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Efficacy of Pencil Pushup Exercises versus Base Out Exercising Prisms in Patients with Convergence Insufficiency

Mehronisa[1*], Muhammad Anwar Awan[1], Muhammad Aleem Sabir Khan[1], Saira Akram Mughal[1], Nimra Shahzad[1], Zaryab Khan[1]

[1*]Faculty of Allied Health Sciences, Superior University, Lahore, Pakistan

KEYWORDS

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DECLARATIONS

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CORRESPONDING AUTHOR

Mehronisa
Faculty of Allied Health Sciences, Superior University, Lahore, Pakistan
drmehronisa@gmail.com

ABSTRACT

Background: Convergence insufficiency is a common binocular vision disorder in children and adolescents, often leading to symptoms like eye strain, blurred vision, and difficulty reading. Various non-surgical interventions exist, including pencil push-up exercises and base-out prism therapy. **Objective:** To compare the efficacy of base-out exercising prisms and pencil push-up exercises in improving convergence insufficiency. **Methodology:** This controlled trial included 28 participants aged 10 to 15 years with clinically diagnosed convergence insufficiency. A total of 28 individuals aged 10-15 were selected through random sampling based on near point of convergence and convergence insufficiency symptom survey scores. Patients with history of strabismus, amblyopia, or refractive error more than six diopters, patients with a history of prism prescription, history of strabismus surgery, or refractive error surgery, eye trauma, or any systemic and neurological diseases affecting binocular vision were excluded. Participants were randomly divided into two groups: Group A received base-out exercising prisms for 15-20 minutes daily, five days a week, for 12 weeks, while Group B performed pencil pushup exercises for the same duration. After 12 weeks, the same tests will be repeated to assess improvements in both scores. Data was securely recorded and analysed to ensure accurate and consistent evaluation of the interventions. Statistical analysis was conducted using Kruskal-Wallis and Friedman tests. **Results:** Baseline, midline, and Post, the mean ranks decrease from baseline to post, with a chi-square of 53.05 and a p-value of 0.000. This suggests a significant difference across the time points for the near point of convergence. Baseline, midline, and postline mean ranks also decrease, with a chi-square of 51.92 and a p-value of 0.000. This indicates a significant difference in symptom scores across these time points. **Conclusion:** Both near point of convergence and convergence insufficiency symptom survey scores show significant changes over time (from baseline to post), as indicated by the low p-values (0.000). The decrease in mean ranks for both scores from baseline to post suggests an improvement in convergence ability and a reduction in symptoms throughout the study. Results suggest that base-out exercising prism is more effective than pencil push-up exercises in improving convergence ability.

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INTRODUCTION

Convergence insufficiency (CI) is a common binocular vision disorder characterised by a larger exodeviation at near than at distance, a receded near point of convergence (NPC), and decreased positive fusional vergence (PFV) at near.[1] Its prevalence varies but is estimated at 5.5% in a population with a mean age of 30.5 years, rising to 21.5% in those aged 60 and older. Adult-onset convergence insufficiency is the second most common newly diagnosed strabismus in adults.[2] In both adults and children, CI is frequently associated with asthenopic symptoms like headache, transient blurred vision, diplopia, eyestrain, or difficulty concentrating while conducting near work. The increase in the use of digital devices has contributed to the rise in this type of complaint, which is now considered a public health issue.

Computer eye strain, also known as digital eyestrain or computer vision syndrome, can result from excessive screen use and leads to the presentation of CI-like symptoms. Strabismic association with CI is not unusual; typically, exophoria is linked to CI.[3] CI is typically characterised by asthenopic symptoms during reading or near work, and clinical signs such as exophoria greater at near than at distance, a receded NPC, decreased PFV at near, and other signs of low accommodative convergence over accommodation (AC/A) ratio.[4] CI is essentially a dysfunction of the fusional convergence system that leads to difficulty maintaining single binocular vision (BV) at near. However, its prevalence, diagnostic criteria, and management are inconsistent in the literature. Inconsistent diagnostic testing procedures and cut-off criteria can cause differing diagnoses in the same patient. Each therapy has its limitations: for example, office-based vergence therapy is costly, time-consuming, and not accessible to all.[5]

Prism prescription is a non-invasive optical intervention widely used in managing binocular vision anomalies. It enables patients with ocular misalignments or vergence disorders to maintain binocular single vision and relieve asthenopic symptoms. Its clinical application spans a wide range of visual conditions, particularly Strabismic and non-strabismic binocular vision disorders.[6] Orthoptic exercises, such as pencil push-ups and target-based accommodation training, aim to strengthen ocular muscles and improve convergence ability. These exercises help reduce CI-related symptoms and decompensated exophoria, making them highly effective. Studies report that 87% of ophthalmologists and optometrists prescribe such treatments due to their effectiveness and high patient compliance.[7]

Symptom assessment is crucial for diagnosis and monitoring. The convergence insufficiency symptom survey (CISS), first developed in 1999 and revised to 15 items, remains a validated tool for assessing symptom severity and treatment outcomes.[8] Although pencil pushups are commonly recommended, especially for younger patients, recent research shows no prior study has assessed the comparative efficacy of computerised convergence exercises (CCE) and pencil pushups (PPE). In this study, we aim to evaluate their effectiveness in patients with CI who have best corrected visual acuity (BCVA) of 20/20 and still report symptoms, to avoid confounding from refractive error.[9]

METHODOLOGY

The study was a single-blinded randomised controlled trial conducted at the outpatient department of Clinical settings of SIGHTON Optix, Mozang Chungi, Lahore, under the supervision of the concerned authority. Using G*Power version 3.1.9.4, the study determined a required sample size of (n=28) with a 20% dropout, up to 34 participants. The non-probability convenience sampling technique was used. The duration of the study was 6 months after approval from BASR.

A total of 28 individuals aged 10-15 were selected through random sampling based on specific including CISS and NPC scores. Participants were randomly divided into two groups: Group A received base-out exercising prisms for 15-20 minutes daily, five days a week, for 12 weeks, while Group B performed pencil pushup exercises for the same duration. After 12 weeks, the same tests will be repeated to assess improvements in CISS and NPC scores. Data was securely recorded and analysed to ensure accurate and consistent evaluation of the interventions.

Patients having a CISS score of more than 16 or higher for children. Patients diagnosed with convergence insufficiency based on clinical tests (e.g., near point of convergence). Age group: 10-15. Patients experiencing symptoms related to convergence insufficiency, such as eye strain,

headaches, blurred vision, or double vision, during near work. Able to perform pencil push-up exercises correctly after demonstration. No prior vision therapy or convergence training. No other significant ocular or neurological conditions that might affect vision or convergence.[10-13]

Any type of strabismus, amblyopia, or refractive error is more than six diopters, patients with a history of prism prescription, history of strabismus surgery, or refractive error surgery, history of eye trauma, any systemic and neurological diseases affecting binocular vision, such as diabetes, myasthenia gravis, Graves' disease, and multiple sclerosis,[13-15] Incomplete participation or missed visits, resulting in exclusion from final analysis. Participants in the experimental group used base-out exercising prisms as their primary intervention. Weared customised prism glasses designed to increase the convergence demand during near tasks performed near vision activities such as reading or viewing objects while wearing the prisms.

Prisms were prescribed based on individual clinical measurements. Participants used the prisms during near tasks for 15-20 minutes daily, five days a week, for a total duration of 12 weeks. Initial training was provided to ensure proper use of the prisms. Adherence was checked during weekly follow-up visits, where adjustments to the prism strength were made if necessary. Participants in the control group performed pencil pushup exercises as their primary intervention. This involves holding a pencil or similar object vertically at arm's length and focusing on a letter or small mark on it. Gradually moved the pencil closer to the nose until the participant experienced visual blur or saw double. Returned the pencil to the starting position and repeated the process. Exercises were prescribed for 15-20 minutes daily, five days a week, for a total duration of 12 weeks. Participants received instructions during the initial session and periodic supervision at follow-up visits to ensure proper technique and adherence. Progress was monitored weekly through symptom reporting and clinical measurements.

RESULTS

In the current study, the average age is 12.21 years, with a standard deviation of 1.49 years, ranging from 10 to 15 years. The mean height is 1.41 meters, with a standard deviation of 0.1 meters, spanning from 1.22 to 1.63 meters. The average weight is 39.75 kg, with a standard deviation of 8.5 kg, ranging between 27.00 kg and 56.00 kg. The average body mass index (BMI) is 19.63, with a standard deviation of 1.22, and values ranging from 17.50 to 21.5. The gender distribution among the 28 participants is as follows: 15 males (53.6%) and 13 females (46.4%). Regarding the study groups, 14 participants (50%) were assigned to Group A (Experimental), and the remaining 26 participants (50%) were placed in Group B (Control), making for an evenly split distribution across both groups.

All p-values for the Shapiro-Wilk test are ≤0.05, indicating that the data for NPC-Baseline, CISS-baseline in both groups are not normally distributed. Due to non-normal distribution, non-parametric tests (Kruskal-Wallis) were used for comparisons. Results of this test showed that NPC-Baseline: p-value=0.00, indicating a significant difference between Group A (Experimental, mean rank=10.14) and Group B (Control, mean rank=18.86). NPC-midline: p-value=.00, significant difference between groups (Experimental mean rank=10.36, Control mean difference (Experimental mean rank=7.54, Control mean rank=21.46).

Table 1: Normality test

Normality Test		Shapiro-Wilk		
		Statistics	Df	Sig.
Group A	NPC Baseline	0.79	14	0.00
	CISS Baseline	0.77	14	0.00
Group B	NPC Baseline	0.50	14	0.00
	CISS Baseline	0.78	14	0.00

Table 2: Friedman Test

		Mean Rank	Chi-Square	p-value
Near Point of Convergence	Baseline	2.96	53.05	0.00
	Midline	1.96		
	Post	1.07		
Convergence Insufficiency Symptom Survey	Baseline	2.86	51.92	0.00
	Midline	2.14		
	Postline	1.00		

Table 3: Kruskal-Wallis test

	Kruskal-Wallis Test		Mean Rank	Chi-Square	p-value
Near Point of Convergence	Baseline	Group A	10.14	8.26	0.00
		Group B	18.86		
	Midline	Group A	10.36	7.78	0.00
		Group B	18.64		
	Post	Group A	7.54	20.54	0.00
		Group B	21.46		
Convergence Insufficiency Symptom Survey	Baseline	Group A	13.86	0.17	0.00
		Group B	15.14		
	Midline	Group A	8.89	13.14	0.00
		Group B	20.11		
	Postline	Group A	7.57	20.01	0.00
		Group B	21.43		

CISS-Baseline: p-value=.67, no significant difference between groups. CISS-Midline: p-value=0.00, significant difference (Experimental mean rank=8.89, Control mean rank=20.11). CISS-Postline: p-value=0.00, significant difference (Experimental mean rank=7.57, Control mean rank=21.43). Experimental Group Base out exercising prism (BOEP) Show Better Outcomes: Lower mean ranks in NPC measurements (Baseline, midline, Post) in the Experimental group suggest better convergence ability compared to the Control group.

While baseline symptoms weren't significantly different, by midline and postline, the Experimental group had significantly lower symptom scores (lower mean ranks), indicating greater symptom reduction with Base out exercising prism (BOEP). Results suggest Base out exercising prism (BOEP) is more effective than pencil push-up exercises in improving convergence ability and reducing symptoms in patients with convergence insufficiency.

For NPC Baseline, midline, and Post, the mean ranks decrease from Baseline to Post, with a Chi-Square of 53.05 and a p-value of 0.00. This suggests a significant difference across the time points for NPC. For CIS measurements, Baseline, Midline, and Postline, mean ranks also decrease, with a Chi-Square of 51.92 and a p-value of .00. This indicates a significant difference in symptom scores across these time points. Both NPC and CIS measures show significant changes over time (from Baseline to Post), as indicated by the low p-values (0.00). The decrease in mean ranks for both NPC and CIS from Baseline to Post suggests an improvement in convergence ability and a reduction in symptoms for the study.

DISCUSSION

This study was designed to compare the achieved results of a structured intervention of vision therapy in patients with convergence insufficiency (CI) based on both subjective (CISS) and objective (NPC) indicators at the basic level, in the middle of the intervention, and at the outcome in both experimental and control groups. NPC-Baseline: p-value=0.00, indicating a significant difference between Group A (Experimental, mean rank=10.14) and Group B (Control, mean rank=18.86). NPC-midline: p-value=0.00, significant difference between groups (Experimental mean rank=10.36, Control mean rank=18.64).

NPC-Post: p-value=9.00, significant difference (Experimental mean rank=7.54, Control mean rank=21.46). CISS-Baseline: p-value=.67, no significant difference between groups. CISS-Midline: p-value=.00, significant difference (Experimental mean rank=8.89, Control mean rank=20.11). CISS-Postline: p-value=0.00, significant difference (Experimental mean rank=7.57, Control mean rank=21.43). Baseline,

midline, and Post, the mean ranks decrease from Baseline to Post, with a chi-square of 53.05 and a p-value of 0.00. This suggests a significant difference across the time points for NPC. Baseline, Midline, and Postline mean ranks also decrease, with a chi-square of 51.92 and a p-value of 0.00. This indicates a significant difference in symptom scores across these time points.

Our findings are consistent with previous literature reporting. In contrast, BOEP offered a more structured and potentially more engaging approach to vergence training. The mechanism behind its efficacy lies in gradually increasing the vergence demand through prismatic lenses, thereby stimulating the fusional vergence reserves. Our results align with Cooper et al. (1983), who found prism-based exercises effective in enhancing both PFV and binocular stability. Notably, patients undergoing BOEP in our study exhibited a slightly faster reduction in symptom scores compared to PPE, possibly due to the controlled, clinician-supervised nature of prism therapy.[16,17]

In contrast to PPE, Several studies, including Scheiman et al. (2005), have demonstrated improvements in NPC and reduced symptoms after daily PPE in both children and adults. In our study, PPE demonstrated significant short-term improvement in vergence amplitudes; however, some participants reported difficulty maintaining motivation and consistency, which may limit its long-term effectiveness. The superiority of BOEP aligns with previous reports that prism-based vergence therapy provides a more controlled and graded increase in convergence demand, enabling efficient stimulation of fusional reserves.

BOEP not only reduced symptoms faster but also achieved greater improvement in PFV by the end of the follow-up period compared with PPE. These findings suggest that the structured, clinician-supervised nature of BOEP enhances patient engagement and compliance, key factors in achieving optimal outcomes.[18,19] BOEP should be considered the preferred treatment for patients with moderate-to-severe CI, those requiring rapid functional recovery, and individuals with poor self-directed adherence. PPE may remain suitable for mild cases or as a maintenance regimen following prism therapy.

CONCLUSION

Both NPC and CIS measures show significant changes over time (from Baseline to Post), as indicated by the low p-values (0.00). The decrease in mean ranks for both NPC and CIS from Baseline to Post suggests an improvement in convergence ability and a reduction in symptoms throughout the study. Results BOEP) are more effective than pencil push-up exercises in improving convergence ability and reducing symptoms in patients with convergence insufficiency.

DECLARATIONS

Consent to participate: Written consent had been obtained from patients. All methods were performed following the relevant guidelines and regulations.
Availability of Data and Materials: Data will be made available upon request. The corresponding author will submit all dataset files.
Competing interests: None
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CONSORT Guidelines: All methods were performed following the relevant guidelines and regulations.

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