

Effectiveness of Vision Therapy for Binocular Single Vision Anomalies

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Abstract

Background: Binocular single vision is the ability to maintain visual focus on an object with both eyes, resulting in a single visual image. Anomalies in this system can cause various visual symptoms and impact daily activities such as reading, driving, and using a computer. Despite the abundance of available data, there is a significant lack of clarity regarding precise definitional criteria, standardized methods for testing and diagnosis, and global prevalence studies.

Aim: To report the frequency of binocular vision (BV) anomalies in symptomatic patients (e.g., blurring, headache, or eyestrain) and to evaluate the effectiveness of vision therapy (VT)

Methodology: This was a retrospective observational study conducted at the B B Eye Foundation, Kolkata, India. The analysis included 45 healthy subjects, both male and female, aged 5 to 25 years. All patients underwent a comprehensive ophthalmic examination, including visual acuity, subjective/objective refraction, and assessment of accommodative and vergence facilities. A comprehensive eye examination with binocular vision (BV) evaluation was performed, followed by the application of vision therapy (VT). Statistical analysis was conducted on pre- and post-vision therapy (VT) parameters.

Results: Among 45 patients' binocular vision (BV) anomalies were found in 44 (97.7%). 35 (77.4%) had convergence insufficiency followed by fusional vergence dysfunction in 3 (6.7%), convergence excess in 3 (6.7%), divergence insufficiency in 1 (2.3%), accommodation insufficiency with convergence insufficiency in 1 (2.3%) and accommodative infacility in 1 (2.3%). Statistical analysis and data comparison were performed using the Mann-Whitney U test with SPSS v.25 statistical software. Descriptive statistics were used to interpret the results. Statistically significant differences were found in binocular vision (BV) parameters between pre- and post-vision therapy measurements

Conclusion: Following vision therapy, the symptoms associated with binocular vision (BV) anomalies improved. In particular, significant improvements were noted in: accommodation insufficiency, near point of convergence, positive fusional vergence, and negative fusional vergence.

Key words: Binocular vision anomalies, vision therapy, accommodative facility, vergence facility, near point of convergence, near point of accommodation.

Acronyms

AA	Amplitude of Accommodation
AC	Anterior Chamber
AC/A	Accommodative Convergence / Accommodation ratio
BAF	Binocular Amplitude Facility
BBEF	B B Eye Foundation
BCVA	Best Corrected Visual Acuity
BD	Base Down
BI	Base In
BO	Base Out
BOU	Bangladesh Open University
BSV	Binocular Single Vision
CC	With correction
EOM	Extra-Ocular Muscle
IOL	Intra-Ocular Lens

IOP	Intra-Ocular Pressure
MAF	Monocular Accommodation Facility
NFV	Negative Fusional Vergence
NPA	Near Point of Accommodation
NPC	Near Point of Convergence
NRA	Negative Relative Accommodation
OPD	Out Patient Department
OD	Oculus Dexter (Right Eye)
OS	Oculus Sinister (Left Eye)
OU	Oculus Uterque (Both Eyes)
PRA	Positive Relative Accommodation
PH	Pinhole
PD	Pupillary Distance
PCT	Prism Cover Test
RAF	Royal Air Force Rule
SC	With correction
SPSS	Statistical Package for the Social Science
TNO	Trans-Neptunian Object
VA	Visual Acuity
VT	Vision Therapy

I. Introduction

Background

Binocular single vision (BSV) refers to an individual's ability to use both eyes simultaneously to achieve a single, unified visual image. It requires the simultaneous perception of two images—one from each fovea (bifoveal perception)—and the absence of any manifest ocular deviation. Anomalies of binocular single vision are visual disorders that affect clarity, binocularity, and the comfort and efficiency of visual performance, particularly during near tasks such as reading, writing, and computer-based work.

Among school-age children, especially high school students, symptoms associated with accommodative and vergence anomalies tend to increase with advancing grade levels. This is primarily due to the higher visual demand placed on the accommodative and vergence systems for prolonged near work and increased information processing. Several studies have reported a higher prevalence of vergence and accommodative anomalies in this age group (Samuelwajuihian, 2015).

BSV anomalies are commonly associated with reading and writing difficulties in children and young adults. Affected individuals often present with dysfunctions of vergence and accommodation that interfere with reading speed, comprehension, and overall visual efficiency. Symptoms may include blurred vision, headache, eyestrain, and diplopia. Daum (1984) reported a high incidence of blur (47%), headache (54%), asthenopia (36%), and diplopia (47%) among such individuals. These problems are typically linked to binocular vision anomalies, including various forms of vergence insufficiency or excess, with or without accompanying accommodative dysfunctions. Convergence insufficiency (CI) may occur alone or in association with accommodation insufficiency (AI).

Management strategies for these conditions include refractive error correction, prism therapy, and vision therapy (VT)—either home-based or office-based. Home-based therapies, such as pencil push-ups, are often used as the initial treatment, particularly for CI. However, office-based vision therapy, supplemented by home exercises, is generally more effective. Among the available treatment modalities, vision therapy has been shown to be a highly effective approach for managing CI and other binocular vision anomalies in both children and adults. Pesudovs (2005) demonstrated the efficacy of vision therapy in 78 participants aged 5–73 years. Numerous studies have since confirmed that vision therapy improves binocular single vision parameters, thereby enhancing the visual comfort, accuracy, and efficiency required for reading and writing tasks.

As controversy persists regarding the most appropriate and effective treatment approach for binocular vision anomalies, there is a growing need to identify a cost-effective and convenient method for managing convergence insufficiency (CI) and related

conditions. Despite the recognized importance of vision therapy (VT) in managing such disorders, limited research has been conducted in Bangladesh to evaluate its effectiveness in patients with binocular single vision (BSV) anomalies.

Furthermore, individuals presenting with symptoms such as headache and eye pain—often resulting from undiagnosed binocular vision dysfunction—tend to receive insufficient clinical attention. Addressing this gap is essential to improve both diagnosis and management outcomes.

Therefore, the present study aimed to determine the prevalence of binocular single vision anomalies among children and young adults and to evaluate the efficacy of vision therapy in improving binocular vision parameters and alleviating associated symptoms, particularly headache and eye pain.

Rationale/ Justification of study

Anomalies of accommodation and vergence are among the primary causes of binocular single vision (BSV) dysfunction and constitute a major part of clinical ophthalmology and optometry. There is growing evidence that vision therapy (VT) can serve as an effective, non-invasive, and cost-efficient treatment for accommodative and vergence anomalies.

Clinical studies have demonstrated significant improvements in both visual symptoms and objective measures of accommodation and vergence following structured vision therapy. For instance, a randomized clinical trial published in *Optometry and Vision Science* found that vision therapy was more effective than placebo treatment in improving symptoms and clinical measures of accommodative function in children with accommodative dysfunction (Pesudovs, 2005).

Vision therapy can also be customized to address the specific visual needs of individual patients. A comprehensive binocular vision evaluation allows clinicians to identify precise accommodative and vergence deficiencies, enabling the design of personalized therapy programs that directly target those dysfunctions. This individualized approach has been shown to yield more effective and sustained outcomes (Wang & Zhao, 2016).

Importantly, vision therapy addresses the underlying causes of accommodative and vergence anomalies rather than merely alleviating symptoms. For example, a study published in *BMC Ophthalmology* found that vision therapy effectively reduced the progression of myopia in children with accommodative dysfunction. By improving accommodative control, vision therapy may reduce dependency on corrective lenses and prevent visual deterioration.

Moreover, vision therapy represents a cost-effective alternative to invasive options such as surgery or prism correction. A study in the *Journal of Optometry* reported that vision therapy was more cost-effective than surgical intervention for the treatment of convergence insufficiency (CI), making it especially valuable for populations with limited access to expensive care options.

Non-strabismic accommodative and vergence disorders—typically functional rather than organic in origin—are among the most common ophthalmic conditions encountered in optometric practice, second only to refractive errors (Classé et al., 1995). These conditions may first present to optometrists, ophthalmologists, orthoptists, or even educators and allied health professionals. Failure to diagnose such disorders can significantly impair patients' quality of life and, in some cases, lead to medico-legal consequences.

Epidemiological data highlight the high prevalence of these dysfunctions among symptomatic non-presbyopic patients: accommodative insufficiency (9.2%), accommodative infacility (5.1%), and accommodative spasm (2.5%) (Hokoda et al., 1985). Among patients with manifest binocular dysfunction, prevalence rates can rise as high as 60–80%. Similarly, the prevalence of fusional vergence dysfunctions is notable, with convergence insufficiency (7%) being the most common type observed in both children and adults (Scheiman et al., 1996). Other vergence dysfunctions include convergence excess (5.9–7.1%), basic exophoria (2.8%), fusional vergence dysfunction (<7%), and vertical phoria (9%) (Cooper et al., 1998; Scheiman et al., 2008; Amos et al., 1987).

Patients with non-strabismic accommodative and vergence disorders often present with a broad spectrum of symptoms, including blurred vision (distance and/or near), diplopia, headaches, eyestrain, ocular discomfort, difficulty concentrating, and reduced reading efficiency. These symptoms frequently lead to task avoidance behaviors that can impair academic and occupational performance (Cooper et al., 1988).

The therapeutic success rate for these conditions is remarkably high. Reported cure rates for accommodative disorders range from 80% to 100%, while vergence disorders show cure rates of 70% to 100% (Cooper et al., 1988). These outcomes highlight the significant plasticity of the oculomotor system and its ability to respond to structured visual training.

The clinical practice of vision therapy has evolved over more than 75 years within the optometric community, tracing its roots to the orthoptic exercises introduced by ophthalmologist Javal in France in 1858 (Duane, 1915). Today, both optometrically based vision therapy and ophthalmologically based orthoptics are integral to the management of oculomotor dysfunctions, including non-strabismic accommodative and vergence anomalies. Decades of laboratory, clinical, and epidemiological research have refined these methods into effective, evidence-based, and cost-efficient treatment protocols (Cooper et al., 1988).

Although extensive research on vision therapy efficacy has been conducted in countries such as Pakistan, Nepal, Singapore, Malaysia, Australia, the United Kingdom, and the United States, there remains a significant research gap in Kolkata, India

(Evans, 2021). Given the high prevalence of binocular vision anomalies and the potential for vision therapy to improve both functional vision and quality of life, it is essential to evaluate its effectiveness in the Bangladeshi population.

Aim

To assess the frequency and effectiveness of vision therapy (VT) for binocular single vision anomalies among patients attending a tertiary eye hospital in India.

Objectives

General Objective

To find out the effectiveness of vision therapy for binocular single vision impairment among patients attending at a tertiary eye hospital in India.

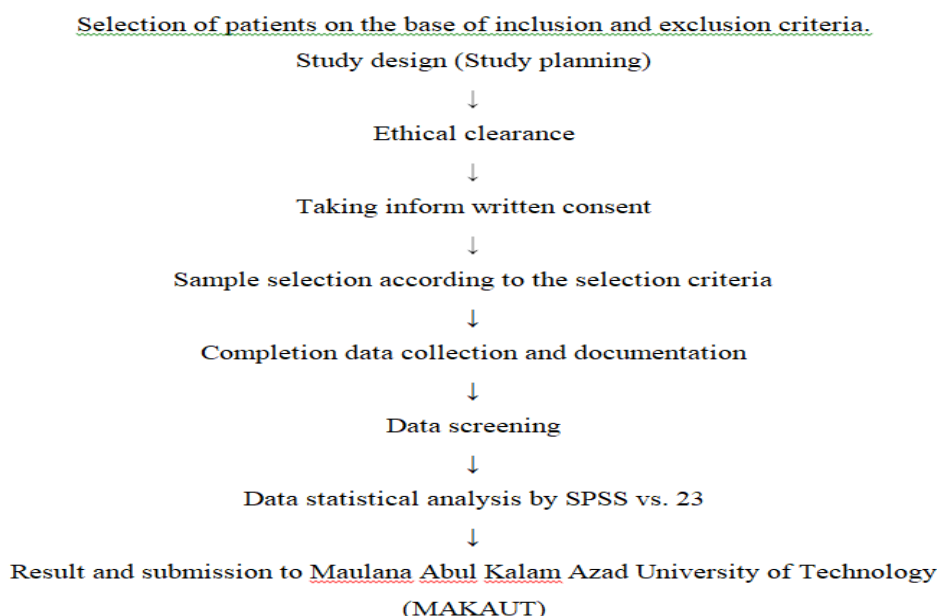
Specific Objectives

1. To determine changes in clinical finding before and after optometric vision therapy (OVT) sessions.
2. To determine the prevalence of binocular single vision in patients.
3. To explore which age group of patients, where most likely to have binocular single vision anomalies.

Research Question

Does vision therapy have a significant effect on improving binocular single vision anomalies in patients?

Flow chart showing the sequence of tasks



Operational Definitions

Construct variables need operational definitions to be accurately measured. An operational definition is a specification of the actions or procedures followed by the researcher to establish and quantify the value of a variable.

Headache

Headache is a common symptom with a wide range of possible causes. For eye care practitioners, it is essential to determine whether the headache is associated with visual activity. Decompensated heterophoria is one such visual condition that can cause headaches, typically occurring after prolonged eye use under adverse visual conditions. According to Pickwell (1984), these headaches are most often frontal, whereas Duke-Elder and Abrams (1970) noted that asthenopic headaches can present in various forms and locations. Headaches linked to binocular vision problems usually worsen as the day progresses, especially following extended near work, and tend to be less intense or absent upon waking.

Refractive errors are also well-recognized as a contributing factor to headaches in both children (Hendricks et al., 2007) and adults (Akinci et al., 2008). Another, though less frequent, cause is trochlear headache, which results from inflammation in the trochlear region and can be misdiagnosed as migraine or tension-type headache. Furthermore, while migraine patients may show a slightly higher prevalence of heterophoria, fixation disparity, and reduced stereopsis (Harle & Evans, 2006), there is no strong evidence that these binocular vision anomalies are a direct cause of migraine.

Diplopia and Related Symptoms

Diplopia, or double vision, is uncommon in cases of long-standing strabismus due to the development of sensory adaptations such as suppression or anomalous retinal correspondence. The presence of diplopia generally suggests a recent-onset deviation, which may indicate an underlying pathological cause (von Noorden & Campos, 2002). Diplopia should be carefully characterized as constant or intermittent, and its direction noted as horizontal, vertical, or diagonal, as these features assist in determining the nature and location of the ocular misalignment (Khurana, 2007).

Intermittent diplopia in individuals with heterophoria often signals decompensation into manifest strabismus. This may arise from severe fatigue, illness, or other decompensating factors that reduce fusional reserves (Evans, 2007). In some cases, intermittent diplopia can represent an early manifestation of a pathological process, with sudden and dramatic onset requiring prompt investigation to exclude neurological or vascular causes (von Noorden & Campos, 2002).

Blurred Vision and Asthenopia

Blurred vision is a common symptom in individuals with heterophoria and may also be associated with accommodative difficulties, such as under-corrected presbyopia or hypermetropia, particularly during sustained near work. Its clinical significance should not be underestimated, as frequent episodes of blur can adversely affect a patient's functional visual performance and quality of life.

Asthenopia is a descriptive term referring to symptoms related to prolonged or sustained eye use, including eyestrain, headache, and discomfort, which can originate from both internal factors (such as binocular or accommodative anomalies) and external factors (such as dry eye) (Sheedy et al., 2003). The term literally means "weakness of the eyes" and should ideally be used to describe symptoms arising specifically from visual anomalies. Asthenopic symptoms associated with prolonged use of digital devices are collectively referred to as Digital Eye Strain (DES) or Computer Vision Syndrome (CVS) (Rosenfield, 2016). Asthenopia is more likely to occur when visual compromise coincides with visually demanding tasks (Nahar et al., 2011).

In older adults, the presence of binocular vision anomalies may contribute to an increased risk of falls, highlighting the broader functional implications of these disorders (Evans & Rowlands, 2004).

Older people, binocular vision anomalies may increase the risk of falls (Evans & Rowlands, 2004).

Accommodative Anomalies

Accommodation is the mechanism by which the eye changes refractive power by altering the lens shape to focus at different distances. Subjective methods of measuring the amplitude of accommodation are prone to large variability (Burns et al., 2020). Expected amplitudes can be calculated using the Hofstetter formulae:

Accommodative anomalies are classified into four main types, provided the condition is not explained by uncorrected refractive error:

1. **Accommodative Paralysis:** Characterized by the absence of accommodation. Requires cycloplegic refraction and referral to exclude pathology.
2. **Accommodative Insufficiency (AI):** A lower-than-expected amplitude of accommodation for the patient's age. A common cause of symptoms.
3. **Accommodative Infacility:** Accommodation responds slowly to changes in fixation (e.g., from near to distance or vice versa), causing a delay in focus clearance.
4. **Accommodative Fatigue (Ill-Sustained Accommodation):** Accommodation cannot be sustained for long periods of near work, leading to blurring after a short time.

Vergence Anomalies

Vergence is a condition affecting the normal movement and convergence ability of the eyes. Anomalies are classified based on a system modified from Duane for heterophoria and intermittent strabismus:

1. **Convergence Insufficiency (CI):** The "classic" form includes a receded Near Point of Convergence (NPC), exophoria at near, and reduced Positive Fusional Convergence (PFC). It is a deficiency of PFC relative to demand or a deficiency of total convergence.
2. **Divergence Excess (DE):** Exophoria or exotropia is at least 10 prism diopters (PD) greater at far than at near. Can be divided into true or simulated DE based on the response to occlusion.
3. **Basic Exophoria:** The deviation magnitude is similar at both distance and near.
4. **Convergence Excess (CE):** The near deviation is at least 3 PD more esophoric than the distance deviation, often indicating a high Accommodative Convergence/Accommodation (AC/A) ratio.

5. Divergence Insufficiency (DI): Tonic esophoria is high at distance but less at near. Symptomatic patients usually have low fusional divergence amplitudes at distance and low AC/A ratios.
6. Basic Esophoria: High tonic esophoria at both distance and near, with a normal AC/A ratio.
7. Fusional Vergence Dysfunction: Patients often have normal phorias and AC/A ratios but reduced fusional vergence amplitudes, resulting in a small Zone of Clear, Single Binocular Vision (CSBV) (Optometric Clinical Practice Guideline, 1997).

II. Literature Review

Binocular single vision anomalies are common visual problems in children and young adults that can cause symptoms such as eyestrain, headaches, and blurred vision. Optometric vision therapy (VT) is a structured program of exercises designed to improve binocular vision function. This literature review examines the efficacy of VT in the management of binocular single vision anomalies.

Several studies have investigated the effectiveness of VT for binocular vision anomalies. A systematic review by Scheiman et al. (2005) found VT to be effective in improving accommodative function in children with accommodative insufficiency and in enhancing vergence function in children with convergence insufficiency (CI). Scheiman et al. (2005) also compared VT with placebo therapy for CI in children, reporting that VT produced significantly greater improvements in symptoms and clinical measures of convergence.

Aletaha et al. (2018) compared three VT approaches for CI in 221 children aged 9 to 17 years. Participants were randomly assigned to a 12-week course of office-based VT or a home-based computer therapy program. The study reported significantly greater improvements in CI symptoms and near point of convergence (NPC) in the office-based VT group compared to the computer therapy group.

Rouse et al. (2019) conducted a randomized controlled trial comparing office-based vergence/accommodative therapy with home-based computer therapy for CI. Both approaches improved clinical measures, but office-based therapy produced superior gains in NPC and symptoms.

A meta-analysis by Mitchell et al. (2019) reviewed the literature on VT for CI, accommodative insufficiency, and oculomotor dysfunction in children. The authors concluded that VT significantly improves symptoms and clinical parameters in these conditions.

The Convergence Insufficiency Treatment Trial (CITT) Study Group (2008) compared office-based VT, home-based VT, and placebo therapy in 221 children aged 9 to 17 years with CI. Both office- and home-based VT were significantly more effective than placebo therapy, though benefits diminished after treatment cessation.

Birnbaum et al. (1999) reported the first controlled trial demonstrating the effectiveness of VT for CI in adults. Sixty men over 40 years of age were randomized into office-based plus home VT, home-based VT only, or no therapy. Office-based plus home VT achieved a 61.9% success rate, significantly greater than the no-treatment group (10%). Home-based VT alone showed a 30% success rate. Limitations included lack of blinding and possible Hawthorne effect bias.

Several other studies provide additional evidence of VT benefits. Ciuffreda (2002) noted that most studies were over 25 years old, with small sample sizes. Grisham et al. (1999) and Cooper et al. (1983) reported objective improvements in convergence function following VT. Reviews by Grisham (1988) and Griffin (1987) summarized more than 15 large case series involving over 2,000 patients, estimating an overall VT success rate of approximately 70% for CI. However, these studies lacked placebo-controlled designs.

For divergence excess exotropia, Kran and Duckman (1987) found no controlled trials evaluating VT efficacy. Coffey et al. (1992) reviewed 59 studies on intermittent exotropia, finding methodological flaws and calling for robust controlled trials. Similarly, Francois and James (1955) reported no significant difference between occlusion and occlusion plus visual-motor therapy in amblyopia, though combined therapy reduced treatment duration.

Hoffman (1982) and Weisz (1979) reported objective improvement in accommodative function in children receiving VT, though results varied by age and study design. Rouse (1987) reviewed retrospective studies showing success rates between 53% and 87% for accommodative insufficiency, though all lacked controlled designs. No recent large-scale controlled trials exist for accommodative dysfunction, highlighting a significant research gap.

Overall, the literature supports the conclusion that VT is effective for CI and accommodative anomalies in children and young adults, with office-based therapy generally producing superior outcomes. Nevertheless, important gaps remain:

1. A lack of large-scale controlled trials for accommodative deficiencies.
2. No controlled trials assessing VT for divergence excess.
3. Uncertainty regarding optimal duration, frequency, and type of VT for various anomalies.

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4. Need for accessible, scientifically robust studies quantifying VT effectiveness.

III. Methodology

Study Design

This was retrospective observational study.

Study Area

The site of study was at selected hospital in India- B B Eye Foundation, Kolkata, India

Sample size

The sample size was calculated to measure a given proportion with a specified degree of accuracy at a 95% confidence level using the following formula:

To determine the sample size, the formula is used;

$$n = \frac{Z^2 pq}{d^2}$$

Where:

n = Desired sample size

Z = Standard normal deviate (1.96 at a 95% confidence level)

p = Estimated prevalence of binocular vision anomalies = 5.4% (0.054) (Khan KA, 2013)

q = 1-p = 1-0.054=0.946

d = Margin of error = 5% (0.05)

Putting the values in the above equation the sample size was estimated as

$$n = \frac{Z^2 pq}{d^2}$$

$$= (1.96)^2 \times 0.054 \times 0.946 / (0.05)^2$$

$$= 78.49$$

$$= 78$$

The estimated sample size was 78

But, in this study, a total sample size of 45 was considered for this study.

Study population

Patients aged 5–25 years who had binocular single vision anomalies and presented with symptoms such as asthenopia, headache, diplopia, eye strain, or difficulty focusing, and who met the predetermined inclusion and exclusion criteria, were enrolled in the study.

Sample Selection

Inclusion criteria

1. Age: 19 to 30 years old, inclusive.
2. Visual Acuity: Best-corrected visual acuity of 6/6 (or 20/20 in the US system) in both eyes at distance.
3. Sex: Both male and female.
4. Symptoms/Conditions: Patients experiencing Asthenopia, headache, double vision (diplopia), eye strain, difficulties focusing, with or without a need for refractive error correction (like glasses or contacts).

Exclusion criteria

1. Age: Less than 5 years old and more than 24 years old.
2. Non-cooperative subjects: Participation in vision and eye studies often requires the patient's active and reliable input (e.g., reporting what they see or responding to instructions).

3. Neurocognitive disability: This could affect a patient's ability to understand instructions or accurately respond to subjective tests, introducing unreliable data.
4. Dyslexia: Although not a vision problem, it affects reading and visual processing, which could act as a confounding factor in a study focused on visual function or eye strain.
5. Any pathology (general exclusion): This is a broad safety net to exclude any disease or condition not relevant to the study's focus.
6. Severely ill patients: Excludes individuals whose systemic health is unstable or whose illness could interfere with the study.
7. Active intraocular inflammation or infection: Excludes acute, infectious, or inflammatory eye conditions that could make examination unsafe or whose symptoms would interfere with the study results.

Equipment and Materials

For Examination: Trial frame and trial lenses, Retinoscope, Occluder, Pen torch, Lang fixation stick, Maddox Rod, Modified Thorington Card, Bar prisms and loose prisms, Worth 4-DOT torch with red-green glasses, RAF ruler, Stereo Fly Test Book, Vision charts (near and distance)

For Vision Therapy (VT) Sessions: Brock string, Aperture rule, Bernell-O-Scope, Lifesaver fusion cards, Black Transglyphs, Vectograms, Barrel card, Dual Polachrome Orthopter, Two Quoits/Clown, Liquid Crystal Computer Orthopter, Loose lenses (+2.00 to -6.00 D in 0.5 D increments), Accommodative rock cards, Hart Chart, Aperture rule random dot pads, Clear eccentric circles, Opaque eccentric circles, Life Saver cards (clear and opaque), Lens flippers (+1.50/-1.50 D, +2.00/-2.00 D), Prism flippers (8Δ base-out / 4Δ base-in), Polaroid bar, Random Dot Stereogram (RDS), Polaroid flippers and glasses, Loose prisms (6Δ, 8Δ, 10Δ, 12Δ, 15Δ, 20Δ, 25Δ).

Measurement Tools

Visual Acuity measurement

Visual acuity (VA) is measured for each eye, either unaided or with the patient's current refractive correction, using a standard letter chart. If the patient does not consistently wear refractive correction, it is recommended to record VA both with and without correction. Recording VA early in the examination is important, as it can provide insights for subsequent investigations. For instance, an eye with reduced VA is more likely to be the deviated eye in cases of strabismus.

When measured carefully, visual acuity demonstrates high repeatability: the 95% limits of agreement are approximately ± 1 line (Smith, 2006). In children aged 6–11 years, 95% of repeated measurements fall within ± 1.5 lines (Manny, Hussein, Gwiazda, Marsh-Tootle, & COMET Study Group, 2003).

In amblyopia, additional information may be inferred from how the patient reads the chart. For example, difficulty reading the middle letters of a line in the correct order may indicate eccentric fixation with a small accompanying scotoma, a common feature in strabismic amblyopia.

Binocular single vision Measurement

Binocular single vision (BSV) was assessed using both monocular and binocular measurements with the push-up test.

Amplitude of Accommodation (AA): Monocular AA was considered abnormal if it was more than 2 diopters below the age-expected value, calculated using Hofstetter's formula: $\text{Average AA} = 15 - 0.25 \times \text{age (years)}$

Accommodative Facility (AF): AF was evaluated monocularly and binocularly using ± 2.00 D accommodative flipper lenses at 40 cm. Test targets consisted of simple N8 font size. AF was expressed in cycles per minute (cpm). Normal monocular AF values were defined as: 7 cpm for ages 8–13 years, 11 cpm for ages >13 years

Accommodative Response: Measured using the Monocular Estimate Method (MEM). A lag between +0.25 D and +0.75 D was considered normal.

Vergence Measurement

Vergence Measurement

Near Point of Convergence (NPC):

- Assessed both objectively and subjectively.
- An NPC break >6 cm was considered abnormal.

Sensory Measurement:

- Evaluated at near using the Titmus Stereo Fly Test.

Motor Measurement:

1. Phoria or Tropia:

- Determined using cover/uncover or alternate cover tests.
- The angle of deviation was measured using the prism bar cover test (PBCT).

2. Extraocular Motility:

- Tested in all diagnostic gaze positions.

3. Fusional Amplitudes:

- Convergence and divergence fusional amplitudes were measured with prisms for both distance and near.
- Negative Fusional Vergence (NFV) was measured first, followed by Positive

4. Fusional Vergence (PFV).

- Normal values were used to assist in diagnosing accommodative and vergence anomalies.

Diagnostic Criteria for Binocular Single Vision Anomalies

1. Convergence Insufficiency (CI):

- Exophoria $> 4\Delta$ BI for near compared to distance
- NPC > 6 cm break with accommodative target
- PFV $< 15\Delta$ BO (blur value)

2. Convergence Excess (CE):

- Significant esophoria at near, $> 2\Delta$
- Reduced NFV $< 13/10\Delta$ (break/recovery)
- High MEM lag $> +0.75$ D

3. Divergence Insufficiency (DI):

- Esophoria $> 2\Delta$ BO for distance
- NFV $< 7\Delta$ BI (break)

4. Divergence Excess (DE):

- Intermittent to constant exodeviation for distance $> 5\Delta$ compared to near
- Low PFV break $< 11\Delta$ BO for distance

5. Accommodative Insufficiency (AI):

Reduced monocular amplitude of accommodation (AA): At least 2 D below Hofstetter's minimum amplitude:

Minimum AA = $15 - 0.25 \times \text{age}(\text{years})$

Minimum AA = $15 - 0.25 \times \text{age}(\text{years})$

Monocular accommodative facility (MAF) difficulty: Using -2.00 D lenses

High MEM lag: Greater than +0.75 D

6. Accommodative Infacility (AIF):

Monocular accommodative facility: Difficulty with both plus and minus lenses, with < 7 cpm for ages 8–12 years and < 13 cpm for ages > 13 years (± 2.00 D lenses)

Binocular accommodative facility: Difficulty with both plus and minus lenses, < 5 cpm using ± 2.00 D lenses

7. Fusional Vergence Dysfunction (FVD):

Near NFV break: $< 12\Delta$ BI

Near PFV break: $< 23\Delta$ BO

Distance NFV break: $< 7\Delta$ BI

Distance PFV break: $<11\Delta$ BO

Note: For diagnosis of FVD, a minimum of **two signs** is required. (Criteria adopted and modified from Scheiman & Wick, 2014)

Intervention:

After correcting any refractive errors, patients were advised to regularly perform the pen exercise as part of home-based therapy to address residual issues related to convergence insufficiency (CI). A follow-up evaluation was scheduled one month after initiating home therapy.

In cases of non-compliance or if accommodative and vergence parameters showed minimal or no improvement at the one-month follow-up, patients were enrolled in office-based vision therapy (VT) sessions. These sessions utilized tools such as: Brock String, Aperture Rule, Bernell-O-Scope, Life Saver Fusion Card, Bar Reader, Tranaglyphs, Vectograms, Flippers

Patients with accommodative and vergence anomalies other than CI were recommended to complete 6–10 office-based therapy sessions over several days.

All participants were scheduled for a final follow-up one month after completing therapy to re-evaluate accommodative and vergence parameters.

Objectives of vision therapy:

Devices and systems were used to provide accommodation and vergence training.

1. Convergence training: Aimed to improve the convergence fusion range and enhance accommodative function.
2. Accommodative infacility training: Focused on improving monocular accommodative facility through fusional vergence exercises.

Post-vision therapy evaluation:

After completing home and office-based vision therapy, patients' histories of asthenopia, headache, and eye pain were recorded, and their accommodative and vergence parameters were re-evaluated.

Data Collection Procedures

The study was conducted after obtaining ethical approval from the Ethical Committee of this institution. Data were collected using the following procedure:

The study was carried out at the B B Eye Foundation, India, and included patients who were willing to participate. A total of 45 patients aged 5–25 years were enrolled. Written informed consent was obtained from the parents of all participants. Data were collected only from subjects with no history of eye injury, ocular pathology, or current medication, and none of the selected patients had any ocular disease. only from subjects with no history of eye injury, ocular pathology, or current medication, and none of the selected patients had any ocular disease.

Eye Examination

Preliminary tests included a comprehensive case history, covering all relevant symptoms through detailed questionnaires. In addition, the following assessments were performed: Distance and near visual acuity, Distance and near cover test, Near Point of Convergence, (NPC) using a fixation stick (Bernell), Distance and near pupillary distance (PD-85, Vitzro, Korea), Ocular motility assessment, Fusion evaluation using the Worth 4-Dot test

Stereopsis assessment with the Titmus Stereo Fly test.

Refractive errors were determined using an auto-refractor (HRK-8000A, Huvitz, Korea), and subjective refraction was measured using a phoropter (DU-7000, Korea) and auto chart projector (CCP-3100, Huvitz, Korea). Subjective refraction was performed using the monocular fogging method with cross-cylinder, followed by binocular balancing to a standard endpoint of maximum plus for best-corrected visual acuity.

The accommodative and binocular visual systems were examined to assess overall binocular vision function. Tests were performed with the patients' subjective refractive correction in place. A 6- Δ base-up dissociating prism was placed in front of the right eye, and a 12- Δ base-in Risley rotary prism was placed in front of the left eye. Positive and negative fusional vergences were measured using the prism bar method.

The accommodative convergence/accommodation (AC/A) ratio was measured using the gradient method. Positive and negative relative accommodation (PRA and NRA), along with monocular and binocular accommodative facility (MAF and BAF), were measured using ± 2.00 D flipper lenses.

During NRA and PRA testing, a high-contrast 20/20 near chart at 40 cm was used as the fixation target. Accommodation was modified using minus lenses for PRA and plus lenses for NRA, added binocularly in 0.25 D steps until the first sustained blur

appeared, which was recorded as the test endpoint. NRA was tested before PRA to avoid any accommodation influence on measurements. The NPC was assessed using the standard push-up technique, and abnormalities were considered for NPC >10 cm.

Vision Therapy Program

All participants underwent a 6-session (6-week) vision therapy program. Participants visited the elementary vision therapy clinic three times per week, with each session lasting 90 minutes. This clinic-based therapy was supplemented with daily home therapy sessions of 10 minutes.

The vision therapy program followed three progressive phases: Home therapy sessions lasted 10 minutes each, three times per day, with individualized tasks assigned by the vision therapy clinic. Participants' progress was evaluated at the end of each phase before moving to the next. Instruments and manuals were provided, and parents maintained a daily log of practice. Instruments used included Brock String, Barrel Card, Mirror Stereoscope, Prism Goggle, and Aperture Rule. Prior to therapy, general information on binocular dysfunction, treatment options, and the VT program was explained to participants and parents to encourage adherence and cooperation.

Success Criteria of Vision Therapy: Success criteria were based on Daum et al. (1997) and Jang et al. (2017). In this study, children who completed 8 weeks of VT at the school clinic and home therapy system (HTS) were considered successful if: Symptoms were absent, NPC was less than 6 cm, and Near PFV was more than twice the amount of heterophoria, meeting Sheard's criteria (Scheiman et al., 2002).

Ethical consideration

1. Approval for the study was obtained from the Ethical Committee of George College of Management and Science, under the Maulana Abul Kalam Azad University of Technology (MAKAUT), India.
1. Permission to conduct the study was obtained from the concerned authorities of the hospital.
2. Informed consent was obtained from each respondent prior to data collection. The objectives of the study were explained briefly to all participants.
3. Voluntary participation was ensured, and respondents were informed of their right to withdraw from the study at any time during the data collection period without any consequences.
4. Participants were assured that there would be no physical or emotional harm, as no invasive procedures were involved.
5. All information and records were treated with strict confidentiality and used solely for the purpose of the study.

Data Analysis

Completed Vision Therapy (VT) data were collected and analyzed using Microsoft Excel (2007) and SPSS software (version 25).

1. The normality of the data was assessed using the Kolmogorov–Smirnov test. Data were checked, cleaned, and properly edited prior to analysis.
2. Frequency analysis and descriptive statistics were calculated, and 95% confidence intervals (CI) were reported where appropriate.
3. The Wilcoxon signed-rank test was used to compare changes in parameters between the pre- and post-VT groups.
4. Effect size (r) was calculated to determine the magnitude of differences between interventions, and the results were interpreted following the guidelines proposed by Cohen (1988).
5. Spearman's correlation was employed to assess the relationship between the Developmental Eye Movement (DEM) ratio and the reading rate.
6. A p -value < 0.05 was considered the threshold for statistical significance.

IV. Results

A total of 45 patients aged 5 to 25 years underwent a comprehensive eye examination, of which 44 participants with accommodative and vergence anomalies were enrolled in the study. During the initial 1–2 weeks of the Vision Therapy (VT) program, some participants reported eyestrain, likely due to adjustment to therapy. All participants reached Phase 3 by the end of the 6-week program, although a few were unable to achieve the final treatment goal. The effectiveness of VT for accommodation anomalies depends on the type and severity of the disorder; however, previous studies have demonstrated that VT can improve visual function and reduce symptoms such as eyestrain, headaches, and reading difficulties.

Table 1 : Sex distribution of patients

SEX					
		Frequency (n=45)	Percent	Valid Percent	Cumulative Percent
Valid	Female	27	60.0	60.0	60.0
	Male	18	40.0	40.0	100.0
	Total	45	100.0	100.0	

Table 1. Of the 45 patients, 60% were female (27/45) and 40% were male (18/45).

Table 2: Age distribution of patients

Statistics of age (year)	
Mean	11.89
Median	12.00
Std. Deviation	3.298

Table 2. The mean ($\pm$ SD) age of the patients was 11.89 ± 3.298 years. The majority of patients were 14-year-old females (15.6%), and the interquartile range (IQR) of age was 9–14 years.

Table 3. Frequency of binocular single vision anomalies

Type	Frequency(n=45)	Percentage
Convergence insufficiency	35	77.4
Fusional vergence dysfunction	3	6.7
Convergence excess	3	6.7
Divergence insufficiency	1	2.3
Accommodation insufficiency with convergence insufficiency	1	2.3
Accommodative infacility	1	2.3
Normal	1	2.3
Total	45	100.00

Table 3. Among the 45 patients, 44 (97.8%) exhibited accommodative or vergence anomalies. The most frequent anomaly was convergence insufficiency (35/45; 77.4%), followed by fusional vergence dysfunction (3/45; 6.7%), convergence excess (3/45; 6.7%), divergence insufficiency (1/45; 2.3%), accommodation insufficiency with CI (1/45; 2.3%), and accommodative infacility (1/45; 2.3%). One participant (2.3%) exhibited normal binocular vision.

Table 4. Binocular single vision components pre- and post-vision therapy

Parameter	Before VT-Median (IQR)	After VT Median (IQR)
NPC break (cm)	8 (7-10)	7 (6-7)
NPC recovery (cm)	10 (10-12)	9 (8-9)
Distance NFV break (in PD)	8 (6 - 8)	12 (10 - 12)
Distance NFV recovery (in PD)	6 (4 - 6)	10 (8 - 10)
Near NFV break (in PD)	8 (4 - 10)	12 (10 - 14)
Near NFV recovery (in PD)	6 (6 - 6)	8 (8 - 10)
Distance PFV break (in PD)	8 (10 - 10)	15 (13 - 15)
Distance PFV recovery (in PD)	6 (6 - 8)	10 (10 - 10)
Near PFV break (in PD)	12 (4 - 15)	20 (20 - 25)
Near PFV recovery (in PD)	8 (6 - 10)	15 (15 - 15)

NPA OD (D)	10 (8 - 10)	8 (8 - 9)
NPA OS (D)	10 (8 - 10)	8 (8 - 9)

Table 4. Comparison of pre- and post-VT parameters demonstrates improvements across all measured components of binocular single vision. Statistically significant differences were observed in NPC break and recovery, as well as in near PFV break and recovery (Wilcoxon signed-rank test, $p = 0.036$). These findings indicate that vision therapy effectively enhances binocular visual function in patients with accommodative and vergence anomalies.

V. Discussion

The present study demonstrates a high prevalence of accommodative and vergence anomalies among symptomatic patients, with the majority being cases of convergence insufficiency (CI) (77.4%). These findings are consistent with previous research reporting similar trends.

A notable prevalence of refractive errors was also observed, with astigmatism (80%) being the most common. Vora et al. (2010) similarly reported astigmatism (27%) as the leading refractive error, followed by myopia (24.3%) and hyperopia (18.6%).

In a randomized, placebo-controlled, multicenter trial, Scheiman et al. (2005) demonstrated significant relief of symptoms in CI patients following vision therapy (VT). Earlier reviews by Cooper (1983) and Grisham (1988) also reported symptom relief in over 90% of adult CI patients after VT; however, these studies were limited by their reliance on self-reported outcomes without objective clinical verification.

Scheiman et al. (2005) further highlighted differences in treatment outcomes between children and adults, noting that pencil push-ups were ineffective in improving signs or symptoms in children with CI. In contrast, office-based VT was found to be more effective for children than for adults.

Although only one patient in the present study presented with both CI and accommodative insufficiency (AI), Marran et al. (2006) reported that these conditions often coexist in children and that AI requires targeted office-based VT for optimal treatment.

Office-based VT demands greater physical, mental, and financial commitment compared to home-based therapy, prompting many patients to prefer home therapy (e.g., pen exercises). Nevertheless, non-compliance or inadequate response to home therapy often necessitates transitioning to office-based VT.

In the present study, after a few sessions of office-based VT for CI and other accommodative and vergence anomalies, most patients experienced substantial symptom relief and improvements in accommodative and vergence parameters. Patients with CI were advised to continue pen exercises at home for one month following office therapy.

Post-treatment outcomes revealed that 36 out of 44 subjects reported complete symptom resolution, while 8 subjects achieved partial improvement. Statistically and clinically significant gains were observed in near positive fusional vergence (PFV) break and recovery, as well as in near point of convergence (NPC) break and recovery.

These findings align with those of Scheiman et al. (2005), who reported similar improvements in NPC and PFV to near-normal clinical levels after VT. In the current study, an NPC break greater than 6 cm was considered abnormal; however, diagnostic thresholds for CI vary across studies—6 cm in Scheiman et al. (2005), 7.5 cm in Cooper et al. (1988), and 10 cm in Adler (2002)—likely reflecting age-related differences and variations in clinical protocols.

A key limitation of this study was the lack of a non-intervention control group. Additionally, although the same optometrist conducted VT and performed both pre- and post-treatment assessments, baseline accommodative and vergence parameters were not evaluated until after the VT program, potentially limiting the interpretation of treatment-related changes.

VI. Limitations, Recommendations And Conclusion

Limitations

The limitations of this study included:

Absence of a Non-Intervention Control Group: The lack of a control group meant that the effect of vision therapy could not be conclusively isolated from natural improvement or placebo effects.

Sample Size and Duration: The sample size was small and the duration of the study was short.

Recommendations

Based on the findings of the present study, the following recommendations emerge for future research:

1. Studies utilizing a non-intervention control group and a larger sample size are necessary to strengthen the evidence base.
2. Future research should continue to explore factors influencing accommodation and vergence after conditions such as concussion.

3. Randomized, controlled studies are required to definitively determine whether performing vision therapy promotes the recovery of the visual system.

Conclusion

Anomalies of binocular single vision are common targets for vision therapy (VT). Accommodation refers to the eyes' ability to focus on objects at varying distances, whereas vergence describes the coordinated movement of both eyes to maintain single binocular vision. VT is designed to enhance the functional coordination of the visual system—eyes and brain—through specific exercises that improve visual processing and integration.

This retrospective observational study, conducted using purposive sampling, involved a comprehensive eye examination that assessed ocular motility, visual acuity, stereo acuity, near point of convergence (NPC), distance and near negative/positive fusional vergence (NFV & PFV), vergence facility, amplitude of accommodation, NRA, PRA, monocular accommodative facility (MAF), and binocular accommodative facility (BAF). Data were cleaned and analyzed using SPSS v.25.

The main limitations of the study were the absence of a non-intervention control group, a relatively small sample size, and a short study duration. Headache emerged as the most common presenting symptom, often linked to a receded NPC. Female patients were more likely than males to report asthenopia and diplopia.

Post-vision therapy, patients showed notable improvements in symptoms associated with accommodative and vergence anomalies. Significant clinical gains were observed in accommodative insufficiency, NPC, and both positive and negative fusional vergence.

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References

1. Adler, P. (2002). Efficacy of treatment for convergence insufficiency using vision therapy. *Ophthalmic and Physiological Optics*, 22(6), 565–571.
2. Aziz, S., Cleary, M., Stewart, H. K., & Weir, C. R. (2006). Are orthoptic exercises an effective treatment for convergence and fusion deficiencies? *Strabismus*, 14(4), 183–189.
3. Bade, A., Boas, M., Gallaway, M., Mitchell, G. L., Scheiman, M., Kulp, M. T., ... & Rouse, M. (2013). Relationship between clinical signs and symptoms of convergence insufficiency. *Optometry and Vision Science: Official Publication of the American Academy of Optometry*, 90(9), 988–995.
4. Convergence Insufficiency Treatment Trial (CITT) Study Group. (2008). The convergence insufficiency treatment trial: Design, methods, and baseline data. *Ophthalmic Epidemiology*, 15(1), 24–36.
5. Classé, J. G., & Rutstein, R. P. (1995). Binocular vision anomalies: An emerging cause of malpractice claims. *Journal of the American Optometric Association*, 66(5), 305–309.
6. Cooper, J., Selenow, A., Ciuffreda, K. J., Feldman, J., Faverty, J., Hokoda, S. C., & Silver, J. (1983). Reduction of asthenopia in patients with convergence insufficiency after fusional vergence training. *American Journal of Optometry and Physiological Optics*, 60, ... [add page range].
7. Cooper, J. S., Cotter, S. A., Daum, K. M., Amos, J. F., Beebe, K. L., & Cavallerano, J. (1998). *Optometry: The primary eye-care profession*.
8. Cooper, J. S., Burns, C. R., Cotter, S. A., Daum, K. M., Griffin, J. R., & Scheiman, M. M. (1998). American Optometric Association Consensus Panel with Accommodative and Vergence Dysfunction. Care of the patient with accommodative and vergence dysfunction: Optometric clinical practice guidelines. St. Louis: American Optometric Association.
9. Daum, K. M. (1983). Accommodative insufficiency. *American Journal of Optometry and Physiological Optics*, 60(5), 352–359.

10. Duane, A. (1915). Anomalies of the accommodation clinically considered. Transactions of the American Ophthalmological Society, 14(Pt 1), 386–402.
11. Dusek, W. A., Pierscionek, B. K., & McClelland, J. F. (2011). An evaluation of clinical treatment of convergence insufficiency for children with reading difficulties. BMC Ophthalmology, 11, 1–9.
12. Evans, B. J. (2021). Pickwell's binocular vision anomalies (E-book). Elsevier Health Sciences.
13. Gallaway, M., Scheiman, M., & Malhotra, K. (2002). The effectiveness of pencil-push-ups treatment for convergence insufficiency: A pilot study. Optometry and Vision Science, 79(4), 265–267.
14. Grisham, D., Powers, M., & Riles, P. (2007). Visual skills of poor readers in high school. Optometry – Journal of the American Optometric Association, 78(10), 542–549.
15. Grisham, J. D. (1988). Visual therapy results for convergence insufficiency: A literature review. American Journal of Optometry and Physiological Optics, 65(6), 448–454.
16. Hayes, G. J., Cohen, B. E., Rouse, M. W., & De Land, P. N. (1998). Normative values for the near point of convergence of elementary-school children. Optometry and Vision Science, 75(7), 506–512.
17. Hokoda, S. C. (1985). General binocular dysfunctions in an urban optometry clinic. Journal of the American Optometric Association, 56(7), 560–562.
18. Hoffman, L., Cohen, A. H., & Feuer, G. (1973). Effectiveness of non-strabismus optometric vision training in a private practice. American Journal of Optometry and Archives of the American Academy of Optometry, 50(10), 813–816.
19. Hussaindeen, J. R., Shah, P., Ramani, K. K., & Ramanujan, L. (2018). Efficacy of vision therapy in children with learning disability and associated binocular vision anomalies. Journal of Optometry, 11(1), 40–48.
20. Jang, J. U., Jang, J. Y., Kim, T.-H., & Moon, H. W. (2017). Effectiveness of vision therapy in school children with symptomatic convergence insufficiency. Journal of Ophthalmic & Vision Research, 12(2), 187–193.
21. Marran, L. F., De Land, P. N., & Nguyen, A. L. (2006). Accommodative insufficiency is the primary source of symptoms in children diagnosed with convergence insufficiency. Optometry and Vision Science, 83(5), 281–289.
22. McGregor, M. L. (2014). Convergence insufficiency and vision therapy. Pediatric Clinics of North America, 61(3), 621–630.
23. Muzaliha, M. N., Nurhamiza, B., Hussein, A., Norabibas, A. R., Mohd-Hisham-Basrun, J., Sarimah, A., ... & Shatriah, I. (2012). Visual acuity and visual skills in Malaysian children with learning disabilities. Clinical Ophthalmology, 6, 1527–1533.

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We, the undersigned, certify that we have carefully read and hereby recommend to the Maulana Abul Kalam Azad University of Technology the acceptance of this dissertation entitled:

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Declaration

I hereby declare that the work presented in this dissertation is my own and has not been submitted previously, in whole or in part, for any degree or diploma at any other institution. All sources of information and data used have been properly cited and acknowledged. Any errors or inaccuracies are solely my responsibility.

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