Article • Effect of Yoga Ocular Exercises on Binocular Vision Functions

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ABSTRACT

Background: Globally, non-strabismic binocular vision anomalies (NSBVAs) are some of the most commonly reported conditions with asthenopic symptoms in the non-presbyopic population. It is necessary to get relief from the eye fatigue for better near and intermediate tasks. The aim of this study was to analyze the effect of yoga ocular exercises on binocular vision functions.

Methods: Thirty-two undergraduate optometry students were included after a baseline comprehensive eye examination that determined whether the subject was symptomatic or asymptomatic. Participants were assigned to a control group or an exercise group in such a way that there was no significant difference in the baseline frequencies of NSBVAs between both groups. A complete binocular vision assessment was done in both groups. The exercise group performed yoga ocular exercises for up to 6 weeks, after which binocular vision function and subjective response for asthenopic symptoms were reassessed.

Results: In the exercise group, there was a statistically significant improvement in the distance and near exophoria ($p=0.011$, $p=0.001$ respectively), binocular accommodative facility ($p=0.000$), subjective and objective near point of convergence ($p<0.05$), vergence facility ($p=0.001$), and distance and near negative and positive fusional vergence ($p<0.05$). When considering the type of horizontal phoria, a significant change in the distance ($p=0.030$) and near phoria ($p=0.005$) was noted in the exercise group after 6 weeks, while there were non-significant results in the control group.

Conclusions: Yoga ocular exercises improve vergence-related binocular vision function and reduce NSBVAs by increasing the efficiency of extraocular muscles. Hence, it could be considered as a therapeutic and non-pharmacological intervention for improving vergence-related binocular vision function.

Keywords: asthenopia, binocular vision function, eye fatigue, non-strabismic binocular vision anomalies, yoga ocular exercises

Introduction

Yoga is a branch of an ancient Indian science that involves the practice of various specific body postures, body cleansing, and meditation, improving balance, concentration, and alertness of mind and soul.[1] It is a traditional Indian system of practicing exercises with the purpose of prevention and treatment of disease and rehabilitation.[2] Yoga balances and harmonizes the body, mind, and emotions through the regular practice of asanas, pranayama, mudra, bandha, shatkarma, and meditation.[3,4] A recent survey done by a social development foundation, The Associated Chambers of Commerce and Industry of India (ASSOCHAM), suggests that there has been a spurt in the number of people that have taken up yoga by up to 30%

in the past year in India.[5] In addition, as of 2015, the number of people practicing yoga in the U.S. alone stood at around 36.7 million and is projected to reach over 55 million by 2020.[6] Therefore, the practice of yoga is subsequently growing to become widely popular in Western societies as well.

In today's dynamic world, the need for near and intermediate visual tasks has been dramatically increased, requiring prolonged near work, including computer use and reading books. Comfortable working at near and intermediate tasks depends upon the efficiency and coordination of the accommodation and vergence systems.[7] These tasks demand excessive work of the extraocular muscles (vergence) and ciliary muscles (accommodation), which may lead to eye fatigue. In turn, this may lead to non-strabismic binocular vision anomalies (NSBVAs).[8,9] Globally, they are the most commonly reported conditions in a non-presbyopic population with asthenopic symptoms.[8-11] Most people working for prolonged periods on a computer complain of ocular visual discomforts.[12-15] Proper diagnosis and treatment, including vision therapy and near-point stress lenses, should be considered in order to improve the quality of life of these patients.[7,8]

Kumar et al.[1] discussed that yoga eye exercises are believed to improve ocular motility and help to reduce eye fatigue by improving the binocular vision functions associated with accommodation and vergence. Various yogic websites, online yoga videos, and many yoga practitioners suggest simplified practices of yoga exercises and their benefits for the eyes. There are claims of improvement of the visual system, coordination of the two eyes, and refractive error.[16-18] The availability of studies on this topic is lacking. This study was designed to evaluate whether yoga ocular exercises could be an important tool to improve binocular vision function.

Table 1. Binocular Vision Tests Used Pre- and Post-Yoga Ocular Exercises

Evaluation	Tests
Sensory	Stereopsis (Titmus Fly test)
	Worth Four-Dot test (WFDT)
Motor	Extraocular motility (EOM)
	Cover-Uncover test
	Modified Thorington test (Horizontal and Vertical)
	Prism bar cover test (PBCT)
Accommodation	Near point of accommodation (NPA; push-up method)
	Amplitude of accommodation (AA)
	Hofstetter's minimum AA
	Monocular estimation method (MEM) retinoscopy
	Relative accommodation a. Negative relative accommodation (NRA) b. Positive relative accommodation (PRA)
	Accommodative facility (± 2.00 DS flippers)
Vergence	AC/A ratio (gradient method with -1.00 DS)
	Near point of convergence (NPC; push-up method)
	Fusional vergence amplitudes (step vergence) a. Negative fusional vergence (NFV) b. Positive fusional vergence (PFV)
	Vergence facility (12^{Δ} BO/3^{Δ} BI flippers)

Subjects and Methodology

This prospective study was done at the Sankara College of Optometry (SCO), Bengaluru, India from January 2017 to August 2017. Optometry students at the college were enrolled in the study. After obtaining permission from the college and hospital authorities in accordance with the tenets of the Declaration of Helsinki, an informed consent was obtained from each subject after explanation of the nature and possible consequences of the study. All of the subjects underwent a comprehensive eye examination, and those who met the inclusion criteria were considered in the study. Subjects with best-corrected visual acuity better than or equal to 20/20 (6/6) and eye fatigue were included in the study. Subjects with systemic or ocular pathology, ocular surgery, high ametropia (≥ ±6.00 D), any strabismic anomaly, or who were undergoing any kind of vision therapy were excluded from the study.[19,20] After a complete orthoptics evaluation (Table 1), the subjects were divided equally into two groups, an exercise group and a control group, with 16 subjects in each. The groups were divided in such a way that there was no significant difference in the baseline frequencies of NSBVAs between both groups. The examiner was blinded regarding the recruitment of the subjects into the two groups.

A trained yoga instructor guided the subjects in the exercise group. Each session of yoga ocular exercises involved the following 10 steps in a sequence: palming, blinking, sideways viewing, front and sideways viewing, diagonal viewing, rotational viewing, preliminary nose-tip gazing, near and distant viewing, concentrated gazing, and acupressure point on the palm.[3,4,21] The subjects in the exercise group practiced these exercises for 30 minutes an average of 5 days/week. None of the subjects in the control group were provided any kind of therapy. After 6 weeks, a complete orthoptics re-evaluation was performed to evaluate the changes in binocular vision function along with the subjective response regarding asthenopic symptoms. The recordings noted during the orthoptics evaluation of each subject pre- and post-yoga exercises were based on the subjective response. For the clinical assessment of binocular vision function, published and accepted norms were followed. The orthoptics data were compared to the normative data for the particular group given, and the diagnosis was made based on the criteria given by the same.[9] Data input and statistical analysis were done using the International Business Machine Statistical Package for the Social Sciences (IBM SPSS Statistics) v 23.0 for Microsoft Windows.

Results

The mean age of the control group and the exercise group were 20.94 ± 1.72 (18-24 years) and 21.13 ± 1.70 (19-24 years), respectively, with 7 males and 9 females in each.

I. Sensory functions: There was no change in the sensory functions as determined by sensory tests such as steropsis (Titmus fly test) and Worth Four-Dot test (WFDT) between the baseline and post-exercise measurements in either group.

II. Motor functions: Extraocular motility functions did not show any changes in the baseline and post-exercise measurements in either group.

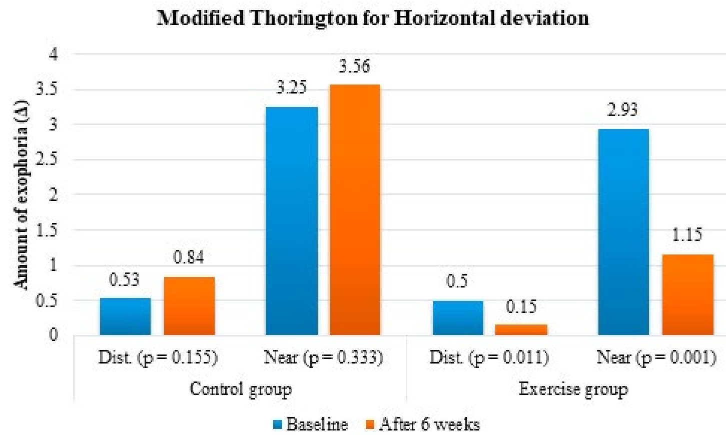

Figure 1. *Mean amount of horizontal exophoria for distance and near (modified Thorington) pre- and post-yoga for the two groups*

The exercise group showed a significant decrease in the mean amount of horizontal exophoria for distance, from 0.50 ± 0.70$^{\Delta}$ to 0.15 ± 0.39$^{\Delta}$ (p=0.011), and for near, from 2.93 ± 3.19$^{\Delta}$ to 1.15 ± 1.98$^{\Delta}$ (p=0.001) after 6 weeks. In the control group, the mean amount of horizontal exophoria for distance and near increased from 0.53 ± 0.80$^{\Delta}$ to 0.84 ± 0.88$^{\Delta}$ (p=0.155) and from 3.25 ± 2.64$^{\Delta}$ to 3.56 ± 2.09$^{\Delta}$ (p=0.333), respectively after 6 weeks; these findings were statistically insignificant (Figure 1).

The type of horizontal phoria at distance showed a statistically significant change between the two groups after 6 weeks (p=0.030), whereas it was statistically insignificant during baseline measurement (p=0.696, Figure 2). Similarly, the type of horizontal phoria at near showed a statistically significant change between the two groups after 6 weeks (p=0.005), whereas it was statistically insignificant during baseline measurement (p=0.686, Figure 3). In the exercise group, there was a borderline

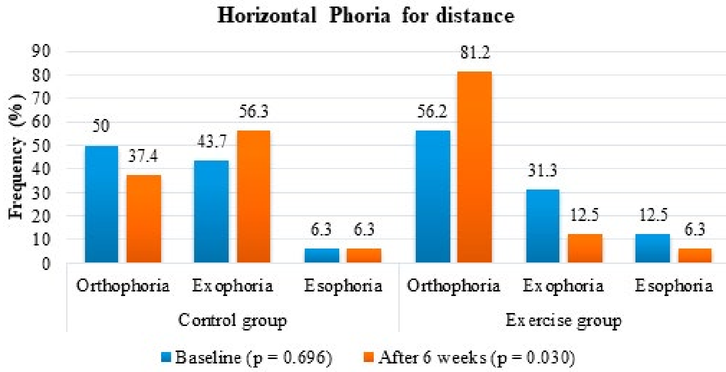

Figure 2. *Frequency of the type of distance horizontal phoria pre- and post-yoga between the two groups*

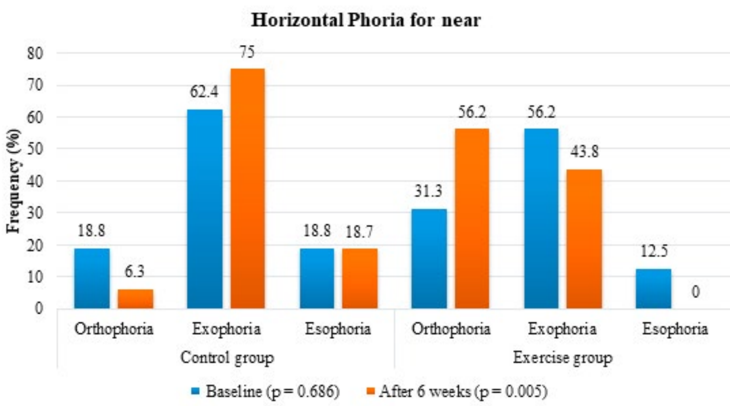

Figure 3. *Frequency of the type of near horizontal phoria pre- and post-yoga between the two groups*

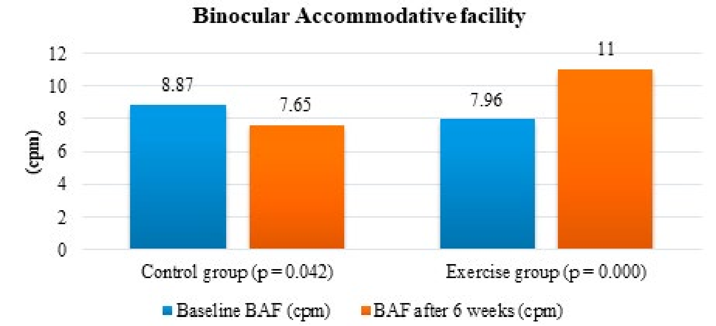

Figure 4. *Mean binocular accommodative facility pre- and post-yoga between the two groups*

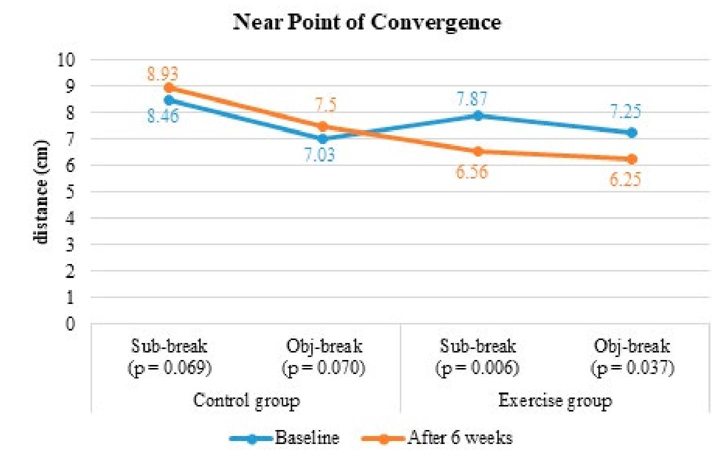

Figure 5. *Mean NPC pre- and post-yoga between the two groups*

significant improvement in the mean prism bar cover test (PBCT) for near, from 1.68 ± 3.11$^{\Delta}$ to 0.62 ± 1.78$^{\Delta}$ after 6 weeks (p=0.050). There was no change in amount and type of vertical phoria for either group.

III. Accommodative functions: The exercise group showed a highly significant improvement in the mean binocular accommodative facility, from 7.96 ± 4.61 cpm to 11.00 ± 4.56 cpm (p=0.000), whereas the control group showed a statistically significant decrease in the mean binocular accommodative facility, from 8.87 ± 3.83 cpm to 7.65 ± 2.65 cpm (p=0.042) after 6 weeks (Figure 4). There was an insignificant change in the amplitude of accommodation (AA), monocular estimation method (MEM) retinoscopy, negative and positive relative accommodation (NRA/PRA), and monocular accommodative facility in both groups (p>0.05).

IV. Vergence functions: In the exercise group, the mean break and recovery values for subjective NPC showed statistically significant improvement, from 7.87 ± 2.24 cm to 6.56 ± 1.03 cm (p=0.006) and from 9.81 ± 3.10 cm to 7.90 ± 1.52 cm (p=0.004), respectively. Similarly, the mean break and recovery values for objective NPC showed statistically significant improvement, from 7.25 ± 2.01 cm to 6.25 ± 0.57 cm (p=0.037) and from 9.06 ± 3.06 cm to 7.31 ± 0.79 cm (p=0.020), respectively (Figure 5). There was insignificant change in both subjective and objective NPC (p=0.069 and 0.070, respectively) in the control group after 6 weeks.

In the exercise group, the baseline mean vergence facility increased from 7.93 ± 5.62 cpm to 14.40 ± 3.77 cpm after 6 weeks, which was statistically significant (p=0.001), whereas in the control group, the baseline mean vergence facility changed from 7.60 ± 4.64 cpm to 8.16 ± 3.42 cpm after 6 weeks, which was statistically insignificant (p=0.16, Figure 6).

In the exercise group, the mean negative fusional vergence (NFV) for distance and near

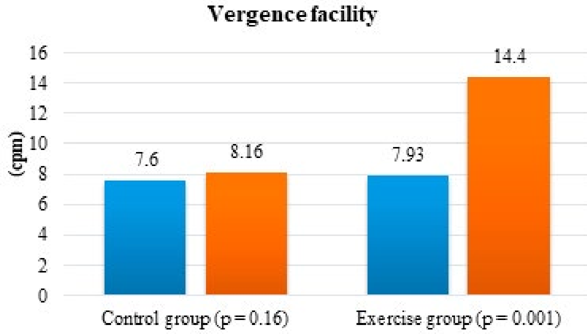

Figure 6. *Mean vergence facility pre- and post-yoga between the two groups*

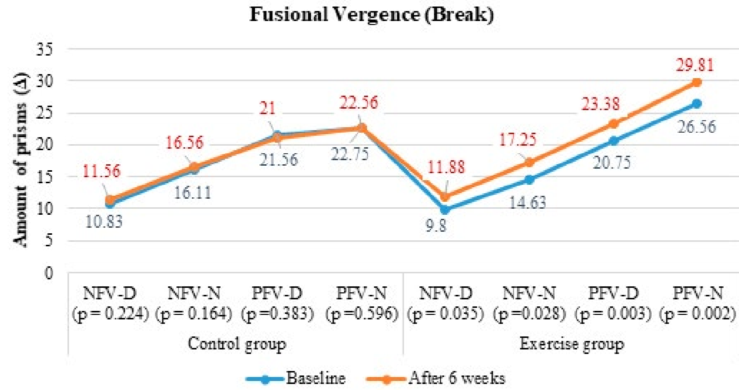

Figure 7. *Mean fusional vergence (break value) for distance and near pre- and post-yoga between the two groups*

showed statistically significant increases, from 9.80 ± 3.22$^{\Delta}$ to 11.88 ± 4.09$^{\Delta}$ (p=0.035) and from 14.63 ± 5.34$^{\Delta}$ to 17.25 ± 5.87$^{\Delta}$ (p=0.028), respectively. The mean positive fusional vergence (PFV) for distance and near also showed statistically significant increases, from 20.75 ± 7.02$^{\Delta}$ to 23.38 ± 8.39$^{\Delta}$ (p=0.003) and from 26.56 ± 8.11$^{\Delta}$ to 29.81 ± 11.96$^{\Delta}$, respectively (p=0.002, Figure 7). In the control group, both NFV and PFV showed insignificant change (p>0.05).

In addition in the exercise group, there was a borderline significant improvement in the mean gradient accommodative convergence/ accommodation (AC/A) ratio, from 1.62 ± 0.86 to 2.12 ± 0.71 after 6 weeks (p=0.050).

V. Diagnosis of NSBVAs: The frequency of the subjects in the control group with normal binocular vision with asthenopia was reduced at the completion of the study. The percentages given in Table 2 represent the number of subjects (frequencies in percentage). At the end of the study, 6.3% of subjects in the control group remained normal binocularly, which is down from 31.1%. This decrease indicates that the previously normal subject with symptoms developed an NSBVA. The frequency of the normal BV subjects in the exercise group improved from 18.1% to 62.2% in contrast. There was a statistically significant difference in the frequency of NSBVAs between the two groups after 6 weeks (p=0.005), while they were statistically insignificant during the baseline evaluation (p=0.341, Table 2).

Table 2: Comparison of frequencies (%) of NSBVAs between two groups

NSBVAs	Baseline (p = 0.341)		After 6 weeks (p = 0.005)	
	Exercise group	Control group	Exercise group	Control group
Normal	18.1%	31.1%	62.2%	6.3%
Accommodative Insufficiency	12.6%	0%	12.6%	0%
Accommodative Excess	12.6%	0%	12.6%	0%
Accommodative Infacility	12.6%	6.3%	6.3%	6.3%
Basic Exophoria	0%	6.3%	0%	12.6%
Basic Esophoria	0%	6.3%	0%	6.3%
Convergence Insufficiency	12.6%	31.1%	6.3%	37%
Convergence Excess	6.3%	6.3%	0%	12.6%
Divergence Insufficiency	0%	0%	0%	0%
Divergence Excess	12.6%	0%	0%	6.3%
Fusional Vergence Dysfunction	0%	0%	0%	0%
Convergence Insufficiency + Accommodative Excess	12.6%	12.6%	0%	12.6%

Discussion

The results from the current study indicate that there was a significant improvement in binocular vision function, especially vergence-related function, after 6 weeks. Kumar et al.[1] also showed that NPC improved and fusional range increased, which can aid in sustained near effort. Yogic eye exercises also caused a significant reduction in eye fatigue in undergraduate nursing students.[19] The proposed explanation of the action of yoga ocular exercises on eyes has been described as follows:[3,4,21]

- Palming relaxes and revitalizes the extraocular muscles and stimulates the circulation of the aqueous humor.
- Blinking exercises embolden the blinking reflex to become spontaneous, inducing relaxation of the extraocular muscles.
- Sideways viewing relaxes the tension of the extraocular muscles strained by constant near work, preventing and correcting squint (mostly phoria).
- Front and sideways viewing encourages the coordination of medial and lateral recti.
- Diagonal viewing balances the superior and inferior recti and superior and inferior obliques.
- Rotational viewing restores the balance in the extraocular muscles around the eyeball and improves the coordinated activity of the eyeball and its muscles.
- Preliminary nose-tip gazing encourages the accommodating and focusing power of the ciliary muscles.
- The benefits of near and distant viewing are similar to that of preliminary nose-tip gazing, but the range of movement is increased.
- Intense concentrated gazing balances the nervous system, relieving nervous tension, anxiety, depression, and insomnia, thus improving memory and helping to develop good concentration.
- Acupressure point stimulation in the palm gives relief to eye fatigue and helps in sound eye health.

Binocular accommodative facility is an indirect measure of vergence because it assesses the interactions between accommodation and vergence.[9] A problem in either system could result in poor binocular performance. Since the yoga ocular exercises involved in our study had an improved effect on vergence by involving more action of

Video *on Yoga ocular exercises.*

extraocular muscles and thereby increasing their efficiency, this could be the reason for the improvement of the binocular accommodative facility. On the other hand, not much stimulation of ciliary body muscles was done in the yoga ocular exercises used, which could be the reason for no improvement in monocular accommodative facility, as well as other accommodative functions.

While performing NRA at 40 cm, the patient accommodates approximately 2.50 D to see the target clearly. An NRA finding greater than +2.50 D suggests that the patient was overminused during the subjective refraction or potentially has a binocular vision issue. However, there is no consistent endpoint for PRA, which varies depending on the patient's amplitude of accommodation, AC/A ratio, and NFV. Because the primary objective of NRA and PRA is to determine whether the range is balanced, it makes sense to stop the PRA after reaching a value of –2.50 D.[9] Further studies are required to estimate the effect of yoga ocular exercises on NRA/PRA.

This study showed the significant improvement of NSBVAs in the exercise group but the significant deterioration of NSBVAs in the control group. The probable reason is that studying continued during the time this study took place, which included excessive near work. The exercise group continued their yoga therapy, which helped the subjects to maintain and improve their BV parameters within the normal range in spite of the sustained near work. The control group was restricted from any kind of therapy, which might be the reason for the worsening of the BV parameters in the control group.

The subjects in the exercise group were asked to attend the yoga ocular exercise sessions 6 days per week. Their attendance and regularity were strictly monitored. All subjects did exercises for 4-5 days per week except two subjects, who did yoga for 6 days per week. Those two subjects majorly contributed to the highly significant differences in the vergence facility and binocular accommodative facility between the groups. It is also believed that the activities during yoga ocular exercises invigorate the extraocular muscles to work more efficiently, embolden the blink reflex, and stimulate the aqueous humor circulation, which helps to reduce eye fatigue.

The mechanism of an efficient working of the extraocular muscles and stimulation of aqueous humor flow due to these exercises can be complex. There is constant movement of eyes during the day and reduced movement at night. While practicing the yoga ocular exercises, the bulbomotor muscles/extraocular muscles are maximally and continuously stretched in all directions, which dramatically increases the metabolic demand (oxygen consumption) of the muscular tissues.[22,23]

Yoga ocular exercises can be referred to as isotonic/dynamic exercises of extraocular muscles (skeletal muscles), where both the concentric contraction (shortening) and eccentric contraction (elongation) of extraocular muscles occurs.[19,24] Regular exercise of skeletal muscles causes an increase in the amount of energy stores, such as fat and glycogen, that are held in the muscle and an increase in proteins that are required to use these energy stores efficiently (e.g., the glycolytic and Kreb's cycle enzymes). It is most notably seen that there is an increase in the muscle content of mitochondria, where oxidation of lipids and carbohydrates primarily occurs in muscle. This process changes the energy taken in into a form of fuel that the cells can use. The net effect of these changes is that the muscle is trained to be able to undertake the exercise more efficiently. Surprisingly, it has recently been shown that much milder repeated eccentric contractions where the elongation of the muscle is slow can be an efficient way of increasing muscle strength.[25,26] Hence, it is believed that the extraocular muscles get stronger, which in turn invigorates the muscles to work more efficiently. On the other hand, the concentric and eccentric contraction of extraocular muscles leads to an increase in the intraorbital blood circulation, which acts as a pump for a more efficient intraorbital venous outflow.[27,28] Also, palming may have a vasodilatory effect on episcleral veins and thus trigger the circulation and outflow of aqueous humor, which helps in the proper nourishment of the ocular structures in the anterior segment.[22] The levator palpebral superioris and orbicularis oculi are responsible for the blinking mechanism. Motor control of the levator muscle is through the oculomotor nerve, which is identical to the innervation of the extraocular muscles (except superior oblique and lateral rectus).[29] Like extraocular muscles, both levator and orbicularis are striated muscles[30] and work in conjunction with the extraocular muscles during the yoga practice. Hence, the blinking exercise (rapid and voluntary)[3] increases the working efficiency of the levator and orbicularis, stimulating the blinking mechanism and thus causing the blink reflex to become more spontaneous.

One limitation of the study was not being able to assess whether the improvements in the BV parameters with yoga ocular exercises were sustained over a period of time due to the limited time period for the study to be carried out and completed. Also, the sample size for subjects with esophoria was insufficient and inappropriate for analysis purpose. Further studies are required to estimate these effects.

To the best of our knowledge, this is the first report concerning the effect of yoga ocular exercises on binocular vision functions. Further studies are required evaluating the effects of yoga ocular exercise involving larger population of different age groups. Also, clinical trials on patients with binocular vision anomalies are necessary to establish the potential benefits of yoga ocular exercise for the prevention and treatment of NSBVAs. These further studies are indispensable to evaluate the sustaining effect of yoga ocular exercises on obtained improvements in BV parameters.

Conclusion

Yoga ocular exercises improve vergence-related binocular vision functions by increasing the efficiency of ocular motility muscles. They also decrease the prevalence and incidence of NSBVAs, minimizing asthenopic symptoms. Therefore, these findings confirm that yoga ocular exercises can be considered as a non-pharmacological and therapeutic intervention for improving vergence-related binocular vision function, as well as relieving symptoms of eye fatigue.

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