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The effect of the action observation physical training on the upper extremity function in children with cerebral palsy

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The purpose this study was to investigate the effect of action observation physical training (AOPT) on the functioning of the upper extremities in children with cerebral palsy (CP), using an evaluation framework based on that of the International Classification of Functioning, Disability and Health (ICF). The subjects were divided into an AOPT group and a physical training (PT) group. AOPT group practiced repeatedly the actions they observed on video clips, in which normal child performed an action with their upper extremities. PT group performed the same actions as the AOPT group did after observing landscape photographs. The subjects participated in twelve 30-min sessions, 3 days a week, for 4 weeks. Evaluation of upper extremity function using the following: the power of grasp and Modified Ashworth Scale for body functions and structures, a Box and Block test, an ABILHAND-Kids questionnaire, and the WeeFIM scale for activity and participation. Measurements were performed before and after the training, and 2 weeks after the end of training. The results of this study showed that, in comparison with the PT group, the functioning of the upper extremities in the AOPT group was significantly improved in body functions and activity and participation according to the ICF framework. This study demonstrates that AOPT has a positive influence on the functioning of the upper extremities in children with CP. It is suggested that this alternative approach for functioning of the upper extremities could be an effective method for rehabilitation in children with CP.

Keywords: Action observation physical training, Cerebral palsy, Upper limb function

INTRODUCTION

Cerebral palsy is a clinical syndrome that presents as disorders in the development of postures and movements due to brain damage occurring in the fetal period or infancy. The result is motor or sensory nerve damage or affective disorders and the inability to perform many activities of daily living (Bax et al., 2005). Diverse therapeutic approaches are applied to resolve the motor disorders associated with cerebral palsy and to improve ability. Task oriented training is one therapeutic approach taken to enhance motor abilities in the upper extremities. This type of training associated with actual activities of daily living is effective for recovering motor ability (Harvey, 2009). It helps with functional organization by repeatedly training on activity tasks associated with daily living based on motor learning (Blundell et al., 2003). Task oriented training efficiently promotes controlled movements that are actually used when performing functional tasks (Wu et al., 2000).

The performance of imitation activities through observation is an efficient method that can reduce trial and error and save time in teaching new actions. Imitation activities play an important role in human development (Bekkering et al., 2000), as humans develop cognitive and preceptual ability through their ability to imitate. This enables efficient learning and the development of physical skills (Hayes et al., 2008). As such, children's development is closely related to their observational learning and imitation. Positive effects can be expected in rehabilitation by having

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the patient imagine movements by combining action observation and action imitation, and then performing movements in accordance with the imagination (Page et al., 2001). Thus, changes in motor ability can be effectively induced by considering training through observational learning and imitation as rehabilitation training methods.

Action observation physical training has become a new rehabilitation approach. This type of training involves the observation of actions and repeated training on those actions by imitating them. This training is closely related to observational learning and imitation and has been introduced for effective induction of neuroplasticity by doubling the effects of task oriented training.

The World Health Organization presented the International Classification of Functioning, Disability, and Health (ICF) as a framework for a system for expressing health and health related conditions and a unified standard classification and definition of the elements of health. The ICF defines functioning as having the interactions of the components of physical functions, structures, activities, and participation in harmony in environmental and personal factors. Recent studies have emphasized that functions based on the framework of the ICF should be included to identify problems in children with cerebral palsy. Children's physical functions, structures, and activities should be measured but so should the area of participation (Huang et al., 2009). Previous studies of action observation and physical training have been mostly limited to the measurement of the area of activities because these studies did not consider the three areas of functions based on framework of the ICF as they did not consider activities and participation. However, a comprehensive viewpoint is needed that encompasses physical functions, structures, activities, and participation to identify difficulties in real life and this viewpoint should be reflected in the treatment.

The purpose of the present study was to evaluate and examine the effects of action observation physical training where the patient observes actions and then imitates those actions. The study focus was the upper extremity functions of children with cerebral palsy in the areas of physical functions, structures, activities, and participation. The aim was to examine the potential of action observation physical training as a new rehabilitation approach for these children.

MATERIALS AND METHODS

Study subjects

The present study was conducted with 16 children diagnosed with cerebral palsy who were being treated at S Hospital. The general characteristics who participated in the present study are shown in Table 1. The 16 children completed the training course and measurement processes for 4 weeks. Children who satisfied the following conditions were selected by checking the medical records of the subjects:

1) Children at least 5 yr old diagnosed with cerebral palsy due to brain lesions

2) Children with no problems in vision and hearing

3) Children with language comprehension ability suitable for their ages

4) Children who could follow the researcher's instructions

5) Children with upper extremity muscle strength not lower than A+ (poor+) in manual muscle tests

6) Children with Modified Ashworth Scale (MAS) not exceeding grade 3 in passive movements of the upper extremities

The subjects participated in the experiments of the present study after their parents or guardians were given sufficient explanations about the purpose and procedure of the study.

Table 1. General characteristics of the subjects (n=16)

Characteristics		AOPT (n=8)	PT (n=8)	*P*
Sex	Male	4	6	
	Female	4	2	
Non-dominant side	Left	4	2	
	Right	4	6	
School attendance	Yes	5	5	
	No	3	3	
Type of paralysis	Hemiparalysis	4	3	
	Diplegia	3	5	
	Quadriplegia	1	0	
Age (yr)		9.13±2.36[a]	9.25±3.15	0.930[b]
Height (cm)		5.75±19.86	125.38±20.93	0.971
Weight (kg)		30.50±12.80	29.69±12.89	0.901
GMFCS		2.38±0.74	2.25±1.16	0.802

[a]Mean±standard deviation. [b]Independent sample t-test. GMFCS, Gross Motor Function Classification System.

Process of study progress

Children who satisfied the subject selection criteria were included as subjects. After their parents or guardians prepared written agreements for participation in the experiment, eight children were assigned to an action observation physical training group and eight children were assigned to a physical training group. The upper extremity functions were measured in all subjects in both groups. The training was implemented 30 min per day, three days per week, for a total of four weeks. The upper extremity functions of the subjects were measured again after implementation of the training for four weeks and were measured again two weeks after completion of training using the same measurement method. All subjects' scores from upper extremity function measurement tools were compared and analyzed

Study tools and measurement procedure

In the present study, the subjects were evaluated in the areas of physical functions, structures, activities, and participation based on the framework of the ICF (Fig. 1). The subjects' Grasp & Pinch strength and MAS were measured to evaluate their physical functions and structures and Box and Block Tests (BBT), Wolf Motor Function Tests (WMFT), ABILHAND-Kids, and Wee Functional Independent Measure (WeeFIM) tests were conducted to determine the subjects' activities and participation. In addition, the Cerebral Palsy Quality of Life Questionnaire for Children (CP-QOL-Child) was implemented to measure the quality of life of the children.

Videos for action observation physical training

The contents of videos for action observation related to upper extremity functions were composed of 12 actions related to the children's daily lives (Table 2). The videos used in the training were recorded from the front, sides, and rear of the actions so that the subjects could observe movements in the actions in three dimensions. Each action was recorded at two levels of difficulty. For instance, in the case of 'putting blocks into a bucket,' 'putting large blocks into a bucket' was defined as an easy action and 'putting small blocks into a bucket' was defined as a difficult action to divide the levels of difficulty. Upper extremity action videos were presented to the subjects in line with the levels of their functions. Each video was edited to a length of approximately 2 min and 30 sec and was repeated 2 times so that the replay time of each video was approximately five minutes.

Action observation and physical training methods

The children in the action observation physical training group were instructed to sit comfortably on chairs (with backs) in the laboratory (which was shielded from noises) and to observe the computer screens carefully. After observing the videos containing upper extremity functional actions, the children repeatedly practiced imitating the observed actions. The subject children were directed to observe the actions in the videos with concentration by having the researcher explain, "I will ask questions about the vid-

Table 2. Upper extremity functional training tasks

Putting blocks into a bucket
Holding a pencil to draw a line
Turning cards upside down
Putting coins into a money box
Piling up cups
Using a spoon
Removing bottle caps
Opening and closing zippers
Fastening buttons
Pouring water into a cup and drinking the water
Towel folding
Moving drink cans

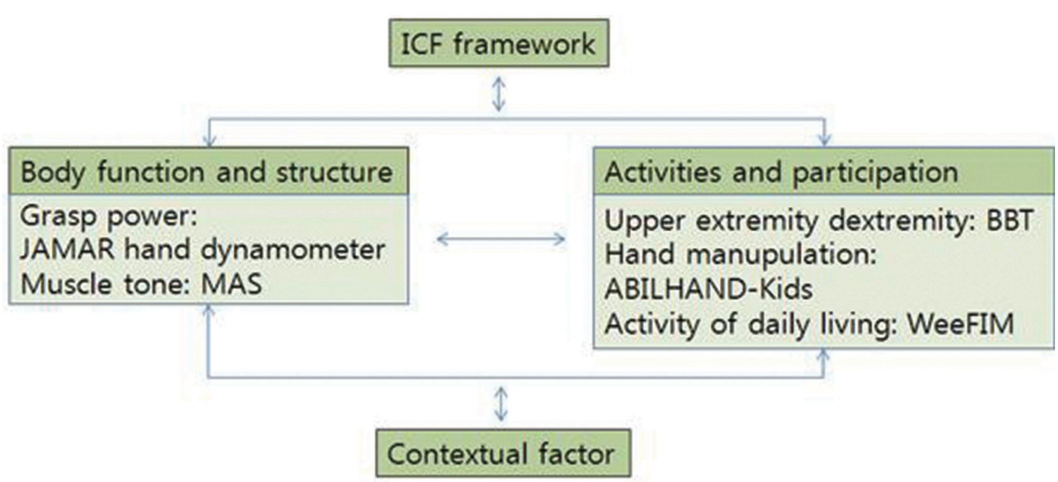

Fig. 1. Measurement tool based on ICF.
ICF, International Classification of Functioning, Disability and Health; MAS, Modified Ashworth Scale; BBT, Box and Block Test; WMFT, Wolf Motor Function Test; WeeFIM, Wee Functional Independent Measure.

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eos. Observe the videos carefully." The subject children were also instructed not to imitate any actions other than those they observed in the videos.

The subjects in the action observation physical training group observed upper extremity functional actions with videos at normal speed, then twice at lower speed and then again at normal speed. The observation time for each video was five minutes and two videos were shown during each training session. After observing the videos, the subjects repeatedly practiced the same actions as they had observed in the videos, for 10 min per task, while they were helped by therapists. The training was implemented for 30 min per time, three times per week, for four weeks. The total number of training sessions per subject was 12.

The subjects in the physical training group were instructed to observe photos of diverse landscapes such as mountains and the sea instead of actions. Except for the videos observed, all of their training time, trained actions, and training tasks were the same as those of the action observation physical training group.

Data analysis

Descriptive statistical analysis was conducted for the subjects' general characteristics and independent sample t-tests were conducted to compare differences in general characteristics between the groups. Differences in upper extremity functions among measurements before, after, and two weeks after completion of training were analyzed by Friedman tests. Differences among individual time points were examined by adjusting the significance levels of the measurements using Bonferroni correction and the measurements were compared using Wilcoxon's signed rank tests. Mann-Whitney U tests were conducted to compare the action observation physical training group and the physical training group. All data were analyzed using the SPSS (ver. 17) statistical program and the significance level α for testing significance was set at 0.05

RESULTS

Change made in body function and structure

The action observation physical training group showed significant differences in grasp at the three measurement time points (Friedman test, $\chi^2 = 12.968$, $P = 0.002$). Ex post facto analysis showed that grasp significantly increased after training compared to before training ($P = 0.012$) and the grasp at two weeks after training was also significantly higher compared that before training ($P = 0.012$). The physical training group showed no significant difference in grasp at any time point (Friedman test, $\chi^2 = 1.000$, $P = 0.607$). Comparison between the groups indicated that the action observation physical training group underwent significantly more improvement when compared to the physical training group ($P < 0.05$) (Tables 3, 4).

The MAS tests revealed significant differences for the action observation physical training group at the three measurement time points (Friedman test, $\chi^2 = 14.889$, $P = 0.001$). Ex post facto

Table 4. Comparisons of functions between the groups

	AOPT (n=8)	PT (n=8)	Z	P
Grasp power	1.61±0.76[a]	0.23±0.62	-2.950[b]	0.002
MAS	-0.62±0.38	-0.25±0.34	-2.159	0.031
BBT	7.88±2.90	2.38±1.92	-3.188	0.001
ABILHAND-Kids	3.75±3.06	1.63±2.67	-1.488	0.137
WeeFIM	1.13±0.83	0.75±0.71	-0.955	0.340

[a]Mean±standard deviation. [b]Mann-Whitney U test. MAS, Modified Ashworth Scale; BBT, Box and Block Test; WeeFIM, Wee Functional Independent Measure.

Table 3. Comparisons of functions before and after training

		Before training	After training	2 weeks later	χ^2	P
Grasp (kg)	AOPT	3.94±4.18[a,b]	5.54±4.15[c]	5.89±4.78[c]	12.968[d]	0.002
	PT	4.46±3.55	4.69±3.83	4.61±3.13	1.000	0.607
MAS	AOPT	2.12±1.05[b]	1.50±0.85[c]	1.21±0.96[c]	14.889	0.001
	PT	1.75±0.71	1.50±0.82	1.46±0.73	7.000	0.030
BBT	AOPT	14.50±9.29[b]	22.38±11.58[c]	21.25±11.18[c]	14.857	0.001
	PT	13.75±9.82	16.13±8.99	16.38±8.98	8.000	0.018
ABILHAND-Kids	AOPT	25.63±8.62[b]	29.38±7.76	30.50±7.86[c]	13.613	0.001
	PT	25.63±7.27	27.25±6.43	28.75±6.58	10.286	0.006
WeeFIM	AOPT	89.00±26.41	90.13±25.80	90.38±25.62	21.882	0.000
	PT	80.50±27.36	81.25±27.26	81.13±27.04	6.500	0.039

[a]Mean±standard deviation. [b,c]Results of ex post facto analysis, different letters indicate significant differences ($P<0.05$). [d]Friedman test. MAS, Modified Ashworth Scale; BBT, Box and Block Test; WeeFIM, Wee Functional Independent Measure.

analysis showed that the MAS test scores were significantly decreased after training compared to before training ($P=0.011$) and the MAS test scores were significantly lower at two weeks after the completion of training than before training ($P=0.011$). The MAS tests of the physical training group showed significant differences at the three measurement time points (Friedman test, $\chi^2=7.000$, $P=0.03$). Ex post facto analysis indicated no significant differences among the measurement time points. Comparison between the groups before and after training indicated significantly more improvement for the action observation physical training group than for the physical training group ($P<0.05$) (Tables 3, 4).

Change made in activities and participation

The BBT tests showed that the action observation physical training group showed significant differences at the three measurement time points (Friedman test, $\chi^2=14.857$, $P=0.001$). Ex post facto analysis indicated that the BBT test scores were significantly increased after training compared to before training ($P=0.012$) and the BBT test scores were significantly higher at two weeks after the completion of training than before training ($P=0.012$). The BBT tests of the physical training group showed significant differences at the three measurement time points (Friedman test, $\chi^2=8.000$, $P=0.018$). Ex post facto analysis revealed no significant differences among the measurement time points. Comparisons between the groups before and after training indicated significantly more improvement in the action observation physical training group than in the physical training group ($P<0.05$) (Tables 3, 4).

The ABILHAND-Kids scores used to measure the subjects' ability to use their hands in daily life activities revealed significant differences at the three measurement time points for the action observation physical training group (Friedman test, $\chi^2=13.613$, $P=0.001$). Ex post facto analysis indicted that the ABILHAND-Kids scores were significantly higher compared at two weeks after completion of training than before training ($P=0.012$). The ABILHAND-Kids scores of the physical training group showed significant differences at the three measurement time points (Friedman test, $\chi^2=10.286$, $P=0.006$). Ex post facto analysis indicted that the ABILHAND-Kids scores were significantly higher at two weeks after completion of training than before training ($P=0.011$). Comparisons before and after training revealed no significant differences between the two groups ($P<0.05$) (Tables 3, 4).

The WeeFIM scores, which measured the subjects' independence in daily living activities, revealed significant differences in the action observation physical training group at the three measurement time points (Friedman test, $\chi^2=21.882$, $P=0.000$). Ex post facto analysis showed no significant differences among the measurement time points. The WeeFIM scores of the physical training group showed significant differences at the three measurement time points (Friedman test, $\chi^2=6.500$, $P=0.039$). Ex post facto analysis showed no significant difference among the measurement time points. Comparison between the groups before and after training showed no significant difference between the two groups ($P<0.05$) (Tables 3, 4).

DISCUSSION

Among the physical functions and structures examined in this study, grasp showed significantly greater improvement in the action observation physical training group than in the physical training group. When a subject observes actions, the excitability of the corticospinal tract involved in actual performance of the action increases (Buccino et al., 2001; Hari et al., 1998). Transcranial magnetic stimulations (TMSs) transmitted while the subject was observing actions resulted in great increases in the size of motor-evoked potentials (MEPs), indicating increases in the excitability of the corticospinal tract. Muscle activities showed very similar muscle contraction patterns to those observed while the actions were actually conducted (Fadiga et al., 1995; Gangitano et al., 2002). Corticospinal tract excitability determines the degree of muscle contraction and mobilizes more muscles. Given these results, action observation is considered to have promoted motor functions by inducing the activity of the brain region and muscle contraction.

One hypothesis holds that muscle strength exercises aggravate spasticity, and many studies have been conducted to confirm or refute this hypothesis. For example, MacPhail and Kramer (1995) reported that when 17 cerebral palsy youths had performed muscle strength exercises, their muscle strength was improved at rates similar to those of healthy persons and their spasticity had decreased when the exercise program was completed. Another study involving stroke patients showed that muscle strength increased without any aggravation of spasticity (Sharp and Brouwer, 1997). Repeated muscle strength exercises were thought to reduce spastic stiffness by improving neural control over muscles and maintaining the extensibility of muscles. The results of these studies do not support the hypothesis that muscle strength increases aggravate spasticity; instead, they suggest that increases in muscle

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strength generally improved function. The results of the present study also confirmed that muscle strength for grasping increased as a result of action observation physical training and that significantly greater relief in spasticity, measured as MAS scores, occurred in the action observation physical training group than in the physical training group, in agreement with previous studies.

Grasp and MAS, which measure abilities the areas of physical functions and structures, showed significantly greater increases in the action observation physical training group than in the physical training group in the present study. Additional improvement is obtained only when motor ability is based on more fundamental physical functions and structures. If physical functions or structures have been impaired, this may restrict the area of activities. Therefore, improvement in the area of fundamental physical functions will enhance the level of activities and might bring about functional enhancement in daily living activities in items not evaluated.

A study conducted by Ertelt and colleague (2007), also with stroke patients, showed significantly more improvement in upper extremity functions in the action observation physical training group than in the physical training group and the results of fMRI measurement showed that functional reorganization of areas corresponding to MNS occurred in the action observation physical training group. These researchers suggested that a greater effect would be achieved by conducting physical training in parallel with action observation than by conducting physical training alone, and this would positively affect neural rehabilitation.

Buccino and colleague (2012) examined whether action observation physical training could improve the upper extremity functions of children with cerebral palsy. In this study, the action observation physical training group was instructed to observe videos of actions of the hands and the upper extremities required in daily living activities such as holding objects, using a pencil, Lego playing, etc. and repeatedly practice the activities, while the physical training group saw only a screen without any movement but then underwent the same physical training as the action observation physical training group. Upper extremity functions were measured using the Melbourne assessment scale before, immediately after, and two weeks after completion of training. The upper extremity functions were significantly improved in the action observation physical training group that conducted action training after observing actions. These researchers advised that action observation physical training was a promising intervention method for rehabilitation of children with cerebral palsy. Their results confirmed that action observation physical training can have positive effects on the performance of daily living activities and upper extremity functions not only in adult rehabilitation but also in child rehabilitation.

Action observation physical training is a training method in which actions are observed before training and imitated actions are repeatedly practiced. Action observation involves observation of actions conducted by others and this observation can activate the same neural structures as those involved in conducting the actual actions (Page et al., 2001). Imitation of these actions mobilizes an observation/execution matching system based on the MNS. The involvement of the MNS in imitation has been confirmed through brain imaging studies (Rizzolatti et al., 2001); for example, MNS activities appeared more strongly when action imitation of moving fingers was conducted in response to actions shown on the screen than for other motor conditions (Iacoboni et al., 1999). The fact that the motor projection area is activated simply by observation and imitation is considered quite meaningful for motor rehabilitation.

The combined findings of the present and previous studies indicate that action observation physical training that considers the characteristics of the MNS can positively affect neural rehabilitation. Motor imitation includes the processes of action observation, motor imagery, and motor execution and is related to a wide range of neural networks (Iacoboni et al., 2001), and changes in those networks improve the ability to conduct functional activities (Buccino et al., 2006). Children with cerebral palsy who did not experience normal development due to damage before birth or immediately after birth can be aided by observing normal movements and imitating those movements. The recovery of those movements can then bring about functional changes in the motor ability of the upper extremities and in daily living activities. Action observation can positively affect motor imitation and performance and if action observation is combined with general physical therapy, so that patients can conduct intensive after observing functional activities, additional effects can be anticipated (Sharp and Brouwer, 1997; Levy et al., 2001).

The two groups in the present study showed no significant differences in WeeFIM. The measurement tools used to assess daily living activities were in the forms of interviews and questionnaires, which required participation by the patients and their guardians. Difficulties in using assessment tools in the forms of interviews and questionnaires came from the lack of sensitivity of subjects. The sensitivity to changes felt by patients and their guardians could not be easily assessed. Since these assessment tools score subjective feelings of patients and their guardians, indicating the changes occurring in daily living activities and the quality of life would be difficult even if increases in physical functions, structures, and activities had occurred.

Studies that have examined the upper extremity functions in children with cerebral palsy using constraint induced movement therapy showed improvements in all areas of physical functions, structure, activities, and participation (Martin et al., 2008; Wallen et al., 2008). These studies had a training period of 8 weeks, which was longer than that used in the present study, or had an intervention time of 6 h, which again was longer than that used in the present study. These other studies suggest that the intervention time and period used in the present study might have been insufficient to reflect the changes occurring at the level of participation of the subjects.

The area of participation measured in the present study was the index of independency of daily living, but the content of training was the upper extremity motor ability and ability to perform activities. Therefore, even if the ability to perform several upper extremity activities was improved, it is difficult to say that the degree of independence would be improved substantially only because of this. Therefore, in future studies, the ability to move or activities that involve children's participation in society should be incorporated into the training and their effects examined.

The findings indicate that greater positive effects were seen on upper extremity functions in children with cerebral palsy in response to action observation physical training compared to simple physical training.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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