Original Article

Impact of Vision Therapy on Eye-hand Coordination Skills in Students with Visual Impairment

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Abstract

Purpose: To evaluate the enhancing effects of vision therapy on eye–hand coordination skills in students with visual impairments.
Methods: Thirty-five visually impaired patients who underwent vision therapy comprised the treatment group, and 35 patients with impaired vision who received no treatment comprised the control group. Full ophthalmic examinations were performed, including biomicroscopy, retinoscopy, and assessments of subjective refraction and visual acuity. Eye–hand coordination was evaluated using the Frostig test. Vision therapy in the treatment group was performed using the Bernell–Marsden ball, perceptual-motor pen, random blink test, and random shape assessment.
Results: Data were analyzed for the 35 visually impaired patients and 35 control participants. The mean age was 11.51 ± 3.5 and 11.09 ± 3.1 years in the treatment and control groups, respectively. Female participants comprised 80% of the treatment group and 57% of the control group. Before treatment, the mean scores on the Frostig test were 22.74 ± 4.32 and 21.60 ± 4.10 in the treatment and control groups, respectively, and after treatment, the mean Frostig test scores were 24.69 ± 3.99 and 21.89 ± 3.92, respectively. Statistically significant intergroup differences were found in eye–hand coordination ($P < 0.05$). No significant intergroup differences were noted in the distance and near visual acuity values.
Conclusion: The results demonstrated that vision therapy could significantly improve eye–hand coordination, but no enhancement was found in near or distance visual acuity.

Keywords: Eye–hand Coordination; Eye Movement; Low Vision; Visual Impairment; Vision Therapy

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INTRODUCTION

Vision plays a leading role in different aspects of education, employment, adaptation, and communication, and is the mode by which 80%–90% of all information from the environment is perceived.[1] Therefore, any visual impairment can dramatically affect the quality

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of life and increase the risk of injury.[2-9] The challenges associated with severe visual impairment in children are different from those encountered in adult blindness. Since all failures in normal visual development cannot be corrected in adulthood, it is essential to treat any ocular and visual disorders during childhood.[10] The World Health Organization (WHO) has categorized visual impairments with respect to the best-corrected visual acuity as follows: blindness (Snellen visual acuity of 3/30), severe visual impairment (Snellen visual acuity between 6/60 and 3/30), moderate visual impairment (Snellen visual acuity between 6/18 and 6/60), and mild or no visual impairment (Snellen visual acuity of 6/18). In this classification, low vision constitutes both moderate and severe visual impairments.[11] The prevalence of visual impairment was estimated to be 3% in an adult population[12] and 4.4% in school children.[13] Based on the WHO classification, visual impairment in children is categorized according to the anatomical region affected by the impairment, the etiology of the disease, and whether the causes are avoidable or unavoidable. As estimated by WHO, approximately half of the causes of visual deficiency in children are preventable or treatable.[14] According to this organization, the principal causes of visual impairment include refractive errors, cataract, and glaucoma, in which refractive errors are recognized as the main contributing factors for visual impairment internationally. Eye–hand coordination, which is defined as the use of vision to guide hand movements such as reaching and grasping, is essential for upper extremity dexterity.[15] It requires the integrated use of eyes, arms, hands, and fingers to produce controlled, accurate, and rapid movements.[15] Normal eye–hand coordination occurs in an ordered sequence as follows: 1) visual detection of the target, 2) focused attention, 3) perceptual identification of the target location, 4) cognitive planning and programming of the reaching movement, and 5) activation of arm muscles to initiate the action.[16] In fact, eye movements are associated with hand movements, even though the eyes begin and complete their movements more rapidly than the hands.[17] Coordination disorder is defined as any problem or limitation in motor coordination, resulting in a lower than expected performance, depending on the patient's chronological age.[18] Improvement of eye–hand coordination as a perceptual-motor skill depends on the visual system as well as efficient eye muscle control.[19] Vision therapy is recognized as an individualized intervention to improve the binocular system, ocular motor control, visual processing, visual motor skills, and perceptual or cognitive deficiencies.[18] According to several studies, vision therapy could improve binocular skills, ocular motor control, visual attention, visual perception, and visual processing skills.[20-24] Since the first essential stage of normal eye–hand coordination is the visual detection of the target, reduced visual acuity could affect stereo-acuity and eye–hand coordination. Therefore, improvements in both eye–hand coordination and visual acuity can remarkably improve the quality of life in individuals with low vision. However, to the best of the authors' knowledge, very few publications are available in the literature that discuss the efficacy of vision therapy in eye–hand coordination, so the present study aimed to assess the efficiency of a vision therapy protocol using the Marsden ball technique, perceptual-motor pen, random blink test, and random shape assessment in improving eye–hand coordination in patients with low vision.

METHODS

Study Population

The study population included 35 visually impaired individuals who underwent vision therapy and 35 age- and sex-matched visually impaired individuals who received no treatment. The participants were recruited from a low vision school of rehabilitation according to the following inclusion criteria: 1) students with low vision at schools for the blind and visually impaired; 2) willingness to participate in the study; 3) healthy sensorimotor system; 4) corrected monocular distance visual acuity less than or equal to 20/70; and 5) ability to perform the Frostig Developmental Test of Visual Perception. The WHO criteria were used to define low vision in the participants. Each participant underwent comprehensive ophthalmologic and eye–hand coordination examinations. Follow-up tests were conducted for each patient in an identical order.

Clinical Examinations

Objective refraction was determined using a Heine Beta 200 Retinoscope (Heine Optotechnik, Herrsching, Germany) as an effective method for prescribing corrective lenses in cases where subjective refraction assessment was not possible. The fogging method was also applied if there was any sign of accommodative spasm or pseudo-myopia. Radical retinoscopy, a useful technique to distinguish the dim astigmatism reflex easily, was also performed by moving closer to the patient and neutralizing the reflex. Radical retinoscopy is widely used in cases of opacity, miosis, or pupil invisibility.[25] In the next step, monocular and binocular subjective refractions were assessed. Visual acuity was assessed using a LogMAR (minimum angle of resolution) chart (Bailey-Lovie chart) both at far and near distances. The subjects were asked to wear their best visual aid throughout the test. The biomicroscopic examination was also performed using a Topcon slit lamp (Topcon Corporation, Tokyo, Japan; Neitz Instruments Company, LTD, Tokyo, Japan).

In this stage, both anterior and posterior segments were evaluated for any existing abnormalities. Evaluation of eye–hand coordination was performed after complete ophthalmic examinations using the eye–hand coordination subtest of the Frostig test (Welty Leteuer and John R.B. Whittleseey, United State of America) [Figure 1]. This subtest consisted of 16 sequential sections, each containing an image with straight, curved, or angled lines drawn between two points at various distances without any guiding lines. The Frostig booklet and two pens were used to initiate the test. Pens with wide tips were preferred, as these were easy to distinguish for students with low vision. The subjects were asked not to pick up the pen from the page until the test was completed. Picking up the pen from the page or even departing from the straight line showed a weakness in eye–hand coordination skill, which necessitated proper treatment. The test had a maximum score of 30 marks. For each patient, scoring was done as follows: two points were recorded if the patient could match the two distance objects correctly and also if there was no interruption, deviation, or angulation in the line. One point was recorded if the pencil crossed the line more than once or if the drawn line exited from the two objects (less than 0.5 inches). Zero points were recorded if the drawn line crossed the guidelines, or there was any interruption, deviation, or angulation in the line and if the line exited from the objects by more than 0.5 inches. After careful evaluation of ophthalmic status and eye–hand coordination, vision therapy was performed for each subject in the treatment group. The vision therapy protocol included the Bernell–Marsden ball technique (Bernell, A Division of Vision Training Products Incorporation, United State of America) [Figure 2], use of a perceptual-motor pen (Wayne Engineering, United State of America) [Figure 3], random blink test (Farakavosh Communication Technology, Islamic Republic of Iran) [Figure 4], and random shape assessment (Farakavosh Communication Technology, Islamic Republic of Iran) [Figure 5].

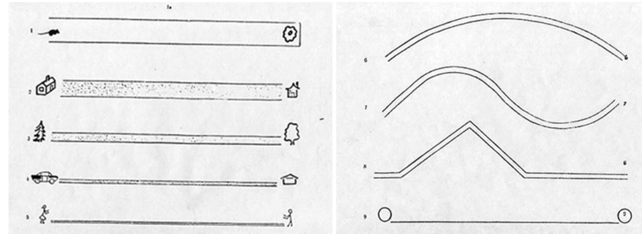

Figure 1. The Frostig test, which consists of an image with straight, curved, or angled lines drawn between two points at various distances without any guiding lines. The Frostig booklet and two pens were used to initiate the test. The subjects were asked not to pick up the pen from the page until the test was completed.

Figure 2. Bernell–Marsden Ball. The ball was hung from the ceiling, and each participant was asked to bunt the ball with a dowel.

Marsden Ball Technique

In this technique, the ball was hung from the ceiling, and each participant was asked to bunt the ball with a dowel. A similar and distinctive pattern needed to be followed for every 20 hits. The test was performed both monocularly and binocularly. The entire test took 6 minutes for each participant.

Figure 3. Perceptual-motor pen. Each subject was asked to move a specific pen on the lines of the page. No sound was produced if the pen was moved correctly, while errors in tracing the lines resulted in auditory feedback.

The Perceptual-motor Pen

In this task, each subject was asked to move a specific pen on the lines of the page. No sound was produced if the pen was moved correctly, while errors in tracing the lines resulted in an auditory feedback. This biofeedback encouraged the subjects to increase their accuracy and improve their eye–hand coordination. The test took 6 minutes for each subject.

Random Blink Test

In this test, a circle was presented on a computer screen in a random order. The color, size, and time of presentation were adjustable and could be changed. The subjects were asked to mark the circle on the screen. It was preferable to choose a size that was initially difficult for the subject to distinguish. The test took 6 minutes for each subject to complete.

Random Shape Assessment

In this test, the subjects were asked to find and draw pictures that were presented on the computer screen. The size, line thickness, and contrast of the pictures were adjustable. Both size and contrast were selected on the basis of the participant's detection threshold. The duration of the monocular test, binocular task, and the entire test was 3 min, 6 min, and 12 min, respectively. Vision therapy was performed for 30 min three times a week. Follow-up examinations were performed for three months for each participant. Vision therapy was implemented in a simple-to-hard order. After completing 36 sessions of vision therapy, all subjects were re-examined using both ophthalmic and eye–hand coordination tests.

Statistical Analysis

All data are expressed as mean ± SD values. Statistical analyses were performed with SPSS version 11.5 (SPSS Institute, Chicago, IL, USA). The Student *t*-test was used to assess the statistical significance of continuous variables. A *P* value of <0.05 was used as the criterion for statistical significance.

Ethics

All participants were informed about the objectives of the investigation, and informed consent forms were obtained before inclusion in the study population. The study protocol was approved by the Ethics Committee of Mashhad University of Medical Sciences and the protocol adhered to the tenets of the Declaration of Helsinki.

RESULTS

The study was conducted on 35 patients in the control group (mean age = 11.09 ± 3.1 years) and 35 participants in the treatment group (mean age = 11.51 ± 3.5 years) from 50 visually impaired individuals who were initially invited. Fifteen individuals were excluded because of missed follow-up examinations. Table 1 shows the demographic data of the participants. The mean spherical equivalent of the treatment and control groups was 2.06 ± 7.61 D and 2.50 ± 7.36 D, respectively. Before treatment, the mean distance and near best-corrected visual acuities were respectively 1.11 ± 0.27 LogMAR and 0.78 ± 0.27 LogMAR in the treatment group and 1.07 ± 0.26 LogMAR and 0.81 ± 0.25 LogMAR in the control group. The results showed no statistically significant intergroup differences in improvements in both distance (P = 0.27) and near (P = 0.30) visual acuities following vision therapy. Frostig test scores showed a statistically significant improvement in eye–hand coordination in the treatment group. The mean Frostig test score was 22.74 ± 4.32 and 21.60 ± 4.10 before treatment in the treatment and control groups, respectively. After treatment, the mean Frostig test scores improved to 24.69 ± 3.99 and 21.89 ± 3.92 in the treatment and control groups, respectively. The test results showed

Table 1. Demographic characteristics of the participants

	Age (years)	Male	Female	Total
Treatment	11.51±3.5	7	28	35
Control	11.09±3.1	15	20	35

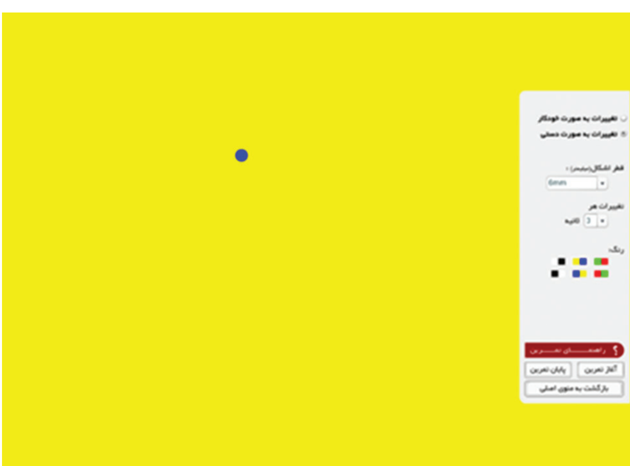

Figure 4. Random blink test. A circle was presented on a computer screen in a random order. The color, size, and time of presentation were adjustable and could be changed. The subjects were asked to mark the circle on the screen.

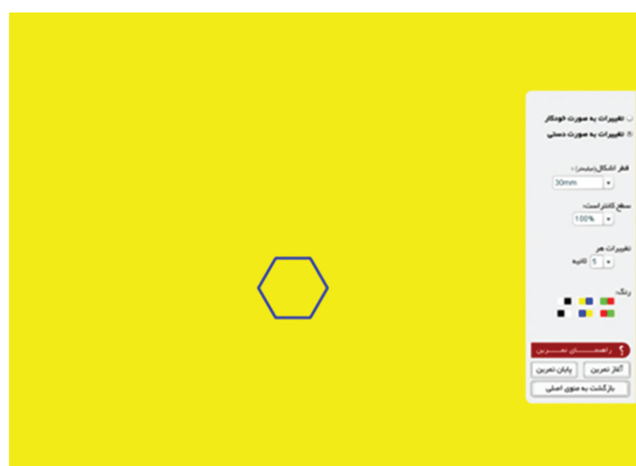

Figure 5. Random shape assessment. The subjects were asked to find and draw pictures that were presented on the computer screen.

Table 2. Clinical measurement results

	Frostig improvement	Distance VA improvement (LogMAR)	Near VA improvement (LogMAR)
Treatment	1.94±2.0	0.04±0.09	0.02±0.1
Control	0.4±0.94	0.02±0.07	0.006±0.04
P	*P*=0<0.001	*P*=0.27	*P*=0.30

VA, visual acuity

that vision therapy could significantly enhance eye–hand coordination skills ($P < 0.05$). The overall measurement results are summarized in Table 2.

DISCUSSION

The main purpose of the paper was to evaluate the effect of vision therapy on eye–hand coordination in patients with low vision. We have also assessed the consequences of vision therapy on vision and visual acuity. Based on the findings, a statistically significant difference was noted in eye–hand coordination between the treatment and control groups ($P < 0.05$). Following vision therapy, the mean eye–hand coordination score improved by 1.94 ± 2.01 in patients with low vision. Consistent with our findings, Aki et al also found a significant difference in motor skills before and after vision training in children with low vision.[26] Abrams stated that eye–hand coordination is essential for daily activities such as eating, working, and competing.[27] Moreover, the results of a study by Jeon showed that training and activity played an important role in the development of independence in patients with low vision.[28] Considering the higher vulnerability and sensitivity of visually impaired children, this population requires more attention and needs to be trained on the use of residual vision. Therefore, vision therapy could be a useful method for improving the quality of life in these individuals. This experiment revealed that vision therapy did not improve distance and near visual acuity. Regan[29] showed that vision guides hand movements, while Ren[30] believed that the hands guide saccadic eye movements via stereoscopic vision. In this regard, Suttle employed a three-dimensional motion capture system to evaluate the reach-to-grasp performance of the preferred hand under binocular and monocular conditions in two groups of amblyopic (aged 4-8 years) and normal (aged 5-11 years) children. They reported that binocularity training in amblyopic children could improve eye–hand coordination.[31] Moreover, visual perceptual learning could improve visual acuity by increasing visual sensitivity. Kasten evaluated the efficacy of vision restoration therapy in subjects with homonymous visual field defects (mean age: 40.8 ± 3.3 years) by using high-resolution and conventional perimetry to plot the visual field. A two-dimensional eye tracker (Chronos Vision GmbH, Berlin, Germany) was used to record the eye movements. The device could measure horizontal and vertical eye movements at a sampling rate of 200/s (2 ms latency). The results suggested that continuous peripheral visual stimulation could diminish scotoma.[32] Moreover, Maples showed that eye–hand coordination plays an important role in students' achievements, and vision therapy could improve eye–hand coordination.[33] These findings were in congruence with the present results, indicating the effectiveness of vision therapy in improving eye–hand coordination in school children with low vision.

In conclusion, the outcomes of this study showed that vision therapy is effective in improving eye–hand coordination in visually impaired individuals. However, the results showed no improvement for both distance and near visual acuities with treatment. Although the research fulfilled its objectives, there were some unavoidable limitations. First, because of the small number of intended participants, patient identification was done using a non-random sampling method. Second, the examiner was not blinded to the applied treatment methods.

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Conflicts of Interest

There are no conflicts of interest.

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