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Abstract

A case study was performed on a child with cerebral palsy to evaluate the effects of providing postural support on visual performance, including oculomotor control, visual acuity, and reading comprehension. The hypothesis was that providing postural support for specific visual tasks would help the subject perform at a level of maximal efficiency for learning. We tested the subject with and without postural support, and measured the effects on visual acuity, oculomotor accuracy and reading comprehension. Oculomotor skills were measured by using a modified NSUCO Oculomotor Test and Visagraph II. The Visagraph II was also used to test reading comprehension. Postural support was provided in the form of a cervical collar. Results suggest that postural support does not improve visual acuity or oculomotor control. Instead, postural support seemed to impede those precise visual tasks by restraining the child's head movement. We have found that in this case study, this subject had learned to use head movement for reading and precise visual tasks. Postural head support seemed to restrict the head movement, thereby restricting the child's visual function.

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THE NATURE OF EYE MOVEMENTS IN CEREBRAL PALSY: A CASE STUDY ON THE EFFECTS OF POSTURE ON OCULOMOTOR CONTROL AND VISUAL FUNCTION

By

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TRAM N. DINH, BS

A thesis submitted to the faculty of the College of Optometry Pacific University Forest Grove, Oregon for the degree of Doctor of Optometry May 2000

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BIOGRAPHIES

Jennifer K Ruprecht

Jennifer K. Ruprecht first became interested in optometry at the age of 12 when she began wearing her first pair of eyeglasses and has enjoyed learning about vision ever since. She went on to earn a Bachelors of Science in Zoology from Idaho State University and is currently earning a Doctor of Optometry degree from Pacific University College of Optometry. She is a member of the Beta Sigma Kappa International Optometric Honor Society and was accepted by the American Academy of Optometry to present a poster on this particular thesis.

Upon earning her O.D. in May 2000, Jennifer plans on becoming an associate and practicing primary care optometry in Idaho as well as raising a healthy and happy family with her husband, Karl.

Tram N. Dinh

Tram N. Dinh became interested in healthcare after she became a nursing assistant in high school. While earning her Bachelors of Science in Psychology at U.C. Davis, California, she chose to pursue optometry as a career. She was accepted by the American Academy of Optometry to present a poster on this thesis with Jennifer Ruprecht.

Tram plans to graduate in May 2000 with a Doctor of Optometry degree from Pacific University College of Optometry and then go on to practice primary care optometry in Oregon. She also plans to do Christian ministry with her husband, Shawn Nguy.

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The Nature of Eye Movements in Cerebral Palsy: Effects of Posture on Oculomotor Control and Visual Function

Abstract:
A case study was performed on a child with cerebral palsy to evaluate the effects of providing postural support on visual performance, including oculomotor control, visual acuity, and reading comprehension. The hypothesis was that providing postural support for specific visual tasks would help the subject perform at a level of maximal efficiency for learning. We tested the subject with and without postural support, and measured the effects on visual acuity, oculomotor accuracy and reading comprehension. Oculomoto skills were measured by using a modified NSUCO Oculomotor Test and Visagraph II. The Visagraph II was also used to test reading comprehension. Postural support was provided in the form of a cervical collar. Results suggest that postural support does not improve visual acuity or oculomotor control. Instead, postural support seemed to impede those precise visual tasks by restraining the child's head movement. We have found that in this case study, this subject had learned to use head movement for reading and precise visual tasks. Postural head support seemed to restrict the head movement, thereby restricting the child's visual function.

Keywords: *cerebral palsy, postural support, oculomotor,visual function, eye movements*

INTRODUCTION

The visual difficulties that postural deficits create for children with cerebral palsy are recognized by a variety of healthcare professionals, including occupational therapists, physical therapists, optometrists, and teachers of the visually impaired. One postural deficit, poor head control, is a very significant physical limitation because it affects the entire body including effective use of the sensory sytems.[1] Children expend increasing amounts of energy maintaining their posture during visually demanding tasks.[2] This effect is amplified in children with cerebral palsy, where maintaining adequate head and trunk posture to sustain visually demanding tasks is often impossible. In a cerebral palsy child's overall development, emphasis is typically placed on training gross-motor skills to encourage postural development. Thus, children with cerebral palsy are typically not given postural support if they can maintain an upright posture on their own.

Children with limited postural control who have difficulty maintaining a stable sitting posture, may spend less energy attending to academic or pre-academic tasks because they are struggling to maintain the necessary posture. Rather than using their vision and upper extremities for academic tasks, they are forced to use them to maintain upright posture. In these examples it may be useful to offer more postural support to the child rather than having him struggle to maintain ocular alignment and waste energy and concentration.[1,2]

The purpose of this study was to determine whether providing postural support for school age children with cerebral palsy improves visual performance including oculomotor control, visual acuity, and reading comprehension. These are critical elements that contribute to reading. We hypothesized that providing postural support for specific visual tasks will help children with cerebral palsy perform at a level of maximal efficiency for learning. Previous research indicates that postural support including correct adaptive seating devices increases social interaction as well as the ability to independently track a moving object.[2] However, the literature is limited on this particular issue.

Cerebral palsy has been correlated with multiple visual anomalies including strabismus, amblyopia, high refractive error, nystagmus, and optic atrophy.[3,4] Scheiman indicates that hyperopia greater than +1.50D is three times more common in children affected with cerebral palsy compared to non-affected children. And strabismus affects the cerebral palsy population more than ten times as frequently as the normal population. On average 43% of persons with cerebral palsy are strabismic (27% esotropes, 16% exotropes).[4] Duckman reported a prevalence of 92% oculomotor dysfunction, including 100% accommodative insufficiency in children with cerebral palsy. Additionally, he demonstrated improvement of accommodative facility and ocular motilities with the use of vision therapy.[5,6] Other disabilities associated with cerebral palsy include mental retardation, auditory and language disorders, epilepsy, behavioral, and emotional disorders. Mental retardation is prevalent in approximately 60-70% of this population.[4]

In addition to developmental delays in motor skills, perceptual learning problems may also occur with cerebral palsy. As a result of difficulty maintaining upright posture, the child shows delays or perceptual difficulties with spatial localization due to the lack of a stable postural foundation from which to view the world. This postural foundation is inconsistent due to poor gross motor and oculomotor control. Without stable neck control, it is very difficult for the eyes to develop adequate functioning. Without an organized postural system, the visual system acquires distortions and inconsistent input which lends itself to an inadequate perceptual base for later learning.[2,7] Children with cerebral palsy may have disjointed movements that are inappropriate for the task at hand, even when the child is fully aware of what actions need to be performed. When an inadequate postural and movement message is delivered from the central nervous system, all other systems, including vision must compensate to organize function. The strongest system of compensation is the visual system. The visual system learns to function in a way that maximizes the safety of the individual and delivers the best information regarding the environment.[1] The eyes allow the individual to anticipate movement in space and provides constant feed-forward information to the system.[7] However, the visual system compensatory efforts may begin to interfere with normal maturation; adaptation interferes with new learning. The child with high postural tone, or spasticity, typically relies on total patterns of movement and may use eye movements upward to initiate extension. Relaxation of the eyes, on the other hand, reduces high tonus and allows the child's head to fall forward into gravity.[1] Understanding the nature of the constant interaction between the visual and postural systems is critical in order to increase the successful evolution of children with cerebral palsy.[7] The study we present here provides us with some insight into the visual adaptations that a child with cerebral palsy makes in order to achieve maximal function despite poor postural control.

The methods used for this study include: visual acuity, Northeastern State University College of Optometry (NSUCO) Oculomotor test, and the reading performance recorded by Visagraph II. Visual acuity was used as an indirect measurement of the subject's fixation skills, assuming that lack of stable fixation degrades acuity.

In addition to visual acuity, critical reading components such as saccades and pursuits were assessed via the NSUCO Oculomotor test.

The NSUCO evaluates four factors for both pursuits and saccades: ability, accuracy, head movement, and body movement (Appendix A). The first two factors are quantitative aspects while the latter is qualitative. The NSUCO test is to be performed standing, without any support. Due to the significant physical limitations of cerebral palsy and the decreased visual acuity of the subject, a modified NSUCO was performed.

A more technologically advanced quantitative measure of oculo-motor performance was provided via the Visagraph II. The Visagraph is an eye-movement recording system used to analyze oculomotor performance. This system utilizes goggles, which contain infrared sensors that monitor the subject's eye movements. While a subject reads a given passage provided by the Visagraph, his or her reading performance is automatically calculated and graphed. Measurable components calculated by the Visagraph include: fixations, regressions, average span of recognition, average duration of fixation, and rate of comprehension.

METHODS:

Subject 1: TY

TY is a 16 year-old wheelchair bound male with a combination of athetoid and spastic cerebral palsy. He has optic atrophy in both eyes and is a right eye esotrope with secondary amblyopia. TY reads at a 6^{th} grade level and currently participating in an Individual Education Program. He is legally considered visually impaired based on reduced visual acuity.

TY has an inability to maintain an upright head posture for sustained visual tasks. When fatigued, he rarely utilizes visual contact with others.

The following measurements were made with and without support: distance and near acuity, pursuit and saccadic eye movement accuracy, reading rate and efficiency utilizing the Visagraph instrument. All aspects of testing were videotaped with permission from TY and his parents in order to document and review the dynamics of his posture and visual function.

A. Vision with Habitual Posture

1. Visual Acuity

We recorded the subject's visual acuity using the Feinbloom chart at 6m and the Lighthouse cards at 40 cm. TY's visual acuity was assessed through his habitual spectacle correction with and without postural support.

Habitual Rx: OD +1.00-4.00x015
OS +1.00-4.00x150

2. Modified NSUCO:

We performed the NSUCO oculomotor test modified for TY. The standard NSUCO protocol demands that the patient stand during the procedure. However, we performed the test while subject was in his wheelchair. Instead of using the standard bead target, we used a 20/30 single lighthouse target (apple and house) appropriate for TY's reduced acuity needs. The 20/30 lighthouse target is equivalent for a near acuity demand of 20/100.

a. Saccades:
The targets were held 10cm on each side of midline (20cm total) in horizontal meridian only. The test distance was at 40cm. TY was instructed to look back and forth between the two targets. We performed 5 round trips for saccades and evaluated his skills according to NSUCO protocol. (See appendix A).

b. Pursuits:
The test distance was 40 cm. The target was an equivalent 20/100 single lighthouse apple. Two rotations were made in each direction, clockwise & counterclockwise.

We scored his performance according to NSUCO protocol. (See Appendix B).

3. Visagraph:

A third grade level passage was used for testing reading because it was well within TY's acuity range at the 40cm testing distance.

Test distance: 40cm
Target: Visagraph test booklet. Level 3-29, reading passage titled "Stamps."

a. Reading and Comprehension:

TY was fitted with Visagraph goggles and then read a passage at his reading level (level 3). We recorded reading eye movements as directed by Visagraph manual. When TY finished reading, he answered the questions provided in the Visagraph test booklet. Comprehension was scored according to his answers.

Besides comprehension, other reading components calculated by the Visagraph II include fixations, regressions, average span of recognition, average duration of fixation, and rate with comprehension.

II. Vision with postural support.

Reading and comprehension on the Visagraph were repeated with various forms of postural support (cervical collar, reclined position, and supine position). TY was positioned for each method of postural support and an examiner held the reading material at 40 cm perpendicular to his visual axis. The program recorded his eye movements while he read each passage. The subject was then asked 10 yes or no questions provided for each passage in the Visagraph manual. The questions were printed on the page opposite from the passage. They were also shown on the computer screen after each passage was read, and the subject's answer was entered into the computer. Reading comprehension was scored by the Visagraph program.

A. Cervical Collar: TY was fitted with the Headmaster cervical collar approved by a consulting physical therapist and provided by Symmetric Designs LTD.
Target used: Visagraph test booklet. Level 3-30, reading passage titled "Postcards."

B. Reclined: The subject was reclined in his wheelchair at a forty-five degree angle beyond his habitual sitting posture with his head supported by a head rest.

Target used: Visagraph test booklet. Level 3-31, reading passage titled "Playing Cards."

C. Supine: The subject was laid in a supine position similar to the habitual reading posture used at home. Target used: Visagraph test booklet. Level 3-34, reading passage titled "Picture Puzzles."

The Visagraph summarized the reading components in a Reading Profile for each trial and compared the results against age norms. This profile included the following:

Fixations - number of eye pauses per 100 words
Regressions - number of reverse eye movements in right-to-left direction per 100 words
Average Span of Recognition - the word of word parts perceived during a fixation
Average Duration of Fixation – the length of time of time of an eye pause to fixate
Rate with Comprehension – words read in relation to time

RESULTS

Visual Acuity

No change in visual acuity was measured with or without postural support (Table 1).

Table 1: Visual Acuity

		Habitual Posture	With Cervical Collar
Distance	OD	20/800	20/800
	OS	20/320+	20/320+
	OU	20/320+	20/320+
Near	OD	20/400	20/400
	OS	20/80	20/80
	OU	20/80	20/80

Modified NSUCO

The ability and accuracy of the subject's saccades and pursuits remained unchanged regardless of postural support.

A summary of the NSUCO scores is provided in Table 2.

Table 2: NSUCO Scores

		Habitual Posture	With Cervical Collar
Saccades	Ability	5	5
	Accuracy	2	2
Pursuits	Ability	5	5
	Accuracy	3	3

Visagraph

TY demonstrated the least number of fixations and regressions were recorded while TY was in his habitual posture, sitting in his wheelchair without any head support. In this condition, he progressively degraded into a kyphotic or hunched-over posture. The largest average span of recognition occurred in the habitual posture as well as the least average duration of fixation. The reading rate (words/min) and grade equivalent were highest in this test condition.

In contrast, the greatest number of fixations and regressions were recorded while the subject was in the supine position. He also had the lowest average span of recognition and highest average duration of fixation while lying supine. His grade equivalence was lowest in this condition. However, he achieved 100% comprehension in supine versus 80% in the habitual posture.

He achieved the lowest percentage of correct comprehension questions while in the reclined position.

The data is summarized in Table 3.

Table 3: Results from Visagraph Reading Profiles

	Habitual Posture	With Cervical Collar	Recline	Supine
Fixations/ 100 words*	145	178	206	298.5
Regressions/ 100 words*	24	48.5	59	95
Av. Span of Recognition*	.68	.56	.49	.34
Av. Duration of Fixation (sec)*	.34	.39	.45	.47
Rate with Comprehension	120	86	64	42
Grade Level Equivalent	3.0	1.3	1.0	1.0
Comprehension Q Correct	80%	80%	60%	100%

*For these test conditions, values from the right and left eyes were averaged.

It is important to note that the subject's head movement was considerably more while reading in his habitual posture compared to the other test conditions. The three forms of postural support seemed to limit his head movement. This was especially noted while he was reclined. However, the cervical collar and supine position allowed him to move his head slightly. The amplitude of head movement while he wore a cervical collar was estimated to be half the amplitude of his habitual head movement. In the supine position, his head movements were noted during approximately twenty-five percent of the duration of the test.

DISCUSSION

The NSUCO was performed in order to assess any observable change in eye movements with postural support. The results indicated no significant change in eye movements seen while wearing a cervical collar.

The original hypothesis stated that providing postural support for specific visual tasks will help children with cerebral palsy perform at a level of maximal efficiency for learning. However, the results of the Visagraph reading profiles suggest that his overall efficiency was better without postural support.

Reading efficiency is characterized by a minimal amount of fixations and regressions. A fixation refers to a pause in eye movement during which perception takes place. Fewer number of fixations imply that the subject is able to perceive more during each pause. Regressions are fixations that occur in a right-to-left saccadic eye movement. These can indicate poor binocular coordination, an ingrained need to double check words, or difficulty with content. Efficiency is also characterized by an increase in the following characteristics: span of recognition, duration of fixation, and rate of comprehension.

TY's reading was most efficient while in his habitual posture even while he had to expend energy to hold his head upright. The wheelchair was in an upright position causing TY to lean forward in a kyphotic posture. The most notable difference between TY's habitual posture and the other test conditions was his head movement. This may be explained by a developmental adaptation. Since TY lacked fine motor control which includes eye movements, his natural adaptation was to utilize head movement to move his fixation across the page and back.

The cervical collar provided support to keep TY's head upright, but it hindered lateral movement of his head. This prevented him from using his developmental adaptation. Hence, there were more fixations and regressions compared to the habitual posture, and there was a decreased average span of recognition, average duration of fixation, and rate of comprehension. This suggests that his reading efficiency was decreased while wearing a cervical collar.

In both reclined and supine positions, he does not move his head as much as sitting upright without support. This may explain the decrease in reading efficiency as measured by fixations, regressions and other components quantified by the Visagraph.

Whereas reading efficiency was best in the habitual posture, TY's comprehension was 100% in the supine position compared to 80% in the habitual posture. This may be due to TY's experience in reading in this position at home. He was able to sustain reading in this position for longer periods of time because postural fatigue is not a factor. He was more relaxed in this posture and read more slowly.

We conclude that TY read more efficiently in his habitual posture. This is likely due to limitation of head movement created by postural support. However, further research is needed in order to explore the role of postural support in oculomotor function in cerebral palsy. It would be intriguing to explore research in the realm of oculomotor vision therapy in children with cerebral palsy during early development before introducing postural support to see if the support would in fact, improve visual efficiency.

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APPENDIX A

STANDARD SET OF THE NSUCO OCULOMOTOR TEST

I. Posture:

Standing, with feet a shoulder-width apart, directly in front of the examiner.

II. Head:

No instructions are given to the patient to move or not to move his head.

III. Target characteristics:

Small (approximately 1/2 cm in diameter) colored, reflective spheres (balls) mounted on dowel sticks. One target is used for pursuits, two for saccades. For those unwilling or unable to be tested with the colored ball targets (red and green), substitute different colored Disney targets (clowns) on pencils (one for pursuits, two for saccades).

IV. Movement of the target:

A. Directional

1. Saccades are performed in the horizontal meridian only.
2. Pursuits are performed rotationally, both clockwise and counterclockwise.

B. Extent:

1. Saccade extent should be no more than 10 cm on each side of the patient's midline (20 cm total).
2. Pursuit path should be no more than 20 cm in diameter. The upper and lower extent of the circular path should coincide with the patient's midline.

V. Test distance from the patient:

No more than 40 cm and no less than the Harmon distance, i.e., the distance from the subject's middle knuckle to his elbow.

VI. Ocular condition:

Binocular only

VII. Age of the patient:

2 years to adult

VIII. Instructions:

A. Saccades:

"When I say red, look at the red ball (clown). When I say green, look at the green ball (clown). Remember, don't look until I tell you to."

B. Pursuits:

"Watch the ball (clown) as it goes around. Try to see yourself in the ball (watch the clown's eyes). Don't ever take your eyes off the ball (clown)."

APPENDIX B

NSUCO METHOD OF SCORING SACCADES AND PURSUITS ABILITY

(Can the patient keep his attention under control to complete five round trips for saccades and two clockwise and then two counterclockwise rotations for pursuits?)

SACCADES

1. Completes less than two round trips
2. Completes two round trips
3. Completes three round trips
4. Completes four round trips
5. Completes five round trips

PURSUITS

1. Cannot complete 1/2 rotation in either the clockwise or counterclockwise direction
2. Completes 1/2 rotation in either direction
3. Completes one rotation in either direction but not two rotations
4. Completes two rotations in one direction but less than two rotations in the other direction
5. Completes two rotations in each direction

ACCURACY

Both pursuits and saccades are graded alike.

(Can the patient accurately and consistently fixate so that no noticeable correction is needed in the case of saccades or tracking the target so that no noticeable refixation is needed when doing pursuits?)

SACCADES

1. Large over- or undershooting is noted one or more times
2. Moderate over- or undershooting noted one or more times
3. Constant slight over- or undershooting noted (greater than 50% of the time)
4. Intermittent slight over- or undershooting noted (less than 50% of the time)
5. No over- or undershooting noted

PURSUITS

1. Refixations more than 10 times
2. Refixations five to 10 times
3. Refixations three or four times
4. Refixation two times or less
5. No refixations

HEAD AND BODY MOVEMENTS

(Can the patient accomplish the saccade or pursuit test without moving his head or body? Both saccade and pursuit scoring use the same criteria for this aspect of the testing.)

1. Large movement of the head (body) at any time
2. Moderate movement of the head (body) at any time
3. Consistent slight movement of the head (body) (greater than 50% of the time)
4. Intermittent slight movement of the head (body) (less than 50% of the time)
5. No movement of the head (body)

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