SYSTEMATIC REVIEW

Dichoptic Vision Therapy in Adults with Anisometropic Amblyopia: A Systematic Review

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ABSTRACT

Introduction: Amblyopia is a condition with reduced best corrected visual acuity in absence of any ocular pathology. Different treatment approaches of amblyopia have been researched for decades. Recent studies on binocular dichoptic therapy using different software and video game based training showed drastic improvement in visual functions in amblyopic adults. Aim of this review is to assess the effect of vision therapy with dichoptic training in adults with anisometropic amblyopes. **Method:** Review was conducted in articles published within last 25 years from databases like PubMed, research gate, google scholar. **Results:** Dichoptic therapy has promising results in treatment of adults with anisometropic amblyopia. However, several limitations of these said researches were observed. **Conclusion:** Further studies particularly RCTs with strict methodology and treatment protocol, larger sample size and longer follow ups are recommended before clinicians could impart dichoptic therapy as a management option of adults with amblyopia into their evidence based practice.
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Keywords: Adult anisometropic amblyopia, Dichoptic therapy, Visual acuity, Contrast sensitivity, Stereoacuity

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INTRODUCTION

Amblyopia is a monocular or binocular condition with decrease best corrected visual acuity in absence of any structural abnormality or organic cause. In eyes with amblyopia, apart from impaired visual acuity other visual functions like stereopsis, contrast sensitivity, binocular vision, fixation pattern, spatial distortion, accommodation, color vision, saccadic and pursuit eye movement are also found to be impaired (1-8). Amblyopia may also affect the quality of life, limit the choice in career among young adults. It may economically results in $7.4 billion loss in yearly earning (9, 10). The mean prevalence of amblyopia varies from 2 to 5% among the adult population (11-14). Major causes of amblyopia include strabismus, anisometropia, and visual deprivation due to media opacity in early childhood during the critical period of visual development (15). Anisometropic amblyopia is the most prevalent type of amblyopia (61.6%) (16). Risk factors associated with anisometropic amblyopia include unequal refractive error in both eyes, myopia greater than -3 D, hypermetropia greater than 1 D and astigmatism greater than 1.5 D (17). The degree of anisometropic amblyopia in adults is higher as the uncorrected refractive error is left untreated for several years (18). Amblyopia especially monocular amblyopia if left untreated can lead to higher risk of blindness with any accidental loss of the affected eye. Thus, early treatment of amblyopia is very important. The gold standard treatment for amblyopia is patching and penalization with atropine. With treatment, 75% of the young children within the age of critical period of visual development might show significant improvement in visual acuity (VA) (19, 20). However, treatment of adults with anisometropic amblyopia still remains a challenge to clinicians. Major reason behind this was believed to be the plasticity of human brain that was thought to be decreased in older age after critical period of development, resulting in reduced treatment effectiveness (21-23). However, in recent studies it has been shown that the plasticity of human brain is present even after the critical period of development (24, 25). In some of the recent human and animal studies, it has been found that the vision of the amblyopic eye has improved even after the critical period especially in patients who have developed amblyopia in later age. It was postulated that the improvement could have happened in those eyes due to unmasking of the amblyopic eye with regaining the lost connection (26-29). Considering these latest factors, there are some new modes of behavioral

treatment developed to improve the visual functions in adult amblyopic patients. Dichoptic therapy with video games is one of the latest modes of therapy that has potential to show improvement in visual functions like visual acuity, contrast sensitivity and stereo acuity.

Dichoptic therapy is a type of behavioral therapy in which the two eyes are dissociated with the help of anaglyph red green goggles and changing contrast. The concept has originated from the fact that amblyopia is a binocular disorder of the visual system leading to intra ocular suppression, thus binocular treatment is useful than monocular. In dichoptic training, one eye (amblyopic eye) receive image with higher contrast and the good eye receive image in reduced contrast until the patient gain uniform contrast in both eyes. This insists binocular fusion with the use of dissociating red green anaglyph glasses. Primarily the task was based on motion coherence, where the participant need to identify the direction of the motion of the signal dots presented to amblyopic eye, in contrast to the noise dots presented to the good eye (30). Recently, a Tetris game is being used, in which blocks were seen by the two eyes separately with red green anaglyph filters along with contrast of the two eyes changed to stimulate fusion to successful completion of the game (31, 32). Recent studies have showed improvement of visual acuity, contrast sensitivity, stereopsis in both children and adult amblyopic patient employing this new mode of dichoptic therapy (33, 34). Dichoptic therapy using tetris (puzzle video game) video game is available on ipod and different mobile based software which become very convenient for the mode of treatment. It also shows significance difference in the patient response rate and training duration compared to monocular therapy. However, before incorporating this approach into the clinical practice, one would need sufficient reported evidence. Thereby, the aim of this study is to systematically review the scientific research evidences to assess the effectiveness of binocular dichoptic therapy on adult anisometropic amblyopes.

METHODOLOGY

The current systematic review study was performed as per the criteria of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Figure 1).To evaluate the validity of the included studies ROBINS-1 tool was used.

Literature search was done from the databases like PubMed, research gate and google scholar using searching strategies. Keywords used in search strategies of free language and controlled vocabulary includes “amblyopia”, “anisometropia”, “anisometropic amblyopia”, “dichoptic vision therapy”, “adult amblyopia”, “perceptual learning”, “ video game based therapy”, “ orthoptics”, “ virtual reality”, “strabismic amblyopia”, “mixed amblyopia”, “lazy eye”, “intraocular suppression”, “visual acuity”, “contrast sensitivity”, “stereopsis”, “binocular vision”, “children”, “young”, “adult”. All types of amblyopia in every age group were included in the primary search to avoid any missing article. Then refinement of the selected article was done according to the following criteria:

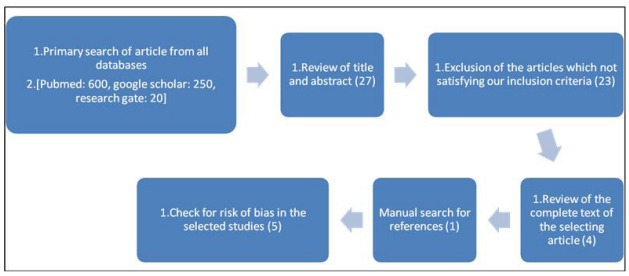

Figure 1: Schematic methodology of review

Inclusion Criteria:

1. Sample population that included adult anisometropic amblyopia
2. Original research article that aimed to improve visual function in adult anisometropic amblyopia with dichoptic visual therapy.
3. Randomized clinical trial and non-randomized interventional studies
4. Article published in English since 2000

Exclusion criteria:

1. Studies showing result with no segregation of anisometropic and strabismic amblyopia

RESULTS

Total of 870 documents were initially found. After title and abstract review 27 articles were included for complete text review. Twenty-three articles (35-55) out of 27 articles were rejected after text review. Reasons of exclusion are mentioned in table I. It has been found that most of the studies hadn’t concluded the result based on the different types of amblyopia. Two articles were found relevant to include after manual search. Thus, a total of six articles (31, 32, 34, 56, 57 and 58) were included in the present literature review. Hess et al. in consecutive researches have evaluated effectiveness of dichoptic therapy in treating amblyopia (30, 31, 33). In 2012, Hess et al. conducted a study with 10 amblyopic adults including, 5 anisometropic amblyopia, 2 strabismic amblyopia and 3 mixed amblyopia to evaluate the efficacy of a newly developed ipod that provided controlled, convenient dichoptic stimulation. However, the results of the study have not separately shown for each type of amblyopia. In the said study, suppression was completely eliminated in five amblyopic patients whereas reduction of suppression was observed in another four patients after the training. Visual acuity and contrast sensitivity improved in 90% patients whereas stereoacuity improved in 6 patients. A significant relation between the total number of training

Table I: Articles that were rejected after text review

Author	Reasons for exclusion
Gao et al. (2018) (35)	Result was not explained by the type of amblyopia
Evans et al. (2011) (36)	Result was not explained by the type of amblyopia
Guo et al. (2016) (37)	The study include both anisometropic, strabismic and mixed type of amblyopia and does not explained the results according to the type
Rajavi et al. (2021) (38)	The study excluded because it doesn't match the age group criteria
Elhusseiny et al. (2021) (39)	The study doesn't match with the inclusion criteria and the result also not sorted according to the type of amblyopia
Kampf et al. (2001) (40)	This study doesn't match with the inclusion criteria
Polat et al. (2004) (41)	This study doesn't satisfy our inclusion criteria
Singh et al. (2017) (42)	This study doesn't satisfy our inclusion criteria
Mansouri et al. (2014) (43)	Result was not explained by the type of amblyopia
Pang et al. (2020) (44)	Result was not explained by the type of amblyopia
Sauvan et al. (2019) (45)	Result was not explained by the type of amblyopia
Li et al. (2011) (46)	The study was excluded as it doesn't shows result according to the types of amblyopia
Hess et al. (2010) (47)	The study was excluded because it only shows the results in strabismic amblyopia
Hess et al. (2013) (48)	The study was excluded as it only showing the result on strabismic and mixed anisometropia
Li et al. (2008) (49)	The study doesn't satisfy our inclusion criteria
Huang et al. (2008) (50)	The study doesn't satisfy our inclusion criteria
Waddingham et al. (2006) (51)	The study doesn't satisfy our inclusion criteria
Herbison et al. (2016) (52)	The study doesn't satisfy our inclusion criteria
Hess et al. (2014) (53)	The study was exclude as the age group is not satisfying our inclusion criteria
Cleary et al. (2009) (54)	The study was excluded didn't explain the result as per the types of amblyopia
Bhombal et al. (2020) (55)	The study shows combined training protocol which doesn't satisfy our inclusion criteria
Thompson et al. (2011) (56)	The study was excluded as it didn't explain the result based on the type of amblyopia

sessions and the improvement of VA in amblyopic eye, contrast ratio and stereo acuity was also observed in this study. Furthermore, improvement in visual acuity was positively correlated with stereo sensitivity (rho = 0.71, P = 0.02) (31). Li et al. have reported a significantly more improvements in visual acuity, stereopsis and reduction in suppression with dichoptic therapy compared to monocular therapy in a comparatively small cohort of 9 adults with amblyopia. In this study, dichoptic therapy was provided by means of a video game whereby stimulus elements were presented separately to each eye with lower contrast stimuli in the fixing eye to counteract suppression and allow for binocular combination. However, in this study the numbers of anisometrpic amblyopia has not been segregated (32). In another study, Li et al. have assessed the improvements of contrast sensitivity along with other visual functions in 15 adults with amblyopia including 8 anisometropic amblyopia that underwent dichoptic therapy. In the first group of dichotic therapy, all the 8 adults with anisometropic amblyopia showed improvement in visual acuity, contrast sensitivity and suppression whereas 6 patients showed improved stereoacuity in which 3 patients developed only gross stereopsis and rest 3 had developed fine stereopsis (58). Similarly, in another study, Žiak et al. used a virtual reality head mounted system to provide dichoptic training in 17 adults with anisometric amblyopia and found significant improvement in visual acuity in and stereopsis. In this study, 8 patients gained a visual acuity of 20/40 or better after the training. Mean stereoacuity changed from a value of 263.3 ± 135.1 to 176.7 ± 152.4 seconds of arc after dichotic training (34). Vedamurthy et al. developed dichoptic version of a commercial first-person-shooter action video game and evaluated the efficacy of the same in treating adults with amblyopia and reported a reduced suppression, improved visual acuity and stereopsis with the said videogame. In this study, 23 adult amblyopes with 10 anisometropic amblyope, 13 strabismic and mixed amblyope were evaluated. However, the results of each type are not shown separately. It is important to note that pre treatment visual function such as visual acuity and stereopsis did not show any correlation with the reduction of intra ocular suppression (56). In another study, Vedamurthy et al. compared dichoptic action video games and monocular patching therapy in amblyopic adults and reported a better improvement in stereo acuity, reading speed and contrast sensitivity along with visual acuity in dichoptic group compared to monocular occlusion group. However, while subjects with anisometropic amblyopia showed similar improvements in visual acuity of around 1 and half line in logMAR chart in both dichoptic and monocular treatment group, subjects with strabismic amblyopia improved only after dichoptic therapy. Patients with anisometropic amblyopia in the dichoptic therapy group showed the largest improvements of stereoacuity compared with all other types. Similarly, contrast sensitivity showed greater improvement in individuals with anisometropic amblyopia in the dichoptic group. Reading speed also improved with game group. However, there was no difference in the improvement of reading speed between the types of amblyopia (57). All the studies are summarized in table II.

In systematic reviews, it is important to evaluate the strength of the study before any inference could be drawn. Thus, in the present review, ROBINS-1 tool was used to assess risk of bias. ROBINS-1 tool is a well developed recommended tool that is employed for non-randomized studies. Result of ROBIN-1 tool is shown in table III.

DISCUSSION

Management of adults with amblyopia is challenging as it requires restoring or developing the visual abilities after the critical period of development (30,31). In this systematic review, all the included studies reported dichoptic therapy as an effective approach to manage adults with anisometropic amblyopia. Included studies mainly used two types of devices that are ipod and

Table II: Tabulated summary of all articles included in this literature review

Author	Study design	Sample size	Age	Amblyopia types	Study protocol	Intervention	Follow up	Outcome measures	Results	Inference
Hess et al. (2012) (31)	NRIS	n=10	Mean age =33.8 years, age range =17-51 years	• 5 anisometropic amblyopes • 4 mixed amblyopes • 1 strabismic amblyope	• 10 amblyopic participants were tested • Inclusion criteria's were history of amblyopia (20/40 or worse in amblyopic eye) with absence of binocularity, no ocular pathology, no health condition • Visual acuity measured using LogMAR chart (with Snellen optotype), stereoacuity measured with Randot stereogram • All subjects were corrected fully for distance and near • Optical correction was given in mixed anisometropia, contact lens correction was given in purely axial anisometropia, prism correction given for strabismic amblyopia	• iPod based dichoptic Tetris video game was used where contrast of the fixating eye was reduced to reduced the suppression of amblyopic eye • The game was designed to be played successfully only when fusion of two eyes was present • contrast of the good eye increased with time to achieve normal binocular viewing condition • Duration of training : 0.5 to 2 hrs per session for 1 to 9 weeks	Follow ups was done after 9 weeks, 1 and 2 month after end of training(4 out of 10)	• Visual acuity • Contrast sensitivity • Stereo acuity • Suppression	• 9 out of 10 subjects showed significant (P = 0.008)improvements in visual acuity of the amblyopic eye (0.19 Log MAR; standard error, 0.17), • 6 out of 10 subject showed significant (P = 0.028) improvement in stereo acuity.	Although, separate baseline descriptive data was shown for five anisometropic amblyopia, statistical analysis was done with all the types of amblyopia together. It was concluded that the dichoptic therapy improves visual functions of adults with amblyopia.
Li et. al. (2013) (32)	NRIS	n=18	Mean age 22.3 years, age range=21-31 years	• 13 anisometropic amblyopes • 3 strabismic amblyopia • 2 mixed amblyopia	• Participants were divided into two groups, 9 in monocular and 9 in dichoptic training • Refractive correction done and used in trial frame during testing • Visual acuity measured using tumbling E LogMAR chart at 4 m distance • Stereopsis measured using Randot preschool test at 40cm • Suppression measured using dichoptic motion coherence threshold technique	• Tetris video game presented with head mounted system. • Training was given for one hour per day for two weeks • 9 participants had undergone monocular game play for two weeks followed by dichoptic training • Another 9 participants had undergone game play dichotically for two weeks only	Follow ups was done after 3 months	• Visual acuity • Stereopsis • Intra ocular Suppression	• Visual acuity showed better improvement with dichoptic training than monocular training (p<0.0001) • Stereopsis also showed significant improvement with dichoptic training group compared to monocular training (p<0.0001) • Dichoptic training also resulted in significant improvement in reduction of suppression than monocular training (p<0.0001)	Statistical analysis and result didn't mention improvement in different types of amblyopia separately. However, result showed improvement in visual functions in overall all types of amblyopia at adult age. Authors of the study concluded that human brain plasticity is proved to be present at adult age as amblyopic eye suppression was reduced.
Li et al. (2015) (58)	NRIS	n=30	Mean age= 22.2 ± 3.5 years	• 30 adult amblyopes that includes 20 anisometropic amblyopes, 9 strabismic and 1 mixed type amblyopia	• Inclusion criteria were intra ocular difference of 0.2 LogMAR with history of anisometropia, strabismus or both in absence of any ocular pathology. • Subjects had taken part in one of the two study groups. Visual acuity, stereopsis, suppression and contrast sensitivity were assessed at baseline, interim and post training in each group.	• 1 study group (15 subjects) received Ipod based dichoptic training game along with a-tDCS and sham tDCS for 5 days/week for 2 weeks.7 participants has received a-tDCS followed by sham tDCS and 8 participants received sham tDCS followed by a-tDCS. • Another study group (15 subjects) received dichoptic therapy (one group: 6 subjects) and monocular training (in another group : 9 subjects) using head mounted video goggles for 5 days/week for 2 weeks followed by dichoptic training for another 10 days • Another separate group with 12 amblyopic participants who did not receives any dichoptic or monocular therapy undergone two sets of measurement of visual acuity and contrast sensitivity	Follow up was done after 10 sessions of dichoptic training	• Contrast sensitivity using Gabor patches at different frequencies • Visual acuity using log MAR Chart	• iPod group showed mean improvement in CS of 0.33 Log units for 10 CPD, .03 log units for 3 CPD and .13 log Unit for .5 CPD • video game training group showed improvement in CS of 0.13 log unit at 0.5 CPD, 0.22 Log units at 3 CPD, 0.15 log unit at 10 CPD	Primary aim of this study was to measure contrast sensitivity pre and post intervention and the statistical analysis was done combining all the types of amblyopia. However, the visual functions of all types of amblyopia including anisometropic amblyopia were tabulated separately. This study has reported that dichoptic therapy also improves binocular visual functions rather than only monocular function in anisometropic amblyopic adults as apart from improvement in visual acuity and contrast sensitivity, stereoacuity improved in majority of the patients.

Table II: Tabulated summary of all articles included in this literature review

Author	Study design	Sample size	Age	Amblyopia types	Study protocol	Intervention	Follow up	Outcome measures	Results	Inference
Žiak et al. (2017) (34)	NRIS	n=17	Mean age 31.2 years, age range=17-69 years	• 17 subjects (10 me, 7 women) with anisometropic amblyopia	• Inclusion criteria was anisometropic amblyopes with age ≥17 years • Exclusion criteria were corneal irregularity, corneal opacity, strabismus, cataract, active ocular diseases, previous history of eye surgery • All subjects underwent detailed ophthalmological investigation that include measurement of visual acuity, stereoacuity, manifest and cycloplegic refraction, cover test, ocular health examination, fundus evaluation, corneal topography. • Visual acuity was measured using LCD display with Snellen's optotype and stereoacuity was measured using Randot graded circle test both pre and post therapy.	• Subjects underwent Dichoptic visual training with beta version of video game using head mounted Oculus rift (OC DK2 virtual reality system) • Two games were used using dichoptic stimulus: space game and block breaker game • All subjects underwent 8 sessions of training of 40 min with two different game (20 min each)	Follow ups was done after 8 sessions of training	• Best Corrected Visual Acuity (BCVA) • Stereo acuity	• Significant improvement in BCVA pre training mean value 0.58±0.35 LogMAR improved post training 0.43±0.38LogMAR(p<0.01) • Mean stereoacuity pre training 263.3± 135.1 sec of arc improved significantly post training mean value 176.7 ± 152.4 sec of arc (p<0.01)	This study only showed results of dichoptic therapy in adult anisometropic amblyopia. The study concluded that dichoptic training with head mounted virtual reality system is an effective treatment for adult anisometropic amblyopes.
Vedamurthy et al. (2015) (56)	NRIS	n=23	Mean age 39.57±15.74 years, age range= 19 -62 years	• 23 adult amblyopes: 10 anisometropic amblyope, 13 strabismic and mixed amblyope	• Inclusion criteria was subjects having unilateral amblyopia with at least two line difference between the eyes • Visual acuity, contrast sensitivity, Gabor resolution acuity, Intraocular ratio measured pre and post therapy • Visual acuity was measured with high contrast ETDRS chart with Solan optotypes and Stereoacuity was measured with Randot circles stereo test • Intra Ocular Ratio (IOR) was measured by reducing the perceptual strength of the good eye. (IOR = ratio of luminance of the good eye to amblyopic eye / contrast)	• Dichoptic custom made Unreal first person shooter action video game was used to reduce suppression and promote fusion. • The videogame was presented on a gamma corrected monitor (Mitsubishi Diamond Pro 2070 SB) • The game included perceptual learning and also suppression check of amblyopic eye. • The game used split screen view and control the images to be presented to the amblyopic eye and fixating eye. • Psychological resolution task using orientation discrimination of Gabor target presented to the amblyopic eye. • Each participants played total of 40 hours of video game with increase in difficulty level after each 3 hours	Follow ups was done after 2 month	• Visual acuity • Interocular suppression ratio(IOR) • Stereo sensitivity • Gabor resolution acuity	• Visual acuity in Log MAR improvement from pre training mean 0.58±0.30 to post training 0.44±0.29 (p<0.01) • Stereo sensitivity (1/ arc sec) pretraining 0.005±0.01 to post training 0.012±0.017 (p<0.05) • IOR and Gabor resolution acuity also shows significant improvement (p<0.05)	Although the baseline data of different types of amblyopia were mentioned separately, the results of patients with anisometripc amblyopia was not reported separately. This study concluded that dichoptic game play improves visual acuity, reduce suppression and improves stereopsis in adults with amblyopes
Vedamurthy et al. (2015) (57)	NRIS	n=38	Mean age 39.7±15.4 years, age range=19-66 years	• 38 unilateral adult amblyopic patients with anisometropic, strabismic and mixed type.	• Participants assigned into two intervention group : 23 subjects in game group played custom made dichoptic video game with mirror stereoscope , 15 subjects in movie group watching movie monocularly with good eye patched • Visual assessment done at baseline, mid assessment after 13 and 26 hours of intervention and final assessment after 40 hours of training • Participants who needed new glass prescription, was given 6 weeks of refractive adaptation prior to the therapy	• For participants of first group, dichoptic custom made Unreal first person shooter action video game was used for total of 40 hours (1.5 to 2 hours at least 2-5 sessions/week • The videogame was presented on a gamma corrected monitor • Anti suppression dichoptic therapy • For the other groups, Monocular viewing of action movies on computer screen for 40 hours was used	follow up assessment done after 8 weeks	• VA • Stereo acuity • CS • Reading speed • Self-report of amblyopia state (ASQE)	• Subjects with anisometropic amblyopia showed similar improvement in VA with game play (by 0.15 ± 0.01 logMAR; 29 ± 2%) and movies (by 0.16 ± 0.03 logMAR, 31 ± 5.8%) • Anisometropic amblyopia subjects showed significant improvement in stereoacuity (0.27 ± 0.1 log arcsec; 46 ± 17%) • Significant improvement in contrast sensitivity in anisometropic amblyopia patients (1.68 ± 0.4 to 2.2 ± 0.2)	Here the results for anisometropic amblyopia was separately reported. This study concluded that modified dichoptic action video game with perceptual learning and suppression check improves visual function in adult amblyopes compare to supervised patching. Patients with anisometropic amblyopia showed significantly better improvement compared to the other groups of amblyopia.

NRIS= non-randomized interventional studies, a-tDCS =visual cortex anodal transcranial direct current stimulation

Table III: Risk of biased was assessed with ROBINS-I tool for non-randomized studies of intervention studies

Author name	Bias due to confounding	Bias in selection of participants into the study	Bias in classification of interventions	Bias due to deviations from intended intervention	Bias due to missing data	Bias in measurement of outcomes	Bias in selection of the reported result	Overall
Hess et al. (2012) (31)	Low risk	Low risk	Low risk	Low risk	Low risk	serious risk	Low risk	serious risk
Li et al. (2013) (32)	Low risk	Low risk	Low risk	Low risk	Low risk	Serious risk	Low risk	Serious risk
Li et al. (2015) (58)	Low risk	Low risk	Low risk	Moderate risk	Low risk	serious risk	Low risk	serious risk
Žiak et al. (2017) (34)	Low risk	Low risk	Low risk	Low risk	Low risk	serious risk	Moderate risk	serious risk
Vedamurthy et al. (2015) (56)	Low risk	Low risk	Low risk	Low risk	Low risk	serious risk	Moderate risk	serious risk
Verdamurthy et al. (2015) (57)	Low risk	Low risk	Low risk	Low risk	Low risk	serious risk	Low risk	serious risk

virtual reality head mounted systems. Functioning of these devices was explained in details justifying the principle of dichoptic therapy. Visual components and suppression of the study patients were evaluated with standard instruments before and after therapy. Dichoptic therapy being an active vision therapy was found to improve different visual functions including visual acuity, stereo acuity and contrast sensitivity, reading speed of adult patients with anisometropic amblyopia (31-34, 56, 57). Li et al. and Vedamurthy et al. found that dichoptic binocular training showed better effect than monocular training improving several visual functions and reducing suppression (56, 58). One to two hours of dichoptic training showed improvement in visual acuity with more effect in anisometropic amblyopia (31). One research also reported significantly better improvements of visual function with dichoptic therapy in adults with anisometropic amblyopia compared to strabismic or mixed amblyopia (57). In addition to the above findings, recent research by Hou et al. reported a significant correlation between the reduction in intra ocular suppression and improvement of visual attention in the adult amblyopic eye with dichoptic training. In this study, training tasks employed counting of large size Gabors that involves visual attention process, higher level of visual pathways and intraparietal sulcus. The study results suggested dichoptic therapy with high attention demand task has the potential to improve ambyopia in adults (59). Furthermore, Swal et al. 2022 has recently reported improvement of postural stability after active vision therapy in an adult with anisometropic amblyopia (60).

Similarly, compared to the traditional therapy, there was a significant improvement in stereopsis in adult anisometropic amblyopia patients with the dichoptic therapy (34). These results are similar with treating children with amblyopia with dichoptic therapy (61-64). A recent research have also found that binocular function like vergence range, intra ocular suppression and eccentric fixation improve after dichotic vision therapy among children with amblyopia (65). However, there is no evidence of improvement of other binocular vision functions like accommodation and convergence anomalies, improvement of amount of strabismus associated with amblyopia while managing amblyopic adults with dichoptic vision therapy.
No study, included in the present review, has reported any adverse effect of dichoptic vision therapy. While, monocular occlusion therapy might lead to post treatment diplopia particularly in adults (66), in post dichoptic training no risk of developing diplopia with reduction of intra ocular suppression has been reported. The reason behind this could be the fact that dichoptic training induces binocular fusion during the procedure and thereby leads to elimination of diplopia (67). Similarly, the response rate of this binocular dichoptic therapy showed more improvement compared to the traditional long hours of patching (57). Vision therapy with dichoptic training shows much more effect for adult amblyopia and reduced the processing time.
Although, the included studies showed promising results that can be considered as revolutionary in the treatment of adults with amblyopia, there are some major concerns that were recognized during the present review. All the researches included in this review were non-randomized studies of intervention with serious risk of bias as assessed with ROBINS-I tool. All of the studies showed serious risk in measurement of outcome thereby, exhibiting serious risks. None of the studies used separate examiner for measurement of dependent variables. Thus, the validity of the evidences was compromised to be widely accepted for clinical practice.

Furthermore, there was lack of homogeneity in the treatment protocol like frequency of follow up, duration of therapy among the different authors of reviewed studies. Besides, some authors combined dichoptic therapy with transcranial direct-current stimulation (tDCS) , monocular therapy. However, a validated protocol with minimum duration of treatment that gives maximum effect to consider patient compliance has not been studied yet. Similarly, the protocol of treatment was same for all types of amblyopia. It has been recommended that the protocol of treatment should also vary for different types of amblyopia in adults as studies reported poorer outcome of vision therapy in strabismic and mixed amblyopia compared with anisometropic amblyopia. The reasoSn of such findings could be because of different amount of intra ocular suppression in different types of amblyopia (68).

Further limitations recognized in these studies include small sample size and shorter follow ups. While, only one of the included studies reported visual outcome of solely adults with anisometropic amblyopia (34),

two studies reported visual outcomes among adults with anisometropic, strabismic and mixed amblyopia separately (57, 58). Three of the discussed studies did not segregate the visual outcome of anisometric amblyopia from other types of amblyopia (31, 32, 56). The sample size of each group was small, often within 10 to 20 in number. Similarly, the follow up period of the reviewed studies was only few months with no evidence of longer follow ups. Besides, among the reviewed evidences there is lack of control group. Thus, future studies could be done with large sample size, long follow up, RCT with placebo group and double blinded approach.

CONCLUSION

Management of adults with amblyopia is challenging for clinicians. In the present review, dichoptic vision therapy has shown to have the potential to be considered as an effective treatment approach for adult-anisometropic amblyopia. However, efficacy of this treatment is still questionable due to inadequate number of scientific evidences and several constrains of the existing literature. Therefore, further studies particularly RCTs with strict methodology and treatment protocol, larger sample size and longer follow ups are recommended before clinicians could impart dichoptic therapy into their evidence based practice to treat adults with amblyopia.

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