CASE SERIES

The Effects of Increased Near Point Stress on the Visual System of Pediatric Patients with Strabismus

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ABSTRACT

Background
Due to the COVID-19 pandemic, school closures resulted in children participating in remote learning and a subsequent increase in near demand associated with increased computer work. Prolonged near work has been shown to impact the visual system and possibly myopia progression. This case series shows the functional visual effects near point stress may have on pediatric patients with strabismus.

Case Reports
This case series includes 3 patients who reported an increase in computer work with the implementation of virtual learning. First, a 10-year-old female presented prior to the pandemic with a 16-prism diopter intermittent alternating exotropia (IAXT). Nine months later, the magnitude of her deviation increased to 30 prism diopters (PD), with reduced control. She demonstrated myopia progression in her non-dominant eye during this time. The second patient, a 6-year-old female, initially manifested a 25PD IAXT. In a 4-month timespan, the control of her strabismus significantly declined. She also demonstrated significant myopic progression in both eyes during this 4-month period. Finally, a 16-year-old female initially presented with a 20PD intermittent alternating esotropia (IAET). After 18 sessions of vision therapy and the use of fusional prism, she manifested a small esophoria and adequate compensating ranges. Eight months later, after virtual learning, her deviation worsened to a 25PD IAET through her prism glasses. None of the patients in this case series received active vision therapy between evaluations, though they did undergo vision therapy following the hiatus imposed by COVID-19.

Conclusion
These cases highlight how increased time spent on digital devices can impact the visual system. Increased digital device use results in increased near point stress, resulting in an activation of the autonomic stress response. Subsequently, there is poor coordination between the binocular and accommodative systems. The pandemic has emphasized the importance of proper visual hygiene, myopia control, and vision therapy to improve visual function.

BACKGROUND
Coronavirus disease (COVID-19) caused by the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) had its first reported case in the United States in January 2020. The response to the pandemic resulted in the implementation of non-pharmaceutical interventions including the prohibition of gatherings greater than 10 people and the closure of non-essential businesses, schools, bars, and restaurants. By March 2020, schools nationwide had closures and resorted to remote learning methods and lasted for up to a year. According to the Digital Eye Strain among Kids Study (DESK study-1), the average duration of
digital device use increased significantly during the implementation of online learning, as well as the number of children using digital devices for more than five hours per day.²

There was a dramatic increase in near point stress experienced by children during this time. According to Skeffington, the human visual system was not evolutionarily developed for the type or amount of near work that is required by modern society. Skeffington notes that during near work there is a mismatch between the accommodative and convergence responses. There is a high level of attention associated with the near tasks required by today’s society. This high level of attention comes with unique physiological and psychological demands that result in a stress response.³ For example, during extended periods of near work, an individual is required to suppress movement to ensure a constantly steady retinal image. The near work that individuals in today’s society partake in involves high intellectual demands as well. More attention is also required during these near tasks due to poor multisensory reinforcement for the visual system associated with the two-dimensional targets on digital devices and paper.⁴ Birnbaum presents a physiological model to support Skeffington’s model of near point stress.⁵ The autonomic reflex and the activation of the sympathetic nervous system due to the physiological and psychological demands associated with near work result in a cycloplegic-like effect on the individual. With the sympathetic response reducing accommodation, there is overcompensation by the accommodative system to achieve a clear image. This increase in accommodation also leads to an increase in accommodative convergence, resulting in an esophoric posture. It has been theorized that several vision disorders are the result of adaptations to this accommodative and convergence mismatch.³ Some adaptations that may present as a result include high exophoria, convergence insufficiency, accommodative insufficiency, and strabismus. These adaptations are likely the result of the visual system overcompensating for the initial esophoric posture and overaccommodation, leading to esophoric posture and accommodative insufficiency. Symptoms are elicited in individuals whose adaptations are ineffective.

The effects of near point stress became more prevalent with the implementation of online learning during the COVID-19 pandemic. This case series will specifically look at the effects of increased near point stress during remote learning on three pediatric patients with strabismus. The control of an intermittent exotropia in the following cases will be quantified using the office-based scale developed by the Mayo Clinic.⁶ This scale ranges from zero to five. A score of 5 indicates a constant exotropia. A score of 4 indicates the presence of an exotropia prior to dissociation for greater than 50% of the exam, while 3 indicates the presence of an exotropia prior to dissociation for less than 50% of the exam. A control score of 2 indicates the need for dissociation to elicit the exotropia and recovery is noted in greater than five seconds, while a control score of 1 indicates the need for dissociation to elicit the exotropia and recovery occurs in one to five seconds. Finally, a control score of 0 indicates the need for dissociation to elicit the exotropia, with a recovery in less than one second.

CASE REPORTS

Case 1

A 10-year-old Black female presented to the University Eye Center at the SUNY College of Optometry with a history of intermittent alternating exotropia and bilateral reduced vision, likely of psychogenic origin secondary to anxiety. The patient complained of intermittent diplopia at distance more than near and the mother reported an intermittent outward eye turn.

The best corrected visual acuities at the initial evaluation prior to remote learning were 20/25 in both the right and left eyes, with a refractive error of low simple myopia. The cover test revealed a 16-prism diopter intermittent alternating exotropia at distance with strong left eye fixation and a control score of 3. Her near cover test revealed a 16-prism diopter exophoria. On random dot stereopsis testing, the patient was able to appreciate 250 seconds
of arc. Upon assessing stereoacuity with Wirt circles, the patient appreciated 40 seconds of arc. The patient’s fusional vergence ranges revealed a reduced convergence break and recovery at both distance and near, with adequate fusional divergence ranges. Accommodative amplitudes were 5.75 diopters in the right eye and 6.75 diopters in the left eye, measured with the minus lens method. The patient was also found to have reduced but balanced negative and positive relative accommodation. Vision therapy was recommended at this time, but the patient was unable to initiate therapy due to quarantine measures enacted during the COVID-19 pandemic.

After restrictions were lifted, 10 months later, the patient presented to the clinic again to begin vision therapy. She reported intermittent distance vision blur and intermittent distance diplopia. Her mother also noted an increased magnitude and frequency of the outward eye turn. Due to the implementation of online learning during the COVID-19 pandemic, there was a significant increase in digital device use and near work. Although the exact number of hours of increased device use was unable to be determined by the patient, they did report participating in fully remote learning. This would indicate at least five hours per school day of additional digital device use. A re-evaluation was performed, which revealed 1 diopter of myopic progression in the right eye only and no progression in the left eye. Cycloplegic refraction confirmed the unilateral myopic progression. The best corrected visual acuities were 20/20 in both the right and left eyes. The cover test revealed a divergence excess-type intermittent alternating exotropia. At distance, the magnitude was 40 prism diopters with a control score of 4 and a left eye fixation preference. At near, the magnitude was 20 prism diopters with a control score of 3 and a right eye fixation preference. The patient was still able to appreciate 250 seconds of arc on random dot stereopsis testing, but a reduced stereoacuity of 70 seconds of arc on Wirt Circles. Stereoacuity was re-assessed with the updated refractive correction, and the patient was able to achieve 20 seconds of arc on Wirt Circles. While fusional divergence ranges were still adequate, the patient’s fusional convergence range at distance had improved and at near was more reduced. Minus lens testing for amplitudes of accommodation revealed improved, but still reduced amplitudes of 8.75 diopters in the right eye and 9.25 diopters in the left eye. Negative relative accommodation and positive relative accommodation were now adequate and balanced. Due to the development of a larger magnitude and more poorly controlled divergence excess-type intermittent exotropia from a basic-type intermittent exotropia, vision therapy was recommended to improve control of the exotropia. Additionally, due to the unilateral myopic progression, a first-time spectacle prescription was released at this visit and a myopia control consultation was recommended.

Table 1: Pertinent examination findings in Case 1 before and after virtual learning

<table>
<thead>
<tr>
<th>Pertinent Findings</th>
<th>Initial Evaluation</th>
<th>10 months later</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refraction</td>
<td>OD: -0.25sph, VA 20/25 OS: -0.25sph, VA 20/25-</td>
<td>OD: -1.00sph, VA 20/20* OS: plano, VA 20/20* *Confirmed with cycloplegia</td>
</tr>
<tr>
<td>Cover Test</td>
<td>Distance sc: 16PD IAXT, Control Score (CS) 3, strong OS fixation Near sc: 16PD XP</td>
<td>Distance cc and sc: 40PD IAXT, CS4, OS fixation preference Near cc and sc: 20PD ILXT, CS3, OD fixation preference</td>
</tr>
<tr>
<td>Stereopsis</td>
<td>RDS: 250” Wirt Circles: 40”</td>
<td>RDS: 250” Wirt Circles: 70”, improved to 20” with updated refraction</td>
</tr>
<tr>
<td>Vergence Ranges</td>
<td>Distance BO: X/10/1 Distance Bl: X/28/18 Near BO: X/24/-4 Near Bl: X/30/18</td>
<td>Distance BO: 18/14/12 Distance Bl: X/20/18 Near BO: X/6/-4 Near Bl: X/25/20</td>
</tr>
<tr>
<td>Amplitude of (Minus Lens Method) Accommodation</td>
<td>OD: 5.75D OS: 6.75D</td>
<td>OD: 8.75D OS: 9.25D</td>
</tr>
<tr>
<td>NRA/PRA</td>
<td>+0.75/-0.50</td>
<td>+2.75/-2.50</td>
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Case 2
A 6-year-old Hispanic female was referred to the University Eye Center for a strabismus evaluation to determine if vision therapy was indicated. At the initial evaluation, the patient had already participated in roughly three months of remote learning due to the COVID-19 pandemic but was on summer break at the time. The patient had no refractive error in the right eye and mild mixed astigmatism in the left eye with best corrected visual acuities of 20/20 in both the right and left eyes. The cover test revealed a 25-prism diopter intermittent alternating exotropia at both distance and near. Accommodative near point of convergence was to the nose. The patient was able to appreciate 250 seconds of arc on random dot stereopsis testing and a stereoacuity of 140 seconds of arc on Wirt Circles. Versions and ductions were full and no muscle restrictions were noted. Vision therapy was recommended to improve control of the exotropia.

The patient presented 4 months later to begin vision therapy. The patient’s mother reported increased frequency and magnitude of the eye turn. In addition, the patient reported frequent diplopia. She also complained of severe blurred distance vision. She and her mother reported significantly increased near demands and digital device use due to returning to full school days of remote learning. Uncorrected visual acuities were 20/80 in the right eye and 20/50 in the left eye. Refraction revealed myopic progression of 2 diopters in the right eye and 1.5 diopters in the left eye with best corrected visual acuities of 20/20 in both the right and left eyes. Cycloplegic refraction confirmed the myopic progression. Upon cover test, the patient had a 25-prism diopter intermittent alternating exotropia at both distance and near. The patient demonstrated a control score of 3 at distance and 2 at near. Random dot stereopsis was stable at 250 seconds of arc, but stereoacuity had improved to 20 seconds of arc. A first-time glasses prescription was dispensed at this visit and vision therapy was recommended to address the signs and symptoms associated with the patient’s intermittent alternating exotropia. Due to the significant amount of myopic progression in 4 months, a myopia control consultation was also recommended.

Case 3
A 16-year-old Hispanic female initially presented with intermittent diplopia at distance and near. The patient manifested a concomitant 20 prism diopter intermittent alternating esotropia at both distance and near. There was no accommodative component noted. She had moderate compound myopic astigmatism in each eye. A prism trial was performed at this visit, and a minimum of 10 prism diopeters of base-out prism was required for fusion of a letter at both distance and near. Cover test through this trialed prism revealed a 2-prism diopter intermittent left esotropia at distance and 6 prism diopeters esophoria at near. She was given prism glasses with 5 prism diopeters of base-out prism in each eye and was recommended vision therapy. She completed 18 sessions of vision therapy before being forced to discontinue due to the implemented COVID-19 restrictions. At the last session before discontinuing therapy, cover test

<table>
<thead>
<tr>
<th>Pertinent Findings</th>
<th>Initial Evaluation</th>
<th>4 months later</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entering VA</td>
<td>OD sc: 20/25-1</td>
<td>OD sc: 20/80-</td>
</tr>
<tr>
<td></td>
<td>OS sc: 20/25-1</td>
<td>OS sc: 20/50-</td>
</tr>
<tr>
<td>Cover Test</td>
<td>Distance sc: 25PD</td>
<td>Distance sc: 25PD</td>
</tr>
<tr>
<td></td>
<td>IAXT, CS 3</td>
<td>CAXT, CS 2</td>
</tr>
<tr>
<td></td>
<td>Near sc: 25PD</td>
<td>Near sc: 10PD</td>
</tr>
<tr>
<td></td>
<td>IAXT, CS 3</td>
<td>IAXT, CS 2</td>
</tr>
<tr>
<td>Near point of</td>
<td>To the nose</td>
<td>1”/2”, (+)</td>
</tr>
<tr>
<td>convergence (NPC)</td>
<td></td>
<td>diplopia</td>
</tr>
<tr>
<td>Stereopsis</td>
<td>RDS: 250”</td>
<td>RDS: 250”</td>
</tr>
<tr>
<td></td>
<td>Wirt Circles: 140”</td>
<td>Wirt Circles: 20”</td>
</tr>
<tr>
<td>Refraction</td>
<td>OD: plano, VA 20/20</td>
<td>OD: -2.00sph, VA</td>
</tr>
<tr>
<td></td>
<td>OS: +0.25-0.25x086</td>
<td>20/20* OS: -1.50sph, VA</td>
</tr>
<tr>
<td></td>
<td>VA 20/20</td>
<td>20/20*</td>
</tr>
<tr>
<td></td>
<td>*Confirmed with</td>
<td></td>
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<tr>
<td></td>
<td>cycloplegia</td>
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</table>
elicited an 8-prism diopter esophoria at distance and a 16-prism diopter esophoria at near through the fusional prism. Throughout the course of therapy, she developed decent fusional abilities at near and intermediate spaces when assessed with Quoit vectograms, with the ability to achieve fusion at high values while still appreciating changes in size and depth. She denied diplopia and near vision asthenopia through the prism glasses.

Upon returning 8 months later to continue vision therapy, the patient reported intermittent diplopia and asthenopia through her prism glasses. During this time, the patient had been participating in full school days of online learning, resulting in an increased amount of near work and digital device use. Cover test revealed the previous esophoria had broken down to a 25-prism diopter intermittent alternating esotropia at both distance and near through her correction. No change in refractive error was noted at this time. Upon returning to the clinic, further vision therapy sessions, and a near addition were recommended.

**CONCLUSIONS**

All three cases reported participating in consistent full school days of remote learning, with a subsequent increase in magnitude and/or frequency of a previously diagnosed strabismus with reduced fusional ability. In Case 1 and Case 2, there was also significant myopic progression.

In Case 1, the development of a divergence excess from a basic type exotropia may be an adaptation to this increased near point stress. Although the magnitude of the strabismus in Case 2 is indicative of a basic exotropia, the better control at near compared to distance emulates a divergence excess type exotropia. Due to the common history of increased near point stress, it is likely due to a similar etiology as true divergence excess. This aligns with one theory presented by Flax on the etiology of divergence excess exotropia being related to near point stress. To resolve the esophoric posture associated with near point stress in Skeffington’s model, there is an inhibition of fusional vergence. This is then carried over into distance viewing, resulting in exotropia. Flax and Cooper have demonstrated two different methods for the treatment of divergence excess intermittent exotropia with vision therapy. Flax emphasizes achieving postural vergence for alignment rather than emphasizing the development of base out vergence ranges. According to Flax’s method for management, stereoscopic targets are utilized initially in therapy, followed by flat fusion and simultaneous perception targets. Reducing near point stress is a crucial part in managing these patients, as the etiology of divergence excess intermittent exotropia is thought to be associated with near point stress. Flax’s method for management of these patients includes monocular accommodative work and prescribing near addition lenses when indicated. Cooper’s model of vision therapy for divergence excess exotropia differs in that less emphasis is placed on reducing near point stress. His leading theory on the development of divergence excess is based on the “chameleon-like theory.” This theory states that when stereoscopic cues are given, alignment is more easily achieved for near tasks. However, with distance viewing, less stereoscopic cues are present and therefore utilization of panoramic viewing during misalignment provides the advantage of an expanded field of vision. In Cases 1 and 2, the development of a worsened divergence excess after increased near demands aligns more with the theory presented by Flax. In patients with a divergence excess- type intermittent exotropia who do not have success with vision therapy, other treatment modalities should be considered including surgical correction and fusional prism. Surgical correction was not recommended in these cases due to the intermittent nature of their turn. It should be noted

### Table 3: Pertinent examination findings in Case 3 before and after virtual learning

<table>
<thead>
<tr>
<th>Pertinent Findings</th>
<th>Last Therapy Session Pre-Pandemic</th>
<th>8 months later</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Glasses Prescription</td>
<td>OD: -1.25-0.75x180, 5.0 BO, VA 20/20 OS: -1.25-1.50x175, 5.0 BO, VA 20/25-2</td>
<td>OD: -1.25-0.75x180, 5.0 BO, VA 20/20 OS: -1.25-1.50x175, 5.0 BO, VA 20/25-2</td>
</tr>
<tr>
<td>Cover Test</td>
<td>Distance cc: 8PD EP Near cc: 16PD EP</td>
<td>Distance cc: 25PD IAET Near cc: 25PD IAET</td>
</tr>
</tbody>
</table>
that over-minus lens therapy was previously used as an additional treatment modality, using the lowest amount of minus that results in improved control of alignment. In a recent study, over-minus lens therapy was found to improve control of the patient’s exotropia at distance, but an inability to maintain control following weaning off, and an increased myopic shift.

It is also important to note that the patient presented in Case 1 had myopic progression in her right eye only. Based on fixation preference, this eye was the non-preferred eye for distance viewing and the preferred eye for near viewing. In a study by Phillips (2005), monovision correction in children resulted in slowed progression of the eye corrected for near. Phillips assessed accommodative response in both eyes and found them to be equal. Therefore, this lack of myopia progression was contributed to the consistent myopic defocus in the eye corrected for near. Our patient did not have monovision, but it is likely that her eye that was not fixating at near experienced less hyperopic defocus, and therefore was less likely to show myopia progression. In a study by Yang and Hwang (2011), however, it was revealed that an asymmetric accommodative response occurs in patients with exotropia even during binocular viewing, with the nondominant eye having a lower accommodative response. Because of this, it is possible that the differences in accommodative response also contributed to the unilateral myopic progression for the patient from Case 1. These two studies corroborate the findings in Case 1, in which the right eye showed significant myopic progression, as this eye was initially subjected to greater near demands with remote learning, while the left eye only fixating at distance acted as a protective factor against progression, in a similar way that monovision correction did in the aforementioned study. At this time, it is unclear whether hyperopic defocus or accommodative response plays a larger role in myopic progression in a case like this. Further investigation into myopic progression in children with binocular disorders, such as strabismus, is required to make this determination.

The patient in Case 2 also showed a significant myopic progression in four months following increased near point stress during remote learning. This aligns with studies that show that the amount of increased near work and near demand required with academics are directly correlated with the speed of myopic progression in children and the prevalence of myopia.

Both Cases 1 and 2 align with the findings of Ekdwadi et al., that 90% of patients with intermittent exotropia in their population study were myopic by the age of 20, whether surgical intervention was implemented or not. Due to the presence of increased exotropia, these patients were already at high risk for developing myopia, which was further exacerbated by increased near demands. For these patients, proper education on myopia control methods is crucial in order to prevent further progression. Current treatments for myopia control include the use of low-dose atropine, multi-focal soft contact lenses, orthokeratology contact lenses, and progressive or bifocal spectacle lenses. Current guidelines also recommend reducing near demands and spending time outdoors, as these are risk factors for increased myopia progression.

In Case 3, the breakdown of the patient’s esophoria into an esotropia with increased magnitude in the absence of neurological pathology and in the presence of increased near demands is consistent with acute acquired concomitant esotropia (AACE). This condition has been shown to arise in other patients who experience increased near demands. Vagge et al. presented a case series of patients who developed AACE after increased near demands from the lockdown associated with COVID-19. The development of AACE is thought to be another adaptation to near point stress, as demonstrated in Lee et al., who outlined the development of AACE in 12 teenagers following excessive smartphone use. When refraining from smartphone use for one month, a decrease in the magnitude of esodeviation was noted, suggesting this was a contributing factor. It was theorized that esotropia develops in patients who have a history of difficulty with divergence ability. The increased
near point stress results in increased medial rectus action, which leads to development of esotropia.

Along with vision therapy to strengthen the binocular and accommodative systems, other management options for reducing the near point stress associated with near work should be considered. These include the implementation of the 20-20-20 rule, proper visual hygiene, and proper posture. The 20-20-20 rule suggests taking a 20-second break after every 20 minutes of near work and looking at least 20 feet away. This method has been shown to reduce symptoms of computer vision syndrome, especially those associated with dry eye. Visual hygiene and posture are also important in alleviating near point stress in individuals. A proper ergonomic setup and patient education are key factors in addressing these concerns. Mork et al. describe several physiological responses to near work, especially when associated with digital device use. Glare is one such factor that can be addressed with proper patient education of an ergonomic working station. Increased amounts of glare have been shown to induce a postural change of moving the individual’s head forward. It is theorized that moving forward is a response to keeping excessive light out of one’s eyes, but this also decreases the working distance and increases the accommodative demand for the individual. In order to reduce the amount of glare, anti-reflective spectacles and proper ambient lighting should be considered. The proper ambient lighting may also help to alleviate near point stress as there is an apparent association between perceived stress levels and proper ambient lighting during computer use. Perceived stress levels and psychological stress associated with near tasks lead to a further increase of the sympathetic nervous system, and thus an increase in the near point stress model demonstrated by Skeffington and Birnbaum. Reducing these stressors may benefit in the reduction in near point stress. Prescribing prism lenses may also be beneficial in reducing near point stress in the forms of compensatory or yoked prisms. Compensatory prisms allow for the individuals to rest in their natural position if a vertical or horizontal heterophoria is present.

Yoked prisms, on the other hand, function in changing an individual’s awareness, posture, and performance. Specifically, a low amount of vertical yoked prism has been shown to reduce near point stress using either the organizational or rebound methods, as Gruning refers to them. The organizational method utilizes base-up prism for patients with exo deviations and base-down prism for patients with eso deviations. As originally described by Kaplan, this method allows for emphasis on details in patients with exo deviations and emphasis on the peripheral surroundings on patients with eso deviations. On the other hand, the rebound method utilizes the opposite direction of prism: base-down for exo patients and base-up for eso patients. This is based on the theory by Kraskin that with time, the patient will equilibrate to the prescribed prism and allow for improved visual efficiency.

In summary, the closure of schools during the COVID-19 pandemic resulted in increased screen time and near point stress due to online learning. This case series demonstrates the potential impact increased near-point stress has on the visual system of pediatric patients, especially those with strabismus. These patients should be monitored carefully to ensure proper intervention is implemented, including low powered plus lenses at near, fusional prism, and vision therapy. Patient education is crucial to reducing near point stress, especially when associated with digital device use. Frequent breaks and ensuring proper working distance during online learning should be explained thoroughly to pediatric patients partaking in online learning. Although this case series demonstrates the potential effects of increased near demands, further investigation is required to definitively demonstrate these effects.

REFERENCES


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Originally from Buffalo, NY, Kevin Weber moved to New York City to attend SUNY College of Optometry. Upon graduating with his OD degree, he also completed a residency in Vision Therapy and Rehabilitation at SUNY. He is currently an Assistant Clinical Professor at the college as co-instructor of record for the first year Clinical Optometry course, as well as supervising students in the Vision Therapy, Head Trauma, and Pediatrics clinics.