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Sensory Integration Disorders and Balance Deficits in Children with Unilateral Spastic Cerebral Palsy: Review Article

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ABSTRACT

Background: Sensory processing refers to receiving, arranging, and interpreting sensory stimuli from the sensory system. Any aberration in this process affects the brain's interpretation of the information that comes in and the response that follows, resulting in an inappropriate emotional, behavior and motor reactions. This may impair social participation, adaptive responses, and motor skill development. Most children with spastic hemiplegia have associated sensory deficits.

Objective: This article aimed to throw the light on Sensory Integration Disorders and Balance Deficits in Children with Unilateral Spastic Cerebral Palsy.

Methods: A thorough search was carried out in PubMed, Google Scholar, and Science Direct for Cerebral palsy, Unilateral spastic cerebral palsy, Sensory integration disorders and Balance deficits through the period from 2001 to 2025. Only the most recent or comprehensive study was considered. Oral presentations, dissertations, conference abstracts, and unpublished papers are a few examples of works that weren't considered important scientific study. Documents published in languages other than English were ignored as a result of lack of translation resources.

Conclusion: Hemiplegia refers to the paralysis affecting single side of the body. It leads to muscular atrophy on the affected side, hinders gait, diminishes motor skills, and induces instability along with a decline in grip strength. Hemiplegia adversely affects the patient's QOL by impairing cerebral and spinal cord functions. Children suffering hemiplegic CP demonstrate elevated muscle tone, resulting in compromised postural control. Postural control is crucial for sustaining posture along with balance throughout bipedal walking. The maintenance of balance relies on the ongoing integration of the musculoskeletal as well as neurological systems, which provide visual, somatosensory, as well as vestibular information. This integration is impaired among patients suffering hemiplegic CP due to its impact on both key systems, adversely affecting balance.

Keywords: Cerebral palsy, Unilateral spastic cerebral palsy, Sensory integration disorders**,** Balance deficits.

INTRODUCTION

Cerebral palsy:

Cerebral palsy is a multifaceted disorder that impacts numerous motor processes, including bodily movement, control of muscles, coordination of muscles, muscle tone, reflexes, fine motor abilities, oral motor functioning and posture, as well as balance. It is not a singular disease entity. This consequently leads to diminished engagement in leisure as well as community activities, reliance on others for daily living tasks, insufficient functional strength, as well as sedentary behavior **(1)**.

Factors linked to an elevated risk for CP include congenital brain malformations, hypoxic-ischemic encephalopathy, genetic susceptibility, in utero or perinatal stroke, in vitro fertilization or assisted reproductive technology, low birth weight, elevated bilirubin levels, maternal clotting disorders, multiple gestations, maternal-fetal infections, neonatal seizures, and neonatal sepsis or meningitis. Also, post-neonatal meningitis, post-neonatal traumatic brain injury, and preterm birth **(2)**.

Unilateral spastic cerebral palsy:

Hemiplegia is a nonprogressive condition characterized by paralysis on a single side of the body, resulting from trauma to the brain or spinal cord. The extent of hemiplegic symptoms varies based on the injury's location as well as severity. Congenital hemiplegia denotes an onset of hemiplegia prior to, during, or within the initial two years of life. Acquired hemiplegia denotes hemiplegia that develops in later stages of life **(3)**.

Common causes of unilateral spastic CP include damage to the motor areas along with the corticospinal tract (CST), as well as hemi-brain atrophy, periventricular lesions and brain malformations, or post hemorrhagic porencephaly **(4)**.

Motor control deficits, persistence of primitive reflexes, insufficient development of equilibrium and balance responses, muscle contractures, and abnormal postures are the primary causes of balance issues observed in these children. Furthermore, children with spastic hemiplegia experience difficulties with muscular coordination as well as sensory-motor integration, which adversely impact postural control as well as balance **(5)**.

Beside motor impairments, children having unilateral spastic CP frequently demonstrate sensory deficits in their hands. The motor control theory suggests that sensations can influence movement and adversely affecting the reacquisition of skilled hand movements. They have a variety of sensory processing

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deficiencies, the most common of which are related to tactile processing and include astereognosis, impaired two-point discrimination, and problems with position perception [(6)].

Sensory integration:

The neurobiological process of sensory processing entails the brain systems' registration along with modulation of sensory data. Additionally, sensory input from the body or environment needs to be efficiently organized and integrated internally. This approach allows for the management of diverse energy forms generated by a single source or event as a unified entity, facilitating appropriate and effective responses to environmental demands. Because it aids in the simplification of the environment and leads to considerable behavioral efficiency advantages, this enables the individual to carry out every day functional activities and engage in meaningful occupations [(7, 8)]. Sensory integration disorder (SID) is characterized by the inadequate neurological processing of sensory information, resulting in difficulties with learning and development as well as behavior" [(9)].

Sensory modulation:

Sensory modulation disorders involve heightened or diminished responses to sensory stimuli. These interfere with engagement in daily activities such as eating, grooming, and socializing. Over-reactivity to tactile input with behavioral hyperactivity and distractibility is named "tactile defensiveness". failure to notice or register stimuli that would be salient to most children and termed "sensory registration difficulties." Children with poor registration might fail to orient to a sound or visual stimulus that most children would notice or behave as though a tactile stimulus never happened [(10)]. Nevertheless, the predominant and widely recognized taxonomy is that suggested by **Miller *et al.*** [(11)], which identifies 3 main patterns: Sensory modulation disorder, sensory-based motor disorder and sensory discrimination disorder (figure 1).

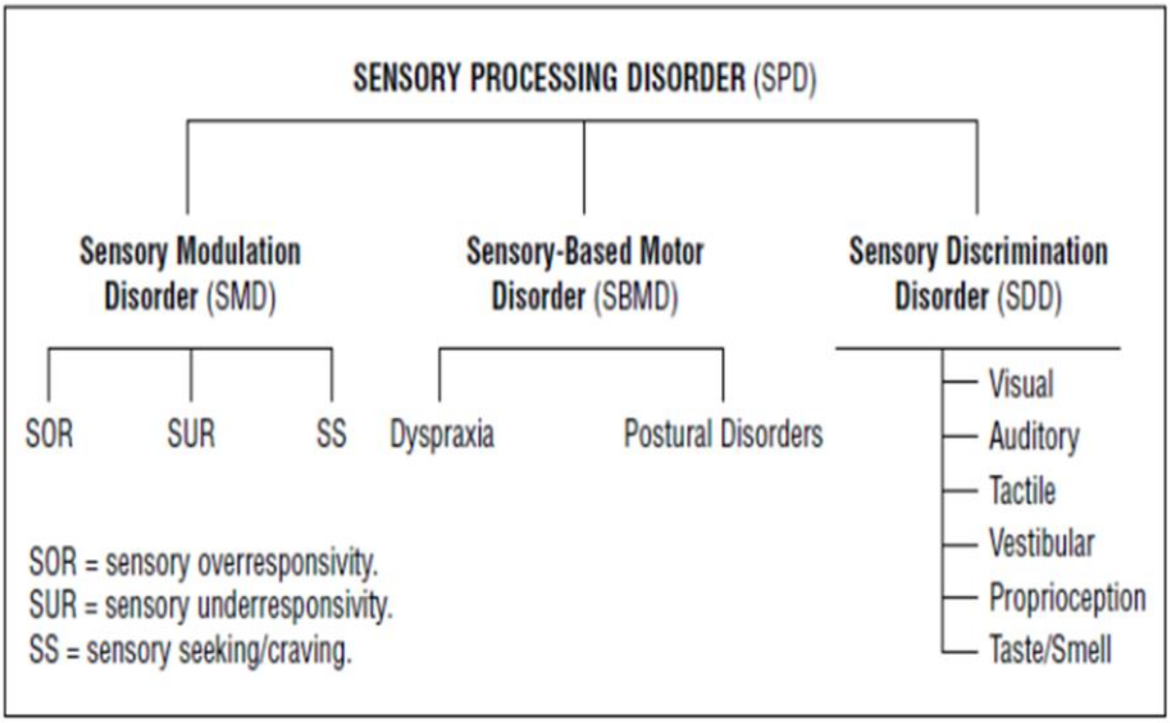

Figure (1): A proposed updated classification of sensory processing disorders [(11)].

The Relationship between motor and sensory functions:

Sensory processing disorder occurs when the brain system is unable to interpret and integrate information from the sensory modalities. Visual, auditory, tactile, Olfactory, kinesthetic, proprioceptive, and balancing or vestibular senses are among the sensory modalities. As a result, sensory information may be received naturally, but it has an abnormal impact on motor and cognitive performances [12].

Motor impairments can accompany sensory processing deficiencies, leading to motor disorders. Information from the senses guides action, as sensory inputs are centrally documented and processed to yield knowledge and feedback regarding body position in space, so enabling adaptive responses [13].

Assessment of sensory integration function

The most used tools for assessing children sensory processing are the Sensory Integration and Praxis Test (SIPT), the Sensory Processing Measure (SPM), and the Sensory Profile (SP) which has two versions [14].

The sensory integration and praxis tests (SIPT): They are a set of 17 comprehensive subtests meant to assess children aged 4 to 8 years and 11 months. The 17 subtests of the SIPT produce standardized scores that are contrasted with those of children who are normally developing on praxis abilities as well as several sensory processes, such as tactile, vestibular, proprioceptive/kinesthetic and visual modalities. The assessment focuses on the child's capacity to identify, distinguish, and perceive sensory events [15].

The sensory processing measure (SPM): It is a uniform, psychometrically valid evaluation tool created by Western Psychological Services. It recognizes sensory as well as environmental challenges that may impact a child's performance in educational settings, at home and within the society. The SPM's design enables clinicians to ascertain if the performance of a child is constrained by sensory processing either sensory integration issues. The SPM comprises three integrated rating scales: Home Form, primary Classroom Form and School Environments Form, which are intended to collect data on sensory processing, praxis, along with social participation among students in primary schools. It offers norm-referenced averages for 2 advanced integrative functions (praxis as well as social participation) along with 5 sensory systems (visual, auditory, tactile, proprioceptive and vestibular functioning) [16, 17].

The sensory profile (SP): It is an evaluation by parents of children's reactions to the sensory stimuli encountered in daily activities. It is used with children aged three to ten years old. The tool is intended to record sensory processing behaviors that show over response or under response to sensory input, causing problems with daily tasks [18]. The SP categorizes sensory processing into six domains: Movement, activity level, taste, smell, tactile, visual, as well as auditory [19].

The sensory profile 2 (SP2): It is the most recent version of **Dunn's** SP. It comprises a collection of standardized caregiver questions, including Infant SP2 (birth to six months of age), Toddler SP2 (seven to thirty-five months), Child SP2 (three to fifteen years), plus Short SP2 (three to fifteen years). Furthermore, there exists the School Companion SP2, a teacher questionnaire designed for students who aged three to fourteen years of age [20]. It is important to note that the adult form from the previous version has not been revised but migrated with the rest of the forms of the new version's online scoring and reporting platform.

BALANCE

The balance ability or maintenance requires sensory input or feedback from 3 systems: Visual, vestibular and proprioception or somatosensory systems, the three systems coordinate and interact together to provide organized sensory input to produce balanced coordinated movements, while the vestibular and somatosensory systems works to provide information about the internal environment of the body, the visual system works to provide information about external environment [21, 22].

Balance maintenance in the body depends on many factors like the feedback image of the body collected by the sensory system, processing of the sensory image that was collected and motor feed forward to adjust body posture in response to the previous stimuli [23] (figure 2).

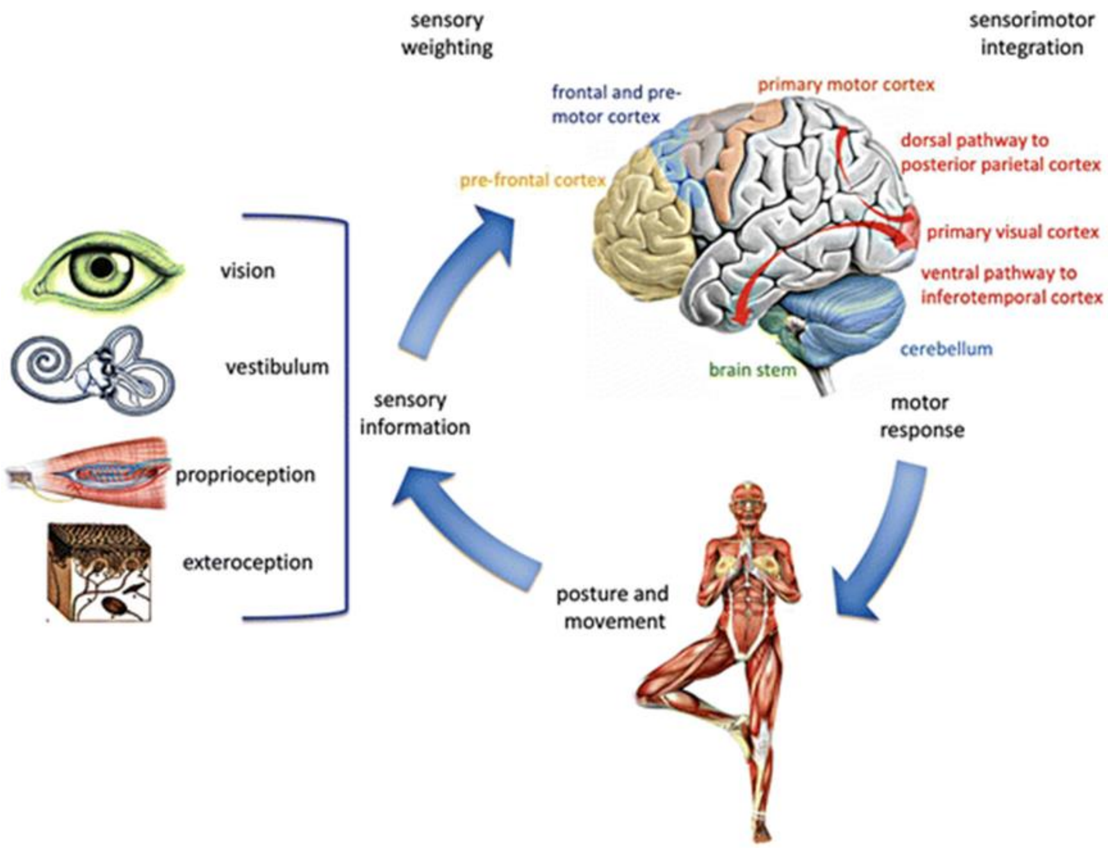

Figure (2): most important elements in the balance control loop [23].

Impaired dynamic balance in children with cerebral palsy:

Early brain injuries among children suffering from CP are accompanied by deficits in balance which are variable considering the site of the brain injury. The motor cortex and its associated white matter are damaged in spastic CP, resulting in heightened muscular tone or spasticity, which directly contributes to balance problems by limiting the child's capacity to respond to postural disturbances [24].

Inadequate balance as well as postural control may adversely impact the child's daily life activities, balance problems could result in problems with gait, locomotion and also could increase the risk of falling, which is one of the causes of mortality in pediatrics, it also could result in serious injuries like fractures, traumas or head injuries [25].

Assessment of balance:

The Biodex Balance System is a multiaxial device that objectively assesses an individual's capacity to stabilize a joint under dynamic load. It utilizes a circular platform capable of simultaneous movement along both AP as well as ML axes, permitting a tilt of up to 20° of the foot platform. Based on the tilt about each axis under dynamic conditions, the BBS computes stability indices, including the medial–lateral stability index (MLSI), anterior–posterior stability index (APSI), as well as an overall stability index (OSI). These indices indicate variations around a specified zero point established before testing, while the platform remains steady [26, 27].

The Pediatric Berg Balance Scale (PBBS): is a variant of the Berg Balance Scale specifically tailored for children by **Franjoine *et al.*** [28]. It assesses functional balance during daily tasks. The scale comprises 14 components, each rated from 0 to 4. The maximum score is 56. Sections have been restructured in a functional order, time requirements for maintaining static posture have been lowered, and instructions have been made simpler [28, 29].

The Balance Master: It comprises a force plate linked to a computer with software that tracks the orientation as well as movement of the COG. The Modified Clinical Test for Sensory Interaction on Balance (mCTSIB) assessed sensory dysfunction as well as static postural stability, whereas the Sit to Stand (STS) as well as Step and Quick Turn (SQT) tests evaluated dynamic stability using the Balance Master. The assessments were conducted in a quiet isolated room to mitigate extraneous disturbances. The Balance Master has been demonstrated to be a valid as well a reliable tool for assessing postural stability among children [30].

The Humac balance system: relies on the Wii balance board technology, which has been validated as a method of evaluating standing balance. By comparing its results to those of more conventional force platforms, the

Humac balance system proves to be a reliable as well as valid means of evaluating a subject's balance [31].

The HUMAC-type technology has been found to detect more imbalances than traditional tests. In addition to the balance assessment tests, the device also provides various games, which are utilized for balance training like the ski, snowboard, pilot, pong and the balance board games [32].

The HUMAC device provides assessment of balance through variable tests:

- The modified clinical test of sensory integration of balance (mCTSIB test)
- The limit of stability test
- The mobility test .
- The stability envelope test .
- The weight bearing test .
- The weight shift test .
- The center of pressure test (COP test) .
- The stability test.

Children having CP encounter functional challenges attributable not just to muscular tone and inadequate posture control but also to sensory impairments. Sensory-processing problems are frequently reported in children with CP, however they often remain unrecognized. Challenges in sensory processing can affect a child's everyday activities, emotional health, along with motor skills [33].

Primary brain injury impairs postural networks, causing postural control failure. Motor production networks are impaired by spasticity, contracture, diminished isometric force generation, aberrant timing, along with reduced muscle recruitment amplitude. Poor visual, tactile, proprioceptive, and vestibular registration as well as perception damage perceptual (orienting) networks [34].

Balance necessitates multisystem feedback together with intact cerebellar as well as cognitive functions. Cognitive processing is crucial for postural control, even in basic activities such as quiet standing, as motor movements require expectation, attention, intention and experience. It is proposed that more challenging tasks demand greater cognitive ability [35].

The utilization of various sensory information is crucial, as several forms of balance disturbances activate different sensors, each exhibiting varying degrees of sensitivity. Inputs from other systems can compensate for any misleading information provided by one or more of the systems to the CNS [36].

CONCLUSION

Hemiplegic children as well as their families struggle with sensory processing, which affects mental, social, along with neurocognitive development. Regular sensory processing development assessment as well as monitoring are necessary. Hemiplegic children's neurocognitive development along with balance from infancy to school age require treatment intervals plus parent discussions on sensory processing.

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