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Comparative Effectiveness of Pencil Push-Up Exercises and Jump Vergence Exercises in Treating Convergence Insufficiency among Digital Screen Users

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Abstract

CI which is also called convergence insufficiency, is a disease occurring in both eyes in which there is no proper eye alignment while doing near tasks, often exacerbated by prolonged near work. That's the reason, most digital screen users have convergence insufficiency. Traditional treatment methods for CI include some orthoptic exercises like pencil push-up exercises and jump vergence exercises to improve coordination and strength of eye muscles. Pencil push-up is that exercise which involves focusing on a small target as it is slowly brought towards the nose, thereby stimulating convergence. While other exercises like JVE train the eyes to quickly alternate attention between close and far targets, helping to improve flexibility. To assess the efficacy of two commonly used orthoptic techniques PPU exercises and jump vergence exercises –in improving CI among those individuals who use prolong digital screens in daily routine. To investigate the effectiveness of jump vergence exercises versus pencil push-ups in the treatment of convergence insufficiency among digital screen users, this study was conducted at Haji Murad Trust Eye Hospital for 4 months through a randomized control trial design. Random sampling was utilized in the recruitment of willing participants. Total 52 patients diagnosed with convergence Insufficiency were enrolled and randomly allocated into two groups, each with 26 patients. Group A received pencil push-up exercise while Group B was treated with jump vergence exercise. The study followed single blind design where outcome assessor was unaware of their treatment allocation group. Baseline NPC and CISS scores were recorded before any intervention, and follow-up measurements were taken at 6 weeks. Post-test data were gathered following the intervention period of 6 weeks through the use of RAF ruler in measuring near point of convergence and the CISS questionnaire in determining symptom severity. The Shapiro-Wilk test was applied to assess the normality of data. Statistical analysis was performed by SPSS 27. After applying Shapiro-Wilk test all variables showed p values greater than 0.005 the data were considered normally disturbed. Within group analysis showed statistically significant reduction in NPC and improvement in CISS scores in Group B from baseline to follow-up visit ($p<0.001$), demonstrating enhancement over time. In Group A, both NPC and CISS scores showed improvement, however, no significant changes were observed after 6 weeks. At 6 weeks, mean scores decreased by 3.8 (SD 1.9) in Group B versus 9.0 (SD 2.2) in Group A. The mean group difference was 5.2 (95% CI: 4.0 to 6.4), $p < .001$. Group B also showed greater improvement in reduction of near point of convergence and symptoms in comparison of Group A. The study

concluded that although improvement had been achieved with the two techniques, the jump vergence exercises showed higher improvements compared to pencil push-up exercises on the NPC and alleviation of symptoms. Despite the temporary nature of the investigation, the results clearly show the high efficiency of jump vergence exercises and make a preferred treatment method a strongly feasible option.

Keywords: Convergence Insufficiency, Pencil Push-Up Exercises, Jump Vergence

Introduction

Convergence insufficiency (CI) is a common binocular vision disorder characterized by a larger exodeviation at near than at distance, a receding near point of convergence (NPC), and decreased positive fusional vergence (PFV) nearby. 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. 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 [1]. Most studies that assess these interventions do so in isolation, often focusing on PPT as the standard approach for treating CI. Moreover, many studies have been conducted with children or young adults, leaving a gap in research focusing on adults who engage in long hours of digital screen usage. Most of these people feel CI symptoms and we have to pay attention to their diagnosis and treatment. For example, these people face more symptoms of CI and more recovery time as compared to young population because of their higher usage of digital screen [2].

Home-based physical therapy and joint range-of-motion (ROM) exercise programs (PPT and JVE) are often recommended as they are relatively inexpensive and easy to implement; however, there is limited knowledge about compliance and efficacy for individuals with a high amount of screen time. Generally, studies show that individuals do not continue with prescribed home exercises; this appears to be particularly true for home exercise programs perceived as uninteresting or ineffective [3]. I have seen that when digital screen use makes us look at screens closely, for a time the visual system has to work hard and that often causes digital eye strain. One of the frequently observed binocular vision disorders in individuals with high screen exposure is convergence insufficiency, in which patient face issues sustaining attention during close work, thereby affecting daily performance and quality of life [4]. Treatment for convergence insufficiency is typically accomplished through the use of vision therapy. The most common form of vision therapy used for CI to do at home are pencil push-ups because they are relatively easy to do and inexpensive, allowing the patient to develop their ability for convergence by practicing sustained focus with a pencil at the near point [5].

Jump vergence exercises are a higher level vergence therapy procedure than was previously described and require rapidly and alternately fixating upon targets at different distances to increase fusional vergence flexibility and speed. Comparison studies indicate that jump vergence incorporated into structured vergence training may provide greater clinical treatment effects of Convergence insufficiency than traditional PPU exercises [6]. On the contrary, the Jump Vergence exercises make use of “step” vergence requirements that involve rapidly and accurately shifting focus from an object close to the eye to another object far away. The demand for a more flexible response of the binocular system beyond that provided by the simple push-up exercise is particularly important for people who work with computers and use smartphones frequently [7]. Whereas both interventions seek to alleviate the effects of CI, it is important to identify which of them works most effectively for individuals who have their main visual needs in digital space. The objective of this study is to develop an evidence-based approach to dealing with CI caused by screens by comparing the effectiveness of PPU (smooth 'ramp' convergence) and Jump Vergence ('step' convergence) [8]. The manifestation of digital fatigue occurs mainly due to the phenomenon of convergence insufficiency (CI), which is a sensory-motor mismatch where the eyes are not capable of making the needed inward movement during near work. This problem is reported to occur in up to 35.2% of schoolchildren and university students, while a

significant association exists between increased academic work using electronic tablets and Definite-CI, which means meeting at least three diagnostic criteria. [9]. While the use of PPT is one of the most suggested options for treating Convergence Insufficiency on an outpatient basis, current scientific research are raising some doubts regarding its efficacy. PPT therapy primarily affects the smooth pursuit pathway through the application of the "ramp" stimulus, implying a continuous increase in the amount of convergence needed. Although it is effective when used with regard to the improvement of the NPC breakpoint, it does not have a great influence on the CISS scores, based on CITT and future 2026 studies [10].

Methodology

This was a single blind Randomized Controlled Trial study conducted at Haji Murad Trust Eye Hospital, Gujranwala for 6 months after BASAR approval. Non-probability random sampling technique was applied. Sample size calculated from g* power 3.1.9.7(n=52) [8]. The inclusion criteria consisted of Digital-screen users' children aged 9-18 years, presenting with symptomatic convergence insufficiency (CI). Both genders were involved. Patients more than NPC > 6 cm break, CISS score ≥ 16 were considered, and having Minimum daily screen usage of 4 hours, individuals capable of providing written informed consent. Potential participants were excluded if they presented with Any history of strabismus, amblyopia, or ocular surgery. Patients with significant uncorrected refractive errors. Patients with any ocular or systemic disease affecting binocular vision. Patients with current participation in other vision therapy programs. Participants were recruited from Haji Murad Trust Eye Hospital's outpatient department under observation. Total 52 individuals aged 9-18 years were nominated using a random sampling technique. All individuals were pre-diagnosed of convergence insufficiency CI were selected according to inclusion and exclusion criteria. Informed consent was obtained from all individuals. The data collection procedure started after assessment of CI by using RAF ruler and CISS questionnaire from the population. People who had NPC > 6 cm break and CISS score ≥ 16 were included for this study. Participants were divided into two groups; Group 1 was assigned PPU treatment and Group 2 was assigned JVE to reduce NPC and symptom severity. In both groups, NPC (RAF ruler) and their symptom severity (CISS questionnaire) were checked before the start of treatment. Group A will be doing 3 sets of 10 pencil-push-ups every day for six weeks. Participants assigned to Group B will be doing 3 sets of 10 near–far jumps every day for six weeks.

Results

A total of 52 patients were included in the study and were equally distributed into 2 groups.26 participants were included in each group 1 received treatment A which was PPU and group 2 received treatment B which was JVE. The baseline demographic and clinical characteristics of both groups were comparable. The baseline questionnaire CISS score was identical in both groups, recorded as 25.50 ± 6.10 showing the same level of convergence insufficiency before intervention. Similarly, the mean NPC in group 1 was 14.23 ±2.62, while in group 2 it was 13.88 ± 2.37 indicating no any significan5t differences at the start of the study. The baseline comparability ensured that any subsequent differences observed between the groups could be given to the treatment modalities rather than pre-existing variations.

Using Tool 1 (Questionnaire)

Table 4.1: Age, Pre-treatment score, and Post-treatment score of CISS

Descriptive statistics				
Treatment Group		**Minimum**	**Maximum**	**Mean± Std. Deviation**
Treatment A PPU	**Age**	9	18	13.03±2.83
	Pre-score	17	36	25.50 ±6.10
	Post-score	6	13	9.00 ±2.22
Treatment B JVE	**Age**	9	18	13.65 ±3.08
	Pre-score	17	37	25.76 ±6.22
	Post-score	1	7	3.76 ±1.98

Table 4.2 : Normality Test Statistics

Test of Normality			
Pre-treatment score	**Shapiro-Wilk**		
	Statistic	**Df**	**Sig.**
Treatment A	0.940	26	0.131
Treatment B	0.945	26	0.174

The Shapiro-wilk test was applied to assess the normality of CISS scores in both treatment groups (n= 26 each). The test showed that all the variable values were >0.05 so the data were normally distributed. Therefore, parametric test was applied for analysis.

Table 4.3: Baseline equivalence

Group	Mean (SD)	t(df)	p-value
Treatment A	**25.5 (6.1)**		
Treatment B	**25.8 (6.2)**	**-0.16(50)**	**0.88**

Baseline equivalence between the two treatment groups was assessed using independent-samples t-tests. Levene's test for equality of variances was non-significant (p = 0.88), indicating that the assumption of equal variances was met. As shown in Table 4.1, there was no significant difference in baseline symptom scores between Treatment A (M = 25.5, SD = 6.1) and Treatment B (M = 25.8, SD = 6.2), t(50) = -0.16, p = 0.88. These findings suggest that randomization successfully produced comparable groups at baseline.

Table 4.4: Within group analysis

Condition	Mean	SD	n	t(df)	p-value
Pre-test	**25.6**	**6.1**	**52**	**18.8(51)**	**<0.001**
Post-test	**6.4**	**3.4**	**52**		

A paired-samples t-test indicated that post-test scores (M=6.4, SD=3.4) were significantly lower than the pre-test scores (M=25.6, SD=6.1), t(51) =18.8, p< 0.001, showing a significant decrease in performance. Variability also decreased slightly, as reflected in the lower SD.

Table 4.5: Between group analysis

Group	Mean (M)	Standard Deviation (SD)	N
Treatment A	**9.0**	**2.2**	**26**
Treatment B	**3.8**	**1.9**	**26**

An independent samples t-test was conducted to compare the outcome scores between Treatment A and Treatment B. Treatment B (M = 3.8, SD = 1.9) had significantly lower scores than Treatment A (M = 9.0, SD = 2.2), t(50) = 8.9, p < .001. The mean difference was 5.2 (95% CI: 4.0 to 6.4).

Independent Samples t-test Results

- t(50) = 8.9, p < .001
- Mean Difference = 5.2 (95% CI: 4.0 to 6.4)
- Cohen's d = 2.53(large effect)

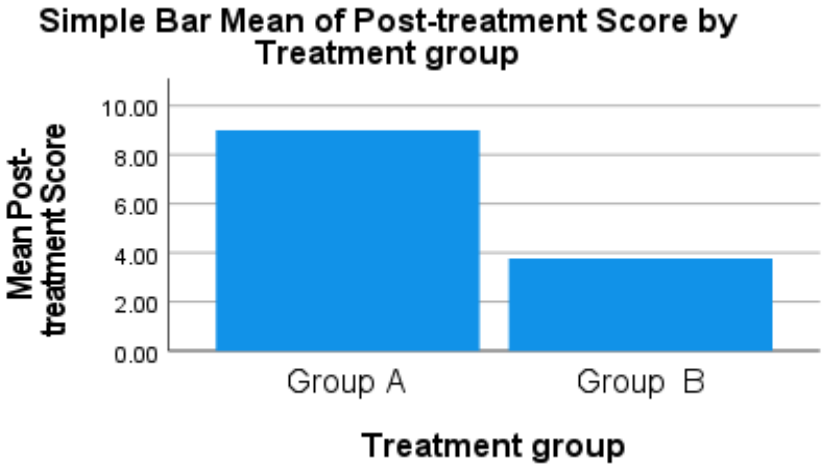

Figure 4.1: Simple Bar Mean of Post-treatment Score by Treatment groups

Figure 4.1 presents a simple bar chart illustrating the mean post-treatment scores for each treatment group. Group A demonstrated a substantially higher mean score compared to Group B, indicating a marked difference in post-treatment outcomes between the two groups. This visual representation suggests that the intervention applied to Group B may have been more effective in improving post-treatment scores than the one administered to Group A, as the reduction of scores indicates improvement in Group B.

Using Tool 2 (RAF ruler)

Table 4.6: Age, Pre-treatment Score, and Post-Treatment Score of NPC

Descriptive statistics				
Treatment Group		**Minimum**	**Maximum**	**Mean± Std. Deviation**
Treatment A PPU	**Age**	9	18	13.03±2.83
	Pre-score	10	18	14.23 ±2.62
	Post-score	7	10	8.65 ±0.89
Treatment B JVE	**Age**	9	18	13.65 ±3.08
	Pre-score	10	18	13.88 ±2.37
	Post-score	5	8	6.07 ±0.97

Table 4.7: Normality Test Statistics

Test of Normality			
Pre-treatment score	**Shapiro-Wilk**		
	Statistic	**Df**	**Sig.**
Treatment A	0.933	26	0.092
Treatment B	0.953	26	0.274

The Shapiro-wilk test was applied to assess the normality of NPC scores in both treatment groups (n= 26 each). The test showed that all the variable values were >0.05 so the data were normally distributed. Therefore, parametric test was applied for analysis.

Table 4.8: Baseline equivalence

Group	Mean (SD)	t(df)	P-value
Treatment A	**14.2 (2.6)**	**0.499 (50)**	**0.62**
Treatment B	**13.9 (2.4)**		

Baseline equivalence between the two treatment groups was assessed using independent-samples t-tests. Levene's test for equality of variances was non-significant (p = 0.62), indicating that the assumption of equal variances was met. As shown in Table 4.4, there was no significant difference in baseline symptom scores between Treatment A (M = 14.2, SD = 2.6) and Treatment B (M = 13.9, SD = 2.4), t(50) = 0.499, p = 0.62. These findings suggest that randomization successfully produced comparable groups at baseline.

Table 4.9: Within group analysis

Condition	Mean	SD	N	t(df)	P value
Pre-test	**14.1**	**2.48**	**52**	**17.2(51)**	**< 0.001**
Post-test	**7.37**	**1.57**	**52**		

A paired samples t-test was conducted to compare participants' scores before and after the intervention. The mean score at baseline (M = 14.1, SD = 2.48) was higher than the mean score at follow-up (M = 7.37, SD = 1.57). The results indicated a statistically significant decrease in scores, t(51) = 17.2, p <0.001, suggesting that participants improved following the intervention.

Table 4.10: Between group analysis

Group	Mean(M)	Standard Deviation(SD)	N
Treatment A	**8.65**	**0.89**	**26**
Treatment B	**6.08**	**0.98**	**26**

An independent samples t-test was conducted to compare the outcome scores between Treatment A and Treatment B. Treatment B (M = 6.08, SD = 0.98) had significantly lower scores than Treatment A (M = 8.65, SD = 0.89), t(50) = 9.9, p < .001. The mean difference was 2.58(95% CI: 2.06 to 3.09).

Independent Samples t-test Results

- t(50) = 9.9, p < .001
- Mean Difference = 2.58 (95% CI: 2.06 to 3.09)
- Cohen's d = 2.75(large effect)

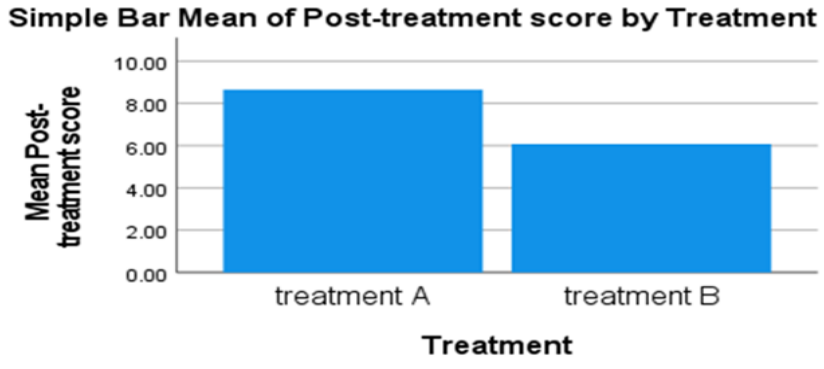

Figure 4.2: Simple Bar Mean of Post-treatment Score by Treatment groups

Figure 4.2 displays a simple bar chart comparing the mean post-treatment scores between Treatment A and Treatment B. Treatment A yielded a higher mean score while Treatment B showed a lower mean score. This visual comparison suggests that Treatment B may have led to more favorable post-treatment outcomes than Treatment A, indicating a potential difference in treatment efficacy.

Discussion

The RCT study was based on the convergence insufficiency in digital screen users and effectiveness of their treatment options including home-based exercises like pencil push-up exercise and jump vergence exercise. PPU and JVE both treatment were compared together. A complete 4-month study had taken for this research. In this research NPC and CISS score all were compared for both groups. Both treatments were effective in lowering CI but jump vergence exercise was better results and better patients' compliance then PPU group.

Scheiman et al. conducted a study in 2005 on randomized clinical trial of vision therapy/orthoptics versus pencil push-ups for treating convergence insufficiency in young adults. It involved 46 participants (between the ages of 19 and 30) and showed that, although the participants who used pencil push-ups had significantly fewer symptoms, they were far less effective at improving their NPC and PFV than those who underwent office-based vision therapy treatment. Specifically, only 20% of the patients in the former group achieved "normal" clinical values while 42% achieved this in the latter group. While this current research addressed 52 digital screen users between age 9-18 years, both the studies concluded that pencil push-up exercise is somehow effective in reducing CI but not the best treatment for a CI patient. Jump vergence exercise and office-based exercises proved to be more effective in treating convergence insufficiency [11]. Moghaddam et al. in 2021 conducted a study on effectiveness of home-based pencil push-up therapy compared to office-based therapy for treating symptomatic convergence insufficiency in young adults. The study comprised of 30 subjects and showed that the PPT as well as the office-based therapies are equally effective in reducing symptoms, although office-based therapies proved superior in improving positive fusional vergence. It is important to note that the results presented by them show that the home-based PPT can be an economic alternative for both students and workers. This current single blind study added value to the findings of these scholars by examining the efficacy of jump vergence for individuals using computers regularly and who are likely to suffer from eye fatigue due to this reason. The current study suggested that jump vergence exercise group showed better NPC and CISS scores as compared to pencil push-up exercise [12].

The CITT study groups in 2008 conducted a study on randomized clinical trial of treatments for symptomatic convergence insufficiency in children which evaluated the effectiveness of the various treatment procedures administered on 221 children. It was found out that both the at-home pencil push-up procedure and placebo had equal effects in improving the near point of convergence or reducing the associated symptoms. In connection with this, this information particularly helpful in relation to this current single blind study involving 52 digital screen users, results showed that the intervention applied to Group B may have been more effective in improving post-treatment scores than the one administered to Group A, as the reduction of scores indicates improvement in Group B, indicating JVE is more effective and far better than PPU [13]. Galli et al. in 2020 conducted a retrospective observational study on effectiveness of pencil push-up exercises in patients with convergence insufficiency-type exotropia with receded near point of convergence, investigated 30 participants to assess the effectiveness of convergence. The findings indicated that consistent pencil push-up exercises performed five days or more per week led to significant progress in the near point of convergence within six months. While their study focused on convergence insufficiency-type exotropia, it sets a benchmark for the dedication required in home exercises. The current study is similar as it is also focused on two exercises for treating CI and concluded that jump vergence exercises yielded superior results in a shorter period for those who use computer screens [14].

Hussaindeen et al. in 2020 accompanied a study to compare home-based vision therapy and pencil push-ups for convergence insufficiency in young adults. The study comprised 40 participants, who were observed by the authors as they found that while pencil push-ups (PPT) had a significant effect on the near point of convergence (NPC), their effects on positive fusional vergence (PFV) were not better than those of home-based vision therapy. The findings suggested that pencil push-up technique lacked the complexity required for the complete rehabilitation of the system of the patients with high expectations. The current study also showed that PPU is less effective in treating CI as compared to jump vergence exercise [15].
Daum et al. in 1988 conducted a study on comparison of three types of vision therapy for convergence insufficiency which consisted of 35 subjects, exploring the difference between smooth vergence, similar to pencil push-ups, and jump vergence training. According to the findings of their research, the latter method yielded faster results in improving vergence facility and flexibility as opposed to smooth vergence training alone. They argue that "jumping" between different focal distances requires more accommodation and vergence adjustment from the brain than smooth motion, making the process more complex. The current study also do comparison of two vision therapies as it consisted 52 participants and 26 received pencil push-up exercise and other 26 of group 2 received jump vergence exercise, and this single blind randomized control trial showed JVE effective than PPU for digital consumers [16].
Brautaset and Jennings' conducted a study on effects of orthoptic treatment on the near point of convergence and fusional vergence, reported on children but the findings of the same are equally applicable to young adults. The total number of subjects was 20 and they found out that the group which had undergone dynamic vergence activities showed 35% improvement in their fusional vergence as compared to the groups which had undertaken static activities like pencil push-ups. The current study also showed that jump vergence exercises is better option for convergence insufficiency patients, as the study measured NPC and CISS scores by RAF ruler and CISS questionnaire and by measuring by both tools JVE showed efficacy [17].
Kim et al. conducted a study on the effect of vision therapy on visual fatigue and accommodative function in computer users, involved 24 subjects and studied the effects of vergence training on computer eye strain. It was found out that whereas basic exercises helped improve NPC, complex jumping vergence exercises proved significantly more effective in reducing CISS scores associated with computer work. The findings from their experiment imply that in case of digital screen users, the "jump" component is very important when it comes to building up tolerance for long hours of screen viewing. This is a direct implication for the current research involving this specific population group [18].

Conclusions

The current research compared the effectiveness of pencil push-up exercises and jump vergence exercises in treating convergence insufficiency CI associated with screen usage. The outcome showed that although improvement had been achieved with the two techniques, the jump vergence exercises showed higher improvements compared to pencil push-up exercises on the NPC and alleviation of symptoms. Despite the small sample and the temporary nature of the investigation, the results clearly show the high efficiency of jump vergence exercises and make a preferred treatment method a strongly feasible option.

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