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Young patients with divergence insufficiency related to excessive near work

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ABSTRACT

The purpose of this study is to explore the relationships between excessive near work and divergence insufficiency esotropia in young adults. A prospective study described a series of young patients with divergence insufficiency esotropia related to excessive near work between 2012 and 2017. The medical records of twelve young patients with divergence insufficiency esotropia and a history of excessive near work were reviewed, and the duration of near work, angle of primary position deviations at distance and at near, and angle of primary position deviations after refraining from near work for 3 months were analyzed. All patients with divergence insufficiency esotropia (age range: 21–35 years) showed an initial esodeviation ranging from 18 to 35 prism diopters for distance fixation and ranging from 8 to 20 prism diopters for near. Neurological evaluation in all cases was normal. Myopic refractive errors were detected in twelve patients. Every patient persisted near work for more than 6 h a day over a period of several months (minimum 4 months). Reductions in esodeviation were noted in twelve patients after refraining from near work for more than 3 months. Only one patient was diplopia free in all positions of gaze. The remaining eleven patients were treated successfully, six with prisms and five with surgery. They were all orthophoric and demonstrated restored binocularity at the post-treatment examinations. Our findings suggested that excessive near work might influence the development of divergence insufficiency esotropia in young adults. Refraining from excessive near work could decrease the degree of esodeviation in these patients.

KEYWORDS

Divergence insufficiency; esotropia; excessive near work; diplopia

Introduction

Divergence insufficiency esotropia is characterized as an acquired comitant esotropia with homonymous diplopia at distance fixation and with minimal diplopia at near.[1–4] Horizontal ductions and versions are normal.[4] The pattern of divergence insufficiency esotropia can be seen in a wide range of ages.[1] Divergence insufficiency esotropia is thought to be more often related to a neurological problem when it occurs in children.[5–7] In the last few years, divergence insufficiency esotropia occurring in older adults was thought to be due to mechanical changes in the orbital connective tissues.[8–11] However, many young adult patients presented to the strabismus clinic with divergence insufficiency esotropia in whom there was no associated with any neurologic diseases, which likely has a differing underlying etiology compared with older adults. In 2006, Guyton introduced the idea that increased visual demands at near may activate the near triad, increase convergence tonus, which results in an inability to maintain balance between the converging and diverging forces of the eye, and the subsequent development of increased tonus of the medial rectus muscles, leading to an esodeviation when fixating on distance objects.[12] Recently, a few studies have assumed that dynamic preponderance of the medial rectus muscles after sustained near work might play a pivotal role in the development of esotropia in young adults.[13–15] Near work is becoming more common with the increasing use of computers and smart devices, and is practically unavoidable in young adults.[16] Given that excessive near work can lead to increased tonus of the medial rectus muscles, resulting in the esodeviation when fixating on distance objects, it is crucial to explore the relationships between excessive near work and divergence insufficiency esotropia in young adults. In this study, we aimed to review our experience with

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divergence insufficiency esotropia in young adults associated with excessive near work.

Materials and methods

We prospectively evaluated 12 young adults diagnosed with divergence insufficiency esotropia at a single practice site during a 5-year period (2012–-2017). Inclusion criteria comprised young patients (the age range 21–35 years) diagnosed divergence insufficiency esotropia who had an esodeviation at least 10 prism diopters (PD) larger at distant fixation than at near, and who all spent a long time on performing near work (more than 6 h a day for more than three consecutive months). Near work was defined as the sum of activities with near working distance such as reading books, drawing, painting, playing musical instruments, playing chess and cards, writing, doing homework, watching TV, playing video games and board games, etc.[17] We excluded patients with thyroid eye disease, myasthenia gravis, a history of previous strabismus or other ophthalmological diseases, recent traumatism, and a prior diagnosis of sixth-nerve paralysis or any neurological disease. This study was approved by the Institutional Review Board of Navy General Hospital and conformed to the principles expressed in the Declaration of Helsinki. Written informed consent was obtained from participants before any study procedures were performed.

All participants had undergone complete ophthalmological examinations and careful motility analysis by an ophthalmologist with fellowship training in pediatric ophthalmology and strabismus, neurological examinations conducted by a neurologist to rule out a diagnosis of esotropia related to any neurological problems, including neuroimaging (magnetic resonance imaging [MRI] scans and/or computed tomographic [CT] scans). The participants completed a questionnaire that included information about near work activities. From the questionnaire, the time spent in near work per day and the duration of near work were determined by asking the participants to estimate the amount of hours spent on viewing a computer or a handheld device, reading printed material, drawing, painting or writing, and playing cards or board games. The following information was recorded on each participant: age, presence of diplopia, best corrected visual acuity, manifest refractive error, cycloplegic refractive error, accommodative convergence to accommodation ratio, fusional divergence amplitudes, ocular deviations at distance and near fixation at initial presentation and after near work restriction, near stereoacuity with the Titmus stereotest, the duration of near work and near work time per day, prism therapy and strabismus surgical treatment. The alternate prism cover test was performed to measure the angle of primary position deviation at distance (6 m) and near fixation (33 cm), as well as for all gaze positions with refractive correction. Cycloplegic refraction was performed by a single ophthalmologist after administration of 1% tropicamide eye drops every 5 min for 6 times for each participant and then resting 20 minutes. The accommodative convergence to accommodation (AC/A) ratio was measured to rule out accommodative esotropia with high AC/A ratio, which was calculated using the distance/near disparity method (the normal range of AC/A ratio was 3–5 Δ/D).[18,19] Fusional divergence amplitudes at distance fixation (6 m) and at near (33 cm) were measured to assess whether deficient divergence was presented in patients. To measure divergence amplitudes, a horizontal prism bar (base-in) was placed in front of one eye while the patient fixated on a target. The prism power was increased in a stepwise fashion. Once the patient noted double vision and the eyes were observed to lose fusion, the break point was recorded. The prism power was then reduced. When the patient reported single vision and a fusional vergence movement was observed, the recovery point was recorded.[20] Ocular motility, patterns, and nystagmus were evaluated clinically. Each patient visited us at least three times in follow-up, with a minimum follow-up period of 2 year from the time of initial presentation. SPSS version 20.0 (SPSS Institute Inc., Chicago, IL, USA) was used for statistical analyses. The Wilcoxon signed rank test was used to compare the angle of primary position deviation for near and distance fixation before and after near work restriction. P values $< .05$ were considered statistically significant.

Results

The Clinical characteristics of 12 young patients with divergence insufficiency esotropia at initial presentation are presented in Table 1. The mean age of the 12 patients was 28.17 ± 4.06 years (range 21–35 years). External and anterior segment examinations and fundoscopic examinations were normal in all patients. Neurological examinations including neuroimaging showed no signs of neurologic disease. Ten patients complained of horizontal diplopia which was constant throughout the day, but two patients stated that horizontal diplopia happened intermittently at distance fixation. The onset of esotropia preceded the presentation at our clinic by an average of 4.75 ± 1.48 months (range 3–8 months). In each patient, the angle of esodeviation at distance was larger than that of esodeviation at near and there was no difference in the angle of strabismus with either eye fixating. There were no apparent gaze limitations in either eye of any patient. Our examination showed that abduction and versions were full in all patients, with no evidence of lateral rectus paresis. All patients had cycloplegic spherical equivalent refraction between −3.50 and −1.50 D in the right eyes and between −3.50 and −1.25 D in the left eyes on their first visit to our clinic. In addition, the best corrected visual acuity of the 12 patients with myopia was 20/20 in both eyes. The accommodative convergence to accommodation (AC/A) ratios was performed in all patients at initial presentation, and the results showed low AC/A ratios (2.12 ± 0.23). After refraining from excessive near work, the AC/A ratios were still low (2.79 ± 0.15), and there was no clinically significant change compared to the AC/A ratios at initial presentation. Fusional divergence amplitudes at initial presentation were normal only in two patients, other patients had decreased at distance fixation. The median fusional divergence amplitude with distance fixation was 4.92 ± 2.36 Δ for break and 2.50 ± 1.76 Δ for recovery, and with near fixation it was 12.50 ± 2.93 Δ for break and 9.75 ± 2.65 Δ for recovery. Following extensive medical history taking and examination, 12 young patients all had a history of excessive near work who stated that they usually worked at a close reading distance (<30 cm) for a long time. The average time of near work per day was 6.51 ± 1.19 h. The average duration of near work

Table 1. Clinical characteristics of patients with divergence insufficiency at initial presentation.

Patient	Age/Sex	Uncorrected visual acuity, Rt/Lt (logMAR)	Cycloplegic spherical equivalent refraction, Rt/Lt (D)	Manifest spherical equivalent refraction, Rt/Lt (D)	Distance fusional divergence amplitude (Δ) (Break/recovery)	Near fusional divergence amplitude (Δ) (Break/recovery)	Duration of esotropia (Months)	Esodeviation distance/near	AC/A ratio	Near work time per day (Hours)	Duration of near work (Months)	Stereoacuity (Arc seconds)
1	27/F	0.9/1.0	−3.00/−3.00	−3.00/−3.00	2/0	8/6	5	30/18	2.2	6	5	200
2	32/M	0.7/0.5	−3.50/−3.50	−3.50/−3.50	4/2	10/8	8	35/20	2.0	5	9	No
3	22/M	0.9/0.8	−2.75/−2.75	−3.00/−3.00	5/2	14/10	5	30/15	1.9	8	5	400
4	23/M	1.0/0.9	−3.00/−3.00	−3.00/−3.00	4/2	12/10	7	20/8	2.1	8	4	100
5	29/M	0.8/0.8	−1.75/−1.50	−2.00/−1.50	10/6	16/14	4	25/12	2.17	6	9	200
6	34/M	0.9/0.8	−2.00/−1.75	−2.25/−2.00	6/3	18/13	5	30/15	1.9	5	6	100
7	29/F	0.8/0.5	−1.50/−1.25	−1.50/−1.25	5/2	10/8	3	30/18	2.3	8	6	200
8	33/M	0.8/0.8	−2.00/−2.00	−2.00/−2.25	3/1	13/8	3	25/12	2.27	8	4	400
9	32/M	0.5/0.6	−3.00/−3.00	−3.00/−3.25	2/1	9/6	5	35/20	1.9	5	4	400
10	26/F	0.8/0.8	−2.00/−2.25	−2.25/−2.25	5/3	12/10	4	25/10	1.8	7	6	100
11	29/F	1.0/0.9	−2.00/−2.00	−2.00/−2.25	9/6	12/10	5	18/8	2.27	6	6	40
12	24/M	0.8/0.8	−2.00/−1.25	−1.75/−1.50	4/2	16/14	3	25/15	2.67	6	5	400

prior to the onset of esotropia was 5.75 ± 1.64 months. The esodeviations at initial presentation were a median of 27.5 (interquartile range, 25–30) prism diopters (PD) ranging from 18 to 35 PD at distance fixation and a median of 15 (interquartile range, 10.5–18) PD ranging from 8 to 20 PD at near fixation with full correction of refractive errors. After reducing the amount of near work per day to no more than 1 hour for 3 months, all patients noted a significant decrease in the degree of esodeviation that were a median of 20 (interquartile range, 18–21) PD ranging from 10 to 25 PD at distance fixation ($P < .002$) and a median of 8 (interquartile range, 8–10) PD ranging from 2 to 13 PD at near fixation ($P < .012$). One of the 12 young patients achieved orthophoria and the disappearance of diplopia in all positions of gaze, other 11 patients showed an esodeviation which were resolved following prism or surgical treatment (Table 2). Six of eleven patients did very well with base-out prism management and reported resolution of diplopia soon. No patient required a change in prism power during the follow-up period. The remaining five patients who do not tolerate prism therapy, or for those with large angles of esotropia underwent bilateral medial rectus recession. The orthophoric position was reestablished in five patients who received bilateral medial rectus recession and in six patients who were managed with base-out prisms. All patients remained stable orthophoric position during follow-up time. Titmus test was performed in all patients at initial presentation, and the results showed that one was with 40 arc seconds, three were with 100 arc seconds, three were with 200 arc seconds, four were with 400 arc seconds and one was no stereopsis. After refraining from the duration of near work for 3 months and base-out prism management or surgical treatment, we repeated the Titmus test in all patients, and the results at last follow-up visit showed improvement (six with 40 arc seconds, four with 100 arc seconds, and two with 200 arc seconds of stereopsis).

Table 2. Clinical characteristics of patients with divergence insufficiency after near work restriction.

Patient number	Esodeviation, distance/near (Δ)	AC/A ratio	Treat	Stereoacuity (Arc seconds)	Follow-up period (Months)
1	20/10	2.87	Surgery	40	32
2	25/12	2.67	Surgery	200	36
3	22/10	2.9	Surgery	40	36
4	16/6	2.77	Prism	100	28
5	20/8	2.5	Prism	40	24
6	20/8	2.9	Prism	100	24
7	18/8	2.97	Surgery	40	24
8	20/8	2.6	Prism	100	24
9	25/13	2.9	Surgery	200	24
10	20/8	2.8	Prism	100	32
11	10/2	2.97		40	30
12	18/8	2.67	Prism	100	36

Discussion

To our knowledge, the present study is the first to explore the relationships between excessive near work and divergence insufficiency esotropia in young adults. Considering that many clinical situations might exhibit some similar presentations with divergence insufficiency esotropia described in our study, it may be important to differentiate divergence insufficiency esotropia from other categories of comitant esotropia. Some patients with a prior bilateral abducens palsies have partially recovered by the time the patients presented, and might present only comitant esodeviation in primary gaze without variable limitation of abduction.[1] In our study, 12 patients presented divergence insufficiency esodeviation as an isolated condition and did not have bilateral abducens palsies before presentation to our clinic. In addition, the reduction in esodeviation after near work restriction could be discriminating factors between bilateral abducens palsies and divergence insufficiency esodeviation in our patients. The manifestations of divergence insufficiency esotropia and divergence paralysis can be quite similar, making clinical differentiation difficult.[15] Divergence paralysis is distance esotropia with divergence loss and is often typically associated with various neurological diseases.[4,21] In our study, none of the 12 patients had any neurological pathology. The typical presentation in all patients was one of gradual or subacute onset of horizontal diplopia unlike the sudden dramatic onset of diplopia in divergence paralysis.[22] Nonrefractive accommodative esotropia is a possible differential diagnosis, which is usually associated with hyperopia and high AC/A ratio.[23] However, all patients in our study were mopic refractive error and had low AC/A ratio at initial presentation. In addition, there was no clinically significant change in AC/A ratio after refraining from excessive near work, which may differentiate accommodation esotropia from divergence insufficiency esotropia. Refractive accommodative

esotropia can be excluded since the degree of esodeviation in our study could not resolve with the correction of refractive error. Although uncorrected mopic refractive error could induce esodeviation, all patients in our study wore right corrected glasses and none of these patients was reluctant to wear glasses before or after presentation to our clinic. Therefore, we did not deem accommodative element, uncorrected refractive error, or neurologic disorders as the genesis of divergence insufficiency esotropia in young adults.

In the present study, extensive and comprehensive questionnaire revealed that excessive near visual activities (more than 6 h per day) for a long period of time (more than 4 months) were common in all patients who spent hours in using a computer, reading, or other possible near visual activities before the onset of diplopia. Near work requires a larger accommodative effort with associated increased convergence tonus to achieve clear and single binocular vision.[16] Increased convergence tonus can cause an inappropriate loss of sarcomeres in the medial rectus muscles via the phenomenon of muscle length adaptation to the increased stimulation, resulting in the shortening of the medial rectus muscles.[15] The increased convergence tonus normally is counterbalanced by fusional divergence to maintain fusion. If fusional divergence is insufficient to counterbalance increased convergence tonus, the shortening of the medial rectus muscles drives the eyes into a progressively more esotropic posture.[12–14] Therefore, we speculated that excessive near work could potentially induce the development of divergence insufficiency esotropia in young patients. Refraining from excessive near work caused a significant decrease in the degree of esodeviation in all patients, which seems to partially support above speculation. It is generally believed that refraining from excessive near work may decrease convergence tonus which results in a significant decrease in the medial rectus muscles action since the medial rectus muscle is primarily involved in convergence.[24] As a result, the amount of esodeviation can be decreased. In our study, only one patient achieved orthophoria and the disappearance of diplopia in all positions of gaze after refraining from excessive near work. The patient had resolution of diplopia without intervention treatment most likely due to the small angle of deviation and good fusional divergence which is directly related to an ability to compensate for an underlying esodeviation.[21] Small esodeviations can be easily corrected because divergent fusion is often prioritized.[15] A significant decrease in convergence tonus with the relaxation of medial rectus muscle after refraining from near work may cause the relative decrease in the degree of esodeviation. Thus, the remnant esodeviation can be easily corrected when fusional divergence can adequately overcome the decreased medial rectus muscle action, resulting in the orthophoric position. However, the exact mechanism by which the patients significantly decreased the degree of esodeviation after refraining from near work remains unclear and yet to be determined.

There were several limitations in this study. First, sample size was small because of the relatively rare occurrence of divergence insufficiency esotropia. Second, the follow-up duration was relatively short and there were some differences in follow-up intervals between a few patients. Further study with a larger sample and longer-term follow-up duration with uniform follow-up intervals is needed to confirm the results of this study. Third, we evaluated near work in young adults with questionnaires, which could cause substantial recall bias in asking subjects to recall the amount of near work over the preceding several months. Fourth, we only studied the patients with excessively near work, and could not perform a comparative analysis between divergence insufficiency esotropia patients with and without history of excessive near work because of the paucity of divergence insufficiency esotropia. In addition, we did not perform objective measure of accommodative power by using dynamic retinoscopy or other accommodation measurements because anomalies of the accommodative power could affect the deviations.

Conclusion

This study suggested that the excessive near work might influence the development of divergence insufficiency esotropia in young patients. Refraining from excessive near work could decrease the degree of esodeviation in these patients. The role of excessive near work in the development of divergence insufficiency esotropia in young adults is still unknown. Further case-controlled studies with larger sample sizes and long-term follow-up periods are warranted.

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Declaration of interest

The authors have no proprietary or commercial interest in the products used in this investigation.

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