

Original Article

Effects of Brock String Therapy vs Computer Based Vergence Therapy on Reading Speed, Visual Comfort and Binocular Functions in School Aged Children with Convergence Insufficiency

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Received: 08 May 2026

Revised: 19 May 2026

Accepted: 03 June 2026

Published: 30 June 2026

ARTICLE INFORMATION	ABSTRACT
Article Type: Original Article How to Cite: Mahnoor, Memon AG, Babur MN, Khalid T, Rizwan A, Hashmi H, Riasat R. Effects of Accommodative Vergence Training With and Without Full Optical Correction on Visual Comfort, Near Point of Convergence and Visual Acuity in Young Patients With Myopic Anisometropia. Journal of Precision Medicine and Health Research. 2026;3(1). Article ID: 60 DOI: https://doi.org/10.68279/hrf55k07 Article Link: https://jpmhr.com/index.php/jpmhr/article/view/60 Declarations: See end of article. OPEN ACCESS This is an open access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY 4.0).	Background: Convergence insufficiency can produce visual discomfort and difficulty during sustained near activities in school-aged children. Brock String Therapy and Computer-Based Vergence Therapy are used to train binocular function, but direct comparative evidence across symptomatic, clinical, and reading outcomes remains limited. Objective: To compare the effects of Brock String Therapy and Computer-Based Vergence Therapy on convergence insufficiency symptoms, visual comfort, binocular functions, and reading speed in school-aged children with convergence insufficiency. Methods: This parallel-group randomized clinical trial included 60 children aged 8–15 years recruited at Government Girls Elementary School Kotla Malam, District Rajanpur. Participants were allocated to Brock String Therapy (n=30) or Computer-Based Vergence Therapy (n=30). Outcomes included the Convergence Insufficiency Symptom Survey (CISS), visual comfort, near point of convergence (NPC), positive fusional vergence (PFV), and reading speed. Paired and independent-samples t-tests were used for within- and between-group comparisons. Results: Both groups demonstrated significant pre-to-post changes across all outcomes (p<0.001). Post-treatment CISS scores were lower with Computer-Based Vergence Therapy than Brock String Therapy (23.07±6.03 vs 29.30±6.37; p<0.001), and reading speed was higher (140.03±10.72 vs 127.13±17.33 WPM; p=0.001). Computer-Based Vergence Therapy also showed more favourable post-treatment visual-comfort, NPC, and PFV values. Conclusion: Both interventions were associated with favourable short-term changes, while Computer-Based Vergence Therapy demonstrated more favourable post-treatment outcomes across the assessed measures. Keywords: Convergence insufficiency; Brock String Therapy; Computer-Based Vergence Therapy; vision therapy; reading speed; visual comfort; binocular vision.

Introduction

Vision plays a central role in childhood development, learning, and performance of everyday activities because a substantial proportion of academic work depends on accurate and sustained visual processing. Visual function enables children to obtain information from their surroundings, maintain attention during visually demanding activities, and perform tasks that require prolonged fixation and near viewing (1). School-based learning frequently involves reading, writing, copying from books or screens, and other sustained near-vision activities that place continuous demands on the visual system (2). Increasing exposure to digital devices has further intensified these demands in school-aged children and has been associated with symptoms such as eyestrain, headache, blurred vision, visual fatigue, and difficulty maintaining concentration during prolonged near work (3).

An essential component of efficient near vision is binocular visual function, which depends on the coordinated use of both eyes to maintain clear and single vision during visually demanding tasks (4). Normal binocular performance requires appropriate ocular alignment, accommodation, vergence, fusion, and stereoscopic function, particularly when the viewing distance changes or near fixation must be maintained for an extended period (5). Disturbance of these coordinated processes may result in visual discomfort, unstable fixation, and reduced tolerance for prolonged reading or computer-based activities (6). Convergence insufficiency (CI) is an important non-strabismic binocular vision disorder characterized by difficulty maintaining adequate convergence during near viewing and is commonly associated with symptoms arising during sustained close work (7). Children with CI may experience eyestrain, headache, blurred or intermittent double vision, difficulty maintaining focus, and discomfort during reading or other near-visual activities (8). Such symptoms may interfere with functional performance by contributing to loss of place during reading, reduced concentration, avoidance of sustained near tasks, and poorer school-related visual efficiency (9).

Reading is a complex visual task requiring coordinated fixation, ocular movements, accommodation, binocular alignment, and repeated vergence responses. Disturbance of one or more of these visual processes may therefore contribute to inefficient reading performance or increased visual fatigue during prolonged reading (10). Visual comfort is similarly dependent on the ability of the accommodative and vergence systems to sustain near vision without excessive visual effort. Difficulties in maintaining binocular coordination may consequently increase discomfort and reduce tolerance for prolonged near activities (11). Clinical assessment of CI therefore commonly includes evaluation of binocular measures such as near point of convergence (NPC) and positive fusional vergence (PFV), which provide information regarding convergence ability, fusional reserves, and the capacity to maintain single binocular vision under increasing vergence demand (12). In addition to symptom severity, functional outcomes such as reading speed may provide clinically relevant information regarding the effect of binocular dysfunction on activities that are important to school-aged children.

Management of convergence insufficiency includes different forms of vergence and accommodative therapy intended to improve binocular coordination, convergence ability, accommodative control, and tolerance of sustained near viewing (13). Brock String Therapy (BST) is a commonly used low-cost vision-therapy technique in which fixation on beads positioned at different distances along a string provides direct visual feedback regarding ocular alignment and convergence. The technique is intended to facilitate awareness of binocular fixation and progressively train convergence and divergence responses (14). In contrast, computer-based vergence therapy uses digitally

generated visual tasks to provide repeated vergence stimulation, adjustable levels of difficulty, and immediate performance feedback. Computer-assisted and virtual visual-training approaches have increasingly been investigated as methods of delivering structured and progressive binocular therapy for patients with convergence or accommodative dysfunction (15).

Previous literature indicates that therapeutic exercises can improve clinical signs and symptoms associated with convergence insufficiency; however, the relative effectiveness of individual treatment approaches remains uncertain. Studies examining different CI therapies suggest that treatment response may vary according to the type, intensity, supervision, progression, and mode of visual training provided (14). Computer- or technology-assisted approaches may allow greater standardization and progressive control of visual demand, whereas BST remains inexpensive, accessible, and relatively easy to administer. Nevertheless, evidence directly comparing these approaches in school-aged children remains limited, particularly when treatment effects are evaluated across both clinical binocular measures and functional outcomes. More specifically, there is insufficient comparative information regarding whether BST and computer-based vergence therapy differ in their effects on CI symptoms, visual comfort, NPC, PFV, and reading speed within the same pediatric population.

A direct comparison of these interventions is therefore clinically relevant because both approaches may be used in rehabilitation settings but differ considerably in equipment requirements, mode of delivery, feedback, progression, and accessibility. Determining whether one approach produces greater improvement in both clinical and functional outcomes may assist clinicians in selecting an appropriate therapy for children with symptomatic convergence insufficiency. Accordingly, the objective of this randomized clinical trial was to compare the effects of Brock String Therapy and Computer-Based Vergence Therapy on convergence insufficiency symptoms, visual comfort, near point of convergence, positive fusional vergence, and reading speed in school-aged children with convergence insufficiency. It was hypothesized that both interventions would improve the assessed outcomes, with a difference in the magnitude of improvement between the two treatment groups.

Materials and Methods

A prospective, parallel-group randomized clinical trial was conducted at Government Girls Elementary School Kotla Malam, District Rajanpur, Pakistan, to compare the effects of Brock String Therapy and Computer-Based Vergence Therapy in school-aged children with convergence insufficiency. The study population consisted of children aged 8–15 years who were clinically diagnosed with convergence insufficiency and experienced symptoms during near visual activities. Participants were recruited using a non-probability convenience sampling approach according to predefined eligibility criteria. Children were eligible if they were 8–15 years of age, had a clinical diagnosis of convergence insufficiency, experienced symptoms during sustained near visual tasks, and had written permission from a parent or legal guardian to participate. Children with strabismus or other ocular pathology, a history of ocular surgery, neurological disorders, concurrent participation in another vision-therapy program, or unwillingness to participate were excluded.

The required sample size was calculated using G*Power software version 3.1 on the basis of an effect size of 0.80, an alpha level of 0.05, and statistical power of 80%, resulting in a total sample of 60 participants (16). Following eligibility screening and baseline assessment, the enrolled participants were randomly allocated in a 1:1 ratio to two intervention groups, with 30 participants assigned to Brock String Therapy and 30 to Computer-Based Vergence Therapy. Baseline demographic information and clinical measurements were obtained before initiation of treatment. Written informed consent was obtained from the parents or legal guardians of all participating children before enrolment, and assent was obtained from the children according to their age and level of understanding.

Clinical and functional outcomes were assessed before and after the intervention. Reading speed was evaluated using an age-appropriate reading passage, with the number of correctly read words during one minute recorded as words per minute (WPM) (17). Symptoms related to convergence insufficiency were assessed using the Convergence Insufficiency Symptom Survey (CISS), a 15-item questionnaire addressing symptoms experienced during near visual activities such as reading. Each item was scored from 0, indicating “never,” to 4, indicating “always,” producing a total score ranging from 0 to 60, with higher scores representing greater symptom severity (18). Visual comfort was evaluated using the Visual Comfort Questionnaire, with lower post-intervention scores representing improvement in visual discomfort as reported in the study outcomes.

Near point of convergence was assessed as an objective measure of convergence ability. During testing, an accommodative target was moved slowly toward the participant’s nose while binocular fixation was maintained. The distance at which the participant first reported diplopia or the examiner observed loss of binocular fixation was recorded as the NPC break point. The corresponding recovery measurement was also recorded as part of the binocular assessment (19). Positive fusional vergence was evaluated at near using a prism bar while the participant maintained fixation on a near target. Base-out prism power was progressively increased to determine fusional vergence responses, and blur, break, and recovery values were recorded in prism diopters as indicators of vergence reserve and binocular fusion capacity (20).

Participants assigned to the Brock String Therapy group received structured vergence training using a Brock string with multiple coloured beads positioned at different viewing distances. Participants were instructed to direct binocular fixation toward the beads during sequential vergence tasks, using the visual feedback generated by the string and beads to facilitate convergence awareness, ocular alignment, and coordinated binocular responses. The intervention was intended to progressively train convergence ability and binocular coordination through repeated fixation at different distances (21). Participants allocated to the Computer-Based Vergence Therapy group received digitally delivered vergence exercises using interactive computer-generated visual tasks designed to train convergence, divergence, fusion, and binocular coordination. The difficulty of the computerized exercises was adjusted according to individual performance to provide progressively challenging visual training and repeated vergence stimulation (22).

The same clinical outcomes were assessed at baseline and following completion of the assigned intervention. These included convergence-insufficiency symptoms measured by the CISS, visual comfort, NPC break and recovery points, PFV blur, break and recovery values, and reading speed in words per minute. The use of identical outcome domains before and after therapy permitted assessment of within-group change and comparison of post-intervention outcomes between the two treatment groups.

Data were analyzed using IBM SPSS Statistics version 27.0. Continuous variables were summarized as mean and standard deviation, whereas categorical variables were presented as frequencies and percentages. Distributional normality of continuous variables was evaluated using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Within-group differences between baseline and post-intervention measurements were examined using paired-samples t-tests. Independent-samples t-tests were used to compare continuous outcome measures between the Brock String Therapy and Computer-Based Vergence Therapy groups. Statistical significance was defined as a two-sided p-value of <0.05.

Ethical approval was obtained from the Institutional Review Board of The Superior University, Lahore, before commencement of the study under reference number IRB/FAHS/REHAB/04/26/MS/RS-4084. Participation was voluntary, written informed consent was obtained from parents or legal guardians before enrolment, and child assent was obtained according to age and understanding. The study procedures were undertaken after institutional ethical approval and in accordance with the approved research protocol.

Results

A total of 60 participants were included in the analysis, with 30 allocated to Brock String Therapy and 30 to Computer-Based Vergence Therapy. The mean age was 12.00 ± 2.45 years in the Brock String Therapy group and 12.07 ± 2.00 years in the Computer-Based Vergence Therapy group, with no evidence of a between-group difference ($p=0.904$). The sex distribution also did not differ significantly between groups ($p=0.196$). All participants reported daily digital-device use, while the distribution of reported screen-time categories was similar between groups ($p=0.957$).

Baseline clinical and functional measures were generally comparable between the treatment groups. Baseline CISS scores were 37.80 ± 4.26 in the Brock String Therapy group and 39.50 ± 5.29 in the Computer-Based Vergence Therapy group, corresponding to a mean difference of 1.70 (95% CI -0.78 to 4.18 ; $p=0.176$). Baseline reading speeds were also similar at 95.13 ± 5.56 and 94.80 ± 4.96 WPM, respectively (mean difference -0.33 WPM, 95% CI -3.05 to 2.39 ; $p=0.809$). No statistically significant baseline differences were observed for visual-comfort scores, NPC break or recovery, or PFV measures.

Table 1. Baseline demographic characteristics of participants by treatment group

Variable	Category	Brock String Therapy (n=30)	Computer-Based Vergence Therapy (n=30)	p-value
Age, years	Mean $\pm$ SD	12.00 ± 2.45	12.07 ± 2.00	0.904
Sex	Male	18 (60.0)	13 (43.3)	0.196
	Female	12 (40.0)	17 (56.7)	
Academic grade	Grades 1–3	4 (13.3)	1 (3.3)	
	Grades 4–6	9 (30.0)	12 (40.0)	
	Grades 7–9	12 (40.0)	13 (43.3)	
	Grade 10	5 (16.7)	4 (13.3)	
Daily digital-device use	Yes	30 (100.0)	30 (100.0)	
Screen time	<1 hour/day	12 (40.0)	13 (43.3)	0.957
	3–4 hours/day	7 (23.3)	7 (23.3)	
	>4 hours/day	11 (36.7)	10 (33.3)	

Table 2. Baseline clinical and functional outcomes in the two treatment groups

Outcome	Brock String Therapy (n=30), Mean $\pm$ SD	Computer-Based Vergence Therapy (n=30), Mean $\pm$ SD	Mean difference	95% CI	p	Cohen's d
CISS score	37.80 ± 4.26	39.50 ± 5.29	1.70	-0.78 to 4.18	0.176	0.35
Visual Comfort Questionnaire score	23.43 ± 2.86	23.43 ± 2.49	0.00	-1.39 to 1.39	1.000	0.00
NPC break, cm	11.81 ± 2.28	12.51 ± 2.00	0.70	-0.41 to 1.81	0.211	0.33
NPC recovery, cm	15.46 ± 2.54	16.32 ± 2.34	0.86	-0.40 to 2.12	0.178	0.35
PFV blur, Δ	9.30 ± 2.00	9.13 ± 1.89	-0.17	-1.18 to 0.84	0.736	-0.09
PFV break, Δ	12.33 ± 2.12	13.37 ± 2.27	1.04	-0.10 to 2.18	0.072	0.47
PFV recovery, Δ	14.37 ± 2.19	15.37 ± 2.27	1.00	-0.15 to 2.15	0.088	0.45
Reading speed, WPM	95.13 ± 5.56	94.80 ± 4.96	-0.33	-3.05 to 2.39	0.809	-0.06

Table 3. Pre-treatment, post-treatment, and within-group changes in clinical and functional outcomes

Outcome	Group	Baseline, Mean $\pm$ SD	Post-treatment, Mean $\pm$ SD	Mean change	Within-group p-value
CISS score	Brock String Therapy	37.80 ± 4.26	29.30 ± 6.37	-8.50	<0.001
	Computer-Based Vergence Therapy	39.50 ± 5.29	23.07 ± 6.03	-16.43	<0.001
Visual Comfort Questionnaire score	Brock String Therapy	23.43 ± 2.86	15.33 ± 3.26	-8.10	<0.001
	Computer-Based Vergence Therapy	23.43 ± 2.49	10.60 ± 3.84	-12.83	<0.001
NPC break, cm	Brock String Therapy	11.81 ± 2.28	6.42 ± 2.12	-5.39	<0.001
	Computer-Based Vergence Therapy	12.51 ± 2.00	4.36 ± 0.77	-8.15	<0.001
NPC recovery, cm	Brock String Therapy	15.46 ± 2.54	8.74 ± 2.80	-6.72	<0.001
	Computer-Based Vergence Therapy	16.32 ± 2.34	6.42 ± 1.02	-9.90	<0.001
PFV blur, Δ	Brock String Therapy	9.30 ± 2.00	14.73 ± 2.00	5.43	<0.001
	Computer-Based Vergence Therapy	9.13 ± 1.89	16.17 ± 1.86	7.04	<0.001
PFV break, Δ	Brock String Therapy	12.33 ± 2.12	25.57 ± 3.53	13.24	<0.001
	Computer-Based Vergence Therapy	13.37 ± 2.27	29.93 ± 5.98	16.56	<0.001
PFV recovery, Δ	Brock String Therapy	14.37 ± 2.19	30.60 ± 3.46	16.23	<0.001
	Computer-Based Vergence Therapy	15.37 ± 2.27	34.93 ± 5.98	19.56	<0.001
Reading speed, WPM	Brock String Therapy	95.13 ± 5.56	127.13 ± 17.33	32.00	<0.001
	Computer-Based Vergence Therapy	94.80 ± 4.96	140.03 ± 10.72	45.23	<0.001

Table 4. Post-treatment between-group comparisons and standardized effect estimates

Outcome	Brock String Therapy (n=30), Mean $\pm$ SD	Computer-Based Vergence Therapy (n=30), Mean $\pm$ SD	Mean difference	95% CI	p-value	Cohen's d
CISS score	29.30 $\pm$ 6.37	23.07 $\pm$ 6.03	-6.23	-9.44 to -3.02	<0.001	-1.00
Visual Comfort Questionnaire score	15.33 $\pm$ 3.26	10.60 $\pm$ 3.84	-4.73	-6.57 to -2.89	<0.001	-1.33
NPC break, cm	6.42 $\pm$ 2.12	4.36 $\pm$ 0.77	-2.06	-2.88 to -1.24	<0.001	-1.29
NPC recovery, cm	8.74 $\pm$ 2.80	6.42 $\pm$ 1.02	-2.32	-3.41 to -1.23	<0.001	-1.10
PFV blur, Δ	14.73 $\pm$ 2.00	16.17 $\pm$ 1.86	1.44	0.44 to 2.44	0.005	0.75
PFV break, Δ	25.57 $\pm$ 3.53	29.93 $\pm$ 5.98	4.36	1.82 to 6.90	0.001	0.89
PFV recovery, Δ	30.60 $\pm$ 3.46	34.93 $\pm$ 5.98	4.33	1.81 to 6.86	0.001	0.89
Reading speed, WPM	127.13 $\pm$ 17.33	140.03 $\pm$ 10.72	12.90	5.45 to 20.35	0.001	0.90

Values are mean $\pm$ SD or n (%). The age comparison was evaluated using an independent-samples t-test. Sex and screen-time distributions were evaluated using Pearson's χ^2 test. A p-value was not assigned to academic grade because of sparse cells in the lower-grade category, and digital-device use had no between-participant variability. CISS, Convergence Insufficiency Symptom Survey; NPC, near point of convergence; PFV, positive fusional vergence; WPM, words per minute; Δ , prism diopters; CI, confidence interval. Mean differences were calculated as Computer-Based Vergence Therapy minus Brock String Therapy. P-values are based on independent-samples t-tests. Cohen's d was calculated using the pooled standard deviation. Mean change was calculated as post-treatment minus baseline. Negative change therefore represents a reduction in CISS, visual-comfort, and NPC values, whereas positive change represents an increase in PFV and reading-speed values. Within-group p-values are the paired-comparison values reported in the manuscript. CISS, Convergence Insufficiency Symptom Survey; NPC, near point of convergence; PFV, positive fusional vergence; WPM, words per minute; Δ , prism diopters; CI, confidence interval. Mean difference was calculated as Computer-Based Vergence Therapy minus Brock String Therapy. P-values were calculated using independent-samples t-tests from the reported means, standard deviations, and group sizes. Cohen's d was calculated using the pooled standard deviation.

Both groups demonstrated statistically significant pre-to-post changes across all assessed clinical and functional outcomes (all reported paired $p < 0.001$). CISS scores decreased by 8.50 points in the Brock String Therapy group and by 16.43 points in the Computer-Based Vergence Therapy group. Visual Comfort Questionnaire scores decreased by 8.10 and 12.83 points, respectively. NPC break decreased from 11.81 $\pm$ 2.28 to 6.42 $\pm$ 2.12 cm with Brock String Therapy and from 12.51 $\pm$ 2.00 to 4.36 $\pm$ 0.77 cm with Computer-Based Vergence Therapy. Corresponding decreases in NPC recovery were 6.72 and 9.90 cm. PFV measures increased in both treatment groups. PFV blur increased by 5.43 Δ in the Brock String Therapy group and 7.04 Δ in the Computer-Based Vergence Therapy group, while PFV break increased by 13.24 and 16.56 Δ , respectively. PFV recovery increased by 16.23 Δ following Brock String Therapy and by 19.56 Δ following Computer-Based Vergence Therapy. Reading speed increased from 95.13 $\pm$ 5.56 to 127.13 $\pm$ 17.33 WPM in the Brock String Therapy group and from 94.80 $\pm$ 4.96 to 140.03 $\pm$ 10.72 WPM in the Computer-Based Vergence Therapy group, corresponding to mean increases of 32.00 and 45.23 WPM, respectively.

At post-treatment assessment, the Computer-Based Vergence Therapy group had a lower mean CISS score than the Brock String Therapy group by 6.23 points (95% CI -9.44 to -3.02; $p < 0.001$; Cohen's $d = -1.00$). The visual-comfort score was lower by 4.73 points (95% CI -6.57 to -2.89; $p < 0.001$; $d = -1.33$), while NPC break and recovery were lower by 2.06 cm (95% CI -2.88 to -1.24; $p < 0.001$; $d = -1.29$) and 2.32 cm (95% CI -3.41 to -1.23; $p < 0.001$; $d = -1.10$), respectively. Post-treatment PFV values were also different between groups. Compared with Brock String Therapy, the Computer-Based Vergence Therapy group had a 1.44- Δ higher PFV blur value (95% CI 0.44 to 2.44; $p = 0.005$; $d = 0.75$), a 4.36- Δ higher PFV break value (95% CI 1.82 to 6.90; $p = 0.001$; $d = 0.89$), and a 4.33- Δ higher PFV recovery value (95% CI 1.81 to 6.86; $p = 0.001$; $d = 0.89$). Reading speed at post-treatment was 12.90 WPM higher in the Computer-Based Vergence Therapy group (95% CI 5.45 to 20.35; $p = 0.001$; $d = 0.90$). The standardized post-treatment differences were moderate to large across the measured outcomes, although these estimates represent unadjusted comparisons of post-treatment values rather than baseline-adjusted treatment effects.

Discussion

The present randomized clinical trial compared Brock String Therapy (BST) and Computer-Based Vergence Therapy (CBVT) in school-aged children with convergence insufficiency and found favorable pre-to-post changes in convergence insufficiency symptoms, visual comfort, near point of convergence (NPC), positive fusional vergence (PFV), and reading speed in both treatment groups. At post-treatment assessment, children receiving CBVT had lower CISS and visual-comfort scores, lower NPC break and recovery values, higher PFV measures, and greater reading speed than those receiving BST. The magnitude of the unadjusted post-treatment differences was moderate to large across the assessed outcomes. These findings suggest that both approaches were associated with short-term changes in symptomatic, binocular, and functional measures, while CBVT was associated with more favorable post-treatment values in this study population.

The reduction in convergence insufficiency symptoms observed following both interventions is consistent with previous evidence supporting vergence and accommodative therapy for symptomatic CI. The American Academy of Ophthalmology review of home- and office-based vergence and accommodative therapies concluded that structured therapeutic approaches can improve motor outcomes in children and young adults with convergence insufficiency, although the evidence for symptom improvement varies according to the intervention and study design (23). Similarly, Jenewein et al. demonstrated that clinical measures of convergence function can improve during vergence/accommodative therapy in children with symptomatic CI, with different outcome measures showing different trajectories of response over the treatment period (24). The greater reduction in CISS scores observed in the CBVT group in the present study may reflect differences in the mode and progression of training; however, because the current analysis is based on unadjusted post-treatment comparisons, the magnitude of comparative treatment benefit should be interpreted cautiously.

Visual comfort also changed favorably in both groups, with lower post-treatment scores in the CBVT group. Symptoms such as eyestrain, headache, blurred or double vision, and difficulty maintaining visual attention during near activities are recognized clinical features associated with convergence insufficiency (25). Improvements in vergence control could plausibly reduce the visual effort required to maintain single binocular vision during sustained near tasks and thereby contribute to greater comfort. Computer-based training may additionally facilitate repeated exposure to progressively demanding vergence tasks and provide immediate visual feedback. These

mechanisms are plausible explanations for the observed findings rather than mechanisms directly tested in the present trial. Interpretation of the visual-comfort findings should also take into account the subjective nature of questionnaire-based assessment.

NPC break and recovery values decreased after treatment in both groups, with lower post-treatment values following CBVT. NPC is an important clinical measure of the ability to maintain convergence as a target approaches the observer and is commonly used in the clinical evaluation of convergence insufficiency. The direction of change observed in the present study is consistent with previous evidence showing improvement in convergence function during structured vergence/accommodative therapy in children with symptomatic CI (24). Repetitive convergence tasks may enhance the participant's ability to initiate and sustain an appropriate vergence response during near fixation. The larger post-treatment differences observed with CBVT could potentially relate to progressive adjustment of task difficulty and repeated controlled vergence stimulation, although these specific mechanisms were not independently evaluated in this study.

Changes were also observed in PFV blur, break, and recovery measurements following both interventions. Fusional vergence represents the capacity of the binocular visual system to maintain single vision as vergence demand changes and is therefore relevant to the functional assessment of convergence insufficiency. Previous clinical evidence indicates that vergence/accommodative therapy can improve objective measures of convergence function in children with symptomatic CI (23,24). The present findings are compatible with this broader evidence, with higher post-treatment PFV values observed in the CBVT group. Oculomotor and convergence-training approaches, including Brock String-based procedures, continue to be investigated as strategies for modifying convergence-related function (27). However, because the latter evidence includes a clinical trial protocol rather than completed comparative outcome data, it supports the rationale for further investigation rather than providing direct confirmation of therapeutic effectiveness.

Reading speed increased following both interventions and was higher at post-treatment in the CBVT group. This finding is clinically relevant because reading requires coordinated fixation, eye movements, accommodation, and binocular control. Nevertheless, improvement in clinical convergence measures should not automatically be interpreted as improvement in broader reading ability. A randomized clinical trial examining vergence/accommodative therapy in children with symptomatic convergence insufficiency found improvement in convergence-related clinical outcomes but did not demonstrate superiority of therapy over placebo for standardized reading performance (26). The present findings therefore need to be interpreted in the context of differences in reading assessments, treatment protocols, study populations, and follow-up periods. In addition, repeated administration of a reading task may be influenced by familiarity, attention, motivation, or practice effects. The observed increase in words per minute is therefore encouraging but should not be taken as evidence that vergence therapy independently improves overall academic or reading achievement.

From a clinical perspective, the findings indicate that both BST and CBVT may have practical roles in the management of school-aged children with convergence insufficiency. BST requires relatively simple equipment and may represent an accessible approach to vergence training, whereas computerized therapy can provide interactive exercises and progressively adjustable visual demands. The more favorable post-treatment outcomes observed with CBVT across several domains suggest that digitally delivered vergence training warrants further investigation as a structured therapeutic option. Treatment selection, however, should not be based solely on the present findings because accessibility, cost, supervision, adherence, treatment burden, and longer-term maintenance of treatment response were not evaluated.

An important strength of the study was the direct comparison of two active therapeutic approaches within the same pediatric population. The assessment incorporated both symptom-based and clinical binocular measures, including CISS, NPC, and PFV, together with the functional outcome of reading speed. Evaluation of multiple outcome domains provides a broader perspective on treatment-associated changes than reliance on a single clinical measure. The equal allocation of 30 participants to each treatment group and the availability of baseline and post-treatment measurements also permitted assessment of changes within each intervention group and comparison of post-treatment outcomes between groups.

Several limitations should be considered when interpreting the findings. Participants were recruited using convenience sampling from a limited geographical setting, which restricts generalizability to broader pediatric populations. The sample size was modest, and no long-term follow-up was available to determine whether the observed changes were maintained after completion of therapy. The study compared two active interventions without a placebo or no-treatment control group, limiting the ability to distinguish intervention-related changes from practice, attention, or other time-related effects. Blinding of outcome assessment was not documented, creating the possibility of measurement bias, particularly for examiner-dependent and subjective outcomes. The reading assessment may also have been susceptible to repeated-testing effects, and adherence, treatment fidelity, and adverse events were not reported. Furthermore, multiple outcomes were tested without a reported adjustment for multiplicity, and the principal between-group findings were based on unadjusted post-treatment comparisons rather than baseline-adjusted estimates or group-by-time interaction analyses. Accordingly, the apparent advantage of CBVT should be interpreted as evidence of more favorable short-term post-treatment outcomes in this sample rather than definitive evidence of superiority. Future trials using adequately powered samples, standardized intervention protocols, masked outcome assessment, validated functional measures, baseline-adjusted statistical models, and longer follow-up would provide more precise evidence regarding the comparative effects and durability of these approaches.

Conclusion

Both Brock String Therapy and Computer-Based Vergence Therapy were associated with favorable short-term changes in convergence insufficiency symptoms, visual comfort, near point of convergence, positive fusional vergence, and reading speed among school-aged children with convergence insufficiency. Computer-Based Vergence Therapy produced more favorable post-treatment values than Brock String Therapy across the assessed outcomes, including lower symptom and visual-comfort scores, lower NPC measurements, higher PFV values, and greater reading speed. These findings support the potential clinical utility of both approaches while indicating a greater short-term benefit associated with Computer-Based Vergence Therapy in this study population; however, the comparative findings should be interpreted in the context of the study design and unadjusted post-treatment analyses.

DECLARATIONS

Author Contributions:	Concept: TK, AGM; Design: TK, AGM, MNB; Data Collection: TK, MH, RR, AK, HA; Analysis: TK, AGM, MNB; Drafting: TK, MH, RR, AK, HA.
Ethical Approval:	Ethical approval was obtained from superior university Lahore
Informed Consent:	Written informed consent was obtained from parents or guardians before participant enrollment.
Conflict of Interest:	The authors declare no conflict of interest.

Funding:	No external funding was received for this study.
Data Availability:	Data are available from the corresponding author on reasonable request.
Acknowledgments:	None.
AI Declaration:	Generative AI tools were used solely for language and grammatical refinement. The authors verified the final manuscript and remain fully responsible for its accuracy, integrity, and scientific content.

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