

Review Article

New Progress in the Study of Convergence Insufficiency

Yanyun Xia¹, Shuxi He²

¹Department of Medical College, Hunan Provincial People's Hospital, The First Affiliated Hospital of Hunan Normal University, Changsha, China

²Hunan Provincial People's Hospital, the First Affiliated Hospital of Hunan Normal University, Changsha, China

Email address:

shuxi9918@163.com (Shuxi He)

To cite this article:

Yanyun Xia, Shuxi He. New Progress in the Study of Convergence Insufficiency. *International Journal of Ophthalmology & Visual Science*. Vol. 6, No. 1, 2021, pp. 41-45. doi: 10.11648/j.ijovs.20210601.16

Received: February 2, 2021; **Accepted:** February 20, 2021; **Published:** March 3, 2021

Abstract: Convergency insufficiency is typical symptoms such as blurring of distant vision, reexamination of near vision, jumping words and walking while reading, visual fatigue and so on after reading or working closely for a period of time. According to the corresponding symptoms and signs, visual function tests were carried out, such as far and near eye position, accommodative response (BCC), positive relative accommodation (PRA), negative relative accommodation (NRA), near point of convergence (NPC), accommodation amplitude (AMP), etc.. The detected visual function data were evaluated according to the normal value of Morgan and Sherad criteria. In daily life, people not only require clear vision, but also pay great attention to the comfort of using eyes, and the convergency insufficiency has become one of the important factors hindering the clarity, persistence and comfort of vision. Making binocular vision system to produce the cognition of regulation, convergence and eye movement through various methods such as optics, psychology and physics, vision therapy improves the application ability of eye vision system, and finally cures visual function problems such as visual fatigue, adjustment and convergence abnormality. We review the incidence, pathogenesis, new progress in the treatment of convergence insufficiency, the mechanism of visual formation and the basic principles of visual training.

Keywords: Convergency Insufficiency, The Pathogenesis of Convergency Insufficiency, Vision Therapy

1. Introduction

Convergency insufficiency is typical symptoms such as blurring of distant vision, reexamination of near vision, jumping words and walking while reading, visual fatigue and so on after reading or working closely for a period of time [1-2]. According to the corresponding symptoms and signs, visual function tests were carried out, such as far and near eye position, accommodative response (BCC), positive relative accommodation (PRA), negative relative accommodation (NRA), near point of convergence (NPC), accommodation amplitude (AMP), etc. The detected visual function data were evaluated according to the normal value of Morgan and Sherad criteria, so as to diagnose the convergency insufficiency [3]. The pathogenesis of convergency insufficiency may be related to extraocular muscles and regulation, and the main treatment is visual training. Today, the 21st century is the era of information technology, the use

of various electronic products has had varying degrees of impact on visual function, the most important performance is the decline of functional vision. Among the most common clinical causes of functional vision loss, about 60% of patients are caused by convergency insufficiency [4]. Some literatures have shown that among the methods to deal with convergency insufficiency, visual training is the first choice. Visual training can not only improve the aggregation and dispersion function of patients with convergency insufficiency, but also has a high success rate in relieving the symptoms of patients with convergency insufficiency [5].

Visual training is also called visual therapy. according to the abnormal visual function of patients, a series of theories and methods such as neurobiology, psychophysics and computer vision are applied to train from the aspects of vision, accommodation, collection and eye movement. for different people, improve vision, visual function, visual skills, so as to correct the corresponding symptoms and signs of abnormal

visual function [6].

1 Incidence of convergency insufficiency

In daily life, people not only require clear vision, but also pay great attention to the comfort of using eyes, and the convergency insufficiency has become one of the important factors hindering the clarity, persistence and comfort of vision [7-8]. Convergency insufficiency is more common, Scheiman et al [9] found that 5.3% of the patients in their study had the problem of insufficient collection. Foreign studies have also shown that it is estimated that children and young people have morbidity rates ranging from 3.6% to 17.6%, and have shown that the incidence increases significantly with age [10-13]. Some domestic studies had shown that the incidence of convergency insufficiency in people with myopia was significantly higher, in which the incidence of convergency insufficiency in high myopia is higher than that in low and moderate myopia, and convergency insufficiency might lead to visual fatigue and decreased functional vision [14]. Chen Xiaolin [15] also had pointed out in his master's thesis that the incidence of abnormal convergency is relatively high in myopic people, mainly due to convergency insufficiency. Among the 81 patients studied, the incidence of abnormal convergency reached 35.80%, of which convergency insufficiency accounted for the main proportion. Liu Ruilin [16] had conducted a study on 81 adult myopic patients who came to his hospital and found that 41 of them had abnormal visual function, accounting for 50.62%, and the incidence of abnormal collective function reached 34.56%. The main reason was that insufficient collection being the most common. Among children, the problem of convergency insufficiency will seriously affect their learning, mainly for lack of concentration, and at the same time interfere with the daily life of adults.

2. The Pathogenesis of Convergency Insufficiency

The convergency process is quite complex, but in many studies, the subordinate set of neural pathways is not fully understood. There may be the following points in the pathogenesis of convergency insufficiency:

First, because the smooth muscle responds to the stimulation changes caused by the increase or decrease of sarcomere, it may be abnormal or unsupervised collective tension that changes the length of bilateral extraocular muscles, which to a large extent leads to the change of strabismus angle with time [17-18]. The increase in the number of mitochondria in the muscle fibers innervated by the orbital nerve of the rectus oculi muscle makes the chemical transmitters of the neuromuscular junction transfer faster, thus increasing muscle activity [19]. This is also one of the causes of convergency insufficiency and anatomical factors such as too wide pupil spacing can also cause convergency insufficiency.

Second, related to sensory fusion, abnormal inhibition of primary targets may be a kind of sensory adaptation, which

eliminates diplopia and visual confusion by creating functional monocular vision, the loss of retinal parallax cues or the decrease of stereoscopic signals. this may make it more difficult for the eyes to maintain fusion, which can lead to convergency insufficiency and related symptoms [20]. convergency is a kind of visual function formed by late evolution, which is closely related to acquired training and learning. Therefore, delayed development is also one of the common factors.

Third, visual interference is also a common factor causing convergency insufficiency, mainly including the linkage relationship between accommodation and convergency. If the coordination between accommodation and convergency reflection has been fully developed, but the accommodation function does not function normally, then the convergency function is in a state of invalidation, so a typical convergency insufficiency problem will occur when hyperopia or presbyopia begins to correct its ametropia with lenses. It is also possible that convergency insufficiency may be caused by the decrease of the function of artificial accommodation.

Fourth, it is related to Maddox divergence components, such as fusion divergence, tonic divergence, proximal divergence, and regulation of divergence. Under the innervation differences of these components, the ability to meet the needs of near point of convergence is limited.

Fifth, although most of the convergency insufficiency are idiopathic, some of them are associated with eye diseases or neurological abnormalities, that is, secondary to head injury, aging, Parkinson's disease, Lyme disease and diseases related to fatigue, such as anemia and myasthenia gravis [21]. And migraine can lead to ophthalmoplegia and convergency insufficiency [22]. The most common eye movement disorder associated with Graves's disease also leads to convergency insufficiency.

Sixth, the instability of mental state is also an important reason for the convergency insufficiency, usually manifested as excessive sadness and excitement and so on.

Convergency has a strong autonomous movement, but also contains non-autonomous motor components, so it is of great significance in the examination of extraocular muscle function. At the same time, when looking at the near object, a certain amount of accommodation movement produces the corresponding accommodation convergency.

3. New Progress in the Treatment of Convergency Insufficiency

3.1. Formation Mechanism of Visual System

Human visual system is an extremely complex information processing and control system composed of a large number of nerve cells with different shapes and functions through certain connections. About 80% of the information from the outside world is transmitted to the brain through the visual system, in which the neural mechanism of visual formation plays an important role. After the external visual information is projected to the retina and fully processed by the retina, visual

pathways such as optic nerve, optic chiasma, optic tract and geniculate body continue to project to the visual cortex, while visual information is transmitted to the center through the visual pathway. In the center, the information is processed through two mechanisms: step-by-step extraction and parallel processing [23]. Due to the plasticity of the cerebral nervous system, through specific visual perceptual learning and visual stimulation, we can activate signal transduction channels and strengthen the connections of brain neurons, so as to correct and process the signals of the cerebral nervous system, so as to achieve the therapeutic effect [24-29]. Due to the development of neuroscience, the research on the development and regulation of visual nerve function provides an effective means for visual function training. There are many visual training projects, in the treatment of convergence insufficiency, visual training mainly includes synoptophore, BVT stereoscope, scatter ball (Brock line), collection card, lifebuoy, variable vector graph, fixed vector graph, crack ruler and so on. Visual training is a series of training programs based on the principle of visual formation and visual skills [30]. The ultimate goal of visual training is to make patients' vision clearer, lasting and comfortable, so as to obtain a better visual quality experience.

3.2. Progress in the Treatment of Convergence Insufficiency

In this paper, a slow adaptive convergence system is proposed, which eliminates the time-dependent requirement in the fast parallax convergence system. Ciuffreda. [31] In the complete discussion of its accommodation and convergence model, it was pointed out that 7 young adult patients with symptomatic convergence insufficiency and abnormal visual adaptation received 8-week fusion convergence vision therapy (push-ups, physiological diplopia consciousness, relatively positive fusion aggregate parallax stimulation). After treatment, fusion amplitude and fusion adaptation were measured, and these two parameters were found to be significantly improved. At the same time, the lack of vision has also been reduced, and the symptoms have been significantly alleviated. A comprehensive analysis of many studies shows that these findings clearly prove the scientific efficacy of fusion ensemble vision therapy, which is reflected in the objective measurement of fusion sensitivity, formal quantitative and informal symptom surveys, as well as standard clinical optometry and ophthalmological results. These results are consistent with a series of clinical case reports and retrospective and prospective clinical studies in the literature on optometry, ophthalmology and axial correction in the past few decades. these literatures show that fusion collective vision therapy has repairable after a relatively short duration, that is, the normalization of neural plasticity and collective response.

However, among patients with convergence insufficiency, not all patients with convergence dysfunction have symptoms and generally do not need treatment for asymptomatic patients. the treatment of symptomatic patients includes basal prism presbyopic glasses, pencil push-ups, orthopaedics, vision therapy and hospital-based collection / adjustment therapy, in

which pencil push-ups have been used as the main means of optometry and ophthalmology for the treatment of convergence insufficiency. Pencil push-ups prompt the patient to maintain a single vision when the target moves toward the patient's nose, so that an adjustable goal, such as letters or pictures with fine details, can be used to promote adjustment, so as to achieve the purpose of promoting fusion [32]. Other studies have shown that adjustable targets are more often used to promote fusion convergence, and it is important to maintain fusion during practice. Both regulatory targets and continuous fusion will strengthen pencil push-ups and may make it a more effective treatment [33].

In their research, Nabovati P [34] et al found that when using the benchmark prism, the symptoms and signs of convergence insufficiency are passively alleviated not by improving the ability of convergence, but by reducing the degree of the system of convergence. Many patients with convergence insufficiency will also produce secondary excess regulation due to the increase of regulatory response, thus increasing the regulatory convergence, so as to achieve the purpose of replenishing insufficient PFV. The use of benchmark prism was statistically significantly correlated with the increase of negative relative adjustment ability and monocular adjustment ability, and it was also found in the study that the regulatory response of the prism group changed significantly in the positive direction, which may be due to the reduced demand for PFV and the need for less accommodation stimulus and accommodation convergence.

HTS is a computerized visual therapy system used by patients in their own homes to guide patients to use within a distance of 40 centimeters. Patients are guided to perform a series of exercises, including saccade, chase, base-in and base-out stereogram, jump induction and adjustment. The subject using this program must use the fused image to perceive the three-dimensional image. These stereoscopic images are analyzed with red / blue glasses. HTS and prism correction are very effective treatment options for convergence insufficiency, and prism correction can be considered as an effective alternative to HTS [35]. Scheiman [36] reviewed the medical records of 42 patients, and the results showed that home-based computer vision training reduced symptoms and improved patient near point of convergence and fusion.

Studies by Saunte et al [19] have shown that botulinum toxin blocks neuromuscular transmission. When injected with a therapeutic dose, the toxin will cause partial chemical denervation of the muscle, resulting in a local reduction of muscle activity. After a few months of weakening the effect of botulinum toxin on agonists, the strength of antagonistic muscles may be greater. The improvement of convergence insufficiency may also be caused by a decrease in the number of mitochondria in the muscle fibers innervated by the single nerve in the orbital part of the rectus.

In recent years, Mary LouMcGregor [37] pointed out in his research that collective therapy is a scientifically proven visual therapy, which is effective in improving the symptoms and regulation of convergence insufficiency in children, and

researchers in Iran, India, South Korea and Egypt have widely confirmed that collective therapy is currently recognized as a scientifically proven method for the treatment of collective dysfunction [38-40]. Related studies have shown that visual therapy not only changes clinical symptoms, but also uses functional magnetic resonance imaging to show that neurophysiological changes and cortical activity increase after treatment, which may be the basis for the reduction of visual symptoms [40-41]. These experiences provide us with more cure opportunities for the treatment of convergence insufficiency in the future.

4. Summary

After consulting a large number of literatures at home and abroad, it is concluded that the incidence of convergence insufficiency is very high in children and adults, and the symptom of convergence insufficiency brings great trouble to people's comfort of using eyes. Collective therapy in visual training is of theoretical and practical significance for the treatment of convergence insufficiency.

5. Prospect

Because the domestic ophthalmology pays less attention to the accommodation and convergence of visual function, the report of abnormal visual function is rare, so, it is of great significance to examine the visual function of the patients and give them substantive treatment opinions. For the problem of convergence insufficiency, early detection and early treatment is an advantage, especially for children, early visual problems in children are mostly caused by abnormal visual function, which is only a functional condition. If there is no early intervention, it will develop into organic lesions, and the visual function training of convergence insufficiency in the early stage can be well improved, if it develops into convergence insufficiency exotropia, surgical improvement will be carried out, and visual function training will be carried out in the later stage. In order to avoid the trauma caused by this kind of operation, the importance of early visual function examination can be imagined. With the progress of science and technology, it is an inevitable trend for new technologies, new technologies, new equipment and new materials in many other scientific fields to be used in visual training to treat the problem of convergence insufficiency.

References

- [1] Barnhardt Carmen, Cotter Susan A, Mitchell G Lynn et al. Symptoms in children with convergence insufficiency: before and after treatment. [J]. *Optom Vis Sci*, 2012, 89: 1512-20.
- [2] Singman Eric L, Matta Noelle S, Silbert David I, Convergence insufficiency associated with migraine: a case series. [J]. *Am Orthopt J*, 2014, 64: 112-6.
- [3] Wang Guangxi. binocular vision [M]. Beijing: people's Health Publishing House, 2004. 62-76.
- [4] Li Lihua. Causes and treatment of functional vision loss [J]. *Chinese Journal of glasses Science and Technology*, 2017 (23): 97-99.
- [5] Zhou Jun. Differential diagnosis and treatment of three kinds of binocular visual dysfunction [J]. *International Journal of Ophthalmology*, 2018 *Journal of Ophthalmology* 18 (07): 1245-1246.
- [6] Li Guanping. Application of visual function training in the treatment of amblyopia and strabismus [J]. *Chinese Journal of glasses Science and Technology*, 2013 (11): 116-119.
- [7] Ángel García-Muñoz, Stela Carbonell-Bonete, Pilar Cacho-Martínez. Symptomatology associated with accommodative and binocular vision anomalies [J]. *Journal of Optometry*, 2014, 7 (4).
- [8] Vestergaard Anders, Ivarsen Anders, Asp Sven et al. Femtosecond (FS) laser vision correction procedure for moderate to high myopia: a prospective study of ReLEx(®) flex and comparison with a retrospective study of FS-laser in situ keratomileusis. [J]. *Acta Ophthalmol*, 2013, 91: 355-62.
- [9] Scheiman M, Gallaway M, Coulter R, et al. Prevalence of vision and ocular disease conditions in a clinical pediatric population [J]. *Journal of the American Optometric Association*, 1996, 67 (4): 193-202.
- [10] Jang Jung Un, Park Inn-Jee, Prevalence of general binocular dysfunctions among rural schoolchildren in South Korea. [J]. *Taiwan J Ophthalmol*, 2015, 5: 177-181.
- [11] Ghadban Rafif, Martinez Jennifer M, Diehl Nancy N, Mohny Brian G. The incidence and clinical characteristics of adult-onset convergence insufficiency. [J]. *Ophthalmology*, 2015, 122 (5).
- [12] Hoseini-Yazdi Seyed Hosein, Yekta Abbas Ali, Nouri Hosein, Heravian Javad, Ostadimoghaddam Hadi, Khabazkhoob Mehdi. Frequency of convergence and accommodative disorders in a clinical population of Mashhad, Iran. [J]. *Strabismus*, 2015, 23 (1).
- [13] Hussaindeen Jameel Rizwana, Rakshit Archayeeta, Singh Neeraj Kumar, George Ronnie, Swaminathan Meenakshi, Kapur Suman, Scheiman Mitchell, Ramani Krishna Kumar. Prevalence of non-strabismic anomalies of binocular vision in Tamil Nadu: report 2 of BAND study. [J]. *Clinical & experimental optometry*, 2017, 100 (6).
- [14] Yang Yue. The incidence of insufficient aggregation in myopic people [J]. *Chinese Journal of Ophthalmic Science and Technology*, 2018 (05): 125-127.
- [15] Chen Xiaoqin. Clinical analysis of aggregation and regulation function in patients with myopia and study of its changes after SMILE surgery [D]. Tianjin Medical University, 2017.
- [16] Liu Ruilin. Data analysis of collection and regulation function in adult myopic patients [J]. *Chinese Journal of Ophthalmic Science and Technology*, 2018 (21): 121122.
- [17] Guyton David L, The 10th Bielschowsky Lecture. Changes in strabismus over time: the roles of vergence tonus and muscle length adaptation. [J]. *Binocul Vis Strabismus Q*, 2006, 21: 81-92.
- [18] Scott A B, Change of eye muscle sarcomeres according to eye position. [J]. *J Pediatr Ophthalmol Strabismus*, 1994, 31: 85-8.

- [19] Saunte Jon Peiter, Holmes Jonathan M, Sustained improvement of reading symptoms following botulinum toxin A injection for convergence insufficiency. [J]. Strabismus, 2014, 22: 95-9.
- [20] Cooper Jeffrey, Jamal Nadine, Convergence insufficiency-a major review. [J]. Optometry, 2012, 83: 137-58.
- [21] Rucker Janet C, Neuro-ophthalmology of systemic disease. [J]. Semin Neurol, 2009, 29: 111-23.
- [22] Bek Semai, Genc Gencer, Demirkaya Seref et al. Ophthalmoplegic migraine. [J]. Neurologist, 2009, 15: 147-9.
- [23] Zhang Wei. The neural mechanism of visual formation [J]. Ophthalmic Research, 2002 (05): 47247.
- [24] Paffen CLE, Verstraten FAJ, Vidnyanszky Z. Attention-based perceptual learning increases binocular rivalry suppression of irrelevant visual features [J]. Journal of Vision, 2008, 8 (4): 25-25.
- [25] Chen Zidong, Li Jinrong, Liu Jing et al. Monocular perceptual learning of contrast detection facilitates binocular combination in adults with anisometropic amblyopia. [J]. Sci Rep, 2016, 6: 20187.
- [26] Huang J, Zhou Y, Liu C, et al. The neural basis of spatial vision losses in the dysfunctional visual system [J]. Scientific Reports, 2017, 7 (1): 11376.
- [27] Moritz Chet, A giant step for spinal cord injury research. [J]. Nat. Neurosci., 2018, 21: 1647-1648.
- [28] Guo Yan, Wang Ping, XI Zhengyan, Luo Jun, Zhang Jinmei. Effect of binocular vision training on postoperative binocular visual function reconstruction in children with intermittent exotropia [J]. International Journal of Ophthalmology, 2013 13 (07): 1338-1340.
- [29] Li Xiaoxia, Li Baibing, Zhou Chunyuan, Lu Yan. Research progress of visual function remodeling after optic nerve injury [J]. International Journal of Ophthalmology, 2019 Journal of Ophthalmology 19 (09): 1512-1515.
- [30] Zhang Qi, he Lidong, Deng Qian, Ma Yaling. Analysis of the curative effect of comprehensive therapy for children with amblyopia [J]. Journal of Ningxia Medical University, 2011 Journal 33 (11): 1075-1077.
- [31] Ciuffreda Kenneth J, The scientific basis for and efficacy of optometric vision therapy in nonstrabismic accommodative and vergence disorders. [J]. Optometry, 2002, 73: 735-62.
- [32] Lavrich Judith B, Convergence insufficiency and its current treatment. [J]. Curr Opin Ophthalmol, 2010, 21: 356-60.
- [33] Sethi HS, Saxena R, Sharma P, Sinha A. Home exercises for convergence insufficiency in children (editorial). Arch Ophthalmol 2006; 124: 287.
- [34] Nabovati Payam, Kamali Mohammad, Mirzajani Ali et al. The effect of base-in prism on vision-related symptoms and clinical characteristics of young adults with convergence insufficiency; a placebo-controlled randomised clinical trial. [J]. Ophthalmic Physiol Opt, 2020, 40: 8-16.
- [35] Dusek Wolfgang A, Pierscionek Barbara K, McClelland Julie F, An evaluation of clinical treatment of convergence insufficiency for children with reading difficulties. [J]. BMC Ophthalmol, 2011, 11: 21.
- [36] Scheiman Mitchell, Treatment of symptomatic convergence insufficiency in children with a home-based computer orthoptic exercise program. [J]. J AAPOS, 2011, 15: 123-4.
- [37] McGregor Mary Lou, Convergence insufficiency and vision therapy. [J]. Pediatr. Clin. North Am., 2014, 61: 621-30.
- [38] Convergence Insufficiency Treatment Trial Study Group, Randomized clinical trial of treatments for symptomatic convergence insufficiency in children. [J]. Arch. Ophthalmol., 2008, 126: 1336-49. Jang Jung Un, Jang Jung Yun, Tai-Hyung Kim et al. Effectiveness of Vision Therapy in School Children with Symptomatic Convergence Insufficiency. [J]. J Ophthalmic Vis Res, 2017, 12: 187-192.
- [39] Hussaindeen Jameel Rizwana, Shah Prerana, Ramani Krishna Kumar et al. Efficacy of vision therapy in children with learning disability and associated binocular vision anomalies. [J]. J Optom, 2018, 11: 40-48.
- [40] Alvarez Tara L, Jaswal Raj, Gohel Suril, Biswal Bharat B. Functional activity within the frontal eye fields, posterior parietal cortex, and cerebellar vermis significantly correlates to symmetrical vergence peak velocity: an ROI-based, fMRI study of vergence training. [J]. Frontiers in integrative neuroscience, 2014, 8.
- [41] Alvarez T L, Vicci V R, Alkan Y, et al. Vision Therapy in Adults with Convergence Insufficiency: Clinical and Functional Magnetic Resonance Imaging Measures [J]. Optometry and Vision Science. 2010, 87 (12): E985-E1002.