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Dipanwita Ghosh
Assistant Professor and Head, Department of Optometry, Swami Vivekananda University, West Bengal, India

Corresponding Author:
Dipanwita Ghosh
Assistant Professor and Head, Department of Optometry, Swami Vivekananda University, West Bengal, India

Does eye exercises along with physical training helps in achieving better sports performance? Effect of vision therapy on basketball players

Dipanwita Ghosh

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Abstract
Aims: To determine the prevalence of binocular vision anomalies and effect of vision therapy on performance of basketball players
Settings and Design: Prospective interventional study
Methods and Material: Total 32 basketball players of the Bharati Vidyapeeth University, Pune, with the mean age of 20.47±1.883 year, were assessed. The examinations included detailed history taking, Visual acuity, Refraction, Slit lamp evaluation and detail orthoptic evaluation. Out of 32 players 21 players were detected with non-strabismic binocular vision anomalies that had undergone 4 weeks of home therapy and 4 weeks of office therapy. Vision therapy included accommodative therapy, convergence therapy, eye hand coordination and body eye coordination exercises, reaction time, saccades. Sports performance was judged objectively by Johnson Basketball test and subjectively by questionnaire both pre and post therapy for comparison. Detail orthoptic evaluation was performed after 4 weeks and 8 weeks of vision therapy.
Statistical analysis used: Statistical analysis was done using SPSS version 20.0 software.
Results: Out of 32 players 25 were males (78.1%) and 7 females (21.9%).Convergence insufficiency was the most Prevalent anomaly of binocular vision (25%) followed by convergence excess (15.6%), divergence insufficiency (15.6%) and accommodative insufficiency (9.4%).Statistically significant improvement in the sports performance (<0.05)were found in post therapy. Following the training period, 8 out of 19 oculomotor variables were improved (p-value <0.001) by 4 weeks and after 8 weeks there was clinically significant (<0.001) improvement in 15 out of 19 oculomotor variables.
Conclusions: Binocular vision skills are trainable and can be improved by appropriate therapy, which in turn are transferable into specific sports performance.

Keywords: Non strabismic binocular vision anomalies, Vision therapy, Orthoptic evaluation, Johnson basketball test

Introduction
Eye is one of the most important sensory organ which helps to receive information from the environment and in many sports there are demands of vision and specific visual skills. Visual sensory input may account for up to 85-90% of the sensory input of an athlete during an athletic contest [1]. In a successful sports performance vision is being an important component as being the first step of information processing.
Binocular single vision is very important aspect of many sports which provides visual cues of spatial orientation, like it helps to judge the exact location of an object in three dimension space and crucial in both static and dynamic conditions, also helps to assess the speed and distance of an object.
Binocular vision is defined as the vision which is achieved by the co-ordinated use of both eyes so that the images which arise in each eye separately are appreciated as a single mental impression in the visual part of the cerebral cortex [2]. A person with a normal binocular single vision (BSV) should have accurate alignment of the two eyes and vergence function, sensory fusion and stereopsis. It is already proven that highly developed binocular vision function has effect on motor skills. Many studies have shown that rapid and accurate visuomotor function in sports activity require better stereopsis.

Besides the normal static visual acuity, there are other visual abilities that might like dynamic vision, stereo acuity, accommodation, vergence, saccadic and pursuit eye movement, hand eye coordination, reaction time, peripheral vision that potentially facilitate the performance in fast-paced sports. In basketball, near-far fixation changes are continual for ball interpretations, control, passing, and throwing the ball, as well as analysing the positioning of teammates and opponents, among each others [3]. This type of activities related with constant implications of accommodation and vergence system, which could produce a comparable effect to vision therapy exercises. Further to make a proper shooting, dribbling and passing visual and motor system must be well co-ordinated. Here comes the significance of eye hand body coordination i.e. the ability of the visual system to guide the motor system [4]. Good eye hand body coordination helps the players to do complex and fluent movement and response effectively to external stimuli. At the same time the players need to judge the exact height of the basket from a distance which is possible only with good stereopsis. Stereopsis is the ability to fuse, with the appreciation of depth, similar images falling on points of retinae which are slightly disparate laterally. Stereopsis is an ability of perceive three dimentional image with binocular vision. Accurate depth perception is essential for the motor system to position the body from a specific distance from the basket for a successful shooting.

One of the most important cognitive ability is the reaction time or response time that refers to the amount of time that takes places between when we perceive something to when we respond to it, depends on the factors of perception, processing and response. In quick interceptive sports of basketball where moving with the ball while doing dribbling, passing and catching the ball during defending, an advance movement and reaction time becomes a deciding parameter of performance. There are also some specific eye movements like saccadic and pursuit eye movements are used for keep the fixation on the ball and on the other players during the game. Also for all team ball sports, it is indispensable to see and observe teammates as well as opponents in order to play effectively and efficiently [5]. The players as well do not have the time to interpret all of the information available [6]. Revien & Gabor stated that visual abilities affect sports performance and the acquisition of motor skills, which can be improved with training [7]. According to Erickson (2007) it is most important to choose particular sports and to identify the visual abilities which are critical to athletic performance [8]. "Visual training may well make the difference between winning and losing, between revelling in keen competition or shrinking from it" [7].

Aim

To determine the prevalence of binocular vision anomalies and effect of vision therapy on performance of basketball players.

Subjects and Methods

This is a prospective interventional study done at Bharati Vidyapeeth Pune from October 2018 to February 2019. In this study basketball players between 18-25 years of age were included with best Corrected visual acuity of 6/9 or better in each eye, practice regularly for minimum of 2 hour with no ocular pathology, no history of ocular surgery, visual field defect, amblyopia, suppression, manifest squint or any injury to the eye. After the approval from the Ethical committee of Bharati Vidyapeeth (Deemed to be University), Medical College, Pune 32 university basketball players were randomly selected and complete OPD optometric workup including detailed history taking both general and sports history, visual acuity measurement, objective refraction, subjective refraction, slit lamp evaluation and detailed orthoptic evaluation were done to select the study population. Data collection were done using proforma for both pre and post evaluation. 21 subjects satisfying the inclusion criteria were included in this study and each subject was informed about the purpose of the study and a well-informed written consent was obtained from each subject before participation. The subjects were given total 30 sittings of vision therapy depending on their detected condition [Table - 1]. 8 weeks of therapy divided as 15 sittings of home therapy in first 4 weeks and 15 sittings of office therapy in the next 4 weeks. That also include Visuo-motor exercises. [Table - 2] Their overall performance in sports and quality of life was assessed subjectively with sports vision questionnaire [9] modified for basketball and objectively with Johnson's basketball test. This was done pre and post vision therapy. A numerical score of 0-4 was assigned to the pre- and post-therapy survey responses of the questionnaire. A score of four points was assigned to symptoms marked "always." Three points were given if the symptom occurred "frequently." Symptoms checked "occasionally" received a score of two. One point was assigned to responses marked "seldom." If a patient marked "never," zero points were scored. The mean score for each question were compared between Visit 1 and the final visit. All the test, exercises and sports performances were done with the full refractive correction of the subjects.

Table 1: Clinical features of binocular vision anomalies and instruments used for VT [18]

Condition	Clinical features	Home based exercises	Office based exercises
Convergence insufficiency	Reduced NPC, Low AC/A ratio, Exophoria at near>distance, Low NRA, Reduced vergence facility, Difficulty with plus lenses during binocular accommodative facility	Pencil push up, Brock string, Cat card	Loose lens rock, Brock string, Accommodative flipper, Eccentric circle card, Life saver card
Divergence insufficiency	Low AC/A ratio, Esophoria dist. > near, Decreased NFV at distance	Brock string, Eccentric circle card, Large Eccentric circle at distance	Brock string, Bug off string, Accommodative flipper, Eccentric circle card
Convergence excess	Esophoria near>distance, High AC/A ratio, Reduced NFV at near, Low PRA, Difficulty with minus lens in flipper	Brock string, loose lens rock, Eccentric circle: divergence and convergence both	Brock string, Loose lens rock, Bug on string, Accommodative flipper, Eccentric circle: divergence
Divergence excess	Exophoria at dist.>near, High AC/A ratio, Normal PFV at dist. and near, Comitant deviation	Loose lens rock, Eccentric circle, Life saver card, Brock string	Brock string, Loose lens rock, Eccentric circle card, Cheiroscopic tracing

Vergence dysfunction	Normally AC/A ratio, Normal phoria at dist. and near, reduced positive and negative vergence facility, Reduced NPV and PFV dist. and/or near, Low PRA and NRA, Normal AA, Fails on accommodative facility testing	Brock string, Loose lens rock, Eccentric circle (Convergence/divergence)	Brock string, Lens sorting, Loose lens rock, Barrel card, Eccentric circle (Convergence and divergence), Accommodative flipper, Lifesaver card, Exercise with prism BI or BO, Adduction abduction exercise with synaptophore
	Esophoria equal at both dist. and near, Normal AC/A ratio, Low PRA, Low NFV both dist. and near, Low accommodative facility with minus lens	Brock string, Loose lens rock, Eccentric circle card: divergence and convergence both	Brock string, Loose lens rock, Eccentric circle, Accommodative flipper, Life saver cards, Large eccentric circle at 1 meter and distance, Exercise with prism BI or BO
	Reduced NPC, Normal AC/A ratio, Equal Exophoria at near and distance, Low PFV both dist. and near, Low NRA, Low binocular accommodative facility testing with plus lens	Brock string, Eccentric circle card, Loose lens rock	Brock string, Loose lens rock, Barrel card, Accommodative flipper, Eccentric circle, Lifesaver card, Adduction abduction exercise with synaptophore
Accommodative insufficiency	Reduced amplitude of accommodation, Difficulty clearing minus lens with both monocular and binocular accommodative facility, High MEM, Reduced PRA	Loose lens rock, Brock string, Hart chart, Eccentric circle	Brock string, Loose lens rock, Hart chart, Barrel card, Accommodative flipper, Eccentric circle, Lifesaver card
Accommodative excess	Difficulty in clearing Plus lenses in both monocular and binocular accommodative facility, Low MEM, Reduced NRA	Loose lens rock, Brock string, Bug on string, Hart chart, Eccentric circle	Brock string, Loose lens rock, Hart chart, Accommodative flipper, Eccentric circle
Accommodative infacility	Difficulty in clearing both plus and minus lenses with accommodative flipper in both monocular and binocular, Reduced PRA and NRA	Loose lens rock, Brock string, Bug on string, Hart chart, Eccentric circle	Brock string, Loose lens rock, Hart chart, Barrel card, Accommodative flipper, Eccentric circle, Voluntary convergence, Lifesaver card

Note. NPC = Near Point of Convergence, AC/A = accommodative Convergence/accommodation, NRA = Negative Relative Accommodation, PRA = Positive Relative Accommodation, NFV = Negative Fusional Vergence, PFV= Positive Fusional Vergence, MEM = Monocular Estimated Method, BI = Base In, BO = Base Out, AA = Amplitude of Accommodation.

Table 2: Visuomotor exercises given in office therapy

Visuomotor function	Exercises
Exercises for eye hand co-ordination	Marsden ball with bat Video games (Assassin's creed)
Exercises for body eye co-ordination	Seesaw exercise with balance board using distance hart chart
Exercise to improve Tracking, Reaction time	Video games (Assassin's creed)
Dynamic vision exercise	Marsden ball with different size target while balancing with balance board
Exercises for Saccades and smooth pursuit	Marsden ball without bat, SCCO system

Note. SCCO = Southern California College of Optometry

Table 3: Comparison between pre and post therapy mean value of ocular variables

Variables		Pre therapy values (At baseline) for both eye	Post therapy values (After 8 weeks of therapy) for both eye	P value
NPA	Blur point	11.286±2.21	8.970±0.750	<.001
	Recovery point	12.286±2.21	10.00±0.775	<.001
NPC	Break point	7.42±2.90	7.95±6.32	.692
	Recovery point	8.47±2.89	8.33±1.72	.696
NFV at distance	Break point	9.42±5.48	14.81±5.07	<.001
	Recovery point	7.09±4.97	12.66±4.48	<.001
NFV at near	Break point	12.61±4.52	24.04±5.39	<.001
	Recovery point	9.90±4.40	20.19±4.64	<.001
PFV at distance	Break point	24.57±10.38	28.81±8.20	<.001
	Recovery point	20.09±9.10	25.28±6.98	<.001
PFV at near	Break point	24.23±9.99	32.85±6.23	<.001
	Recovery point	19.85±9.13	27.85±6.23	<.001
NRA		2.952±0.650	3.524±0.370	<.001
PRA		-2.929±0.826	-3.595±0.422	<.001
AC/A ratio		4.967±1.608	5.729±0.584	.004
Accommodative facility (Binocular)		7.071±3.733	11.000±1.718	<.001
Vergence facility		10.214±3.760	14.42±1.36	<.001

Note. NPA = Near Point of Accommodation, NPC = Near Point of Convergence, AC/A = accommodative Convergence/accommodation, NRA = Negative Relative Accommodation, PRA = Positive Relative Accommodation, NFV = Negative Fusional Vergence, PFV= Positive Fusional Vergence, MEM = Monocular Estimated Method, BI = Base In, BO = Base Out, AA = Amplitude of Accommodation.

Table 4: Pre and post therapy improvement in subjective response using questionnaire

Questions	Pre-Therapy			Post Therapy			p-value
	Min	Max	Median	Min	Max	Median	
1.Intermittent blurry vision at distance /near/both (Please circle)	0	3	2	0	1	0	.002
2.Double vision at distance /near /both (Please circle)	0	3	1	0	1	0	.002
3.Headache associated with near work	0	4	2	0	2	0	.001
4. Words run together when reading	0	4	0	0	2	0	.038
5. Dizzness or nausea associated with near work	0	3	0	0	1	0	.014
6. Do you Squint, cover or close one eye during reading?	0	3	0	0	2	0	.038
7. Do you feel Red / Burning of eyes	0	4	2	0	2	1	.001
8. Do you feel your Eyes Strain / Tired	0	4	2	0	2	0	<.001
9. Do you feel you have short attention span	0	4	1	0	1	0	.002
10. Holding reading material too close	0	1	0	0	2	0	.655
11. Inability to estimate distance accurately	0	3	0	0	1	0	.003
12.Tendency to knock over the objects	0	4	0	0	1	0	.102
13. Starburst or halos around lights	0	3	2	0	2	1	.001
14. Sensitivity to light / lighting / glare	0	3	2	0	2	1	.002
15. Inconsistent / poor sports performance	0	4	0	0	1	0	.024
16. Do you have any problems with balance during sports activity?	0	4	1	0	2	0	.001
17. Does your performance decrease under pressure?	0	4	1	0	2	1	.004
18. Does any of the following interfere which affect your performance? a) bright sun	0	4	3	0	3	2	.001
b) dim light	0	4	2	0	2	1	.002
c) without sunglasses	0	4	2	0	2	1	.003
d) with sunglasses	0	4	1	0	2	0	.014
19. Do you have any difficulty in seeing the basket from distance?	0	4	1	0	1	0	.003
20. Do you have any difficulty in judging the height of the basket?	0	2	0	0	0	0	.014
21. Do you have any difficulty in shooting the basketball through the basket?	0	3	0	0	1	0	.006
22. Do you have any difficulty while deflect passing the basketball?	0	3	0	0	2	0	.020
23. Do you have difficulty following the players coming from sides?	0	4	0	0	2	0	.024

Data analysis

Statistical analysis was done using SPSS version 20.0 software. Paired t test/ Wilcoxon sign-rank test was used for the comparison of pre and post therapy data and p-value < 0.05 was considered as significant.

Results

The result of this study divided in to two parts, "part-A" is based on objective findings and "part-B" is based on Subjective response from the questionnaire.

Part A

In this study total 32 basketball players were examined with a mean age of 20.47±1.883, out of them 7 were female (21.9%) and 25 were male (78.1%).Among them the participants 12 subjects were detected with astigmatism (37.5%), 2 were myopic (6.3%), 1 hyperopic (3.1%) and 17 subjects were emmetropic (53.15%).

21 players out of 32 players were detected with binocular vision anomalies. In this study convergence insufficiency found in 25% of the subjects, which includes convergence insufficiency associated with accommodative insufficiency in 9.4% and convergence insufficiency with vergence dysfunction in 3.1%.Convergence excess found in 15.6% which includes convergence excess associated with accommodative excess in 3.1%.Divergence insufficiency found in 15.6% which includes divergence insufficiency associated with accommodative insufficiency in 3.1%.Purely accommodative insufficiency found in 9.4%.The prevalence of heterophoria found to have in 25.1% at distance and 53.1% for near with Maddox rod test. Pre therapy exophoria was present in 9.1% in distance and 59.1% in near with Maddox rod test and post therapy exophoria was present in 4.5% for distance and 27.3% for near. Pre therapy esophoria was observed in 27.3% for distance and 18.2% for near whereas it improved to 4.5% at distance and 4.5% at near post therapy.

The mean near point of accommodation (NPA), near point of convergence (NPC), negative fusional vergence (NFV), positive fusional vergence (PFV), negative relative accommodation (NRA), positive relative accommodation (PRA), Stereo acuity, accommodative facility, vergence facility and AC/A ratio has also been improved post therapy significantly [Table -3]. The scoring of Johnson test pre and post therapy has found the mean number of basket was 6.286±2.432 pre therapy which was improved by 8.095±1.947 post therapy. The mean score of dribbling was 7.09±1.84 in pre therapy and improved to 7.57±1.20 in post therapy. The mean score of passing was 15.33±6.31 in pre therapy improved to 17.619±5.380 post therapy. The paired t-test revealed significant difference between both pre and post result (p-value < 0.05) in the basket and passing skill. The dribbling skill doesn't show any significant improvement post therapy.

Part B

Total 23 questions [Table-4] were given to the participants to assess their quality of life, symptoms, sports performance and hand eye coordination before and after therapy. 21 out of 23 questions showed a statistically significant improvement (p-value < 0.05) after 8weeks of therapy. [Table-4].

Discussion

This study provides the prevalence of binocular vision anomalies among the basketball players. It also correlates the effects of vision therapy with the sports performance of the players.

Horwood *et al.* (2004) [10] confirmed beneficial effects in testing of convergence function in an asymptomatic typical

young adult population after 2 week period of an intensive training program of various eye exercises [10]. A study done byE. Porcar, A. Martinez-Palomerafound 7.7% CI among university students [11]. In this study convergence insufficiency was found to be the most frequent anomaly of binocular vision (21.9%) among the university basketball playersweremostly asymptomatic. Convergence excess was found in only 1.5% of the university students by E. Porcar, A. Martinez-Palomera (1997) [11], whereas it is found in 12.5% of the subjects in this study. This may be due to excessive involvement in mobile games among these young adults now a day.

According to the study by Teresa Zwierko *et al*. heterophoria was present in 70% of the population for distance and 80% for near [12]. Whereas we have found that about 62.5% had a deviation of visual axis for near and about 25.1% at distance. In this study we have observed there was positive effect of visual training in case of abnormal eye alignment (Heterophoria greater than normal range) as well as in small deviation. In the same study they have found improvement in 3 out of 6 oculomotor variable (p-value <0.05) [12]. Similarly following the training period highly significant improvement (p<0.001) found in 15 out of 19 variables after complete 8 weeks of therapy in this study. Greatest effect was observed in near dissociated phoria (p = 0.001) and fusional convergence (p = 0.014) by Teresa Zwierko *et al*. [12] In this study also significant improvement was found in the fusional vergence amplitude both distance (p<0.001) and near (p<0.001) following the therapy.

It has been observed that receiving controlled therapy had a better effect compared to home-based methods (Scheiman, 2005) [13]. In this study also this has been observed that only 8 out of 19 variable shows clinically significant improvement (p<0.001) after 4 weeks of home based therapy. This may be due to less compliance in home based therapy among the subjects. Lavrich (2010) reported that most subjects with convergence insufficiency demonstrated varying degrees of exophoria or even an intermittent exotropia at near, and some subjects had reduced stereo acuity at near [14]. In this study also low value of fusional convergence and accommodative facility were found in majority of the cases and convergence insufficiency which may have caused the exophoria more at near. One important factor causing misalignment of the visual axes was a weak vergence system (Wilmer and Backus, 2009) [15]. In this study, a low value of fusional vergence, near point of convergence, vergence facility, accommodative amplitude and accommodation facility was observed in the majority of the cases. We have found in some player stereopsis was lower which may be due to presence of binocular vision anomalies and has improved after training with the improvement of the other binocular vision functions. The visual facility of accommodation, vergence amplitude and facility, saccadic motility, eye hand body co-ordination, dynamic vision, reaction time, Depth perception, which plays an important role in the visual challenges of dynamic sport of basketball showed improvement in the subjects undergone the training. This improvement can be in relation to the hypothesis that frequent training of the visual system should lead to stronger muscle fibres and more efficient neuronal response (ZUPAN *et al*.' 2006) [1]. Improvement of binocular vision function by the training in turn improves the sports performance like accuracy in throw the ball in the basket from any distance which may be as an effect of improvement of binocular vision anomalies. These findings were consistent with the study done by Sebastian Schwab and Daniel Memmert (2012) [16] and by Maman Paul *et al*. 2011 [17]. The benefit of such training was likely due to the subject getting more encouragement and reinforcement to try harder (Horwood *et al*., 2014) [10].

Conclusion

Our study suggests that binocular vision functions, like Ocular alignment, fusional vergence, accommodation, stereopsis and all other visual abilities like eye hand coordination, reaction time are trainable and can be improved by means of appropriate training. As these all visual functions are very important and needs in specific sports activity, improvement of the lacking visual skills in turn can improve sports performance. It can be stated that the visual training along with the regular physical training in athletes helps to improve their performance. It is very important to create this awareness among the athletes and their coaches about the importance of proper eye examination. So from this study we can conclude that even asymptomatic young adults who are specifically involve in sports should undergo detailed eye examination and also should train their visual functions appropriately according to the specific needs for specific sports.

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