

Correlation of Short Sensory Profile with MRI Findings in Children with Cerebral Palsy of Age 3 To 10 Years: A Cross-Sectional Study

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Abstract- Background: In cerebral palsy (CP), sensory functions are essential component to achieve motor function, motor control and development which affects activity in daily living. MRI scan findings are an important part of initial diagnostic evaluation of CP. MRI scan are valid tool and proved to be an outcome measure for findings motor deficits in children with cerebral palsy, but percentage varies significantly. Short sensory profile (SSP) is a valid tool to evaluate the sensory deficits in children with CP. It evaluates the sensory deficits (vestibular, olfactory, auditory, visual, proprioceptive, tactile) which can help to understand the sensory processing among children with CP. There is scarcity of data for correlation of SSP with MRI scan findings in children with CP of age 3 to 10 years.

Methods: Total 50 children with diagnosis of cerebral palsy were included (29 males, 21 female) and evaluated for short sensory profile filled by parent of child with cp. SSP was then correlated with MRI scan taken within span of 6 months of duration with scoring system. SSP score was classified into grades of severity of affection and MRI findings was also classified according to area affection in brain.

Results: Total 76% children with CP showed abnormalities in MRI scan. It was also observed that in SSP, the sub-section wise sensory impairment was found in, low energy(100%), under-responsive/seek sensation(96%), auditory sensitivity(90%), tactile sensitivity(80%), visual sensitivity(66%), movement sensitivity(48%), taste/smell sensitivity(22%). It was observed that when correlated SSP with MRI findings there was moderate inverse negative correlation present ($r=-0.061$).

Conclusion: The sensory processing function revealed by SSP scores showed moderate negative correlation with MRI scan findings in children with cerebral palsy of age 3-10 years.

Keywords- Short Sensory Profile(SSP), Cerebral Palsy(CP), MRI Findings, Sensory Processing

I. INTRODUCTION

Cerebral Palsy(CP), a group of non-progressive disorder of movement, posture and often accompanied with sensory disturbance which is due to defect or lesion in the developing brain [1-7]. CP may be classified according to the movement disorders are spastic, hypotonic, dyskinetic and ataxia and according to the anatomical locations are hemiplegic, diplegic, quadriplegic and tetraplegic [1]. There is no single specific cause of the cerebral palsy, it occur in the prenatal stage of development due to vascular events, maternal infection with congenital problems and in perinatal stage or neonatal time period due to problems during labor and delivery whereas other causes such as hypoxic-ischemic encephalopathy, neonatal stroke, severe hypoglycaemia, neonatal jaundice, infection and in the postnatal or post neonatal time periods due to metabolic encephalopathy, infection and injuries etc. [1].

According to World Health Organization (WHO) incidence of CP in India is 3.8% of the population i.e. 3/1000 live birth.⁸ Nearly 15-20% of physical disabled children are

affected by cerebral palsy [8]. Children with CP exhibit sensory as well as motor deficits [7]. Most of the children with CP suffer from sensory deficits [6]. Sensory processing includes auditory, visual, olfactory, proprioceptive, vestibular, tactile processing [6].

In most of children with CP, sensory deficits are due to the white matter lesion but percentage varies [6]. The destruction of white matter can have secondary effect of the development of cortical and thalamic region which are responsible for sensory processing [6]. Sensory impairments restrict the child's level of activity [6]. Intact sensory perception and motor capacities are essential for the development and production of skill motor gesture. Fine motor impairments are associated with sensory deficits, shows better sensory function which also shows better motor outcome [9]. Bleyenheuft and Gardon concluded that there is strong relationship between sensory and motor abilities [9]. In children with CP and normal developing children, the correlation usually found between sensory and fine motor measure varies with other such as age and cognitive level or maturational development [9].

MRI (magnetic resonance imaging) scan is an important part of initial diagnostic evaluation of CP [10]. According to the various studies mostly children with cerebral palsy showed abnormal MRI whereas few showed normal [11-14]. The most common MRI scan finding children with cerebral palsy are periventricular white matter injury, diffuse grey matter injury, cerebral vascular accident, cerebral malformation, cortical and cortical/subcortical atrophy, basal ganglia lesions [15,16]. Impairments and activities may strongly depend on the anatomical characterization of underlying brain lesion that is presumed timing, location and extent [17]. Neuro-imaging helps to elucidating the timing of injury and understanding the aetiology and pathogenesis underlying CP [18]. Neuro-imaging studies suggest a direct association between abnormalities in the somatosensory cortex and diminish somatosensory function in CP [7]. The MRI/CT scan may help to identify the type and timing of lesion that cause CP and it may help to provide early prognosis of sensory outcome but also occurrence and severity of associated disabilities [19]. Structural MRI assist in the elucidating the pathogenesis of CP and also show correlation with clinical finding such as motor type and function [16]. Assessment can be used to identify sensory processing disorder this include child and caregiver interview, assessment of sensory ability and clinical observation [6]. So, it can be stated that in children with CP for better comprehension of sensory function and sensory processing, the somatosensory inputs are essential component of motor function, motor control and motor development. MRI scan provide additional information by understanding aetiology and pathogenesis in depth and help in better prognosis [16]. There is need to find out relationship between structural MRI findings and functional sensory processing deficits in children with cerebral palsy so that evaluation and treatment can be targeted for both sensory as well as motor defect simultaneously in order to achieve functional independence in rehabilitation. To date there is scarcity in literature, regarding the correlation of short sensory profile with MRI finding in children with CP of age 3-10 years.

II. RELATED WORK

Arielle Springer et al (2019) Conducted study on Profile of children with cerebral palsy spectrum disorder and a normal MRI study. In this study, only participants who had undergone a clinically ordered MRI were included in the analysis. Neuroimaging classified according to a system containing 8 categories: normal, deep gray matter injury, white matter injury (bilateral), white matter and cortical injury, near-total brain injury, focal insult, malformation, and other. Since the goal of this study was to compare participants with a normal MRI with those who had received an abnormal one, the 8 neuroimaging categories were then divided into 2 main categories: normal (defined as an MRI where no detectable abnormality has been found) and abnormal MRI. This had information on 1,839 children with CP and an MRI. Of those, 848 had not had their MRI classified by a neuroradiologist according to our

classification scheme and were thus excluded. Of the 991 participants with a diagnosis of CP and a classified MRI, 103 (10.4%) had a normal MRI, while 888 (89.6%) had an abnormal MRI (89.6%) (table3). In participants with a normal MRI, the most prevalent CP subtype was spastic diplegia (36.9%; 38/103), followed by the dyskinetic (24.3%; 25/103), spastic tri/quadruplegic (21.4%; 22/103), spastic hemiplegic (12.6%; 13/103), and ataxic/hypotonic CP variants (4.8%; 5/103). In the participants with an abnormal MRI, spastic hemiplegia was the most prevalent CP subtype (40.1%; 356/888), followed by spastic tri/quadruplegia (31, 4%; 279/888), spastic diplegia (17, 9%; 159/888), dyskinesia (9, 2%; 82/888), and ataxia/hypotonia (1, 4%; 12/888). Hence the distribution of neuroimaging findings across CP subtypes therefore showed a higher prevalence of normal MRI's in patients with the dyskinetic, ataxic/hypotonic, and spastic diplegic forms. Normal MRIs were associated with lack of perinatal adversity as well as with the dyskinetic, ataxic/hypotonic, and spastic diplegic CP subtypes[10].

Martin Bax et al. (2006) conducted study on Clinical and MRI correlates of cerebral palsy. It is a cross sectional study. Five hundred eighty-five children with CP were identified who had been born between 1996 and 1999; 431 children were clinically assessed and 351 had a Brain MRI scan. Their main Outcome Measures was Standardized clinical examination results, parental questionnaire responses, MRI results, and obstetric, genetic, and metabolic data from medical records .They found important findings include the high rate of infections reported by mothers during pregnancy (n=158 [39.5%]). In addition, 235 children (54%) were born at terms while 47 children (10.9%) were very preterm (<28 weeks). A high rate of twins was found, with 51 children (12%) known to be from a multiple pregnancy. Clinically, 26.2% of children had hemiplegia, 34.4% had diplegia, 18.6% had quadriplegia, 14.4% had dyskinesia, 3.9% had ataxia, and 2.6% had other types of CP. Brain MRI scans showed that white-matter damage of immaturity, including periventricular leukomalacia (PVL), was the most common finding (42.5%), followed by basal ganglia lesions (12.8%), cortical/subcortical lesions (9.4%), malformations (9.1%), focal Infarcts (7.4%) and miscellaneous lesions (7.1%). Only 11.7% of these children had normal MRI findings. There were good correlations between the MRI and clinical findings. Hence, These MRI findings suggest that obstetric mishaps might have occurred in a small proportion of children with cp. A systematic approach to identifying and treating maternal infections needs to be developed. Multiple pregnancies should be monitored closely, and the causes of infant stroke need to be investigated further so preventive strategies can be formulated. All children with CP should have an MRI scan to provide information on the timing and extent of the lesion [16].

III. METHODOLOGY

A cross sectional study was carried out in year 2021-2022 in 6 month duration at Physiotherapy OPD and tertiary care hospital in 3 to 10 years cerebral palsy children of both genders (Table 1). A convenient sampling method was used to include diagnosed cases of children with cerebral palsy by pediatrician who had taken MRI scan within span of 6 months duration and whose parents willing to participate in the study whereas any known case of autism spectrum disorder or any attention deficit hyperactivity disorder were excluded from the study. The Short Sensory Profile (SSP) Caregiver Questionnaire [SP; Dunn et al, 1999] was used to measure the possible contributions of sensory processing to children's daily performance patterns by providing information about their tendencies to respond to stimuli and which sensory systems are likely contributing or creating barriers to functional performance [6,15].

The Short Sensory Profile (SSP) comprises of 38-items (7 sub-components i.e. Tactile Sensitivity, Taste/smell sensitivity, Movement Sensitivity, Under responsive / Seeks Sensation, Auditory Filtering, Low Energy/Weak, Visual/ Auditory Sensitivity). SSP scores were further divided into normal, mild, moderate, severe and very severe. The MRI scan report was analyzed and graded according to area affected mentioned in report (Table 2).

Total 29 scores were given and according to areas of affection further grades of affection were given under 5 categories i.e. normal, mild, moderate, severe and very severe (Table 2). In classification system, different areas of brain were allotted total score of 29. Total 11 brain areas, according to MRI findings were selected for scoring, whereas grey matter and white matter affection has been given separated score. Hence, total 13 areas had been selected for score system according to MRI.

Out of 13 brain areas, 6 areas were divided into sub-area i.e. cerebrum into 8 [(frontal lobe(2) , parietal lobe (2), temporal lobe(2), occipital lobe(2)], ventricles into 4 [lateral ventricles (2), third ventricle(1), fourth ventricle(1)], basal ganglia into 3(caudate, putamen, globus pallidus), thalamus into 2, cerebellum into 3 (2 cerebellar lobe, vermis), sella/parasella into 2 each ,whereas other 5 areas i.e. corpus callosum(1), pons(1), midbrain(1), medulla oblongata(1) and internal capsule(1)]given one marks each. Separately for affection of grey matter(1) and white matter(1) one mark each was given.

DATA ANALYSIS

Data was entered in MS Excel and Epi info software version 7.0 was utilized. Descriptive statistic was used to compare quantitative variables i.e. SSP Score and MRI Score with mean and standard deviation while frequency and percentage was used to summarize categorical (qualitative variables grades of scales i.e SSP and MRI Scores). Perception of barrier and facilitators was

estimated as percentage along with 95% confidence interval.

IV. RESULTS AND DISCUSSION

RESULTS

Table1: Distribution And Percentage Of Children With Cerebral Palsy With Age From 3 To 10 Years.

Age (Years)	No. of CP children	%
3 – 3.11	29	58
4 – 4.11	10	20
5 – 5.11	1	2
6 – 6.11	4	8
7 – 7.11	2	4
8 – 8.11	0	0
9 – 9.11	1	2
10 – 10.11	3	6

From Table 1, it was found that 78% children belongs age group of 3-4.11 years whereas 18% children belongs to age group of 5-10.11 years.

Table 2: Classification System Of SSP And MRI Scan Findings Used In Present Study According To Scores.

SSP classification according to score	New classification of SSP used in current study	Classification according to MRI findings score out of total 29 score
Typical performance (190-155)	Normal (190-155)	Normal (0)
Probable performance (154-142)	Mild (154-142)	Mild (1-5)
Definite performance (141-38)	Moderate (141-121)	Moderate (6-15)
	Severe (120-100)	Severe (16-25)
	Very severe (99-38)	Very severe (26-29)

Total 50 children with cerebral palsy were included in present study of age group 3to 10 years [28 males (56%), 22 females (44%)].

Table3: MRI Severity Grading In Children With Cerebral Palsy Of Age 3 To 10 Years. SSP- Short sensory profile

Grades of severity of MRI finding in children with cerebral palsy	No. of children out of 50 with grades of severity of MRI findings	Percentage of children (%) according to grades of severity of MRI findings
Normal	12	24
Mild	05	10
Moderate	30	60
Severe	03	6
Very Severe	00	0

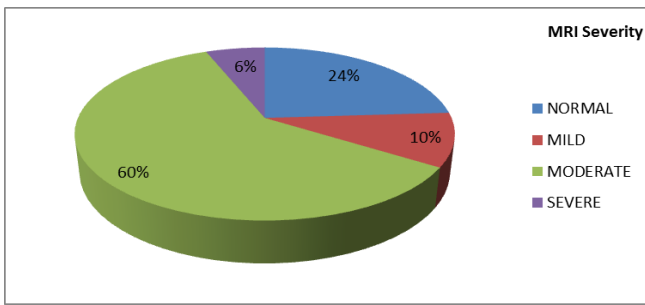


Figure 1: Percentage Of Children With Grades Of Severity Of MRI Finding In Children With Cerebral Palsy

From table 2 and Figure 1, it was found that in total 50 cerebral palsy children, MRI findings were recorded and analyzed and It was observed that 12 (24%) children were showing normal MRI findings though clinically showed some abnormal affection in motor and postural function. It was also observed that 5 (10%) children showed mild MRI affection, 30 (60%) showed moderate MRI affection and 3(6%) showed severe MRI affection. It also indicated that even though the children showed clinical signs of cerebral palsy the MRI findings may not show any abnormality in 24% population. Whereas, 38 (76%) children with cerebral palsy showed definite (grade: mild, moderate and severe) affection in MRI findings.

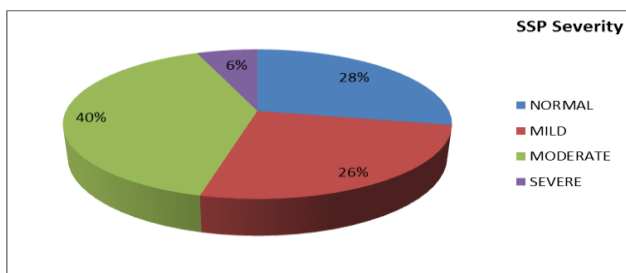


Figure 2: Percentage Of Children With Cerebral Palsy With Grades Of Severity Of Affection Of Short Sensory Profile (SSP)

Table 4: Brain Areas And Side Of Cerebral Lobe Affected In MRI Among Children With Cerebral Palsy

Area of brain	Name and/or Side of brain area	Total 29 area	MRI showed No. of children affected with lobe/area of brain
Cerebral frontal lobe	Left	1	28
	Right	1	27
Cerebral parietal lobe	Left	1	30
	Right	1	30
Cerebral temporal lobe	Left	1	28
	Right	1	28
Cerebral occipital lobe	Left	1	29
	Right	1	30
Ventricular system	Ventricles lateral left	1	20
	Ventricles lateral right	1	21
	Ventricle third	1	5
	Ventricle fourth	1	3
Basal ganglia	Caudate n.	1	2
	Putamen	1	3

	Globus pallidus	1	3
Thalamus	Left	1	12
	Right	1	12
Cerebellum	Left	1	5
	Right	1	5
	Vermis	1	5
Corpus callosum		1	15
Midbrain		1	2
Pons		1	4
Medulla oblongata		1	4
Internal capsule		1	2
Sella		1	1
Parasella		1	0
Grey matter		1	4
White matter		1	21

Table 5: Functions of brain area according to sensory profile

Brain area	Brain area functions	Affection of no. Of children out of 50(n)
Frontal lobe function	Movement sensitivity	24
	Underresponsive/seek sensitivity.	48
	Low energy	50
Parital lobe function	Tactile sensitivity	40
	Movement sensitivity	22
	Taste and smell	11
Temporal lobe function	Auditory sensitivity	45
	Visual s.	33
Occipital lobe function	Visual sensitivity	33
	Occipital lobe affection in mri	31
Thalamus function	Tactile s.	40
	Taste/smell	11
	Movement s.	24
	Underresponsive/seek s.	48
	Auditory filtration	45
	Low energy	50
Corpus callosum function	Visual s.	33
	Movement s.	24
	Underresponsive/seek s.	48
Basal ganglia function	Low energy	50
	Underresponsive/seek s.	48
	Low energy	50
Cerebellar function	Movement s.	24
	Underresponsive/seek s.	48
	Low energy	50
Mid brain function	Auditory filtration	45
	Visual s.	29
	Low energy	50
Pons function	Low energy	50
	Taste s.	11
	Movement s.	24
	Auditory filtration.	45
	Visual s.	33
Medulla oblongata function	Low energy	50
	Tactile s.	40
	Movement s.	24
	Underresponsive/seek s.	48
	Visual s.	33
Sella/ PARASELLA function	Low energy	50
	Tactile s.	40
Sella/ PARASELLA function	Auditory filtration	45
	Visual/auditory s.	33

Table 6: SSP Severity Versus MRI Severity Cross Tabulation Among Children With Cerebral Palsy Of Age 3 To 10 Years

SSP Severity Versus MRI Severity		MRI Severity		Total
		Mild+ Moderate+ Severe	Normal	
SSP Severity	Mild+ Moderate+ Severe	28	8	36
	Normal	10	4	14
Total		38	12	50

Table 7: Comparative Correlational Parameters Of Short Sensory Profile(SSP) With MRI Findings Scores

Parameter	Estimate
Sensitivity	73.68%
Specificity	33.33%
Positive Predictive Value	77.78%
Negative Predictive Value	28.57%
Diagnostic Accuracy	64%
Likelihood ratio of a Positive Test	1.105
Likelihood ratio of a Negative Test	0.7895
Diagnostic Odds	1.4
Cohen's kappa (k)	0.06639

(Table 7) The sensitivity of 73.68% of MRI findings with SSP is indicative of good ability of diagnosing affection of sensory processing with MRI score affection among children with CP. The positive predictive value indicated that 77.78% children with cerebral palsy, who had showed more affected MRI scores/findings, had also showed more SSP score affection when compared. Hence it can be interpreted that SSP scores can show good intra-rater reliability between SSP and MRI findings.

Table 8: Descriptive Statistics (Correlational Coefficient-r) Of Mean Scores of SSP With MRI Scores In Children With Cerebral Palsy

Descriptive Statistics		
	Mean \pm SD	Karl Pearson's Correlation (r)
SSP scores out of total 191	143.84 \pm 14.88	-0.061
MRI scan findings score out of total 29	7.58 \pm 6.08	

Table 8 showed moderate negative correlation coefficient (r) between SSP scores with MRI scan score ($r = -0.061$) in children with CP.

DISCUSSION

The study aimed to find out the correlation of short sensory profile with MRI scan findings in children with cerebral palsy. Nowadays, radiological diagnosis is possible and radially available investigation for children born with some complications. It was observed that in most of the cases though these radiological findings are not specific for any neurological disability but definitely these findings guide us for appropriate management. In current study all

children with CP (n=50) were investigated with MRI findings and clinically diagnosed by paediatrician, because MRI is known to be more sensitive investigation. Present study found that among children with cerebral palsy in MRI scan the percentage of cerebrum affection (i.e. parietal lobe 66%, frontal 62%, temporal lobe 62%, occipital lobe 62%), followed by lateral ventricles (48%), corpus callosum (26%), thalamus(10%), third ventricle(10%), cerebellum (10%), pons(8%), medulla oblongata(8%), fourth ventricle(6%), basal ganglia(6%), midbrain(4%), internal capsule(4%), sella/parasella(2%). Hence, cerebral damage is most common cause of cerebral palsy and children with CP are presented with motor as well as sensory impairments.

In current study, there were 56% male and 44% female and also found that males has more severe grade of MRI findings score than females. In previous study, found more percentage of male are affected than female as well as stated that gender differences in the immature brain injuries have been explained with greater biological vulnerability of male children. The incidence of cerebral palsy is significantly higher in males than females, due to different resistance to hypoxia and higher incidence of preterm births in males [20-24]. The female hormones possess neuro-protective effect and there is larger number of connections and better dendritic organization in females than males, so the better post-lesion reorganization is possible among females [23-26].

In present study, out of 50, 38 (76%) children with cerebral palsy showed abnormalities in MRI scan findings. Previous study by R Yin and colleagues (2001) found MRI abnormalities in 39 (92.85%) out of the 42 scans and stated that MRI was useful in revealing underlying brain abnormalities [11]. Kulak W et al. (2008) studied congenital brain malformations in Children with Spastic Cerebral Palsy, found that CP were evident on MRI in 124 (95.3%) subjects and stated that the neuroimaging result in children with CP may help to determine the etiology and make better prognosis of CP [12]. According to Robinson MN (2009), out of 221 children (126 males, 95 females) with CP, MRI was available for 154 (70%) individuals and abnormalities were identified in 129 (84%) [13]. Kayle Towsley et al. (2011) conducted study in neuroimaging findings in children with CP and found 87% of participants had documented cerebral abnormalities [14].

In the present study, the analysis of the children with CP according to the age group, 3-5 year age group showed more abnormal MRI findings than 6-8yrs and 9-10 years. The age group, as the age advances 6-8yrs and 9 -10 years children may have better reorganisation in brain structures as well present study found normal MRI imaging results among 12 diagnosed CP children out of 50 cases (24%). Similarly, study done by Kayle Towsley and colleagues also found that 13.1% CP children had normal MRI findings [14]. These children may have cerebral lesions or abnormalities which are so subtle to be detected by neuroimaging modalities which have been used.

In present study, the sensory impairment according to SSP (Table 2), out of total 50 cerebral palsy children 46% showed definite difference (i.e. 40% moderate, 6% severe, and none belongs to very severe grade), 28% had typical performance/normal whereas 26% had probable difference/mild grade according to classification. It was observed that the sub-section wise sensory impairment (Table 5) found mostly in low energy (100%), under-responsive/seek sensation(96%), auditory sensitivity(90%), tactile sensitivity(80%), visual sensitivity(66%), movement sensitivity(48%), taste/smell sensitivity(22%).

The most pronounced impairment is present in the sub-section i.e. low energy/weak in which out of 50, 34 children with CP showed definite difference and 7 showed probable differences and 9 showed typical performances. Hence, it can be stated that the reduced levels of endurance and physical activity due to deficits in movement and tonus regulation observed in children with CP contributing not only for the impairments in their motor system, but also responsible for impaired modulation of sensory inputs. It was also observed that children with CP are present with second most pronounced impairment in the sub-section under-responsive/seek sensation of which 35 children showed definite difference, 3 children showed probable difference and 12 children showed typical performance, this shows that children with CP are present with difficulty in fine activities, distractibility, emotional disturbance and hyperactivity. This may due to white matter lesions, pathological changes in the cortical structure or deficits in afferent axons. The next sub-section i.e. CP children with definite difference, 7 children with probable difference and 34 with typical performance were present. Followed by impairments in movement sensitivity, impairments like visual sensitivity, auditory sensitivity and taste/smell sensitivity are affected in cerebral palsy children. In present study, the correlation of sensory impairment and MRI findings was found that, children with frontal lobe affection showed more impairment with low energy followed by under-responsive/seek sensation and movement sensitivity as it is a better correlated because frontal lobe is responsible for muscle weakness and endurance which is a motor function of brain.

Children with CP with parietal lobe affection showed more impairment in tactile sensitivity as in these children, sensory pathways are already been developed and reached their cortical destination sites before the lesion occurs hence damage to the frontal and parietal lobes may thus impact more on sensory outcome, similarly temporal lobe affection showed auditory sensitivity and occipital lobe affection showed visual sensitivity impairments, the basal ganglia injury showed low energy and under-responsive sensitivity. A study by Lisa Maillieux found that the caudate nucleus showed highest correlations with sensory function outcomes [17]. Brain activation of the caudate nucleus has been demonstrated during decision-making tasks [17]. Thalamus affection showed low energy, under-responsive/seek sensation, auditory sensitivity. Thalamus

are known for their important roles in processing sensorimotor signals and all sensory information first passes through the thalamus before reaching the cortex as act as a relay center for all signals to travel from environment to sensory-motor cortex[20,25]. The present study showed moderate sensitivity(73.68%), weak specificity(33.33%) along with diagnostic accuracy of 64% present when correlated MRI findings with SSP scores.(Table 7) The result of present study indicated that sensory processing function (i.e. SSP) of children with cerebral palsy of 3 to 10 years is moderately correlated with area affection present in MRI findings.

V. CONCLUSION AND FUTURE SCOPE

In children with CP, MRI was useful in revealing underlying brain abnormalities, but MRI finding severity scores does show strong moderate inverse correlation present between SSP and MRI findings. So present study, help to understand relation of MRI findings with sensory processing in cerebral palsy children. Similar studies can be incorporated in various neurological conditions such as brain stroke, multiple sclerosis, Parkinson's disease or other brain congenital anomalies affecting sensory processing in patient. The present study knowledge will helps physical therapist evaluate, to understand and to plan sensory integration or sensory re-education techniques at early age in children with cerebral palsy which will play as key role towards solving sensory processing problem in children with cerebral palsy as early intervention approach.

A. Abbreviations and Acronyms

Abbreviations and Acronyms

Cerebral palsy: CP, Short sensory profile: SSP, MRI-Magnetic resonance Imaging

B. Units

Angle-Degrees

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