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Original Article

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Comparing of Lower Extremity Tactile and Trunk Position Sense in Children with Spastic Cerebral Palsy and Typically Developing Children

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Purpose: To determine if there are differences in lower extremity tactile and trunk position sense processing abilities between children with spastic cerebral palsy and typically developing children.

Methods: A total of 30 subjects, 15 children with spastic cerebral palsy and 15 typically developing children, aged 5-10 years, were studied. Tactile sense was measured using monofilament on the non-dominant side of a typically developing children and on the hypertonic side of a child with spastic cerebral palsy. Position sense was measured using dual digital inclinometers on the trunk. Each measurement was performed three times and the average tactile value was calculated. Data were analyzed using independent samples t-test to determine group differences.

Results: Children with spastic cerebral palsy perceived larger diameter filaments in the lower extremity tactile test than typically developing children and trunk position sense tests showed larger postural reproduction errors, confirming that children with spastic cerebral palsy have deficits in somatosensory processing ($p < 0.05$).

Conclusion: We suggest that to improve the physical functioning of children with spastic cerebral palsy, intervention programs should not only consider motor but also sensory processing abilities.

Keywords: Lower extremity tactile, Trunk position sense, Cerebral palsy

INTRODUCTION

Cerebral palsy is caused by non-progressive damage to the brain before, during, and after birth and is characterized by impairments in motor control as well as somatosensory sense.[1] Somatosensory is a neural mechanism that integrates sensory information from the body and is categorized into temperature, nociception, and mechanical somatosensory. Tactile and positional senses, which fall under mechanical somatosensory, transmit information about touch, pressure, vibration, tickling, static position, and movement to the brain. Sensory feedback to the brain about movement helps feed-forward anticipatory strategies that lead to more appropriate movements.[2,3] Therefore, tactile and positional senses are essential for correcting and adjusting to errors that may occur after the body has executed a planned movement.

Accurate and correct sensory input is critical for a child's motor development.[4] Sensory impairment in children with cerebral palsy reduces postural stability, making it difficult for them to move and adapt safely in a variety of environments.[5] Unstable postural control in children with cerebral palsy increases rigidity in the distal part of the body and sends distorted motor senses back to the brain. Approximately 90% of people with cerebral palsy are reported to have impairments in light touch, pressure, two-point discrimination, stereopsis, vibration, pain, and positioning.[6,7]

Senses are transmitted through the spinal cord's ascending nerve pathways to the brain's white matter and then to the higher centers. One of the medical problems of spastic cerebral palsy, periventricular white matter atrophy, can cause severe damage not only to the outer spinal cord, but also to the posterior white matter fibers that connect the thalamus to the sensory cortex.[8] Damage to the thalamus and posterior white matter fi-

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bers can lead to problems with sensory processing, causing significant difficulties in a child's early physical development, motor learning, and body image.[5,9] In addition, the inability to functionally integrate relevant body parts deprives children with cerebral palsy of the opportunity to experience and challenge a variety of senses, leading to greater motor skill deficits.[10]

Identifying specific and appropriate sensory issues in the rehabilitation process can facilitate postural control and functional activities and increase social engagement in children with cerebral palsy.[11,12] Research on sense in children with cerebral palsy includes studies comparing gross and fine motor sensory processing, advantage discrimination, upper extremity tactile sense, and sensory integration interventions.[13-16] In this study, we compare the tactile and positional senses of children with cerebral palsy and typically developing children to provide a basis for understanding somatosensory sense in children with cerebral palsy and to help set up interventions for children with cerebral palsy.

METHODS

1. Subjects

This study included 15 children diagnosed with spastic cerebral palsy and 15 typically developing children without cerebral palsy, aged 5 to 10 years old, living in City Y. All children and their caregivers were informed about the purpose of the study and gave their voluntary consent to participate. The children were able to sit independently, were at level 8 of the Pediatric Consciousness Scale (rancho los amigos), and were able to follow commands for clinical measures and measurements. Children with seizures within the last 6 months, musculoskeletal injuries, history of neurosurgery or orthopedic surgery, or treatment with botulinum toxin injections were excluded. The age, gender, height, and weight of the subjects were recorded by questionnaire and body mass index (BMI) was calculated. This study was approved by the Institutional Review Board of K University (KSU-23-07-002-23091).

2. Experimental methods

1) Measurement

(1) Tactile sense

Tactile sense was measured using monofilaments (Baseline Tactile Semmes-Weinstein Monofilaments, Fabrication Enterprises, NY, USA), selecting the non-dominant side of a normal child and the lower extremity with more tension in a child with cerebral palsy. The lower extremity tactile measurement area was mid-thigh, patella, anterior shank, posterior shank, 1st metatarsal head, lateral malleolus.

Measurements were performed three times per site and averaged for tactile sense. The monofilaments were numbered 2.83, 3.61, 4.31, 4.56, 5.07, and 6.65 depending on their diameter, with 2.83 monofilaments being normal, 3.61 monofilaments being mildly reduced tactile sense, 4.31 monofilaments being reduced protective sense, 4.56 monofilaments being loss of protective sense, 5.07 monofilaments being loss of all sense except deep tactile sense, and 6.65 monofilaments being unresponsive. If the smallest diameter monofilament was not detected, larger diameter monofilaments were used sequentially for measurement.[17] The larger the diam-

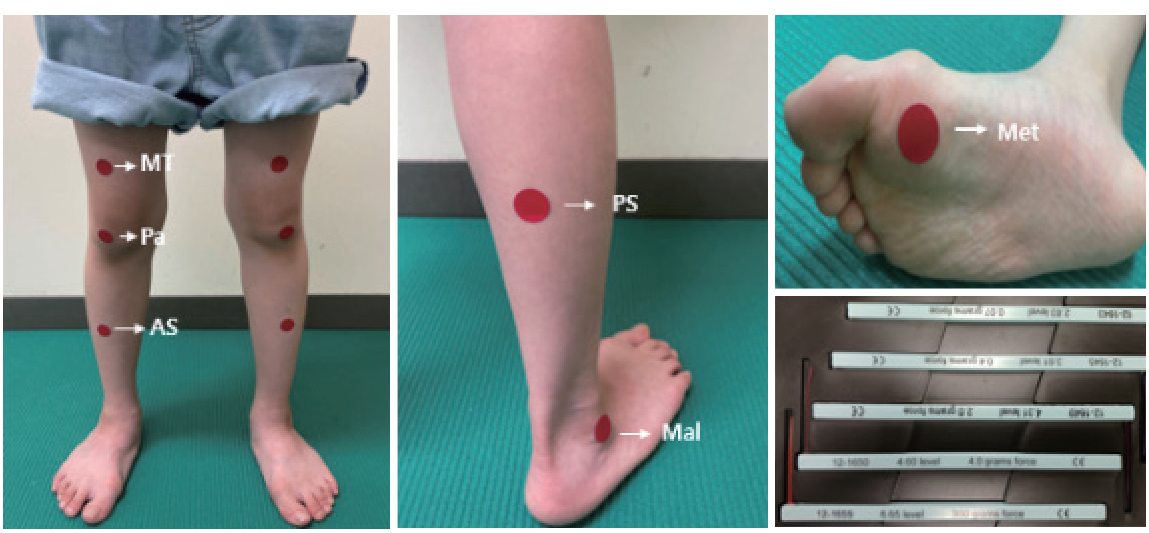

Figure 1. Lower extremity tactile measurement site and monofilaments. MT: mid-thigh, Pa: patella, AS: anterior shank, PS: posterior shank, Mal: malleolus, Met: metatarsal head.

Figure 2. Measurement of trunk position sense

eter monofilament felt, the more dulled the sense (Figure 1).

(2) Position sense

Trunk position sense was measured by using a dual digital inclinometer (Acumar dual digital inclinometer, Lafayette instrument, Indiana, USA) to calculate the error value of the subject's reproduction of the target angle in the sagittal plane. A dual digital inclinometer is a device that has a primary and secondary sensor, so that the primary sensor is located at a fixed point and the secondary sensor is located at a moving point, so that even if the fixed point moves during the exercise process, it is adjusted to the movement and the actual angle moved is displayed. In this study, the primary sensor was placed at the S1 level and the secondary sensor was placed at the T12 level. During the measurement, the child sat in a backless chair with hip, knee, and ankle joints at 90° and spine neutralized as much as possible, and was instructed by the therapist to reach the target angle, hold it for 5 seconds, and return to the starting position. The child was then asked to reproduce the previous target angle position again with eyes closed. The target angle was set at 30° of lumbar flexion, and the smaller the error between the target angle and the reproduced angle, the better the trunk position sense. After three measurements, the average of the pose reproduction error values was taken (Figure 2).[18]

(3) Data analysis

Independent samples t-test was used to compare the ability of children with cerebral palsy and typically developing children without cerebral palsy to process tactile of the lower extremities and trunk position senses. SPSS 26.0 (IBM corp, Chicago, IL, USA) was used as the statistical program, and the significance level (α) was set at 0.05.

RESULTS

1. General characteristics of the subjects

There are 30 participants in the study: 15 typically developing children and 15 children with spastic cerebral palsy. Of the children with spastic cerebral palsy, 9 had diplegia and 6 had hemiplegia. The average age was 6.8 years for typically developing children and 6.3 years for children with cerebral palsy (Table 1).

2. Tactile

When comparing the tactile results of children with cerebral palsy and typically developing children, children with cerebral palsy recognized larger diameter filaments compared to typically developing children ($p < 0.05$)(Table 2).

3. Position sense

When comparing the trunk position sense measures of children with ce-

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Table 1. General characteristics of subjects (n=30)

Variable		Typically developing children	Cerebral palsy
Age (year)		6.8±1.4	6.3±1.5
Height (cm)		116.3±12.8	113.4±15.9
Weight (kg)		22.4±5.7	20.9±8.0
BMI (kg/m²)		16.3±2.0	15.7±1.9
Gender	Male	5	6
	Female	10	9
Type	Diplegia		9
	Hemiplegia		6

Mean±standard deviation. BMI: body mass index.

Table 2. Comparing of tactile and position sense

Variable		Typically developing children	Cerebral palsy	F	p
LET (level)	MT	2.83±0.00	3.14±0.39	14.00	<0.001*
	Pa	2.83±0.00	3.29±0.39	14.00	<0.001*
	PS	2.83±0.00	3.54±0.52	14.00	<0.001*
	AS	2.83±0.00	3.73±0.49	14.00	<0.001*
	Met	2.83±0.00	3.86±0.33	14.00	<0.001*
	Mal	2.83±0.00	4.07±0.34	14.00	<0.001*
TRPS (°)		1.52±0.59	9.26±2.16	28.00	<0.001*

Mean±standard deviation. LET: lower extremity tactile, TRPS: trunk reposition sense, MT: mid-thigh, Pa: patella, PS: posterior shank, AS: anterior shank, Met: metatarsal head, Mal: malleolus. *p<0.05.

rebral palsy and typically developing children, children with cerebral palsy had larger posture reproduction errors than children without cerebral palsy ($p < 0.05$)(Table 2).

DISCUSSION

Sensory input is crucial to the development of the nervous system because it allows for proper synaptic organization in the brain. In particular, somatosensory information is important for motor learning in the early stages of development and provides a foundation for the acquisition of more complex behavioral skills. Abnormal somatosensory processing has been linked to communication, motor, and social skill deficits in a variety of neurodevelopmental disorders, such as cerebral palsy.[19,20] However, because children with cerebral palsy have stiffer muscle fibers and shorter muscle segments than typically developing children with normal muscles, the muscle tissue itself is altered, resulting in impaired joint and positional awareness.[21,22] Furthermore, impaired postural control in cerebral palsy is a combination of factors such as contractures, limited joint range of motion, and changes in postural alignment that limit the ability to reflexively adjust posture to regain stability from unexpected hazards.[23]

This study compared lower extremity tactile and repositioning sensory processing in children with cerebral palsy and typically developing children. The results showed differences in sensory processing between children with cerebral palsy and typically developing children. Cerebral palsy can result in sensory deficits due to motor skill deficits and abnormal activation of the somatosensory cortex due to physical impairment.[24] Wingert et al.[5] found that about 90% of people with cerebral palsy have impairments in tactile, proprioception, and other senses. This study confirmed tactile deficits in cerebral palsy by showing that children with spastic cerebral palsy perceived larger diameter monofilaments than children without cerebral palsy. Lesny et al.[25] also compared sensory perception in children with cerebral palsy and typically developing children and found that children with cerebral palsy had a two-point discrimination cutaneous sensory deficit compared to typically developing children, supporting our findings.

Spastic cerebral palsy is characterized by increased compensatory spasticity, which makes segmental body movements difficult by immobilizing the distal extremities, such as curling the toes and clenching the fists, when stability is lacking. Distal compensatory spasticity, which interferes with selective and voluntary motor control, deprives children with cerebral palsy of the sensory developmental opportunities that come from experiencing a variety of movements and exacerbates sensory problems. Fowler et al.[26] reported that spastic cerebral palsy has more distal spasticity than proximal spasticity, more difficulty with fine motor control, and more tactile reduction. In our study, we found that the mean monofilament recognition of children with cerebral palsy was significantly higher in the malleolus (Mal) 4.07±0.34, metatarsal head (Met) 3.86±0.33, anterior shank (AS) 3.73±0.49, posterior shank (PS) 3.54±0.52, patella (Pa) 3.29±0.39, mid-thigh (MT) 3.14±0.39, showing that distal areas tend to have more severe sensory deficits than proximal areas, which is consistent with previous studies.

The ability to integrate and discriminate between sensory information constantly coming from inside and outside the body improves motor performance. Children with cerebral palsy have difficulty processing sensory information from the outside world, which in turn impairs their motor output. In other words, children with cerebral palsy have difficulty accurately receiving and interpreting sensory information.[27] The children with cerebral palsy in this study also had higher trunk position reproduction errors than typically developing children, confirming that their sense of position is impaired. Lesions of the central nervous system lead to errors in somatosensory processing.[21,28] Errors in trunk positioning increase with decreasing levels of gross motor function.[29] In other words, somatosensory deficits in children with cerebral palsy may be caused not only by primary damage to the cerebral somatosensory shell, but also by secondary effects such as decreased exploration opportunities and abnormal sensory feedback due to limited motor control.[30]

Cerebral palsy is a disorder characterized by impaired postural and motor development, primarily spasticity, limited range of motion, muscle weakness, and poor coordination. Traditional rehabilitation approaches for cerebral palsy have been motor-centered, focusing on improving musculoskeletal and motor impairments, with less attention paid to sensory issues. However, the results of this study suggest that children with cerebral palsy have poorer sensory processing abilities than children without cerebral palsy.[31] Therefore, in order to improve the physical functioning of children with cerebral palsy, accurate sensory assessment and interventions to improve sensation should be combined with improving abnormal motor control. Limitations of this study include the following. It is difficult to generalize the results of this study to all children with cerebral palsy due to the small number of subjects. Therefore, it is recommended that future studies should include more children with various types of cerebral palsy to investigate somatosensory sense and observe changes in somatosensory sense through intervention.

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