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Correlation between Visual Impairments and Hand Function in Children with Cerebral Palsy

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ABSTRACT

Background: Hand regard and goal-directed hand-arm movements, are augmented mainly with inputs from the visual system. More than 40 -75% of Children with Cerebral Palsy (CwCP) have some types of visual problems or impairments. Eye-hand co-ordination is very important for development of appropriate reaching, grasping, and upper extremity dexterity. Independence of the child in activities of daily living depends on upper extremity control to a great extent. The correlation between hand function and visual impairments can help early identification and correction thus facilitating achievement of milestones.
Aim & Objectives: To find correlation between Manual Ability Classification System (MACS) and each of Visual Classification scale (VCS), visual acuity, refraction, binocular vision, ocular motility respectively.
Methodology: 33 children with cerebral palsy between 2 to 10 years of age were recruited Physiotherapeutic assessments, hand function scale MACS, routine ophthalmic examination along with VCS were performed on the recruited subjects.
Statistical analysis used: Data was not normally distributed. Correlation analyses were done using Spearman Rank correlation test. Test of significance was p<0.05.
Results: MACS showed moderate correlation with VCS and visual acuity. Discussion: Majority of participants belonged to level 5B of VCS with 5B indicating highest functional vision. Visual acuity determines the clarity of environment and objects in it, providing fine-tuned visual information required to recruit the appropriate muscle synergies for hand manipulation. Thus clinically children with cerebral palsy need to be assessed on ophthalmological basis for understanding their eye hand coordination and its impact on their hand function.
Conclusion: Thus awareness and examination of visual system in CwCP plays an important role in upper extremity functional training by a physiotherapist.

Keywords: Cerebral palsy, Visual impairments, Visual Classification Scale, Visual acuity, Hand function.

INTRODUCTION

Cerebral palsy (CP) is a prevalent physical disability in childhood. 'Cerebral palsy describes a group of permanent disorders of the development of movement and posture, causing activity limitations that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. [1] Cerebral palsy commonly affects the following systems: neuromuscular, sensory & perceptual, musculoskeletal and respiratory systems. [2] CP mainly presents itself through sensory and movement disorders, such as muscle spasticity or rigidity, random movements or a lack of balance, or a combination of these factors and often accompanied by seizures, abnormal speech, intellectual disability, aberrations of perception, hearing and visual deficits. [3] Independence of the child in daily functions depends on upper extremity control to a great extent. More than 60% of children with bilateral CP have decreased hand function. [4] The Manual Ability Classification System (MACS) was used as the outcome measure for hand function. It describes how children with cerebral palsy (CP) use their hands to handle objects in daily activities. [5] Christopher Morris, 2006, concluded that the MACS offers a valid and reliable method for communicating about the manual ability of children with CP with an Intra-class Correlation Coefficient (ICC) of 0.7-0.9. [6] Vision plays an important role in controlling the position of the head in space. On the other hand, head stability is important for vision, as it fosters gaze stability and therefore image stability on the retina, facilitating the processing of visual information. [7] Motor delay will be seen because of the visual impairment in otherwise normal children. So, if a child with cerebral palsy has visual impairments, the delay will be augmented. [8] Among cognitive functions, vision plays a major role during the development of communication, interaction and bonding, spatial awareness, ocular motor, and motor functions (gross and fine).[9] Hand regard and goal-directed hand-arm movements, are augmented mainly with inputs from the visual system. Children with CP often have difficulty making functional reaching movements. Such movements require a complex sensorimotor transformation that takes into account the visual attributes of the object, the initial direction of gaze, and the initial position of the head, hand and trunk. [10] Reaching deficits observed in children with CP could be due to primary deficits in manual motor control, or anticipatory postural responses, praxis and also occulomotor function. It is the coordination between the eye, trunk, and hand that ultimately drives performance. Reaching deficits in these children contribute to disability and interfere with development of independent life skills. [10] More than 40 - 75% of children with CP have some types of visual problems or impairments. [11] In a study done by Naomi B Ferzigeret al. (2011), the results of the ophthalmological examination were collapsed into a five-level Visual Classification Scale (VCS), with each level indicating a higher degree of visual performance than the previous one. The VCS characterizes clinician-administered measure done specifically during the ophthalmological examination. [3] A systematic review of visual ability measurements was done by Belinda in 2016 suggested the need for a classification system to describe “levels” of visual functioning in children with CP similar to existing functional classification systems. e.g. MACS. A useful finding of this review is that the clinician-administered measures provide information on best performance. There are currently no valid measures of visual ability for predictive or evaluative purposes. Until valid and reliable visual ability measures are developed, it is recommended that practitioners consider using individualized goal-based measures. [12] Eye-hand coordination is defined as the use of vision to guide hand movements such as reaching and grasping and is essential for upper extremity dexterity. [13] Sequence of normal eye-hand co-ordination is as follows: 1) Detection of target by the eyes, 2) focusing attention, 3) Perceptual system identifying the target location, 4) cognitive planning and programming of reaching movement and 5) activation of the required muscles of the upper extremity to initiate the action. [14] A physiotherapist treats a child with cerebral palsy with a broad goal of improving independence and increasing quality of life both for them and their parents. The incidence of visual impairment in children with CP is high. [11] Impaired vision can interfere in the growth emotionally as well as physically. Vision is the motivator for head control, awareness of body parts (hand regard) and reaching activities. Various factors like level of spasticity, tightness, voluntary control, cognition can affect motor development along with vision. For producing controlled, accurate and rapid movements, eyes, arms, hands and fingers-all should be used in an integrated manner. [13] Eye care is an important point of entry into the health care system. Vision problems can interfere with children's abilities to perform to their potential. [15] The correlation between hand function and visual impairments can help early identification and correction to help achievement of milestones. But in this regard there is dearth of literature. Hence the need of study to find correlation of visual impairments with hand function in children with cerebral palsy.

MATERIALS AND METHODS

It was a cross-sectional, observational study conducted in the Physiotherapy centre and Ophthalmology department of a tertiary hospital. Children with cerebral palsy (CwCP) visiting the physiotherapy O.P.D for their routine treatment in the duration of 6 months are the study population recruited through convenient sampling technique. Since the study was a hypothesis generating study, there was no requirement of formal sample size collection. Based on the enrolment record of new patients in the O.P.D a year before the study, sample size of total 36[30+6(dropouts)] was decided upon. Total 50 children coming to Physiotherapy department were screened according to the inclusion and exclusion criteria, out of which 41 children with cerebral palsy were included in the study. The inclusion Criteria was a) children with ante-natal, peri-natal and post-natal events of neurological damage. b) Age criteria: 2 yrs-10 yrs and the exclusion criteria was a) Uncontrolled epilepsy b) Auditory loss or impairment c) severe deformity or tightness. This study was conducted during the routine physiotherapy sessions of the child. The study purpose, procedure and all aspects mentioned in the Inform Consent Document (ICD) were explained to the parent or guardian of the child and written consent was taken. Also, wherever applicable, for children above 7 years of age-the child's assent was taken separately after the study procedure was explained. The child was evaluated for Physiotherapeutic assessment along with Manual Ability Classification System (MACS) scale [5,6,16] during their routine Physiotherapy visits. The child was sent to the ophthalmology OPD for ophthalmic evaluation within the same campus where in addition to the routine visual assessments, the child was assessed for:

1. Visual acuity (using either Snellen's chart/ Lea symbols chart/ Teller Acuity Cards aka TAC cards-depending on what the child responded to appropriately). [15,17,18] Tests performed were age and ability dependent. Fixation preference test can be used for children from 0-2.11 yrs of age; Lea Symbols chart for children between 3-5.11 yrs and Snellen Acuity chart for children above 6 yrs. [15] To be tested using Lea symbols. chart or Snellen's chart, the child should be able to read letters or identify shapes (star, house, bell, etc.). So in children who could not respond in such a manner, visual acuity was tested using Fixation Preference tests. Also in children who were in VCS level 4 or less, visual acuity could not be assessed even with fixation preference test.
2. Refractive error (by cyclotropic retinoscopy-atropinisation / CTC regimen) [15]
3. Binocular vision which included testing for a)Binocular Singular Vision(BSV)-Worth's four dot test, b) stereopsis using TNO chart, [15] c) Strabismus using cover-uncover test, alternate cover test d) Amblyopia-based on visual acuity findings of both eyes tested separately.
4. Ocular motility-which included tests for Nystagmus, oculomotor apraxia.
5. Visual Classification scale (VCS) [3]-where the child's level of functional vision was interpreted based on all the

above tests and other routine eye examinations.

Functional level	Clinical visual performance
1	Pupillary responses only
2	Minimal light perception or OKN positive or Negative
3	Fixation and gaze shift to a targets
4	Fixation, gaze shift, smooth pursuit , visual function may be limited in range, GA testing: unreliable
5	Fixation, gaze shift, smooth pursuit, scanning and detail discrimination: ability to distinguish detail on GA test
5A	Low GA (<2.0 cpd)
5B	Functional GA (2.0–8.0 cpd)

cpd – cycles per degree; GA – grating acuity.

Apart from the diagnosis arrived at regarding vision of a child with CP through regular evaluation, the VCS was effective in predicting an additional 13% - 15% of the child's visual function. [3]

The children required 3-4 sessions for complete vision assessment which were conducted during their routine physiotherapy appointments. During the course of the study, there were 8 drop-outs, so the final sample size was 33.

Statistical Methods

The statistical analysis was performed using GraphPad Prism 8.1.1. Qualitative data like gender, visual acuity, presence of binocular single vision (BSV), refractive error, squint, amblyopia, nystagmus, occulomotor apraxia (OMA), and levels of Visual Classification Scale (VCS) were expressed as frequency and percentages. For statistical purposes, the presence or absence of all visual parameters except VCS and except MACS were assigned numerical values 0 & 1 depending on the direction of the two variables being correlated. All the parameters were tested for normality using the Shapiro Wilk test. The data did not follow normal distribution. The correlation analysis was done between MACS and each of the vision parameters namely, VCS, visual acuity, refractive error, BSV, strabismus, amblyopia, nystagmus, OMA and stereopsis using Spearman Rank correlation test. P value less than 0.05 was considered significant.

RESULTS

Table 1: Distribution of types of cerebral palsy

Types	Quadri-plegic	Sp. Diplegic	Hemi-plegic	Hypotonic	Dystonic	Dyskinetic	Total
Frequency	12	7	7	4	2	1	33

Table 2: Distribution of the levels of Manual Ability Classification System(MACS)

Levels	Level I	Level II	Level III	Level IV	Level V	Total
Frequency	0	2	7	5	19	33

Table 3: Distribution of the levels of Visual Classification Scale (VCS)

Level 1	Level 2	Level 3	Level 4	Level 5A	Level 5B	Observations
0	2	2	5	4	20	33

Table 4: Correlation analysis between MACS and the different visual parameters

	p value	Spearman's co-eff "r"	Significant	No. Of pairs correlated
MACS vs. VCS	<0.05	0.5554	Yes	33
MACS vs. Visual acuity	<0.05	0.5596	Yes	33
MACS vs. Refractive error	>0.05	0.0000	No	33
MACS vs. BSV	>0.05	0.2925	No	33
MACS vs. Strabismus	>0.05	0.1804	No	33
MACS vs. Amblyopia	>0.05	0.2228	No	22
MACS vs.Nystagmaus	>0.05	0.2180	No	33
MACS vs. Occulomotor Apraxia	>0.05	0.2574	No	27
MACS vs. Stereopsis	>0.05	0.3411	No	14

Certain visual parameters such as amblyopia, stereopsis and occulomotor apraxia could not be assessed in all the children due to limitations in their ability to give appropriate response, availability of alternate test equipments, etc. Thus in those 3 parameters mentioned above, only findings of the number of children who allowed the assessment were correlated with their hand function scores.

DISCUSSION

Eye hand co-ordination is very essential for upper extremity dexterity. [13] During normal development, control of task performance changes with age i.e. more of feedforward control at around 5-6 yrs of age; incorporation of visual feedback mechanisms to guide the reach begins at 7-8 yrs; and at 9-11 yrs, more refined visuomotor behaviour is seen with respect to reach as well as grasp. [19] Controlled, accurate and rapid movements require integrated use of eyes, arms, hands and fingers. [13] The purpose of this study was to determine the visual impairments in children with CP (CwCP) and its correlation with hand function. Moderate correlation was seen between MACS-VCS and MACS-Visual acuity.

The Visual Classification Scale (VCS) consists of 5 levels and subjects were categorized in the appropriate level based on their basic ophthalmologic examination. The VCS scores were based on papillary reflex, response to light, fixation on object, saccades and pursuits. The VCS also served as an indicator of whether visual acuity is assessable in a child or not. Those children with VCS score of 4 and less cannot be tested for acuity because in them even the grating acuity testing (Fixation preference test) is unreliable as mentioned in the VCS scale. Moderate correlation between VCS and MACS suggests influence of visual abilities on hand function and vice-versa.

Visual acuity is crucial for identification of environmental stimulus. Acuity of Vision is clarity of vision. In case of growing child presence and identification of novel toy initiates curiosity and motor behaviour to reach out, manipulate, learn and play. In this study, impairment in visual acuity was classified as follows: a) less than 20/20 to 20/60-Mild impairment; b) less than 20/60 to 20/200-moderate impairment; c) less than 20/200-severe impairment. The results showed that visual acuity was impaired in more than 80% of the study population. 10, 8 and 9 out of 33 had severe, moderate and mild impairment respectively. Findings of visual acuity correlated moderately with MACS findings. Impaired acuity would affect the quality of visual input received about the objects in the environment. This will result in lack or reduction of motivation to explore surroundings and also hand manipulation abilities. This would in turn affect adversely the development of eye-hand coordination and thus the achievement of fine motor milestones. In this study it was seen that, CwCP belonging to MACS levels 4 and 5 had severely impaired visual acuity for their age.

Refractive error also causes blurring of vision. 55% (18 out of 33) of the study population were found to have refractive errors amongst which 1 had myopia, 9 had hypermetropia and 8 had astigmatism. No correlation was seen between refractive errors and MACS in this study. CwCP with refractive error were given corrective glasses and parents were counselled to make their child wear it for major part of the day. A retrospective study by Park et al. (2016) investigated the ocular findings in children with spastic cerebral palsy and found high prevalence of refractive errors (53.3%) and strabismus amongst their study population. [20] A study by Paloma Sobrado et.al. (1999) stated that in children with CP and other neuromotor disabilities, refractive error is usually a common cause of amblyopia in early ages. [21] Early correction of refractive error in these children is suggested to help therapy goals.

Binocular vision implies the blending of sight from the two eyes to form a single, three dimensional percept.

Binocular vision was studied with examination of binocular singular vision, strabismus, amblyopia and stereopsis. Binocular singular vision allows fusion of bilateral visual fields to make one clear picture from the observed environment. 52% i.e. 17 out of 33 CwCP did not have binocular singular vision. Impairment of this causes disparity leading to confusion in visual perception, double vision, etc. Strabismus leads to change in optical axis causing disparity between singular visions. So, with impaired binocular singular vision and /or strabismus, tracking of movement in the environment as in a moving toy car or usage of pen in hand or on paper will not be registered as a cohesive picture hence will not be an interesting situation, thus inadequately motivating usage of hands. 58% (19 out of 33) subjects in this study were found to have strabismus.

Amblyopia is reduced visual acuity in one eye as a result of abnormal binocular mechanisms during maturation of the visual system. There is evident dominance of one eye usage over the other causing weaker eye getting weaker. Suppression of this weaker eye is seen causing more reliance on the dominant singular visual field. Thus affecting stereopsis as spatial information is more reliable with binocular vision as compared to monocular vision. [19] Only 22 out of 33 subjects could be assessed for the presence of amblyopia, as others did not allow monocular testing for visual acuity. Out of 22, 11 had amblyopia. Stereopsis could not be assessed in 19 of the 33 children with TNO chart as it requires the child to be able to identify and point to appropriate images during testing. Affected stereopsis impairs the 3 dimensional image of toy for the child thus preventing him/her from manipulating it with curiosity. This further impairs the need to use hands and fingers in variety of ways thus delaying manual ability. Any one or more amongst binocular singular vision, stereopsis, strabismus and amblyopia can disturb binocular vision. There are studies that have inferred that binocular vision promotes control of manipulation, reach and balance related functions more than monocular vision. [22,23] So its impairment will have a great impact on the child's eye-hand co-ordination and hand function abilities.

Amblyopic children took almost double the time in their final approach to objects and made many more errors in grip positioning and reach direction when compared with their non-amblyopic counterparts. [19] Critical period of developing amblyopia in children extends up to 8 yrs of age and is relatively easy to correct until that age by improving the quality of visual input in that eye but becomes increasingly resistant to correction with age. [19] Amblyopia affects manual dexterity tasks that require speed and accuracy significantly. Amblyopes face most difficulty while performing timed motor tasks. Neurological changes associated with strabismus have negative influence on the development of eye-hand co-ordination. Amongst visual acuity, strabismus, refractive error and binocular function; strabismus was found to be a significant factor influencing fine motor performance. [24] In the current study, no correlation was found between MACS and any of the binocular vision components. Interventions prescribed for those with impaired binocular vision components were eye patching regime (for amblyopia, strabismus), corrective glasses (for strabismus) and vision therapy to restore binocularity and stereopsis. Effects of these on children were not assessed since it was not the aim.

Those with binocular vision impairment tend to compensate for defective visual guidance through tactile &/or proprioceptive feedback as demonstrated by increased post-contact adjustments in their grasps and longer contacts with the objects before lifting it. Impaired or decreased stereovision has a more negative impact on timed visuomotor tasks than visual acuity loss in children with impaired binocular vision. Eye-hand co-ordination skills require high grade binocular stereovision and adequate visual acuity in each eye cannot compensate for its loss even over long term. [19] Though a correlation could not be established in this current study between binocular vision components and hand function outcome MACS, more than 50% of the study population had impaired binocular vision. Intervention to promote restoration of binocularity may accelerate some recovery of reach-to-grasp. [19]

Ocular motility allows the child to find favorite or novel toy from variety of toys present in his environment. Difficulty in moving eyes accordingly to interact with surroundings impairs the need to use hands for searching and thus will affect normal development. Nystagmus is a regular and rhythmic to-and-fro involuntary oscillatory movement of the eyes in horizontal or vertical or circular direction. Only 21% (7 out of 33) had nystagmus in the current study. Oculomotor apraxia was detected in only 2 out of the 27 subjects who could be assessed. No correlation was found between MACS and ocular motility components i.e. nystagmus and OMA. Also ocular motility was tertiary outcome.

As seen above, no correlation could be established between hand function scale MACS and visual parameters-refractive error, binocular vision components, ocular motility components; this could be attributed to the variation in the number of subjects in each level of MACS. Also, certain visual assessments could not be done owing to cognitive reasons, age of included children and equipments available. The variation in the number of subjects in each level of MACS makes it difficult to generalize the results of this study. Studying the details of visual parameters and their assessments were beyond the scope of this study. Also, this study highlighted the importance of detailed visual assessment in children with CP in addition to routine eye examination. Future studies in this regard can look at assessing change in hand function with corrective measures for visual impairments.

CONCLUSION

Moderate correlation between MACS and VCS, visual acuity suggests the importance of examining the visual system and modification of therapeutic goals incorporating the visual findings. Awareness & Examination of visual problems at early age will help CwCP in their overall eye-hand co-ordination and upper extremity function training by physiotherapist. Physiotherapeutic goals should be set and modified taking into account the visual impairments of the child.

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