Original Article

Efficacy of dichoptic amblyopia training on visual and binocular functions in adult amblyopia

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Purpose: To evaluate the efficacy of dichoptic amblyopia training (DAT), a cloud-based binocular therapy, in improving distance best-corrected visual acuity (DBCVA), stereoacuity, and contrast sensitivity in adults (>18 years) with anisometropic and meridional amblyopia. **Methods:** This prospective, nonrandomized interventional study enrolled 18 adults (>18 years) with unilateral or bilateral anisometropic or meridional amblyopia. Participants underwent 30 sessions of Bynocs DAT therapy over 6 weeks. Visual parameters, including DBCVA, stereoacuity, and contrast sensitivity, were evaluated at baseline, immediately posttreatment, and at 2, 12, and 24 months post Bynocs DAT. **Results:** DBCVA improved significantly from a mean of 0.629 ± 0.254 LogMAR to 0.491 ± 0.262 ($P < 0.05$), and this improvement was sustained through 24 months. Statistically significant improvement was also observed in stereoacuity ($P < 0.05$). Contrast sensitivity improved from 0.950 ± 0.209 to 0.990 ± 0.351, although the change was not statistically significant ($P > 0.05$). **Conclusion:** DAT using Bynocs is effective in improving DBCVA and stereoacuity in adult amblyopic patients with anisometropic and meridional amblyopia. The visual gains are sustainable through 24 months and support the use of dichoptic amblyopia therapy in adult amblyopic subjects.

Key words: Adult amblyopia, anisometropic, Bynocs, contrast sensitivity, dichoptic amblyopia training, distance best-corrected visual acuity, meridional, stereoacuity

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Amblyopia, defined by Von Noorden as reduced best-corrected visual acuity (BCVA) due to abnormal binocular interaction or form deprivation, has long been considered treatable only during a critical developmental window.[1]

The Pediatric Eye Disease Investigator Group (PEDIG) demonstrated in ATS-03 that conventional amblyopia therapies may benefit children up to 18 years.[2] Furthermore, adult amblyopia patients have shown improvements in visual acuity and contrast sensitivity with therapies such as occlusion and perceptual learning.[3]

The PEDIG conducted a randomized control trial to compare a binocular iPad game with part-time patching therapy in children age 5-12 years. The study found that the visual acuity of the amblyopic eye improved with dichoptic therapy.[4] Another similar study done among 28 participants found that there was statistically significant improvement in visual acuity with dichoptic therapy.[5]

Studies have found that there is improvement in visual acuity in adults with amblyopia by using perceptual learning and dichoptic therapy.[6] It can also improve binocular functions such as contrast sensitivity.[7]

Bynocs® dichoptic amblyopia training (DAT) is an advanced cloud-based software designed for comprehensive binocular vision assessment and training through dichoptic methods.[8] It utilizes anaglyph-based dichoptic training to stimulate both eyes simultaneously yet separately. This binocular approach has shown promise in treating amblyopia by enhancing binocular visual functions, strengthening synaptic connections in the visual cortex, and maintaining a balanced excitatory/inhibitory response over time.[9] In this training, the amblyopic eye is presented with a higher contrast image than the dominant eye, which helps reduce suppression and improve visual acuity, along with overall binocular vision function.[10]

Materials and Methods

Study design and ethical approval

A prospective, nonrandomized interventional study was conducted among 18 amblyopes at a tertiary care centre, after approval by the institutional ethics committee. Written informed consent was obtained from all participants, in accordance with the Declaration of Helsinki and the WHO clinical study protocols.

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Inclusion criteria

- Age >18 years
- Unilateral or bilateral anisometropic or meridional amblyopia.

Anisometropia is defined as:

- 0.50 D spherical equivalent difference between 2 eyes
- 1.50 D astigmatism difference in any meridian[2]
- Stable BCVA (subnormal BCVA without organic pathology or diagnosed amblyopia) and willingness to comply with home-based online therapy
- No amblyopia therapy in the last 12 months.

Exclusion criteria

- Ocular pathology (corneal opacity, cataract, retinal disease, and glaucoma)
- Inability to perform or access home-based online digital therapy.

After enrolling in the study, each subject underwent a complete ophthalmic evaluation, which included BCVA (distance and near, LogMAR), stereoacuity testing (TNO), contrast sensitivity (Pelli-Robson chart), cycloplegic refraction, slit-lamp anterior segment evaluation, and dilated fundus examination. Even though all study subjects were adults, they underwent cycloplegic refraction (considering the fact that most of them had hypermetropic refractive errors with unresolved amblyopia). Optical coherence tomography was done to rule out any posterior segment pathology.

Participants received Bynocs DAT over 6 weeks (30 sessions, 30 min/day, 5 days/week). Sessions included antisuppression, anticrowding, figure-ground perception, fusional vergences, and stereoscopic tasks using anaglyph glasses. Remote therapy was supervised through Google Meet/Zoom/Microsoft Teams.

Assessments were done post-therapy, and at 2, 12, and 24 months. The primary outcome assessed was the change in DBCVA. The secondary outcomes were a change in stereoacuity and contrast sensitivity.

Statistical analysis

Data analysis performed by using SPSS (Statistical Package for the Socialsciences) version 29 (IBM corp.,Armonk,New York,USA). Qualitative data variables were expressed using frequency and percentage (%).

Quantitative data variables were expressed using mean, standard deviation, and median.

Paired *t*-test used to compare the BCVA, stereoacuity, and contrast sensitivity of the disease at all followup.

$P < 0.05$ considered significant.

Results

Eighteen patients (12 males, 6 females; mean age 30.6 ± 9.3 years) were included in the study. Two-thirds (66.7%) were under 40 years. Amblyopia types included anisometropic (72.2%) and meridional (27.8%). Half the patients had severe amblyopia;[11] 38.9% had prior treatment history.

Mean DBCVA improved significantly from 0.629 ± 0.254 to 0.491 ± 0.262 (LogMAR) post-treatment and was sustained over subsequent follow-up till a period of 2 years ($P < 0.05$; paired *t*-test) [Table 1].

Mean contrast sensitivity improved from 0.950 ± 0.209 to 0.990 ± 0.351, although this was not statistically significant ($P > 0.05$) [Table 2].

A statistically significant improvement in stereoacuity was noted post-therapy and maintained at 24 months ($P < 0.05$) [Table 3].

A statistically significant improvement in visual acuity in anisometropic and meridional amblyopia was seen, which was maintained at 24 months ($P < 0.05$). There was a 38% improvement from baseline DBCVA in meridional amblyopia and 17.8% improvement in anisometropic amblyopia.

There was a statistically significant improvement in the DBCVA in patients who had not undergone prior treatment for amblyopia [Table 4].

The maximum improvement occurred immediately after Bynoc's dichoptic therapy in the patients, and the

Table 1: Improvement in distance best-corrected visual acuity

	Number of eyes	BCVA distance (LogMar), mean±SD	*P*
Baseline	21	0.629±0.254	
6 weeks	21	0.530±0.231	<0.001*
2 months	21	0.491±0.262	<0.001*
6 months	21	0.491±0.262	<0.001*
12 months	21	0.491±0.262	<0.001*
24 months	21	0.491±0.262	<0.001*

*Significant (*P*<0.05) Paired *t*-test used. SD: Standard deviation, BCVA: Best-corrected visual acuity

Table 2: Improvement in contrast sensitivity

	Number of eyes	Contrast sensitivity, mean±SD	*P*
Baseline	20	0.950±0.209	
6 weeks	20	0.990±0.351	0.497
12 months	20	0.990±0.351	0.497
24 months	20	0.990±0.351	0.497

P>0.05 (not significant) Paired *t*-test used. SD: Standard deviation

Table 3: Improvement in stereoacuity

	Number of eyes	Stereo acuity, mean±SD	*P*
Baseline	20	467.50±293.66	
6 weeks	20	384.71±272.72	0.012*
12 months	20	384.71±272.72	0.012*
24 months	20	384.71±272.72	0.012*

**P*>0.05 (not significant) Paired *t*-test used. SD: Standard deviation

Table 4: Change in best-corrected visual acuity for patients having no previous treatment of Amblyopia

	Number of eyes	BCVA distance (LogMar), mean±SD	*P*
Baseline	13	0.625±0.260	
6 weeks	13	0.514±0.248	<0.001*
2 months	13	0.483±0.267	<0.001*
6 months	13	0.483±0.267	<0.001*
12 months	13	0.483±0.267	<0.001*
24 months	13	0.483±0.267	<0.001*

**P*<0.05(significant) Paired *t*-test used. SD: Standard deviation, BCVA: Best-corrected visual acuity

improvement was maintained through 2,6,12, and 24 months after cessation of the therapy.

Discussion

Our findings confirm that Bynocs DAT leads to significant and sustained improvements in visual acuity and stereoacuity in adults with amblyopia. This challenges the long-held belief that amblyopia is untreatable beyond childhood.

Other studies have corroborated these results. A study done by Picotti *et al*. compared the efficacy of Bynocs DAT therapy among two groups. One group consisted of children and the other of adults. Both groups showed statistically significant improvement in visual acuity.[12]

Another study by Ganesh *et al*. observed the effect of Bynocs DAT therapy on 59 subjects between the ages of 11 and 30 years. They found a statistically significant improvement in visual acuity.[13]

Studies among children have already established that cloud-based dichoptic therapy is effective in improving both visual acuity and binocular functions in anisometropic and isometropic amblyopia.[10,14-16]

Numerous studies have explored various methodologies involving both simultaneous and independent stimulation of the eyes – an approach known as dichoptic training – with the aim of reducing interocular suppression and enhancing visual acuity in individuals with amblyopia.[17] Nonetheless, the efficacy of visual training in amblyopia is not solely dependent on the dichoptic setup; the choice of visual stimuli also plays a pivotal role in achieving optimal therapeutic outcomes.[18]

Certain factors, such as the selection of visual stimuli, patient adherence, and the specific type of amblyopia, significantly influence the efficacy of dichoptic therapy.[18] For instance, in cases of strabismic amblyopia, dichoptic stimulation cannot be effectively implemented unless stable bifoveal fixation is established and maintained – by interventions such as strabismus surgery or the use of prisms.

Dichoptic training induces neural adaptations, resulting in a more natural pattern of neural activity across the frontal, parietal, and occipital lobes.[19] These neuroplastic changes contribute to reducing the mechanisms underlying interocular suppression, thereby enhancing the visual function of the amblyopic eye.[20]

Bynocs DAT games were conceptualized based on the principle of binocular visual processing, wherein the amblyopic (weaker) eye – often subject to suppression by the dominant fellow eye – is actively engaged. Gameplay was conducted using anaglyph goggles, which facilitated the presentation of separate visual inputs to each eye. As no individual eye was capable of perceiving the complete game environment, binocular integration was essential for successful task performance. Thus, Bynocs helps to improve both visual acuity and binocular function.

Our study showed a statistically significant improvement in stereoacuity. It also showed an improvement in contrast sensitivity.

A study by Ridder *et al*. was done to see the improvement in visual acuity and contrast sensitivity in adult patients undergoing dichoptic therapy. The study found a significant improvement in contrast sensitivity and visual acuity.[3]

Previous studies have found improvement in stereoacuity after dichoptic therapy.[15,21,22]

Pang *et al*.[22] reported that among participants aged 8–51 years, with refractive, strabismic, or mixed-type amblyopia, a 6-week intervention involving contrast-balanced dichoptic video viewing resulted in a mean improvement in stereoacuity of 0.40 log arcseconds. Huang *et al*.[21] also found a significant increase in stereoacuity in children (7–10 years) with bilateral amblyopia.

Bynocs is a user-friendly telehealth platform designed for vision training. It is beneficial for amblyopic patients who are resistant or noncompliant with traditional patching therapies. Its remote accessibility enables patients to engage in therapeutic sessions at their convenience, thereby eliminating the need for frequent in-person visits to eye care facilities. In addition, clinicians can remotely supervise both assessments and therapeutic progress. Thus, it is feasible for adult patients. However, a major limitation of Bynocs DAT is financial constraints.

Conclusion

Bynocs DAT is effective in improving distance best-corrected visual acuity (DBCVA) and stereoacuity in adults with anisometropic and meridional amblyopia. The therapy is noninvasive, engaging, and feasible for home use. The improvements in DBCVA and stereoacuity are sustained through 24 months, well beyond the treatment period. DAT can be considered a viable adult amblyopia treatment option.

Limitations

Our study is limited by a small sample size and a lack of a control group. Future studies with larger randomized cohorts are needed.

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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