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*Original Research Article*

# Binocular Visual Skills in Patients with Mild Traumatic Brain Injury

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## ABSTRACT

**Purpose:** To assess binocular visual skills in patients with mild traumatic brain injury (mTBI).
**Methods:** It was a case control study including medically-documented mTBI subjects aged between the 15-35 years. Subjects with best corrected visual acuity of 0.13 LogMAR or better for distance and those who had head trauma at least six months prior to testing were included. Subjects with moderate to severe brain injury, polytrauma, stroke, visual field loss, a history of vision therapy, other neurological conditions, one eyed and strabismic patients were excluded. The age and gender matched subjects without history of either brain injury or binocular dysfunction were also included as a control group. All subjects underwent binocular visual tests, including near point of convergence (NPC), accommodative amplitude (AA), positive and negative relative accommodation (PRA and NRA), accommodative lens facility, positive and negative fusional vergence for near, reading speed were evaluated.
**Results:** The study included 28 mTBI patients and 28 age and gender matched controls with mean± SD age of 24.57±5.23 and 24.96±4.66 years respectively. An independent t-test was carried out ($\alpha<0.05$) using SPSS 20 which showed that binocular vision skills including, NPC break and recovery, NRA, PRA, AA, accommodative facility, PFV, NFV, and reading speed were significantly reduced in mTBI subjects as compared to control.
**Conclusion:** Binocular visual skills are affected in subjects with mTBI. Impaired binocular visual skills could affect daily living activities and therefore these skills needs to be assessed during optometric examination.

***Keywords:*** Mild traumatic brain injury; binocular visual skills.

## INTRODUCTION

Traumatic brain injury (TBI) is a major public health problem and common cause of death and disability worldwide. [1] Head injuries causes severe disability in 150-200 people per million annually and 25% of these patients were associated with visual defects. [2, 3] It has been reported that in India, about 1.6 million sustain head injury each year, approximately 200,000 deaths occur due to TBI and 1 million populations require rehabilitation services. [4] The prevalence of TBI is 9.7 million. [5] Based on the consciousness or Glasgow coma scale, TBI may be classified as mild, moderate, or severe with Mild TBI (mTBI) being the most common among all forms of TBI. [4] The most common causes of TBI are road traffic accidents, falls, assaults, sports injury, bullets and blast injuries from military conflict. [6,7] Depending upon the severity and site of the injury, a TBI results in general dysfunctions of physical, behavioral, cognitive, and emotional aspects. [8]

There are multiple areas in the brain that are related to vision including six of the twelve cranial nerves. This extensive neural network is responsible for range of visual functions which could be adversely affected, even in the milder form (mTBI). [9] Any injury to the brain and adjacent structures may adversely affect the visual pathways including vergence and accommodative system which could be due to widespread connections of vergence and neural pathway. [10,11] The ocular injuries due to trauma such as corneal tear, traumatic cataract, retinal detachment are easily diagnosed and managed clinically, however subtle binocular vision dysfunctions due to traumatic brain remains undiagnosed. [12]

It has been reported that most patients with mTBI recover within the 6 months to 1 year after injury however some them continues to report binocular function difficulties. [13] If an appropriate evaluation and diagnosis about binocular visual skills are not made, then the patient's visually based symptoms could persist and perhaps become more worse which may affect the patients overall quality of life (QOL), as well as their activities of daily living (ADLs) despite of having excellent vision. [14,15] A comprehensive assessment of binocular visual skills is essential for appropriate diagnosis so that early visual intervention can be implemented. Hence aim of the study was to assess binocular visual skill tests in patients with MTBI at least 6 months after injury.

## MATERIALS AND METHODS

All medically-documented mTBI subjects between the ages of 15 to 35 years were recruited in the study. Written informed consent was obtained from all the subjects. The study was conducted at neurosurgery department of tertiary health care hospital. To be included in the study subjects had to meet the following criteria: [16] loss of consciousness (LOC) less than 30 minutes, Glasgow coma scale (GCS) score between 13-15, Post traumatic amnesia (PTA) less than 24 hours, best corrected visual acuity of 0.13 logMAR or better and 1M for distance and near respectively. To avoid any effects of the natural recovery process on the test results, subjects who had head trauma atleast six months prior to testing were included. [13] Subjects having moderate to severe brain injury, polytrauma, cerebrovascular accident (stroke), one eyed and strabismic patients, subjects with ocular injury, visual field loss, previous history of vision therapy and other neurological conditions were excluded from the study.

Detailed history regarding mechanism, location of injury, loss of unconsciousness, Glassgow coma score, visual symptoms, photophobia, reading difficulty, double vision, peripheral vision, headache and general health was documented for all mTBI patients. All subjects' underwent ocular examination including best corrected distance and near visual acuity using LogMAR charts, objective and subjective refraction, anterior segment examination and pupil evaluation using flash light. Further, stereopsis was measured at 40 cm using the non-random-dot Titmus fly stereo test with polaroid lenses. [10] Near point of convergence (NPC) measures convergence amplitude. It was assessed using accommodative target on Royal air force (RAF) rule, average of 10 repeated readings was taken, break and recovery values were noted. [17] Accommodative amplitude (AA) was assessed monocularly using minus lens method. The patient's ability to stimulate and relax accommodation, that is positive relative accommodation (PRA) and negative relative accommodation (NRA) were determined binocularly using minus lenses and plus lenses respectively. [18] Accommodative facility means ability of eye to change focus at different distances in given period of time and it was measured using +/- 2D flipper lenses. [10] Prior to testing, subjects were allowed to practice the test procedure to get familiarize with the accommodative flipper. Subject's ability to converge and diverge that is positive fusional vergence (PFV) and negative fusional vergence (NFV) respectively were determined for near using horizontal prism bar, break and recovery values were documented. Reading speed was assessed using Wilkin's rate of reading test and recorded as number of words read per minute (wpm). Average of three readings was considered for analysis. [19] Subjects were categorized into non strabismic binocular dysfunction based on results of binocular visual skill tests [20] and were consider for the analysis. Diagnostic criteria's for categorizing non strabismic binocular dysfunction have been described in table 1.

**Table1: Describes diagnostic criteria for non strabismic binocular dysfunction**

| Diagnosis | Diagnostic criteria |
|---|---|
| Convergence Insufficiency | Near point of convergence of ≥6 cm break<br>Reduced positive fusional convergence at near <20 prism diopters |
| Amplitude of accommodation | Amplitude of accommodation ≥2 diopters calculated using formula: (15-1/4 age) |
| Accommodative infacility | Inability to clear both +2.00 and -2.00 lenses monocularly to complete 10 cycles in one minute. |

We compared this data with age matched non-TBI control group, without history of either mild traumatic brain injury or binocular dysfunction. All subjects in control group were recruited from outpatient department at tertiary eye hospital.

**Data analysis:**

The all variables were entered in the Microsoft Excel Sheet and were analysed using SPSS, (Version 20). We calculated the means and standard deviations, standard errors for continuous variables whereas proportions for categorical variables. Independent t test was used for comparison of binocular skill tests between case and controls. Further these skills were compared among subjects with mTBI due to fall versus accident.

## RESULTS

The study included 28 mTBI patients and 28 non-TBI subjects. The mean (SD) age in the TBI group was 24.57 (5.23) years and 24.96 (4.66) years for the non-TBI group. Statistical analysis revealed non significant difference in mean age (p=0.24). The mean (SD) time since head injury was 14.79 (14.11) months. The mean (SD) distance logMAR visual acuity was 0.11 (0.02) and 0.00(0.01) logMAR in mTBI and non TBI group. The mean visual acuity in mTBI group was statistically different from non TBI group however it was not clinically significant. The stereopsis of 40 seconds of arc in all mTBI and non TBI patients were noted.

Out of 28 mTBI patients, 23 patients had GCS score 15, 3 patients had GCS score 14, and 2 patients had GCS score 13. In our study the common cause of mTBI was fall. The distribution of various causes for mTBI has been described in table 2. Asthenopic symptoms were commonly observed in these patients. Distribution of primary symptoms reported during history taking has been described in table 3. In mTBI patients, convergence insufficiency was common finding followed by convergence and accommodative insufficiency. Table 4 describes the distribution of binocular vision disorder in subjects with mTBI.

**Table 2 Distribution of various causes for mTBI**

| Cause of TBI | N=28 | Distribution (%) |
|---|---|---|
| Fall | 14 | 50 |
| Accident | 11 | 39 |
| Hit | 3 | 11 |

**Table 3 Primary symptoms reported during history taking**

| Symptoms | Distribution (Numbers) |
|---|---|
| Eyestrain with near tasks | 10 |
| Headaches with near vision tasks | 16 |
| Near vision blur | 14 |
| Loses place when reading | 11 |
| Covering or closing one eye | 9 |
| Light sensitivity | 2 |

**Table 4 Distribution of binocular vision disorder in subjects with mTBI**

| Binocular vision disorder | Distribution (%) |
|---|---|
| CI | 25 |
| AI | 10.71 |
| AI+CI | 17.85 |
| AIF | 14.28 |
| AI+AIF | 10.71 |

Convergence insufficiency: CI, Accommodative insufficiency: AI, Accommodative insufficiency + convergence insufficiency: AI+CI, Accommodative infacility: AIF, Accommodative insufficiency + accommodative infacility: AI+AIF

We found statistical significant difference for NPC break and recovery ($p<0.001$). Significant reduction in NRA ($p<0.001$) and PRA ($p<0.001$) was found in subjects with mTBI as compared to normals. Amplitude of accommodation in mTBI patients were also significantly affected in both right ($p=0.009$) and left eye ($p=0.009$). Monocular as well as binocular accommodative facilities were significantly affected mTBI patients suggesting inability to switch their focus from different distances. NFV, PFV were also significantly affected in mTBI group as compared to non TBI ($p<0.001$). Reading speed was significantly lower in mTBI groups as compared to non TBI group ($p=0.001$) (Figure 1). Mean ± SD of binocular visual skills among mTBI and non-TBI has been reported in Table 5.

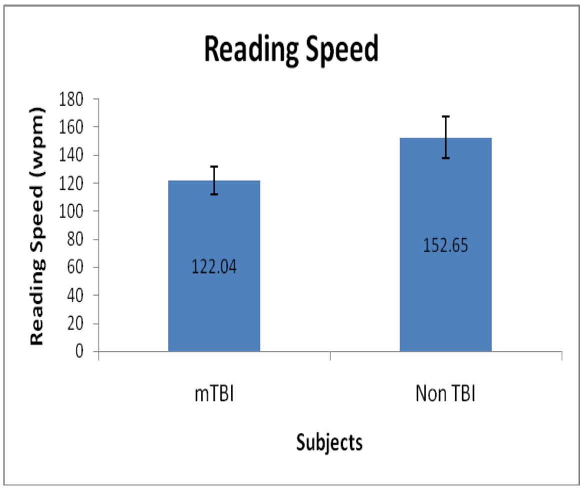


**Figure 1: Mean reading speed in mTBI and non-TBI group. Error Bars represents 2 standard errors.**

**Table 5 shows the Mean± SD of binocular visual skills among mTBI and non-TBI.**

| Tests | mTBI (mean±SD) | Non TBI (mean±SD) | P value |
|---|---|---|---|
| Visual acuity (LogMAR) | 0.11±0.02 | 0.00±0.01 | 0.006 |
| Near point of convergence break (cm) | 8.43±3.99 | 5.11±0.92 | 0.000* |
| Near point of convergence recovery (cm) | 9.74±4.27 | 6.11±092 | 0.000* |
| Negative relative accommodation (D) | 2.12±0.44 | 2.59±0.35 | 0.000* |
| Positive relative accommodation (D) | -2.87±0.82 | -4.48±0.78 | 0.000* |
| Amplitude of accommodation OD (D) | 7.80±1.94 | 9.07±1.55 | 0.009* |
| Amplitude of accommodation OS (D) | 7.69±1.98 | 9.04±1.58 | 0.007* |
| Facility OD (cpm) | 4.61±3.14 | 8.55±1.30 | 0.000* |
| Facility OS (cpm) | 4.53±3.25 | 8.57±1.23 | 0.000* |
| Binocular facility (cpm) | 3.25±2.88 | 7.79±1.39 | 0.000* |
| Negative fusional vergence break (D) | 18.71±2.17 | 22.21±3.48 | 0.000* |
| Negative fusional vergence recovery (D) | 16.35±1.64 | 19.28±3.02 | 0.000* |
| Positive fusional vergence break (D) | 16.89±4.75 | 23.46±3.63 | 0.000* |
| Positive fusional vergence recovery (D) | 14.42±4.33 | 19.89±3.12 | 0.000* |
| Reading speed (wpm) | 122.04±24.17 | 152.65±36.14 | 0.001* |
| Note: OD = Right eye (Latin oculus dexter), OS = Left eye (Latin oculus sinister)<br>* indicates statistical significance at 0.05 level | | | |

**Table 6 Mean± SD of binocular vision skills in subjects with mTBI due to fall and accident**

| Tests | Fall (Mean±SD) | Road accident (Mean±SD) | P value |
|---|---|---|---|
| Near point of convergence break (cm) | 8.78±4.21 | 7.07±3.52 | 0.290 |
| Near point of convergence recovery (cm) | 10.21±4.38 | 8.34±3.92 | 0.280 |
| Negative relative accommodation (D) | 2.25±0.54 | 2.36±0.55 | 0.612 |
| Positive relative accommodation (D) | -3.14±0.63 | -3.50±0.55 | 0.152 |
| Amplitude of accommodation OD (D) | 8.46±2.21 | 7.45±1.29 | 0.193 |
| Amplitude of accommodation OS (D) | 8.39±2.21 | 7.27±1.34 | 0.154 |
| Facility OD (cpm) | 5.75±3.32 | 3.31±2.43 | 0.054 |
| Facility OS (cpm) | 5.71±3.41 | 3.18±2.75 | 0.05 |
| Binocular facility (cpm) | 4.07±3.24 | 2.55±2.69 | 0.222 |
| Positive fusional vergence break (D) | 17.71±4.94 | 17.36±4.20 | 0.853 |
| Positive fusional vergence recovery (D) | 15.14±4.34 | 15.09±3.72 | 0.975 |
| Negative fusional vergence break (D) | 17.07±3.29 | 19.18±2.14 | 0.079 |
| Negative fusional vergence recovery (D) | 14.85±2.79 | 16.90±1.37 | 0.036* |
| Reading speed (wpm) | 118.23±25.77 | 128.75±24.87 | 0.369 |
| Note: Legends are same as described in Table 5. | | | |

Among mTBI patients, fall and road accidents were common etiologies and therefore we compared binocular visual skills between mTBI subjects due to fall versus accidents. Independent t test showed non-significant difference in all binocular visual skills (p>0.05) except better NFV recovery in mTBI subjects with fall versus accident (p<0.03). Table 6 describes the Mean± SD binocular visual skills in subjects with m TBI due to fall and accident.

## DISCUSSIONS

In the present study, we studied the binocular vision function in mTBI subjects. We noted significant reduction in binocular vision functions in mTBI subjects as compared to age matched normal. Here, we discuss our findings in detail.

In the present study headache after near work, blur near vision, eyestrain after near work were commonly reported symptoms. The previous study done on acquired brain injury subjects also reported eyestrain as common symptom. [15] In our study the reported symptoms were common in patients who had mTBI even ≥1 year. A study done on patients with motor vehicle collisions also found that patients continue to report symptoms even after completion of 1 year. [21]

The results of the present study revealed statistically significant difference for NPC break and recovery, NRA, PRA, amplitude of accommodation, accommodative facility, NFV break and recovery, PFV break and recovery between the mTBI group and the control group. The tests of accommodation and vergences were showed statistically significant reduction in different etiologies of injury such as blast and combat. [18,22,23] In the current study there was statistically significant difference for reading speed in TBI and non TBI group, which implies that reading speed is affected in TBI, similar results were found in objective reading speed measurement done by Ciuffreda et al. [9] In the present study convergence and accommodative disorders were common in subjects with mTBI which is in agreement with a previous study of Gallaway et al. [24]

Due to unavailability of appropriate instruments, other skills such as vergence facility, and eye movements were not measured. Previously it has been reported that eye movements are affected in TBI patients. [9,25] Therefore measuring eye movements in these patients could be helpful for appropriate diagnosis and further management. For example, vision therapy can be given to TBI patients to improve various binocular dysfunctions and eye movements. Further, effect of vision therapy on quality of life in mTBI patients can be evaluated in future study.

## CONCLUSION

Binocular visual skills are impaired in subjects with mTBI which could affect activities of daily living and therefore our study suggests the need for the comprehensive binocular vision skills assessment among mTBI patients.

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