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Review Article

Physiotherapy Section

Visual Impairment as a Learning Disability in Children with Cerebral Palsy: A Narrative Review

NAMRATA SANT[1], VAISHNAVI A BHAVAR[2], SMITA A NAND[3], GAURI R JOSHI[4], SAKSHI RUNWAL[5]

ABSTRACT

Cerebral Palsy (CP) is a group of non-progressive brain disorders causing movement, posture, and motor function impairments. Cerebral Visual Impairment (CVI) affects visual pathways, affecting clarity of vision, visual fields, and occulomotor incoordination. Symptoms vary in nature and severity due to the complexity of the visual cortex. Physiotherapy (PT) is essential for treating CP, promoting physical, mental, and social well-being. Physical therapists also teach parents, how to care for their children at home, including feeding, bathing, dressing, and other activities. CVI is often linked to CP and can lead to various visual problems, including reduced visual guidance of movement. To effectively manage this condition, a multidisciplinary approach is required, as children with CVI often have neurological deficits in addition to their visual problems. Visual function assessment involves measuring thresholds or limits for each eye, while functional vision assessment is conducted in the child's environment with both eyes open. Levels of vision can be classified into light perception, intermittent fixation, reliable focus, constant attention to small objects, and reliable visual acuity. Children with Visual Difficulties (CVI) exhibit distinct visual behaviours and require proper training. Sensory room training improves gross and fine motor abilities, and early intervention reduces issues associated with these diseases. Physical therapy interventions are very important for this population's health and wellness, which can be focused on acquiring and improving independence in motor abilities, visual function, coordination, balance and general health improvement. Children with CVI are at danger of developing neurological dysfunction. An early intervention and adequate training for young CP children with CVI can improve motor abilities and reduce issues associated with these diseases. The following review will help to understand briefly about visual impairments in patients with CP, mainly focusing on new therapeutic interventions following visual impairments that are effective and easily administered.

Keywords: Cerebral visual impairment, Motor abilities, Multidisciplinary approach, Physiotherapy, Vision assessment

INTRODUCTION

Cerebral Palsy (CP) is a group of non progressive disorders that mainly affects the brain and causes movement, posture, and motor function impairments [1]. Several disorders that affect the visual pathways are referred to as Cerebral Visual Impairment (CVI). The visual association cortices and the pathways that connect them are affected by several disorders which alter the clarity of vision, visual fields, occulomotor incoordination, and others. Because of the complexity of the visual cortex, developmental abnormalities can lead to a wide range of symptoms that vary in nature and severity. In children with CP, CVI is typical [2]. Children with CP typically experience cerebral lesions in the brain areas that contain the posterior visual system, including the geniculate body, optic radiation, and occipital cortex [3].

"The visual impairments are not linked to the disorders of the anterior visual pathways or perhaps co-occurring ocular pathology; rather, it occurs due to damage to retro-chiasmatic pathways and brain structures" is the definition given for CVI. Metabolic and genetic disorders, hypoxic-ischaemic injury, trauma, infection, and other factors are responsible for the development of CVIs. Lower visual abnormalities, such as reduced contrast sensitivity, visual acuity, visual field sensitivity, and ocular motor skills (such as fixation, saccade, and pursuit movements) are typically present in people with CVI [4]. CP patients may or may not have exceptional eyesight. He or she may require glasses to correct short/long sight or astigmatism. However, in addition to vision issues, all children with CP will suffer from visual processing, or the capacity to grasp what they see. It needs a combination of both interconnected motor and visual skills to move properly [5]. Children with CP have some form of visual impairment or problem between 40% and 75% of cases [6].

Damage to the brain's visual systems (bilateral damage to the occipital cortex) results in blindness which is commonly associated with CVI and both conditions affect the brain [7]. It is clinically characterised by bilateral loss of vision, a typical pupillary reaction, and a normal eye test. The ocular anatomy is often normal in CVI patients [8]. It is a representation of problems in processing and interpreting visual information in the visual brain [9]. CVI stops the brain and eyes from interacting with one another, which is caused by damage to the brain's visual centre. The brain is unable to understand what is seen despite the eyes' capacity to see [10]. Visual aids that make movement easier to notice, such as pinwheels, prefer particular colour combinations, such as brilliant red and yellow, while others prefer blue, green, and pink are used to aware children with CVI. Vision treatment for CVI includes improvement in reaction times by recognising visual latency qualities such as delayed response when staring at objects, problems with visual complexity, light-gazing and visual field preferences, distant vision impairment, and visual blink reflection [11]. CP is a functional disability movement abnormalities (such as spasticity and dystonia), which are associated with motor and learning disorders such as Developmental Coordination Disorder (DCD). The children can develop typical movement patterns and skills but struggle to learn and plan the motions, which is largely a learning issue. However, CP is a physical condition in which children are unable to develop typical movement patterns. Although learning deficiencies may exacerbate the motor issue, the major difficulty with CP is motoric rather than learning [12]. CP associated with vision problems is more common. Almost 75% to 90% of them have some form of visual impairment in which every one in ten children with CP is blind. The injury to the occipital lobe of the brain is a common cause of vision issues, which results in CVI. Collecting and analysing visual information is

the main function of the occipital lobe. According to a study done by the National Institutes of Health (NIH) showed that a squint was present in 52.5% of CP patients, substantial refractive errors (inability to focus properly) affected 50%, normal vision affected 20%, and sleepy eyes (strabismic and anisometropic amblyopia) affected 15% [13].

CP vision problems include [14]:

- **Cortical Visual Impairment (CVI):** It is one of the most typical causes of visual defects in children with CP, which usually occurs due to damage to the occipital lobe.
- **Amblyopia (lazy eye):** It is a condition when one eye is weaker than the other. The weaker eye normally becomes worse since the brain favours the stronger eye by nature.
- **Optic atrophy:** It is a disorder that damages the optic nerve and obstructs brain-to-eye transmissions. Blindness and other visual issues may arise from optic nerve damage.
- **Nystagmus:** It is distinguished by irregular, repetitive, and involuntary eye movements.
- **Visual field defect:** Causes one or both eyes to have a blind area.
- **Refractive errors:** Blurred vision, astigmatism, near sightedness, and farsightedness.
- **Squinting (strabismus):** It occurs when the eyes appear to be crossed. It affects 70.5% of individuals and is the most common CP visual impairment [14].

Physiotherapists generally employ normal Physiotherapy (PT) and neurodevelop-mental therapies to treat children with CP. They emphasise on gross and fine motor skills and use therapeutic exercises such as range of motion, strengthening, stretching, positioning, weight bearing/shifting, alignment of body segments, balance and coordination exercises, and gait patterning for children who may or may not have visual issues. When dealing with children with CVI, physiotherapists should keep numerous useful treatments in mind, such as when and how to use a visual stimulus or attribute, such as distance, contrast, brilliant colours, non-illuminated items, and so on, to elicit a response which provides significant improvement in visual impairments in children with CVI [15]. The PT, which focuses on the child's function, motion, and maximising potential, is an important part of treating this condition. In PT, physical, mental, and social well-being is promoted, maintained, and restored using physical methods. In addition to advising on the use of mobility aids, physical therapists also teach parents how to care for their children at home, including feeding, bathing, dressing, and other activities [16].

Prevalence

In India, the incidence of CVI in children with CP ranges from 21% to 28%. An 18.75% of the patients had complete visual impairment, while 41.5% cases had a visual impairment of 20% or more. Compared to normally developing children, children with common neurodevelopmental disorders (premature birth, CP, hypoxic-ischaemic encephalopathy, hydrocephalus, meningitis, Down's syndrome) are more likely to have visual impairment [17,18].

Pathophysiology

Visual perception and cognitive abilities are impaired in children with CVI due to damage to higher visual processing centres, while damage to the brain's visual input system and occipital cortex results in reduced visual acuity and contrast sensitivity, and reduced visual fields. Varying degrees of low visual acuity, visual field impairment, and perceptual vision problems occur due to impairment in visual systems resulting from either individual or combined causes. Even when visual field and visual acuity are normal or near normal, visual disturbances can occur. As a result, children can experience a variety of problems, including orientation problems (caused by ventral outflow disruption), trouble dealing with complex visual parameters, and erratic visual cues. The ability to recognise people, their faces, shapes, and objects is also affected [2].

Assessment

For assessment of "visual function" the measurement of visual function thresholds or limits for each eye is essential for the physician. On the other hand, an assessment of "functional vision" is often conducted in the child's environment with both eyes open to determine how the visual impairment is affecting daily activities [2].

Vision: To assess each patient's functional vision, the following nomenclature is used:

Level 1- Light perception

Level 2- Intermittent fixation on large objects, faces, or movements

Level 3- Reliable focus on faces or occasional focus on small things

Level 4- Constant attention to small objects; Visual acuity from 20/400 to 20/200

Level 5- With both eyes open, reliable visual acuity is no greater than 20/50

Level 6- Perfectly normal vision [19]

Test for vision:

- Perimetry
- Visual field tracking, Gaze tracking
- Cranial nerve examination (CN -3,4 and 6) [20]

Visual screening tests for an infant:

- Response to light
- Pupil response
- Ability to follow a target
- Visually evoked response testing [20]

Visual screening tests for an older infant and toddler:

- Cover and uncover test

Visual screening tests for a preschooler:

- Visual acuity tests
- Colour testing

Visual screening tests for a school-aged child:

- Using specialised charts or tools that help in measuring vision, formal vision assessments may be carried out on children in this age group [20]

Patterns of Visual Impairment

Quadriplegic CP is a condition most commonly associated with severe visual impairment, although it can also affect the child who has only mild mobility problems. Children with this pattern of visual impairment are visually impaired in several ways. Damage to the occipital cortex and basal ganglia involves most of the cases of hypoxic-ischaemic encephalopathy. Total blindness occurs rarely [21]. Adults, who are blind due to brain damage can essentially have a subliminal perception of moving objects, lights, and colours in the blind area. It has also been reported that people have an unconscious ability to reciprocate facial emotions even when they cannot see them. This is known as affective blind sight [22].

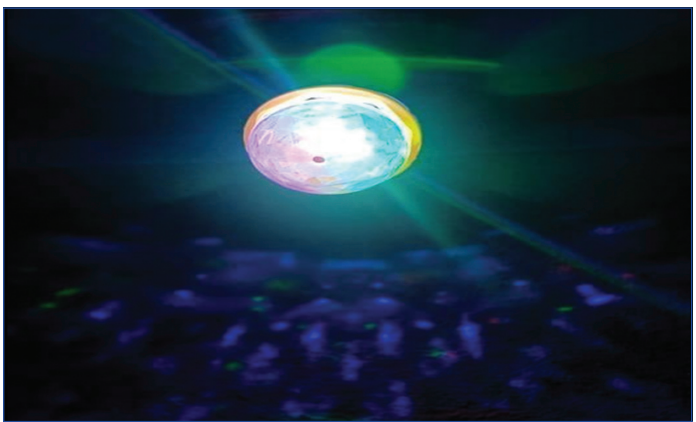
Equipments

A sensory room is a unique space created typically with unique lights, music, and objects to enhance the human senses. Simple household items such as aluminium foil, mirrors, scented oils, recorded music, and textured materials can stimulate the senses, more advanced electronic devices such as projectors, bubble tubes, fibre optic vibration devices, aroma diffusers, and audio equipment can be also used. The visual processing, tracking abilities, hand-eye coordination, and tactile and auditory abilities are enhanced using darkrooms in the comfort of a regulated multi-sensory environment [23].

The following aids were used for visual stimulation during gross motor training:

- **Bubble tube (Column):** A vertical column filled with air and water and available in different colours. Visual stimulation can be added by placing small ball or toy. The bubbles blow continuously when the bubble tube is turned on and lights automatically switch between four colours. The colour controller is used to adjust the shades that come with the tube.
- **Mirror/Disco ball:** Moves through space in super slow motion in a beautiful multi-dot pattern. It is usually hung near the corner of the room on the ceiling beam [Table/Fig-1].
- **Infinity tunnel:** A square enclosure with single row of lights surrounded by a mirror. Hundreds of bright spots seem to disappear.
- **Pin wheel projector:** Images of flowers, butterflies, and stars onto surfaces of different colours and shapes are projected by this tool.
- **Ultraviolet (UV)/Black, Light Emitting Diode (LED) light:** It is a heavily visual medium that encourages engagement, visual challenges, and focus. This is also known as UV or black light [Table/Fig-2].
- Flame throwers, fluorescent drums and colourful ladders, mats, wedges, rollers, and a medicine ball, light up rings [Table/Fig-3] were used to implement the physical therapy plan.
- Light toys, blocks, and toys of different colours and shapes were used to improve motor skills [Table/Fig-4] [23].

[Table/Fig-1]: Mirror/disco balls.



[Table/Fig-2]: Light Emitting Diode (LED) light.

Diagnosis

- **History taking:** History taking should be studied as a first step. A medical history (structural or metabolic) may reveal birth defects, hydrocephalus, CP, prematurity, meningitis, and neurodevelopmental disorders.

[Table/Fig-3]: Light up rings.

[Table/Fig-4]: Light toys.

- **Neuroimaging:** Analysing previous scans can be helpful since most children with developmental problems have already had neuroimaging. Only about one-third of CVI patients have no visible abnormalities on standard structural imaging.
- **Electrodiagnostic Examination (EDT):** For diagnosis of CVI, electrodiagnostic testing is not required. It helps diagnose retinal or optic nerve dysfunction in a patient with ophthalmic (such as nystagmus or severe refractive error) and medical (such as metabolic or genetic disorders) disorders are known to be associated with retinal dystrophy.
- **Ocular Coherence Tomography (OCT):** OCT of the optic disc is gaining popularity as a diagnostic technique for CVI, especially in children who cannot perform normal perimetry.
- **Formal perimetry:** For diagnosis of CVI, a formal visual field test is also not required. Because of the low developmental level, most of the children would not be able to take such test. For children who are functioning better, perimetry can be useful for detecting visual field loss and visual defects.
- **Visuo-perceptual or psychometric testing:** To entirely discover the extent of a child's visual impairment, a visual cognition assessment is performed in children with CVI [24].

THERAPEUTIC INTERVENTION

Hand-Eye Coordination Exercises

According to a study by Alwhaibi RM et al., hand-eye coordination and fine motor skills are improved by using specially designed programmes that improve visual-motor integration, visual perception, and motor coordination. The programme includes activities as follows:

- Taking less than a minute to button and unbutton three buttons.
- Touch the thumb alternately with each finger, starting with the index finger, as quickly as possible (within 10 seconds).

- Put 10 marbles in the bottle as quickly as possible (within 30 seconds).
- Make a circle on a piece of paper.
- Draw a square (both with and without matching between the four dots) on a sheet of paper.
- Draw a triangle on a piece of paper (both with and without matching the three dots).
- Place three to five shapes into the proper holes on the formboard.
- Arrange 10 cubes on top of one another using two hands at first, then the injured hand.
- Sew beads or cubes with square corners to lace.
- Connect the six strip-hole laces.
- Stretching exercises for the affected upper limb's shortening muscles (30-second stretches, followed by 30-second relaxations), three to five times total (10 minutes) [25].

e-linked Upper Limb Exerciser

A study by ALwhaibi RM et al., stated that the E-linked upper limb exerciser is a computerised interactive system used for therapeutic purposes by incorporating games as an exercise. It provides visual feedback and motivation to users. The game is displayed on the screen and runs by a variety of devices (spade, spade grip, cylinder, key handle, and disc tools) depending on the patient's physical and cognitive condition. Upper limb movements, which are essential in sports such as soccer, wall kicking, space shooting, driving, and throwing balls required visual stimuli along with hand coordination. Such games were projected onto a big white screen and simultaneously speakers provided commentary. While performing the game, six levels were developed based on the child's previous performance with each level lasting for 10 minutes. Depending on the performance of the child, the difficulty level of the game increased over time [26].

Visual Stimulation Training

A study by Koch L stated that the dark room with visual feedback was used to encourage the patient's visual activity by placing the patient in that room which stimulate the visual pathways. It improved maximum head alignment by correcting the patient's postural impairments. First, static posture was assumed by the patient to maintain balance, either using lower limbs or by leaning against a wall. Then the patient was asked to follow the light to turn her head horizontally and vertically. To provide visual cues, lights were placed closer to the patient which was approximately 6 inches further away. To avoid concentration, the light was turned up high so that the patient was not able to focus and reliably track the light. To locate the stimulus completely via vision, the therapist asked to remain quiet during treatment otherwise the patient responded directly to the audio cues. This treatment was particularly used to activate visual pathways and facilitate postural correction because the patient had to lift his body in a vertical position to locate the visual stimulus which facilitates the cervical and trunk extension along with forward gaze [27].

Ambulation Training

A study by Koch L stated that the main therapeutic objective of ambulation training is to make the patient able to walk by her/himself. Less therapist assistance and tactile input were used as it leads to loss of balance. Single elastic cable support was provided as the patient could utilise proprioceptive input and provides weight bearing on lower limbs to assist with her need for support. The patient was trained to develop ankle, hip, and step techniques to improve gait and retain balance. Forward gaze and trunk alignment were trained by utilising visual targets, which were placed on the floor and patients were asked to cross the obstacles while walking. Verbal cues were also provided by the therapist since the patient had difficulty concentrating on the visual objects in a crowded setting [27].

Sensory Integration (SI) Therapy

A study by Patel DR and Balci NC stated that the main objective behind SI treatment is that most children have sensory impairments and they are too sensitive to particular stimuli. These children have trouble processing and filtering information at once in their brains as they lack sensory processing input and are highly sensitive to specific kinds of stimuli. Due to a lack of sensory processing skills, they are not able to process sensory inputs effectively. Organised sensory inputs were repetitively provided to the children to stimulate the brain; with time, their brain would adjust and make the patient able to respond to the stimulus more effectively. Reducing motor deficits in patients with CP is the primary goal of treatment. The planning of activities and organising behaviour is difficult in children with a sensory impairment, which occurs due to a lack of vestibular, proprioceptive, tactile, visual, and auditory inputs. SI technique aims to improve sensory processing ability and sensory input including auditory, visual, perceptual, proprioceptive, and other types [28,29].

Virtual Reality (VR)

A study by Balci NC stated that VR is an advanced treatment technique in which a patient is placed in virtual situations in which he can see, hear, and feel like real-world objects and activities by using interactive computer simulations. The virtual objects can move and be changed by users to interact with them. VR can enhance the patient's performance and encourage Activities of Daily Life (ADL). Virtual environments may be designed using various technologies such as standard desktop or laptop computers, as well as gesture control and video recording devices that use cameras [29]. The use of VR in rehabilitation is a popular treatment strategy that focuses on using virtual games and tasks to enhance physical and cognitive capacities in people with a variety of disabilities. In VR, the user may interact with a three-dimensional world using distant input devices like a keyboard or mouse (in a non immersive environment) or more sophisticated tools like a camera, special glasses, or special gloves (in an immersive environment) [30].

CONCLUSION(S)

The review discusses different therapeutic interventions for CVI in children with CP. CVI is often associated with CP. This contributes to various visual problems that can be misunderstood. By identifying each child's visual impairment, a management plan can address the resulting challenges more efficiently and systematically. A group of experts from diverse fields can work together in a specific facility to handle CP children in the best possible way. Numerous therapeutic methods have been adopted by both professionals and families due to the complexity of managing children with CP. These children can benefit from sensory room training that uses visual stimulation modalities to develop their gross and fine motor abilities. A multidisciplinary approach to care is required since children with CVI nearly always have some type of neurological deficit in addition to their visual problems. Early intervention and adequate training for young CP children with CVI has been found to greatly improve motor abilities and decrease the issues associated with these illnesses. Long-term follow-up studies and more research on the advantages of sensory rooms on cognitive issues in those children will be required.

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PARTICULARS OF CONTRIBUTORS:
1. Assistant Professor, Department of Physiotherapy, MGM School of Physiotherapy, Aurangabad, Maharashtra, India.
2. Intern, Department of Physiotherapy, MGM School of Physiotherapy, Aurangabad, Maharashtra, India.
3. Intern, Department of Physiotherapy, MGM School of Physiotherapy, Aurangabad, Maharashtra, India.
4. Intern, Department of Physiotherapy, MGM School of Physiotherapy, Aurangabad, Maharashtra, India.
5. Intern, Department of Physiotherapy, MGM School of Physiotherapy, Aurangabad, Maharashtra, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Namrata Sant,
Assistant Professor, Department of Physiotherapy, MGM School of Physiotherapy, Aurangabad-431003, Maharashtra, India.
E-mail: namratassant@gmail.com

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