Growth, Development and Proprioception in Children

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Growth, Development and Proprioception in Children

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Abstract

In adults, the sensory systems are well organized and act in a context-specific way but in children, the sensory systems are not completely developed.The three afferent sensory systems (proprioceptive, visual, and vestibular) develop more slowly than the hierarchically lower automatic motor processes that mature early in childhood.Although there is limited knowledge on the influence of proprioceptive, visual, and vestibular afferent systems on posture control in children, several studies have been conducted on the development of sensory organization. Sensory and perceptual motor development phases through 4 identifiable stages in the children. These phases are reflexive phase, rudimentary phase, fundamental phase and specialized-advanced motor skills phase.

Keywords: Children; Growth & Development; Proprioception

Introduction

The children collects information and sensations through the senses. The first level of development is sensory motor skills. Sensations of movement and gravity help them to develop postural security and motor planning. Information from their joints and muscles help them develop an awareness of both sides of his body and reflex maturity. Visual, olfactory, gustatory, auditory and tactile experiences foster their ability to screen input. All of these sensations and experiences allow their to develop body scheme. Sensory experiences are crucial to development of children. Children learns to integrate the sensation of gravity, sensations from the muscles and joints and sensations received through their hands and knees, mouth, and ears [1].

The second level of development is perceptual motor development. Perceptual Motor Development is defined as one's ability to receive, interpret and respond successfully to sensory information. Having developed the sensory motor skills to learn about, and starts to control their body, the children moves through their environment gathering more sensory information, and practicing skills to develop motor development and coordination. With new experiences, children develops more complex body schemes, eye-hand coordinations, visual spatial perceptions and auditory language skills. These are the foundation for skills that they will need for behaviors and activities of daily living. This growth and development lays the foundation for cognitive development and intellect [2].

Sensory Development in Children

Infants use their senses to learn about the world around them. Sensory stimulation is linked to emotional, cognitive and physical development. All of the senses need to work together so that infants and toddlers can move, learn and behave in a typical manner. Activities provided for seeing, hearing, touching, smelling and tasting should be numerous and repetitive for proper sensory stimulation.

Sensory systems exhibit plasticity, the capacity to make functionally appropriate adjustments in neural connection patterns.Sensory systems are not mature at birth. Considerable modification takes place postnatally. Also, some reorganization within sensory structures and “rewiring” of neural connections can occur in the sensory pathways in adults.

Young children’s sensory and perceptual motor development phases through 4 identifiable stages.

1. Reflexive- pre and post birth actions including the Moro, sucking and headrighting reflexes
2. Rudimentary-basic movement patterns observed in the first 12 monthsincluding rolling over, commando crawling and hands and knees crawling
3. Fundamental-motor skills including running, galloping, jumping, throwing,catching, hopping and skipping including lateral and cross patterned actions
4. Specialized-advance motor skills where basic actions are combined inreadiness for games situations including kicking on the run to a target.

This restructuring is part of normal processes and may also be an important mechanism for recovery from injury.An important component in the development of sensory systems is normal sensory experience necessary for normal development.

The sensory development occurs in infancy from birth to about 12 months. Here, infants learn about the world through their senses, looking around constantly, looking at faces of caregivers, responding to smiling faces. Their eyes focus on bright colors and they respond to sounds by looking toward the sound. During this time of sensory learning, infants also show interest in light and movement, such as a mobile above the crib. Infants also begin to recognize their own name in this stage.As infants continue to interact with their surroundings and make meaning out of their world, they also learn about themselves, their own bodies. Their hands andtoes become body objects of interest.During this stage of sensory learning, infants reach for, hit at, and grasp objects that are within their reach, such as dangling jewelry and long hair. They also enjoy toys that rattle and squeak and will put any and all things in the mouth [3].

Life is a succession of continuous sensory experiences. The ability to learn depends upon the quality of those experiences and a child’s capacity to uniquely processsensory information. It is important that caregivers not only provide a variety ofsensory experiences, but also understand the role of sensory processing in order tosupport learning and behavior in young children.There are seven major sensory systems in the human body that provide avenues for the processing of sensory information.The five sensory systems of sight, sound, smell, taste, and touch are well known. However, two other systems involving body position and movement (proprioceptive system) and gravity, head movement, and balance (vestibular system) are less familiar (Table 1). Since processing sensory information is the foundation of all learning, all seven sensory systems are important in a child’s development.The Visual System is responsible for sight. By perceiving color, pattern, and light, this system provides visual images to our brains.Hearing is the result of the Auditory System. This system processes and interprets sound. It determines the direction, loudness, pitch, and duration of sound waves.The sense of smell is the product ofthe Olfactory System. Odor influences the flavor and taste of food. Smell alsocreatesmemories and associations that influence our choices and preferences.The sense of smell is a major factor in an infant recognizing and bonding withmother.The Gustatory System is primarily responsible for our sense of taste. The taste buds located on our tongue interpret sweet, sour, bitter, and salty and contribute significantly to our taste preferences and enjoyment of food.The sense of touch is the result of the Tactile System. Located in our skin, it is the largest sensory system and every surface of our body connects to it. This system interprets many aspects of touch including texture, consistency, pressure, pain, temperature, and vibration. The Vestibular System regulates our balance and is very sensitive to subtlechanges in position or movement. Located in the inner ear, this system is responsible for monitoring and maintaining equilibrium. The vestibular system sends information about the body's movements by interpreting the pull of gravity and change in the direction or speed of movement. An effective vestibular system allows us to walkupright and in a straight line. The Proprioceptive System is located in the joints, muscles, and tendons. It isthe second largest sensory system. Thissystem processes sensory information provided by tiny receptors that monitör the contraction and stretching of muscles and the bending, straightening, pulling, and compression of the joints. Information that it sends to the brain helps maintain normal muscle tone or tension and smooth motor movements. Proprioceptive information is necessaryfor any part of our body to move successfully [4].

System	Location	Function
Tactile	Skin	Provides information about the environment and object qualities (touch, pressure, hard, soft…)
Vestibular	Innear ear	Provides information about where our body is in space and whether or not we or surroundings are moving.
Proprioceptive	Muscles and joints	Provides information about where a certain body part is and how it is moving
Visual	Retina of the eye	Provides information about objects and persons.
Auditory	Innear ear	Provides information about sounds in the enviroment (high, low, near, far…)
Gustatory	Chemical receptor in the tongue	Provides information about different types of taste (salty, sweet, sour…)
Olfactory	Chemical receptor in the nasal structure	Provides information about different types of smell (flowery, acrid, putrid…)

Table 1: Location and functions of the sensory systems.

As children play (Table 2), they lay the sensory foundation needed for behavior and more complex learning necessary for later academic and social success. Play is a child's work and provides rich opportunities to make sensory integration happen. Frequent and varied play experiences develops sensory integration and leads to better organization and skills [5]. Generalization of these skills into school and later, results in greater success throughout life. By successfully processing new sensations, children improve their ability to respond appropriately to sensory experiences. As sensory processing skills mature, vital pathways in the nervoussystem are refined and strengthened, and children get better at problem solvingand dealing with life's challenges. For example, an infant may startle and cry when hearing a vacuum. Years later, he might simply cover his ears until thesound stops. As an adult, he may only pause in his conversation until the distractionceases. This change in behavior indicates the progressive maturing of his sensory integration abilities.In childhood, children explore their environment and adapt to many physical and mental challenges. The successful integration of sensory experiences creates an internal model of who children are physically, where they arein relation to their surroundings, and what is happening in the world around them [6,7].

	Touch	See	Hear	Smell	Taste
0-12 months	Texture mats, warm water play	Close face to face interactions, books	Talking with children, listening outdoors	Scented lotions and oils	Sucking on food, bottles and teething rings
1-2 years	Gloves, books, creative experiences with finger paints	Mirrors, other reflective surfaces	Music playing, wind chimes	Scratch sniff books, items in environment	Different foods
2-3 years	Art materials – brushes, sponges, stamps	Books with pictures & print, sun catchers, see through color plates	Rain sticks, games that involve listening	Foods as they bake	Cooked foods

Table 2: Activities for sensory development according to the age for children.

Proprioception Development in Children

Proprioception provides the basis for knowing where our extremities are in space and is comprised of both static (joint/limb position sense) and dynamic (kinesthetic movement sense) components [8]. Sherrington has the first studies on this topics in 1906, he has been established that muscle spindles are a major source of proprioceptive feedback to the central nervous system and appear to mediate the conscious perception of movement and limb position for the proprioceptive information [9]. Followed in the other studies shown that cutaneous and joint mechanoreceptors contribute for the determination of more distal body segment positions and signaling extreme ranges of motion [10,11]. The development of the proprioceptive sense begins in childhood.The first definitive analyses in this area were provided by Bairstow and Laszlo [12].

They who examined children aged 5-12 years in a variety of tasks requiring kinesthetic judgments in three-dimensional space.In a task that involved discriminating hand heights after encountering ramps of differing steepness, accuracy was shown to improve substantially from the ages of 5 to 7 years with errors becoming stable in 8 to 12 year olds.These studies provide evidence that developmental changes in proprioceptive ability are relatively stable by approximately 8 years of age [8].

In the other study it has been suggested that proprioceptive ability continues to improve throughout childhood and well into adolescence [13].

The results of the Goble's study provide strong evidence that the control of proprioceptively guided movements continues to be refined from childhood well into adolescence with an almost 50% reduction in matching error occurring in 16–18 year olds as compared to 8–10 year old children [8].

The results of the present studies determine that the normal development of the proprioceptive system is debate in the children. Examination of the proprioceptive sense is important in determining the development of pediatric-onset motor deficits such as cerebral palsy, neuromuscular diseases or mental reterdation.Also, sensorimotor deficits such as impaired joint proprioception and muscle weakness have been found in association with hypermobility syndrome in children [14].

Proprioception in children with cerebral palsy

Children with Cerebral Palsy (CP) whose upper limb movements are limited by changes in Range of Motion (ROM), impaired motor control, tone, and sensation, maynot have opportunities to develop typical reaching and grasping patterns,resulting in feeding and self-care problems [15]. Consequently, most rehabilitation strategies aim to promote motor function in CP. Less known is the degree to which somatosensory abilities are also impaired. Many prior studies of somatic perception in CP were qualitative, used inexact measures, or lacked comparisons with normative data. To better characterize somatosensory impairments in mild CP, we psychophysically evaluated tactile and proprioceptive abilities in three relatively homogenous groups: diplegia, hemiplegia, and age-matched controls. First, we assessed tactile object recognition and tactile roughness discrimination in the hands. Second, a novel device measured large joint (forearm and hip) proprioception. Joint position sense with and without vision was tested with active limb movement. Kinesthesia was evaluated with passive limb rotation without vision. These studies revealed ubiquitous tactile and proprioception deficits on all limbs, not just those commonly considered to be affected with diplegia and hemiplegia [16].

Next, the organization of somatosensory cortical areas in CP was studied by comparing cortical activity in individuals with diplegia and age-matched controls using tactile stimulation and functional magnetic resonance imaging. Participants with diplegia had decreased evoked cortical activity in most traditional somatosensory regions contralateral to tactile stimulation of the right index finger tip, and bilaterally in primary and secondary somatosensory areas. Diminished cortical responses in diplegia were also observed in areas associated with goal-directed behavior, motor planning, and visual recognition of objects. Yet significant correlations were not found between cortical activity in CP and performance on a particular psychophysical task. However, these studies indicate pervasive somatosensory deficits in CP, even when motor impairments are mild, and found widespread diminution of cortical activity evoked by tactile stimulation. Characterization of the type, magnitude, and cause of these deficits is useful for understanding somatosensory impairments in CP [17].

Sensory feedback is important for learning motor skills in adults and it is increasingly recognized that children with CP have sensory deficits that can affect movement production.A decrease of proprioception in children with CP could have accounted for the difficulty of reproducing different target arm positions. However, the role of specific sensory deficits in motor learning remains unclear [18].

Motor learning is influenced by many factors, including genetics, somatosensory function, prior experience, and gender. Indeed, learning to make faster reaching trajectories was related to better sensation (proprioception and tactile sensation) in our group of children. This supports previous studies on children with CP about the link between these two sensory modalities and motor learning [19].

Children with CP can learn to use new motor patterns and retain improvements after practice. Motor skills learned through practice may be transferred to similar movements in children with CP, and those children with better sensory status are likely to be better learners [15].

Proprioception in children with hypermobility syndrome

Hypermobility Syndrome (HMS) is diagnosed when generalized joint laxity becomes symptomatic with musculoskeletal complaints in the absence of signs of any rheumatic, neurological, skeletal or metabolic disorders [20].

Proprioception deficits at the proximal interphalangeal and knee joints have been found in children with HMS. Muscle weakness has also been observed in children with HMS.

The lack of adequate knowledge of the symptoms associated with HMS in children makes the condition difficult to recognize and manage effectively. Fatoye et. al demonstrated that children with HMS had sensorimotor deficits compared with the healthy peers. This suggests that children with HMS may benefit from appropriate treatment methods of improving such deficits. Interventions to enhance knee joint proprioception and muscle strength should therefore be developed and tested in children with HMS [21,22].

Proprioception in children with autism spectrum disorders and developmental disabilities

Children with Autism Spectrum Disorders (ASD) present with proprioceptive processing difficulties that are different from those of children with Developmental Disabilities (DD) and their typically developing counterparts. Several authors have reported on the motor control difficulties related to poor proprioceptive processing among children with ASD and DD, including decreased postural control and motor planning, overreliance on proprioception, difficulty matching proprioception with vision during reach, decreased organization of space, and poor motor [23-25].

Children with ASD and DD struggle to process information that the senses send to the brain. The brain thus does not respond effectively, which usually leads to an inappropriate response by the body. Sensory processing disorder in children can cause sensory modulation difficulties, sensory-motor difficulties (coordination and motor planning), and/or sensory discrimination difficulties (visual, tactile and auditory processing).

Blanche et al., [26] demonstrated that children with ASD present with distinct patterns proprioceptive processing difficulties on four different category.These difficulties include difficulty with feedback-related motor planning skills; tiptoeing; pushing others or objects; and crashing, falling, and running.Although some proprioceptive difficulties are identifiable in clinical practice through observation, clinicians lack a systematic, comprehensive tool that measures more than one aspect of proprioception in children with ASD. Most of the difficulties in proprioceptive processing are reported in parent questionnaires and standardized tests such as the Kinesthesia and Standing/Walking Balance subtests of the Sensory Integration and Praxis Tests [27,28].

Proprioception and injury related to sports and recreation in children

High rates of injury incidence related to sports and recreation in children aged 10–14 years identify adolescence as a potential period of childhood development in which children may be at an amplified risk for such injuries [29].

Injuries at this age can devastate a child's ability to participate in physical activities and may trigger long-term sequelae such as early onset of osteoarthritis. Although a number of studies have considered such factors as body size, fitness andprevious injury relative to injury risk, there is presently a paucity of evidence that identifies modifiable risk factors for injuries in youth sports. One area that has often been discussed but rarely tested with regard to increased injury risk is that of 'adolescent awkwardness'. Delays or regressions in sensorimotor function relative to rapid growth spurts offer appealing explanations for increased injury susceptibility during adolescence.However, studies that have investigated adolescent deficits in motor control and skills have been inconsistent in their findings and conclusions and no current consensus on the presence or absence of regressions in motor control during adolescence currently exists [30,31].

Testing of Proprioceptive System in Children

Proprioceptive ability should be evaluated and then a program may be designed. Proprioceptive difficulties should be addressed immediately in children. Perfect form, good range of movement and adequate stabilization are all dependent upon proprioception [32].

•Observation of muscle tone in sitting and standing gives clues of the ability to sustain a position against gravity

•Motor sequencing- touching the thumb against the other fingers of the hand in sequence one after the other at a certain speed. Observe the errors in sequence and examine both hands. When attempting fine motor skills, affected individuals often show signs like grimacing or sticking the tongue out.

•Finger-nose test to evaluate proprioception and fine motor coordination.

•Moving a limb against resistance to evaluate strength. Also look for additional movement to evaluate the ability to stabilise a joint.

•Sustained testing- evaluate energy consumption in a movement. Some individuals will quickly fatigue and are unable to maintain energy wasting activities. Fatigue often affects proprioception.

•Isolated movement- single joint and eye movement can easily be evaluated.

•The ability to relax- examiner holds the individuals arm, instructs them to fully relax and lets go of the arm. If able to relax the arm should drop down.

•Ability to detect an externally imposed passive movement. Assess whether the individual can detect passive movements of a joint with their eyes closed.

•Ability to re-position a joint to a predetermined position.

Proprioception Training in Children

Proprioceptive activities can be passive, where deep pressure is given to the child, or active, where the child actively takes part in a heavy work activity. Proprioceptive activities are excellent for sensory-seeking kids who are always craving movement and crashing into things. They can also help stimulate a lethargic child.

Passive proprioception training: Let the child lie on a mat or folded blanket and pack pillows on top to make him into a pizza or sandwich. Weighted vests, weighted blankets and lap blankets are also effective ways to give passive proprioceptive input. The child may also enjoy being wrapped in a blanket or snuggling in a beanbag.

Active proprioception training: Heavy work activities help the children to really "feel" their muscles and joints. Let the child carry groceries, sweep the yard, dig in the garden, or any other activity that lets their muscles work hard. Jumping on a trampoline and climbing on playground equipment also gives good proprioceptive input. If the child struggles to sit still to listen to a lesson, then can try a stress ball to squeeze, chewing gum, or a special chew toy to can give proprioceptive input [33].

When planning proprioception exercises for the children, it is just as important to consider the client's baseline level of skill as it is when designing a flexibility, strength or endurance program [34]. There is no specific test for proprioception as there is for cardiovascular endurance or muscle strength. However, there is a proper progression to follow, starting with static balance activities, progressing to dynamic balance activities and finally advancing to coordination and agility training (Figure 1).

Figure 1: Proprioception Training in Children.

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