinoscopy (NR), Monocular Estimation Method (MEM), and bell retinoscopy [9]. NR uses a fixed accommodative target at 40 cm with the accommodative lag determined by neutralizing the retinoscopic reflex by moving in front of or behind the fixed target [9]. "With-motion" of the retinoscopic reflex is noted if the vertical reflex matches the motion of the retinoscope. When "with-motion" is identified, movement behind the target will neutralize the reflex. This value is then recorded as a positive value also known as a lag of accommodation. An "against-motion" of the reflex is noted if the vertical streak was moving in the opposite direction as the movement of the retinoscope. Movement in front of the target toward the patient leads to a neutral reflex. This value is then recorded as a negative value, also known as an accommodative lead. The retinoscopic reflex is considered neutral or "0" when no with or against-motion is identified at the plane of the target.

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The purpose of this study was to identify any correlation refractive error (myopia, emmetropia, and hyperopia) may have with the amount or direction of accommodative lag in minors under the age of 18.

Methods

The study population consisted of 28 minors between the ages of 3 and 18 who were patients at the University Eye center at the Michigan College of Optometry. Only one patient was 3 years old and one was 18 years old. The majority of patients were between 8 and 13 years old. Patients with strabismus, amblyopia, significant anisometropia, decreased visual acuities or ocular pathologies were excluded from the study. Parental consent was obtained from each minor and/or his or her parent or legal guardian. The data collected included a lag of accommodation via Nott retinoscopy at 40 cm, objective (auto-refraction or retinoscopy) and subjective refractive error, patient age, gender, and parental consent for research. Nott retinoscopy was chosen as the objective accommodative measure because it is a part of the routine clinical battery performed by students, residents and faculty at the University Eye Center and did not significantly interfere with examination efficiency. Accommodation measurements were acquired after refractive assessment to ensure they were taken through optimal correction. However assessment of latent hyperopia using cycoloplegia was not included since this particular study is meant to simulate the normal accommodative state of the children. The data was collected by optometry students, residents, and attending optometrists. Data was analyzed and graphed using Microsoft Excel™. The procedures are described in further detail in Appendix A.

Each eye was treated as an independent sample since accommodative lag is known to commonly vary between eyes of the same patient. Lag of accommodation was categorized as follows: Lead of accommodation (L) for lags -0.50 D to +0.25 D, Normal (N) for lags +0.50 D to +0.75 D, and High Lag of accommodation (HL) for lags +1.00 D to +1.50 D. Refractive error was categorized as follows: Myopic (M) if SE refractive error was < 0 D, Emmetropic (E) if SE was 0 D, and Hyperopic (H) if SE was > 0 D. For purposes of abbreviation, probability is represented as P.

Results

Nott retinoscopy was obtained on 28 minors ranging in age from 3 to 18, however seventy-five percent of patients were between 8 and 13 years old. A total of 15 males and 13 females participated. The mean age was 10.08 years old (SD 3.40). After calculating Spherical Equivalent (SE) it was determined that 25 eyes were myopic, 10 were emmetropic, and 21 were hyperopic. Mean spherical equivalent for the objective refractive error was -0.118 D (SD 1.43 D; range -3.75 D to +4.50 D). Mean SE for the subjective refractive error was -0.37 D (SD 1.11 D; range, -3.50 D to +1.75 D) for the 23 participants able to complete the testing procedures. Five participants of the total 28, all 7 years old or younger, were not included in the subjective refractive error due to unreliability. For those five participants the lag of accommodation was correlated with the objective refractive error. Three eyes had against-the-rule astigmatism (ATR), one eye had oblique astigmatism, and the remaining 52 eyes had with-the-rule astigmatism. Only one of the 28 participants had autorefraction performed in lieu of retinoscopy.

The mean lag of accommodation was +0.64 D (SD 0.46 D; range, -0.50 D to +1.50 D). Scatter plot of the accommodative lag and age demonstrate a possible correlation with higher lags of accommodation and older individuals; however no statistically significant difference was found (Figure 1).

Accommodative lag was shown to vary with SE refractive error. Those with mild to moderate SE refractive errors tended to have a higher lag of accommodation (Figure 2). However, there was no statistical significance. Twenty percent of the participants had a lead of accommodation, 57% had a normal lag of accommodation, and 23% had a high lag of accommodation.

Forty-six percent of participants were myopic, 16% were emmetropic, and 38% were hyperopic. The type of refractive error and how it correlates with the lag of accommodation are demonstrated in Figures 3 and 4. It is apparent that the majority of myopes were found to have a normal amount of accommodative lag and hyperopes tended to have a greater frequency of normal and high lags as compared to leads of accommodation. The Probability (P) of an individual having a certain refractive error and type of accommodation were calculated using probability equations on Exel™. Results are depicted in Figure 5. Through analysis it was evident that there was a high probability for myopes to manifest a normal lag of accommodation

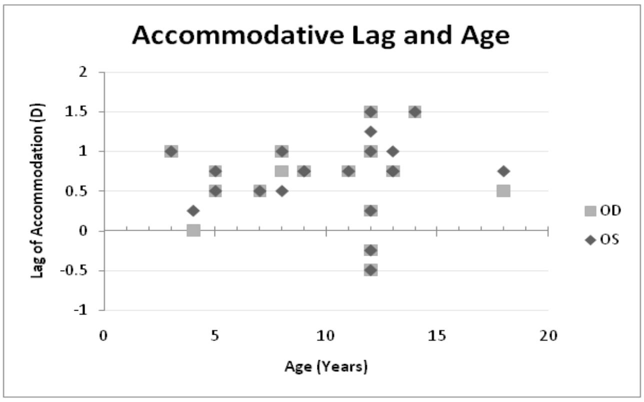

Figure 1: The lag of accommodation as it correlates with the age of the participant.

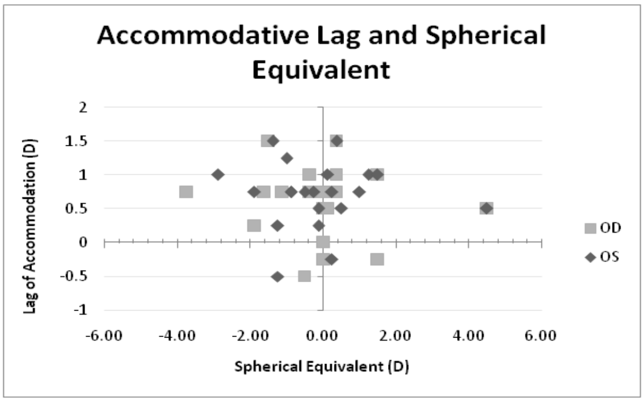

Figure 2: Lag of accommodation as it correlates with the spherical equivalent. Greater lags of accommodation can be seen with mild to moderate spherical equivalents, although the correlation is not statistically significant.

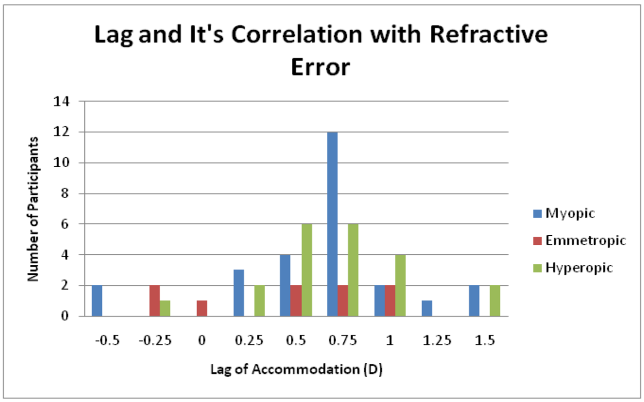

Figure 3: Depicts the number of participants with the type of refractive error (myopic, emmetropic, or hyperopic) compared to the amount accommodative lag. A greater number of participants showed a normal value of accommodative lag from +0.50 D to +0.75 D.

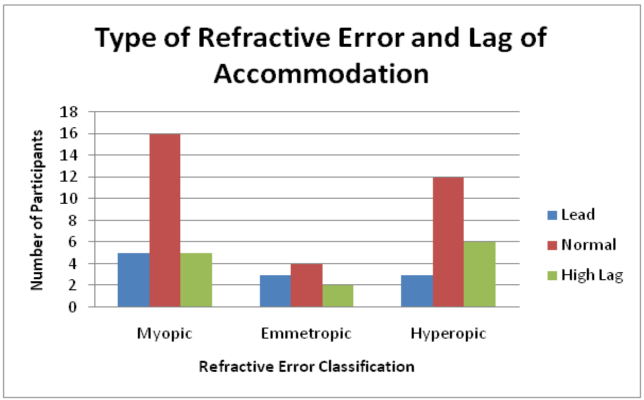

Figure 4: Depicts the type of refractive error with lead, normal, and high lags of accommodation. Each type of refractive error demonstrated a greater number of participants with normal lags of accommodation. Hyperopes who did not have normal lags were more likely to have a high lag of accommodation rather than a lead. Myopes however appeared to have an equal tendency for lead and high lags of accommodations. Emmetropes showed no statistical difference in having a lead or higher lag of accommodation.

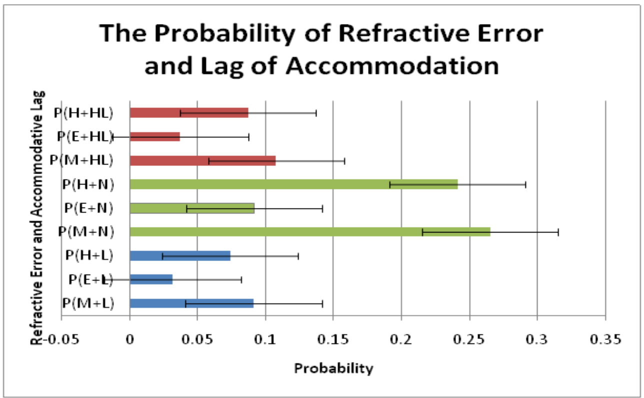

Figure 5: Graphical analysis of the probability (P) of having a type of refractive error and having a lead, high lag, or normal amount of accommodation. Hyperope (H), myope (M), emmetrope (E), high lag (HL), normal lag (N), and lead (L).

(P(M+N) = 0.2653) , and it was not as common to be an emmetrope and have a high lag of accommodation (P(E+HL) = 0.0373). Myopes, emmetropes, and hyperopes tended to have a normal lag of accommodation; however, the probability of having a high lag of accommodation and also being myopic (P(M+HL) = 0.1078) was significantly greater than having a high lag of accommodation and being an emmetrope (P(E+HL) = 0.0373) or hyperope (P(H+HL) = 0.0871) . According to analysis via Excel™ using error bars at a fixed probability value of 0.05, it is evident that the probabilities for being myopic or hyperopic and having a normal lag of accommodation are statistically significant.

Discussion

The purpose of this study was to uncover any correlation between accommodative lag and refractive error in minors under the age of 18. The primary finding is that the majority of myopic, emmetropic, and hyperopic children had accommodative lags that fell within the normal range of +0.50 to +0.75 diopters under non-cycloplegic or natural conditions. Of the 28 children included in the study 57% presented with accommodative lags within the previously mentioned normal range. Myopic children who had accommodative lags outside of the normal range were shown to have an equal tendency for a lead of accommodation or a lag of accommodation, while hyperopic children with an accommodative lag outside of the normal range had a tendency toward a lag of accommodation rather than a lead of accommodation.

The results of this study were inconsistent with a majority of studies comparing refractive error and accommodative lag. Many previous studies have focused primarily on myopic individuals and the link between myopia progression and accommodative lag. Studies have shown that myopic individuals tend to have a higher lag of accommodation, however our study demonstrated a tendency toward equal numbers of myopic patients with both leads and high lags of accommodation [6]. Our findings are consistent with a study preformed by Candy and colleagues in that individuals with high amounts of hyperopia demonstrate greater accommodative lags [10]. The difference between our study, and the study performed by Candy and colleagues, is the population age. In our study, older children were involved rather than a strictly infant population [10].

This study demonstrated the probability of a certain refractive error presenting with a high lag of accommodation. It was found that the probability of having a high accommodative lag and myopia (P=0.1078) and the probability of having a high accommodative lag and hyperopia (P=0.0871) were fairly similar. The probability of having a high accommodative lag and emmetropia (P=0.0373) was significantly lower than with both hyperopia and myopia. The higher probability of being myopic than emmetropic with a high accommodative lag was consistent with the findings of numerous other studies that have found a direct correlation between accommodative lag and myopia [2-7]. However, our study also showed a higher probability of myopia and a lead of accommodation than emmetropes.

Many studies have investigated the effect accommodative lag has on myopia progression in children [2-7]. There has been strong correlation with myopia progression and an increased accommodative lag [2-7]. Our study did not evaluate whether the participants' prescriptions had remained stable or if the myopic children included in the study were undergoing myopic progression. Myopic progression tends to slow as children become older [11]. Children included in our study may have already completed their myopic progression, thus showing a myopic sample with a more normalized accommodative lag than studies using primarily younger children.

There are many additional factors that need to be considered when evaluating the outcomes of this study. The study was conducted under binocular viewing conditions, thus adding the additional component of binocularity to the equation. The patient's ocular posture and further binocular vision testing were not included in this study. Ocular posture may play a role in the accommodative lag that is obtained. An esophoric posture may contribute to an increase in accommodative lag and thus result in myopia progression [6,12]. Patients with an esophoric posture must initiate divergence in order to maintain a single binocular image, consequently reducing the accommodative response [12]. This reduced accommodative response may result in the increased accommodative lag [12]. Exophoric individuals are the opposite and may result in a decreased lag of accommodation, or lead of accommodation, especially when the deviation is large [12]. Large exophoric deviations cause the eyes to converge when viewing a near object [12]. This increase in convergence results in a direct increase in accommodation, well beyond what is needed for the near stimulus [12].

The findings of this study may also be influenced by the efficacy and flexibility of the accommodative system. A full analysis of the accommodative system was not completed on the patients included in this study. Lags in accommodation may be influenced by a faulty accommodative system, such as accommodative insufficiency, fatigue, or infacility. To completely rule out a faulty accommodative system as a cause for the accommodative lag findings in the above study, further accommodative assessments or cycloplegic comparisons should be included.

An additional weakness of this study included a small sample size. The sample size estimated at the study outset was to be significantly larger. In addition to a small sample size, the sample size was from a generalized population area. Minimal history was obtained from each patient, such as the previous or habitual prescription, compliance with habitual prescription, and the above mentioned binocularity issues. There were also several individuals helping to collect data such as student doctors, residents, and attending doctors. Therefore there may be inconsistencies in the judgment of the retinoscopic reflex between the individuals or in the way in which subjective refraction is performed.

In conclusion, this study disagrees with previous studies that myopic refractive errors have a direct correlation only with an increased/high accommodative lag. However, caution should be exercised in interpretation of the results due to study limitations and small sample size. The study demonstrated that the majority of patients had accommodative lags that fell within the normal range of +0.50 and +0.75 diopters with refractive error not serving as a distinguishing factor. Myopic patients that had accommodative lags outside of the normal range had an equal tendency for having a lag or accommodation or a lead of accommodation.

In the future additional studies may want to focus on how the lag of accommodation correlates and impacts phoric posture, and evaluate what effect accommodative insufficiency and accommodative excess may have on the lag of accommodation and how it correlates with refractive error. It would also be interesting to study the lag of accommodation before and after correcting the refractive error with contacts and/or spectacles, then comparing the two methods of refractive error correction. Furthermore, it would be beneficial to repeat this study with a larger population to see if the results are consistent.

Appendix A

Description of Procedures

Nott retinoscopy

The patient was positioned behind the phoropter and asked to focus on a small target of Snellen letters or an Allen figure positioned at 40 cm from the patient. The examiner directed the retinoscope at the patient from 40 cm away next to the target. The retinoscopic reflex was observed with a vertical streak of light. Measurements were recorded based on the retinoscopic reflex observed as described in the background information.

Objective retinoscopy

The patient was positioned behind the phoropter and instructed to fixate on a line of letters at the end of the 12 ft room using a digital visual acuity chart. The refractive error was identified by the examiner in both eyes of the patient by using a retinoscope to evaluate the retinoscopic reflex 360 degrees at a distance of 50 cm from the patient. The refractive error was then recorded.

Subjective refraction

Using a digital chart, the patient was positioned behind the phoropter and instructed to fixate on a line of letters on a digital visual acuity chart at the end of the 12 ft long room under dim illumination. Those patients not able to be placed behind the phoropter received a loose lens refraction. The patients were provided different lens options in which they chose which lens made the image at the end of the room the most clear. The best corrected visual acuity was then recorded based on their preference in lens choices.

Auto-refraction – Nidek tonoref II™

The patient was instructed to sit behind the auto-refractor with his or her chin placed on the chin rest. The examiner then instructed the patient to fixate on the image presented on the auto-refractor screen. The examiner made proper machine alignments and the machine calculated the proper recordings. Measurements provided by the auto-refractor were recorded.

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