Effects of Contact Hand-Orientating Response Training on Balance and Activities of Daily Living in Patients with Cerebellar Ataxia; Single Subject Design

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Purpose The purpose of this study was to investigate the effect of contact hand-orientating response (CHOR) training on balance and activities of daily living in patients with cerebellar ataxia in a single case study. CHOR is the ability to provide stability with only a light touch of the hand to the ground or supporting surface. ***Methods*** This study was conducted using the ABA design for a total of 10 weeks from June to July 2022 with one male and one female diagnosed with cerebellar ataxia. During the study period, a total of 18 sessions were applied to the subjects: 3 sessions of baseline A, 12 sessions of intervention period B, and 3 sessions of baseline A'. During the baseline period, BIORescue and functional reach test (FRT) were measured by dynamic balance evaluation without somatosensory training, and during the intervention period, the same evaluation was performed after applying CHOR training for 30 minutes each session 3 times a week. Berg balance scale (BBS) and Assessment of motor and process skills (AMPS) were conducted as pre- and post-assessments. ***Results*** As a result, BIORescue, FRT, BBS, and AMPS were all improved compared to before applying somatosensory training, and it was confirmed that they were maintained even after the intervention was completed. ***Conclusion*** This study demonstrated that CHOR training showed significant improvements in balance and activities of daily living in patients with cerebellar ataxia.

Key words Cerebellar, Ataxia, Contact hand-orientating response, Balance, Activities of daily living

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Ⅰ. Introduction

In stroke, cerebellar stroke accounts for about 3% to 15%, and disability due to ataxia occurs more frequently than typical stroke symptoms such as hemiplegia and aphasia.[1] Ataxia is a disorder in the control of gait, voluntary upper and lower extremity movements, speech, and eye movements due to damage to the brain function that coordinates balance and movement.[2] These functions are mainly in charge of the cerebellum in our brain, and it is often referred to as cerebellar ataxia because it mainly occurs when cerebellar dysfunction occurs.[3]

The cerebellum is responsible for automatic coordination and control of motor learning, control of muscle tension, and maintenance of balance, and plays a very important role in postural control and balance.[4] In addition, the cerebellum is a sensory processing area through immediate feedback in balance and gait, and plays a role in motor control with a feedback method based on reactivation or sensory stimulation.[5] Representative symptoms of people with cerebellar ataxia are hypotonia, which is a decrease in resistance to passive limb movements, and dysregulation of movement distance, which is a problem in initiating limb movements and controlling the size and speed of movements, and muscle coordination disorders with poor joint coordination. In addition, there are hypermetria and intentional tremor, which tremble while performing voluntary movements, as limitations of motor control. Balance disorders caused by such ataxia significantly reduce the people independence when walking and performing activities of daily living, and have long been considered incurable.[6]

In particular, the somatosensory system is the most basic sense for providing information on balance in healthy adults, and sensory receptors located at the

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periphery of the body are sensitive to changes in muscle length, joint position or movement, and speed.[7] It recognizes sensory information from the back and transmits it to the upper segment of the spinal cord or to the brain. This information plays an important role in maintaining posture and planning and executing movements through the central nervous system.[8] This somatosensory system receives external sensory information from other parts of the brain or spinal cord and transmits it to the cerebellum, and provides motor function control and sensory processing in real time through the processed information. That is, the cerebellum functions to control motor responses in a feedback method using somatosensory.

According to a previous study based on somatosensory, Sue Raine et al. (2013) found that the CHOR is an important factor in the concept of the center line of the torso and of the posture needed to control wrist, elbow, and shoulder movements. said to promote stabilization.[9] A recent study reported that contact hand-orientating response has a positive effect on the standing-up behavior of chronic stroke people.[10] In addition, Song(2012) demonstrated effects on postural control ability, trunk stability, arm function and hand sensation enhancement through CHOR.[11] However, this is a positive study on stroke people with cerebral damage according to the normal cerebellar sensory feedback pathway. On the other hand, patients with cerebellar ataxia have difficulties in balance and normal activities of daily life due to problems in the cerebellar sensory feedback pathway, unlike the normal sensory pathway of the cerebral cortex.

In addition, even if continuous rehabilitation is performed, as the disease progresses, it is difficult to move weight and the ability to walk and balance is gradually lost, such as dragging feet, and is exposed to the risk of falling.[7] Falls are a very frightening factor for people with cerebellar ataxia, and cause psychological atrophy by negatively affecting their independent lives.[12] According to a previous study, about 84% of 113 cerebellar people responded that they experienced at least one fall within a year, and two-thirds of the people who experienced a fall experienced a fall in a front-back direction rather than a left-right direction.[6] Balance ability refers to the ability to maintain the body's center of gravity in a state of equilibrium in a given environment, and it can be said to be an essential factor for the body's stability and independence in daily life.[13] The process of sensory processing during balance control is largely processed through three types of information: somatosensory, visual, and inner courtyard. Information from the somatic senses and the visual and antural systems are integrated in the central nervous system, and based on these sensory processing processes, appropriate exercise planning and execution are made.[14]

The improvement of balance ability and activities of daily living of people with cerebellar ataxia is one of the most important factors. The normal sensory pathways of cerebellar people are considered to be an advantage, and feedback through CHOR will result in more motor skills. Therefore, in this study, the effect of contact hand-position response on balance and activities of daily living in people with cerebellar ataxia was investigated, and it was confirmed whether the improvement in balance ability of people with cerebellar ataxia was generalized to the performance of activities of daily living.

II. Materials and Methods

1. Subjects

This study targeted stroke people with cerebellar damage as a result of magnetic resonance imaging (MRI) who were admitted to the Department of Rehabilitation Medicine at B Hospital located in Seongnam-si, Gyeonggi-do and received comprehensive rehabilitation treatment. The experiment targets people who can stand in a standing position without balance assistance or assistive devices, and people with brain lesions other than the cerebellum or orthopedic problems of the upper and lower extremities that may affect functional tests are excluded from the study. Subject 1, a 24-year-old male, complained of a sudden severe headache while singing three years ago. After visiting the hospital, he was diagnosed with a stroke caused by bilateral cerebellar hemorrhage. He initially had mild diplopia, but it has now improved, and he complained of difficulties in maintaining balance, moving, and walking. As a result of the Korean version of the brief mental state test, the score was 30 out of 30, and there was no difficulty in the therapist's instructions and implementation. The range of motion of the joint was normal, and the overall muscle strength was of good grade. As a result of the manual function test (MFT), 25/32 points were obtained on the left side and 25/32 points on the right side(Table 1). Subject 2, a 45-year-old woman, had sudden weakness, dysarthria, and tremor at home 4 years ago. After visiting the hospital, she was diagnosed with a stroke caused by right cerebellar infarction. She complained of intentional tremor, especially in her lower limbs than her upper limbs. She was limited in mobility during activities of daily living due to the resulting difficulty in maintaining her balance and walking. As a result of the Korean version of the brief mental state test, the score was 30 out of 30, and there was no difficulty in the therapist's instructions and implementation. The range of motion of the joint was normal, and the overall muscle strength was good grade for the upper extremities and fair grade for the lower extremities. MFT results showed 24/32 points on the left side and 25/32 points on the right side (Table 1). Subjects 1 and 2 perform all physical and occupational therapy conducted by the Department of Rehabilitation Medicine, and from 6:00 pm, intervention and all evaluations for this study are conducted. Subjects fully listened to the explanation of the study in advance and filled out the consent form, and data collection was conducted over a total of 6 weeks from June to July 2022.

2. Study design

The experimental design of this study uses the ABA inversion design among single-subject research designs. A total of 18 experiments were conducted. Baseline phase A and baseline phase A' were periods without treatment, and basic data were collected three times each, and intervention phase B was During the treatment period, a total of 12 times, once a day, 30 minutes per session, are applied and basic data are collected. After the baseline measurement for 3 times without any initial intervention, the intervention period is conducted for 12 sessions. After the intervening period, baseline measurements are performed three times.

3. Materials

3. 1. Balance measurement tool

3. 1. 1. BIORescue (RM INGEINIERIE, Rodez, France)

This device is used to accurately determine the degree of static and dynamic ataxia, and measures the amount of body agitation with eyes closed or eyes open. This test is performed using a device consisting of a peripheral vision device, a computer device, and a platform. It can be used as the most basic test method to detect subjective balance problems in patients who cannot maintain their body balance with the device alone. In this study, go up barefoot and place both feet on the platform mark in the most comfortable position. On the monitor, the center of gravity should be voluntarily moved as much as possible along the arrows pointing in 8 directions in for-

Table 1. General characteristics of the subjects

Variable	Subject 1	Subject 2
Age/Sex	24/M	45/F
Duration of onset(month)	39	47
Range of motion	N	N
Manual muscle test(Upper/Lower)	G/G	G/F
Manual function test(MFT)	25/32	25/32
Cognitive function(K-MMSE)	30/30	30/30

korean version of mini-mentel state exam; K-MMSE, manual function test; MFT ward, backward, left, right and each oblique direction. Measure for 10 seconds in each direction, and keep yourself in the maximum state. Make sure that both feet do not come off the floor during the measurement, and re-measure if the feet come off the ground during measurement. Measure the limit of stability (LOS) in 4 directions of forward, backward, left and right and in 4 directions of each oblique line. Data collection is repeated three times, and the average value of the result is measured. A 3-minute break is given for each measurement to minimize the effect on muscle fatigue.

3. 1. 2. Functional reach test (FRT)

In this study, a functional stretching test is used to check the dynamic balance of patients with cerebellar ataxia. FRT measures the maximum reachable distance by extending the arms horizontally while maintaining the support surface in a comfortable standing position, and was used to examine changes in balance ability during dynamic activities. FRT starts with the test subject standing, with the elbow extended and the shoulder joint flexed 90 degrees. Keeping one arm horizontally on the ground, measure from the starting point to the end of the third metacarpophalangeal joint, then re-measure in the maximally extended state to quantify the distance difference. At this time, the posterior tilt of the hip joint and pelvis and bending of the knee joint should not occur.[14]

3. 1. 3. Berg balance scale (BBS)

In this study, the Berg Balance Scale was used to check static and dynamic balance, fall risk, mobility, and activities of daily living due to ataxia after stroke. The BBS consists of 14 items that evaluate the level of balance in three positions: sitting, standing, and posture change. The score for each item ranges from 0 to 4, and the maximum score is 56, with higher scores indicating better balance function.[15]

3. 2. Assessment of activities of daily living

3. 2. 1. Assessment of motor and process skills (AMPS)

AMPS is an observation-based assessment of functional competence in activities of daily living, and simultaneously evaluates 20 motor skills and 16 processing skills. The AMPS assesses all motor and processing skills, regardless of severity of disability or cultural factors, and is designed to assess all ages from 3 years of age. AMPS observes and evaluates individuals while performing two tasks, after ensuring that the assessment environment is as natural and familiar as possible.[16] In this study, it was conducted to confirm changes in daily life activities of the subjects. The test-retest reliability was r=.91 in the motor skill area and r=.90 in the processing skill area. In the homomorphic test reliability coefficient, the motor skill domain r=.91 and the processing skill domain r=.85, and in the split-half reliability analysis, the motor skill domain r=.92 and the processing skill domain r=.91, respectively, for AMPS evaluation. It was confirmed that the tool has a very high reliability.[17]

4. Intervention

Contactual hand-orientating response (CHOR) training refers to contact made in the form of friction with the ground so that the hand can properly perform its functional role. The intervention in this study is to modify and supplement the contents studied by Sue Raine et al. (2013).[9] First, the therapist has the patient support the treatment table behind the hip in an upright position. At this time, after placing the outside of the feet within a range that does not exceed the shoulder line, the left and right weight support is equalized. Next, place an auxiliary table on the left and right of the subject, and repeat so that the floor of both hands can lightly rest on the table ground as an auxiliary form for balance. The height of the left and right auxiliary tables is provided at a height at which the subject's elbow can be sufficiently extended. After that, the body weight is supported with the elbows of the arms extended. Induce active control of wrist, elbow, and shoulder movements of the upper extremity on the same side that supports body weight. Finally, the opposite upper limb crosses the center line and repeats the task of reaching out or moving an object. In this study, an occupational therapist with more than 8 years of experience was assigned and proceeded according to the research

Table 2. The intervention program

Stage	Minutes (min)	Intervention
1	5	Stimulation for enhancing the somatosensory of the hand.
2	5	Make the subject aware of the concept of the center line in an upright posture.
3	5	Repeat asking the subject to rest their hands lightly as a form of balance aid.
4	5	Repeat the state of supporting the subject's weight with the arm supported.
5	5	The therapist provides assistance and induces the subject to actively control the movements of the wrist, elbow, and shoulder of the upper extremity on the same side repeatedly.
6	5	Ask the subject to perform a simple task repeatedly with the opposite hand crossing the center line.

(A) (B) (C) (D)

Figure 1. Application of interventions in this study (A) It is a treatment that improves hand contact with the supporting surface for CHOR. (B) Have the subject recognize the concept of the center line in the correct standing posture. (C) Repeat the state in which the subject's weight is supported while the arm is supported. (D) Ask the subject to repeat a simple task with the opposite hand crossing the center line.

procedure, and the specific intervention procedure is as follows (Table 2)(Figure 1).

5. Process

5. 1. Baseline A, Baseline A’

During baseline A and A’ periods, hands-based somatosensory training was not conducted. Ataxia patients who participated in this study often complained of dizziness and fatigue, so a 3-minute break was given after a program was finished to minimize the effect on muscle fatigue. In order to prevent deterioration of concentration due to other external interference and noise, it is conducted in an independent space as much as possible.

5. 2. Intervention B

Intervention period B is conducted 3 times a week for a total of 12 times. Each session was conducted for 30 minutes, and 5 stages is formed after treatment, LOS and FRT are evaluated each time.

5. 3. Pre and post evaluation

Before the start of baseline A and within one month after baseline A', changes in activities of daily living are measured through AMPS and balance assessment is measured through BBS in the treatment room.

6. Analysis

This study records the LOS value during the baseline and analyzes the subject using a visual analysis method using a graph of the measured data. Calculate the average value within the period of each variable and compare and present the rate of change at each stage. If a value that exceeds the mean ± 2 standard deviations during the intervention period is measured twice consecutively, it is considered to have a treatment effect,[18] and the treatment continuation effect is measured at the baseline according to the method suggested by Marklund and Klassbo. When it is above the average value of, it is considered to have a sustained treatment effect.[19] In addition, before and after treatment, AMPS measurement values are converted into logit scores using OTAP software to confirm changes in activities of daily living, and the significance of balance is verified through BBS.

Ⅲ. Results

1. Changes in balance

As a result of applying CHOR training to patients with cerebellar ataxia, subject 1 scored 40 points beforehand and 41 points afterward on the Berg Balance Scale(Table 3). As a result of the LOS evaluation, on average, baseline A was 8123 mm^2, intervention B was 10417 mm^2, and baseline A' was 10442 mm^2. As a result of the FRT evaluation, the baseline A' was changed to 15.3 cm on average, 18.5 cm in the intervention period, and 18.5 cm in the baseline A'(Figure 2, 3)(Table 4, 5). And subject 2 showed 27 points before and 30 points after the bug balance scale(Table 3). As a result of the LOS evaluation, the baseline A' was 823 mm^2 on average, the intervention period B was 973 mm^2, and the baseline A' was 961 mm^2. As a result of the FRT evaluation, the average baseline A' was changed to 8.8 cm , Intermediate B 10.6 cm , and Baseline A' 11.1 cm (Figure 4, 5)(Table 4, 5).

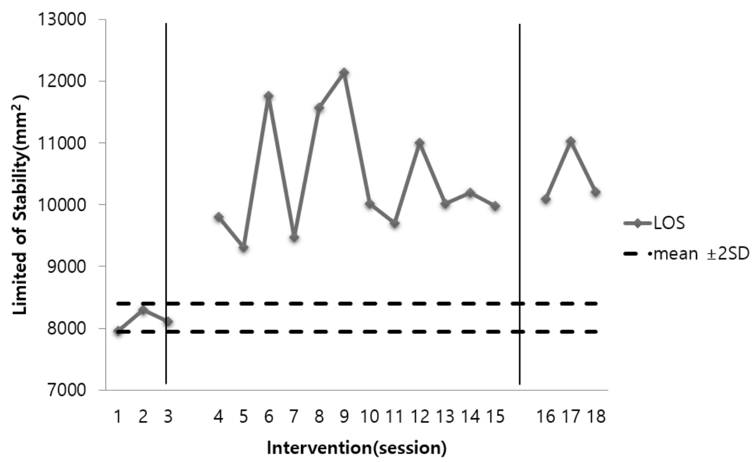

Figure 2. BIORescue change in Subject 1

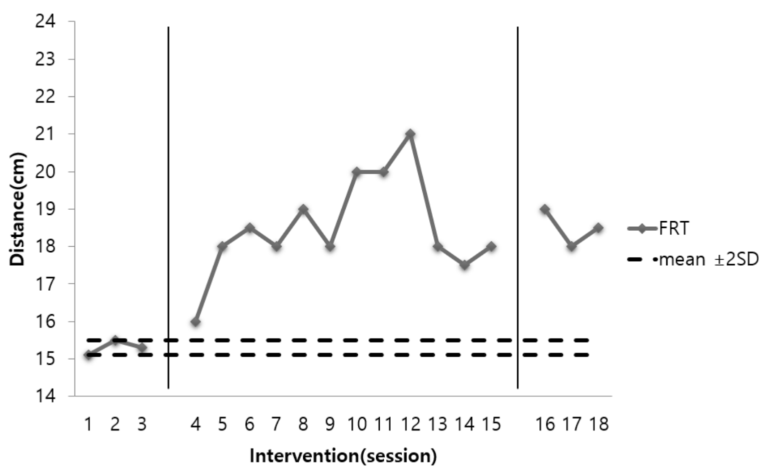

Figure 3. FRT change in Subject 1

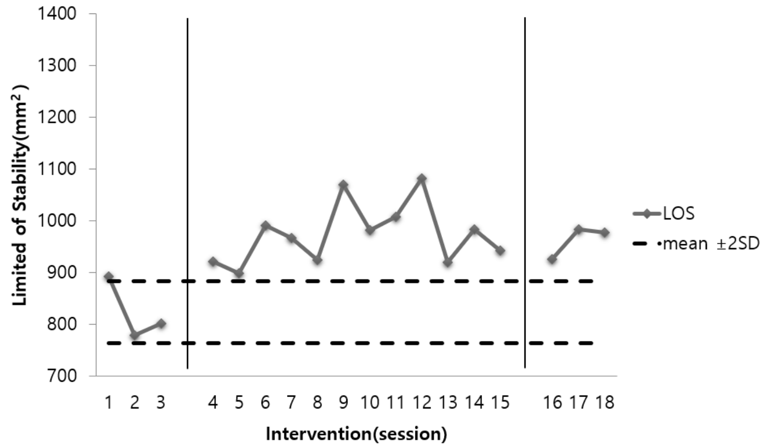

Figure 4. BIORescue change in Subject 2

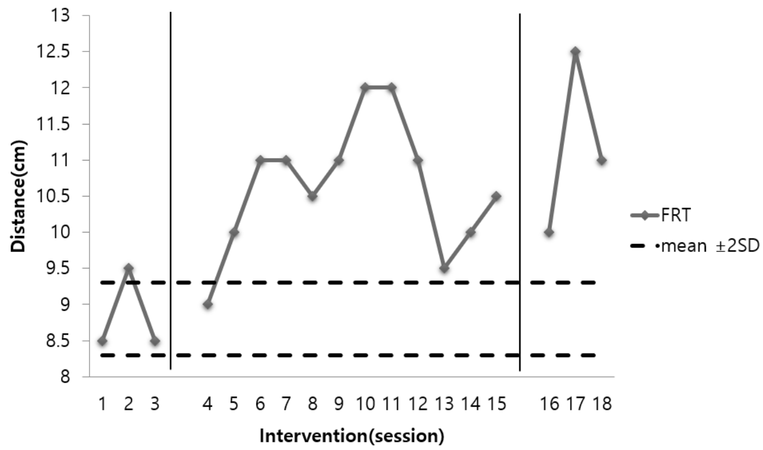

Figure 5. FRT change in Subject 2

Table 3. BBS change in subjects

	Pre(score)	Post(score)	Pre - Post
Subject 1	40	41	1
Subject 2	27	30	3

Table 4. LOS change in subjects

	Baseline A (mm^2)	Intervention B (mm^2)	Baseline A' (mm^2)
Subject 1	8123	10417	10442
Subject 2	823	973	961

Table 5. FRT change in subjects

	Baseline A (cm)	Intervention B (cm)	Baseline A' (cm)
Subject 1	15.3	18.5	18.5
Subject 2	8.8	10.6	11.1

Table 6. AMPS change in subjects

	Motor skills(logit)			Process skills (logit)		
	Pre	Post	Pre - Post	Pre	Post	Pre - Post
Subject 1	-0.1	0.5	0.6	0.2	0.3	0.1
Subject 2	-0.7	-0.3	0.4	0.1	0.3	0.2

2. Changes in activities of daily living

As a result of confirming the change in activities of daily living after CHOR training in patients with cerebellar ataxia, in subject 1, motor skills changed from -0.1 logit to 0.5 logit, and processing skills changed from 0.2 logit to 0.3 logit. In subject 2, motor skills changed from -0.7 logit to -0.3 logit, and processing skills changed from 0.1 logit to 0.3 logit (Table 6).

Ⅳ. Discussion

In this study, we tried to find out the improvement of balance and activities of daily living after applying CHOR training to patients with cerebellar ataxia. The cerebellum maintains equilibrium by combining the movements of each part of the body and fine-tunes the movements so that they occur smoothly. Previous studies have reported that various types of exercise program training have a positive effect on functional recovery in patients with cerebellar ataxia.[20,21] In addition, exercise therapies such as gait and balance training, coordination training, postural control training, and static/dynamic balance training have been shown to be helpful in improving movement disorder symptoms in patients with the cerebellum.[22]

Recent research results have shown that after the acute phase after brain injury, the central nervous system is not fixed in a damaged state, but reorganization occurs due to the morphological plasticity of the nervous system itself, resulting in a significant degree of functional recovery are losing.[23] As theories on the neural reorganization phenomenon are known, various attempts are being made to promote functional recovery. Intervention methods that promote the nerve restructuring process or functional recovery reported in the preceding literature include sensory stimulation including somatosensory and special senses, electrical stimulation, neurophysiological facilitation, application of experience and learning, and biofeedback mechanisms.[24,25] In particular, sensory stimulation has been frequently used as an intervention to promote awareness of consciousness in patients with severe brain damage with reduced consciousness.

In this study, the LOS results showed that subject 1 scored 40 points before and 41 points after the BBS. As a result of the LOS evaluation, on average, baseline A was 8123 mm^2, intervention B was 10417 mm^2, and baseline A' was 10442 mm^2. As a result of the FRT evaluation, the baseline A' was changed to 15.3 cm on average, 18.5 cm in the intervention period, and 18.5 cm in the baseline A'. And subject 2 showed 27 points before and 30 points after the bug balance scale. As a result of the LOS evaluation, the baseline A' was 823 mm^2 on average, the intervention period B was 973 mm^2, and the baseline A' was 961 mm^2. As a result of the FRT evaluation, the average baseline A' was changed to 8.8 cm, Intermediate B 10.6 cm , and Baseline A' 11.1 cm . In previous studies, the correlation between BBS and LOS was demonstrated through the improvement of balance ability through vibration sense, which is consistent with the results of this study.[26] These results show the correlation between the center of gravity (COG) at the base of support (BOS) and are the result of improving stability. In order for us to carry out our daily activities effectively and efficiently, we need the ability to maintain body balance in the basal plane. The ability to maintain a stable posture and maintain balance integrates the performance of motor functions, and as a result, interaction with the environment during movement is essential.[27] Recent studies have reported that feedback through other sensory functions complements motor learning functions. However, this movement control occurs not only in the cerebellum, but also in a deep relationship with the cerebrum. CHOR training helps to maintain balance through the connection between the cerebellum and the cerebrum, and motor learning through somatosensory is thought to be effective in improving the balance ability of patients with cerebellar ataxia. A previous study reported that learning through visual perception promotes interconnection between the cerebral motor cortex and sensorimotor cortex, induces neural reorganization, and improves motor function through rehabilitation treatment.[28)] In addition, it has been reported that such motor learning is effective only when it is repeatedly performed in a task-oriented manner.[29)] In other words, it is thought that somatosensory training through repetitive and direct hand contact will have a positive effect on the balance ability of patients with cerebellar ataxia.

According to a previous study, it was reported that patients with cerebellar disease had stronger torso sway than the general population, and that changes in the center of gravity and speed variability were very large during walking.[30)] It has also been reported that movement disorders, irregular limb control, and limb tremor in patients with cerebellar disease have difficulty stabilizing movements during continuous tasks such as walking.[31)] CHOR training improves the stability of these cerebellar patients and promotes motor learning through sensory information. Various tactile stimuli and physical activities provided by the therapist reorganize the cranial nerves and expand the cortical sensory reception area, so experiences of various senses using the tactile sense change the neural map of the damaged cortical area.[32)] In other words, repetitive stimulation of somatosensory nerves promotes motor learning by acquiring new motor skills and promoting conjunctival efficiency in primary motor areas.[33)] In addition, previous studies reported that sensory stimulation, along with increased use of hands, improves hand function, daily living activities, and improves quality of life. [34)] As a result, stability and participation in daily life can be improved.

The limitations of this study are that this study is an individual experimental study, and although it is possible to know the characteristics and changes of the subjects in detail, it is difficult to generalize due to the small number of subjects.

In future studies, it is necessary to prepare evidence for the balance level and various senses of patients with cerebellar ataxia, and study protocols for specific somatosensory training. In this study, as a result of applying somatosensory training to patients with cerebellar ataxia, it was confirmed that there was a significant improvement in dynamic balance evaluation.

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