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Effects of a lower extremity strength training program on range of motion in children with spastic cerebral palsy

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KEYWORDS

Cerebral palsy;
Exercise;
Strength training;
Range of motion;
ROM.

ABSTRACT

Muscle weakness and limited range of motion (ROM) are common problems which cause activity limitation in children with spastic cerebral palsy (CP). A sliding rehabilitation machine is a rehabilitation machine that allows closed kinetic chain exercises of the lower extremity and exercise using the sliding rehabilitation machine can improve muscle strength and walking ability of children with CP. The objective of this study was to evaluate the effects of a lower extremity strength training program using a sliding rehabilitation machine on active range of motion (AROM) of the lower extremity in children with spastic CP. A single-blind randomized controlled trial was conducted in children with spastic CP, aged 7-18 years, who were randomly allocated into either an exercise (EG) or control group (CG). EG received a lower extremity strength training program using a sliding rehabilitation machine, 3 times per week for 6 weeks. The training loads were progressed every 2 weeks. Both EC and CG received prolonged muscle stretching by standing on a tilt table for 30 minutes, once a week for 6 weeks. AROM of the lower extremity was measured before and after the training. The result showed that AROM for hip extension, hip flexion, knee flexion and ankle dorsiflexion in the EG were improved significantly greater than that in the CG (all, p-value < 0.05). In conclusions, the strength training program using a sliding rehabilitation machine could improve AROM of the lower extremity in children with spastic CP.

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Introduction

Cerebral palsy (CP) is a group of permanent disorder of the development of posture and movement which is caused by a non-progressive lesion in the immature brain(1,2) and the *common type of CP* is *spastic CP. T*he main problems of these children are weakness of the lower extremity and abnormal range of motion (ROM). It has been shown that ROM of the lower extremity which is correlated with alignment in the upright position and walking. Asymmetric alignment in standing is often present in children with spastic CP(3,4) resulting in standing and walking ability limitations(3,4). Therefore, the important treatment goals for spastic CP are to restore abnormal ROM and maximize their ability to perform their functional activities.

Several studies reported that muscle weakness had a strong association with mobility limitations in children with CP rather than spasticity(5-8). Systematic reviews have shown that muscle strength training improves functional activity and strength in CP without adverse effect on spasticity or range of motion(1,9). Children with spastic CP improved their muscle tone, muscle strength, GMFM scores, basic motor abilities including standing and walking and gait function after receiving a functional strength training program(10-12) or a progressive resistance training for the lower extremity(13). A study suggested that ankle plantar flexor strength training program may lead to improvements in strength and spatiotemporal gait parameters of children with CP(14). Eagleton et al. found that a 6-week trunk and lower extremity strength training program using free weights and weight machines improved distance walked in 3 minutes, gait velocity, step length and cadence in adolescents with cerebral palsy(15). Therefore, using exercise machines for children with spasticity CP may be a method for improving ROM, especially when the joint is moved by the muscle that acts on the joint; it is known as active range of motion (AROM).

Functional strength training exercise such as sit-to-stand training has become of interest. It was found that sit-to-stand training can improve basic motor abilities, muscle strength, and walking efficiency in children with CP (10). Nevertheless, the application of sit-to-stand exercises is limited to children who have sufficient power to maintain a standing position or who do not have severe contractures of the plantar flexor. Previous studies reported that exercise using the sliding rehabilitation machine can improve muscle strength and walking ability of children with CP(16,17). Additionally, the sliding rehabilitation machine can provide partial body weight support by altering the inclination of the supporting bearing. Moreover, it is closed-kinetic chain exercises that can prevent the compensatory movement that occurs during exercise. It was also possible to allow children's feet to make full contact with the plate and to adjust for weight bearing exercise by controlling center-of-gravity movement(16,17). However, there are few studies that have observed at the benefit of strengthening exercise using a sliding rehabilitation machine on AROM of hip, knee and ankle joint in children with spastic CP. Thus, the study aimed to evaluate the effects of a lower extremity strength training program using the sliding rehabilitation machine on AROM in children with spastic CP.

Materials and methods

Participants and study design

Children who were diagnosed with spastic CP, aged 7-18 years, were recruited from Sri Sangvalya Khon Kaen School in Khon Kaen Province. All subjects were classified in the gross motor function classification system (GMFCS) level I-III, able to stand up from a chair 5 times independently without hand support, and understand and follow verbal instructions. The study excluded children who had a history of medical treatment for seizures, spasticity using botulinum toxin injections up to 3 months or orthopedic surgical procedures up to 6 months prior to the study. Written informed consent was obtained from participants and their parents or legal guardian. This study was approved by the Ethics Committee for Human Research, Khon Kaen University (HE592389).

A single-blind randomized controlled trial was conducted. Twenty-eight participants were randomly assigned to either the exercise group (EG) or the control group (CG) using stratified randomization of age range (7-12 years, and 13-18 years) and GMFCS by computer. During the research process, 2 participants were lost per group, and then at the end of the experiment, there were 12 volunteers in each group. The characteristics of participants in the study are shown in Table 1 and the participation flow chart is shown in Figure 1.

Table 1 General characteristics of the participants

Characteristics	Exercise group (n=12)	Control group (n=12)	*p*-value
Gender: male/female (n)	6/6	7/5	-
Age (years)	12.58 ± 2.57	12.92 ± 2.15	0.734
Weight (kg)	33.39 ± 9.34	34.03 ± 9.38	0.870
Height (cm)	138.06 ± 16.54	137.48 ± 18.91	0.938
BMI (kg/m^2)	17.48 ± 3.92	17.85 ± 2.84	0.792
(GMFCS: I/II/III) (n)	4/4/4	4/4/4	-

Note: Data are expressed as Mean ± SD, BMI: body mass index,
GMFCS: Gross Motor Function Classification System

Experimental protocol

Both EC and CG received a prolonged muscle stretching which was performed by standing on a tilt table for 30 minutes, once a week for 6 weeks as a conventional physical therapy (PT). Participants in the EG received the lower extremity strength training program for 20 minutes, 3 days per week for 6 weeks. The training program was supervised by an experienced physiotherapist. Five-minute ergometer cycling with free load was conducted as a warm-up period before training session[12]. The 10-minute exercise program included active exercise of the lower extremity against the body weight vest at loads 100% of 8 repetition maximum (8 RM). The 8 RM test was determined based on a previous study[11]. A sliding rehabilitation machine was used for supporting the participants during exercise in EC group (Figure 2). The machine consists of a pad for supporting the body; the footplate and Velcro straps for the safety; and a rail system for helping participants to perform exercises by up and down positioning. Participant was in a starting position of hip flexion to at least 90^o, the knee flexion at 90^o, and the feet evenly placed on the footplate (Figure 2A). A body weight vest (Figure 2C) with the determined loads was wrapped around the trunk. Then, participant was asked to extend the hips and knees (Figure 2B). The exercise was performed 8 repetitions per set, 3 sets a day with a 90-second resting interval. The training intensity was progressed by increasing load every two weeks using the 8 RM test. Another five-minute passive stretching for lower extremity was performed as a cool-down period and was conducted by a physical therapist, as previously described[10,12].

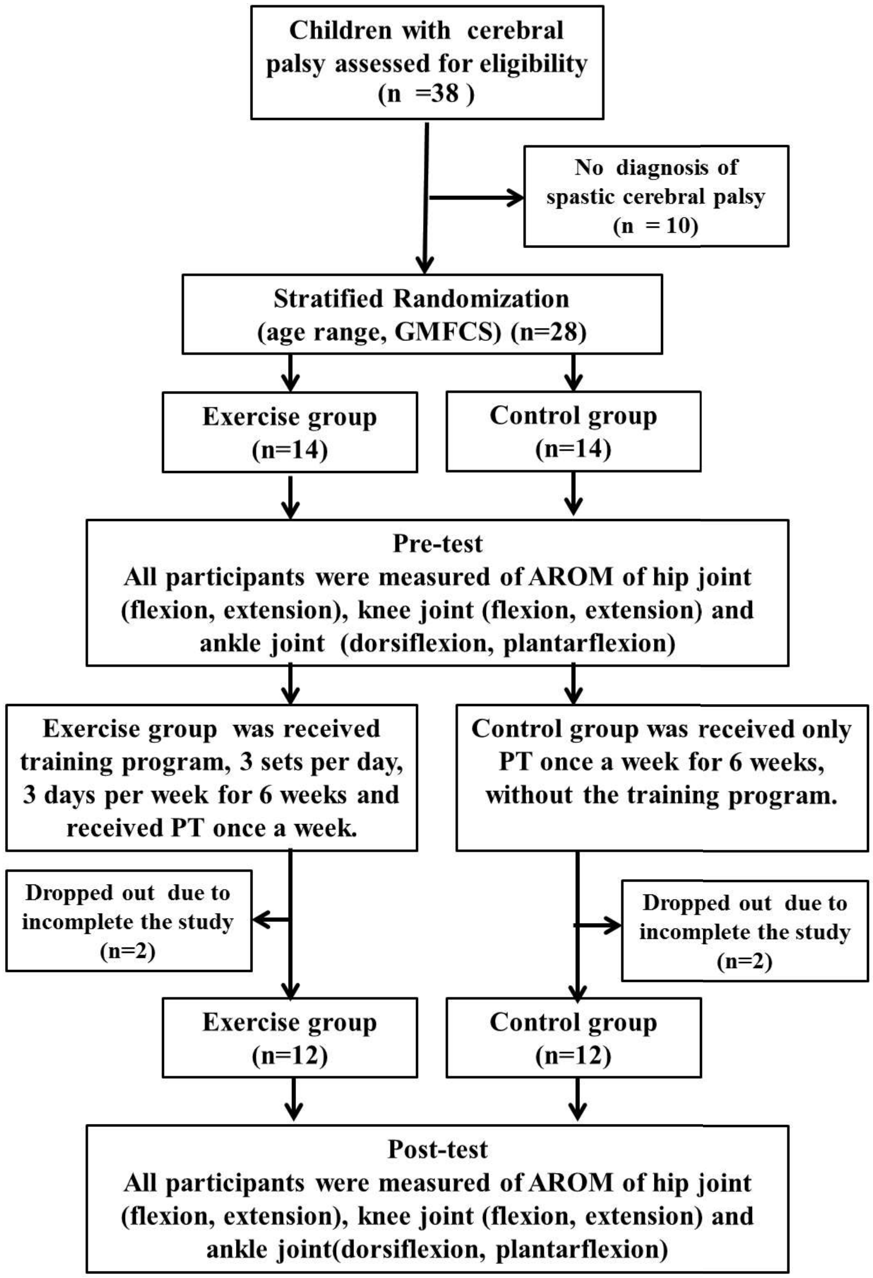

Figure 1 Participation flow chart

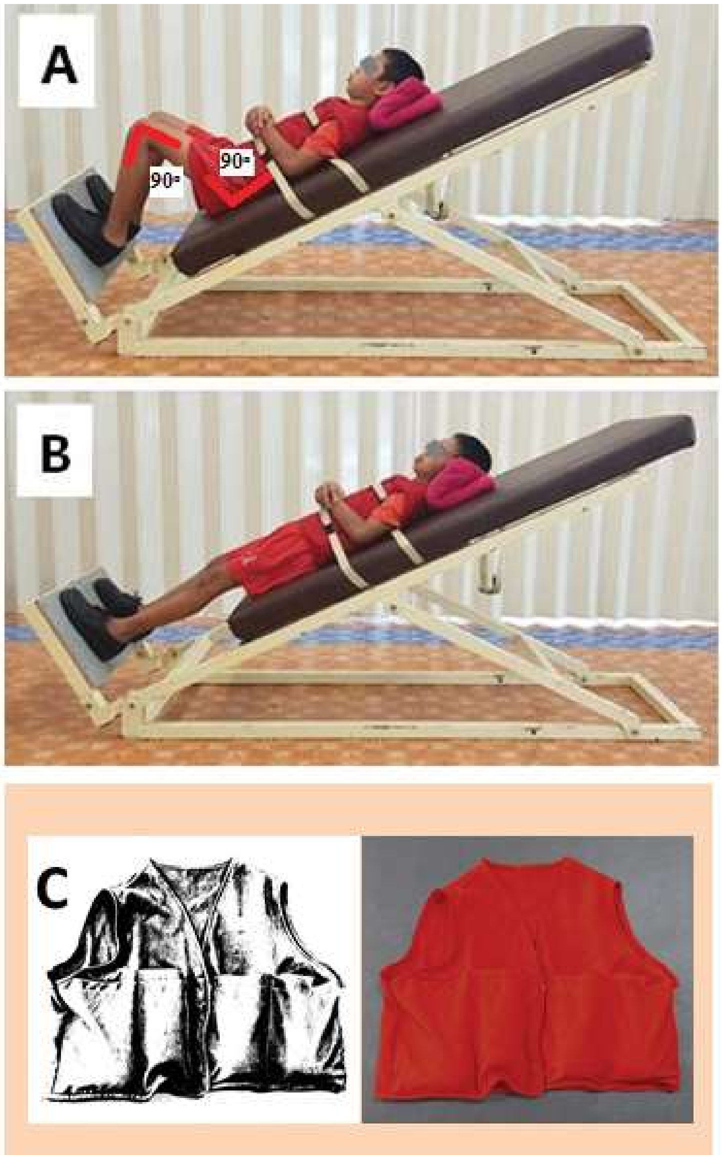

Figure 2 Strength training exercise using a sliding rehabilitation machine; A: starting position, B: participant is lifting up with knees and hip extension, C: weight vest

Outcome measurement

The measurements of AROM of lower extremity were taken using a standard goniometer including hip joint (flexion, extension), knee joint (flexion, extension) and ankle joint (dorsiflexion, plantarflexion) by a blind assessor at pre- and post-test. Previous study showed that the intra-rater reliability of the AROM measurement in children with spastic CP was high[18]. This study showed that the intraclass correlation coefficients (ICCs) were within an acceptable range (ICCs > 0.9, all p-value < 0.001). The weaker leg represented the leg that has less movement of AROM of hip extension than the stronger leg.

Statistical analysis

Statistical analysis was performed with SPSS 17.0 for Windows. Non-parametric tests were used when the data were not normally distributed.

Descriptive statistics were applied to explain baseline demographics. Intraclass correlation coefficient (ICC) was used to analyze the reliability of the AROM measurement. The mean values of the AROM between pre- and post-test within group were analyzed using Wilcoxon signed-rank test, and Mann Whitney U test was used for comparison of the AROM between two groups, with *p*-values less than 0.05 considered as statistically significant.

Results

The AROM for hip flexion and extension, knee flexion, and ankle dorsiflexion and plantarflexion of both legs in EG improved significantly after receiving program compared to those in the pre-test (all, *p*-value < 0.05) (Table 2). AROM of CG significantly improved for hip flexion and extension, and ankle dorsiflexion of both legs, and knee flexion of weaker leg (all, *p*-value < 0.05) (Table 3). In addition, the AROM of hip extension and knee flexion of both legs, hip flexion and ankle dorsiflexion of a weaker leg increased significantly in EG greater than CG (all, *p*-value < 0.05) (Table 4).

Table 2 Mean values of AROM for a weaker and a stronger leg in the exercise group (n = 12)

AROM (Degree)	Pre-test (Mean±SD)	Post-test (Mean±SD)	Mean Change (Mean±SD)	95% CI	*p*-value
Weaker leg					
Hip joint					
Flexion	94.67 ± 20.84	132.25 ± 14.07	37.58 ± 17.70	26.34 – 48.83	0.002*
Extension	5.75 ± 4.98	29.42 ± 8.11	23.67 ± 8.08	18.53 – 28.80	0.002*
Knee joint					
Flexion	111.83 ± 28.51	135.42 ± 22.20	23.58 ± 11.91	16.02 – 31.15	0.002*
Extension	- 4.75 ± 11.44	- 1.92 ± 5.27	2.83 ± 6.62	- 1.37 – 7.04	0.157
Ankle joint					
Dorsiflexion	3.42 ± 14.71	19.92 ± 15.79	16.50 ± 8.56	11.07 – 21.94	0.002*
Plantarflexion	36.50 ± 14.90	54.08 ± 8.26	17.58 ± 15.59	7.68 – 27.49	0.004*
Stronger leg					
Hip joint					
Flexion	102.50 ± 18.01	133.00 ± 13.11	30.50 ± 11.90	22.94 – 38.06	0.001*
Extension	8.08 ± 6.71	30.67 ± 7.96	22.58 ± 8.47	17.20 – 27.96	0.002*
Knee joint					
Flexion	116.17 ± 25.87	142.08 ± 15.05	25.92 ± 15.73	15.92 – 35.91	0.002*
Extension	- 3.58 ± 11.5	- 0.83 ± 2.89	2.75 ± 8.63	- 2.73 – 8.23	0.180
Ankle joint					
Dorsiflexion	5.92 ± 4.30	19.67 ± 8.24	13.75 ± 7.93	8.71 – 18.79	0.002*
Plantarflexion	37.92 ± 14.53	54.83 ± 8.71	16.92 ± 11.34	9.71 – 24.12	0.002*

Note: Mean ± SD: Mean ± Standard deviation, * *p*-value < 0.05

Table 3 Mean values of AROM for a weaker and a stronger leg in control group (n=12)

AROM (Degree)	Pre-test (Mean±SD)	Post-test (Mean±SD)	Mean Change (Mean±SD)	95% CI	*p*-value
Weaker leg					
Hip joint					
Flexion	91.08 ± 31.64	109.00 ± 18.58	17.92 ± 16.75	7.27 – 28.56	0.003*
Extension	8.42 ± 7.49	16.33 ± 12.01	7.92 ± 6.69	3.66 – 12.17	0.008*
Knee joint					
Flexion	109.50 ± 38.21	117.33 ± 31.47	7.83 ± 11.65	0.43 – 15.24	0.036*
Extension	- 5.67 ± 11.94	- 4.17 ± 10.19	1.5 ± 2.65	- 0.18 – 3.18	0.066
Ankle joint					
Dorsiflexion	5.17 ± 4.86	14.25 ± 9.01	9.08 ± 7.93	4.05 – 14.12	0.006*
Plantarflexion	38.67 ± 19.46	44.83 ± 7.83	6.17 ± 17.25	- 4.79 – 17.13	0.332
Stronger leg					
Hip joint					
Flexion	90.00 ± 24.02	112.58 ± 22.55	22.58 ± 14.37	13.45 – 31.71	0.003*
Extension	12.00 ± 9.52	16.08 ± 12.38	4.08 ± 5.50	0.59 – 7.58	0.035*
Knee joint					
Flexion	114.75 ± 35.76	±27.87	6.08 ± 16.86	- 4.63 – 16.79	0.141
Extension	- 4.83 ± 10.15	- 4.17 ± 9.00	0.67 ± 1.61	- 0.26 – 1.69	0.180
Ankle joint					
Dorsiflexion	8.75 ± 6.84	14.83 ± 6.56	6.08 ± 7.09	1.58 – 10.59	0.024*
Plantarflexion	36.67 ± 20.82	46.25 ± 11.51	9.58 ± 19.94	- 3.09 – 22.25	0.125

Note: Mean ± SD: Mean ± Standard deviation, * *p*-value < 0.05

Table 4 Mean difference values of AROM for a weaker and a stronger leg in both study groups

AROM (Degree)	Exercise group (Mean±SD)	Control group (Mean±SD)	Mean difference (Mean±SD)	95% CI	*p*-value
Weaker leg					
Hip joint					
Flexion	37.58 ± 17.7	17.92 ± 16.75	19.67 ± 7.04	5.08 – 34.26	0.012*
Extension	23.67 ± 8.08	7.92 ± 6.69	15.75 ± 3.03	9.47 – 22.03	< 0.001*
Knee joint					
Flexion	23.58 ± 11.91	7.83 ± 11.65	15.75 ± 4.81	5.78 – 25.72	0.007 *
Extension	2.83 ± 6.62	1.50 ± 2.65	1.33 ± 2.06	- 2.93 – 5.60	0.887
Ankle joint					
Dorsiflexion	16.50 ± 8.56	9.08 ± 7.93	7.42 ± 3.37	0.44 – 14.40	0.028*
Plantarflexion	17.58 ± 15.59	6.17 ± 17.25	11.42 ± 6.71	- 2.51 – 25.34	0.089
Stronger leg					
Hip joint					
Flexion	30.50 ± 11.90	± 14.37	7.92 ± 5.39	- 3.25 – 19.09	0.219
Extension	22.58 ± 8.47	4.08 ± 5.50	18.50 ± 2.92	12.45 – 24.55	< 0.001*
Knee joint					
Flexion	± 15.73	6.08 ± 16.86	19.83 ± 6.66	6.03 – 33.64	0.010*
Extension	2.75 ± 8.63	0.67 ± 1.61	2.08 ± 2.53	- 3.17 – 7.34	0.977
Ankle joint					
Dorsiflexion	13.75 ± 7.93	6.08 ± 7.09	7.67 ± 3.07	1.30 – 14.04	0.060
Plantarflexion	16.92 ± 11.34	9.58 ± 19.94	7.33 ± 6.62	- 6.40 – 21.07	0.242

Note: Mean ± SD: Mean ± Standard deviation, * *p*-value < 0.05

Discussion

The strength training program of the current study was the functional strength training exercise for whole lower extremity include hip, knee and ankle joints that importance for standing ability of children with CP. The results showed that after exercise training, the AROM of hip flexion, hip extension, knee flexion, and ankle dorsiflexion of a weaker leg, and hip extension and knee flexion of stronger leg were significantly higher than those of CG.

In this study, the weaker leg was characterized by the AROM of hip extension that degree less than another leg. The training program seems to improve the movement of the joints in the weak legs, especially at the hip joint. It shows that, the machine can help children to exercise more easily and conveniently, resulting in weak legs, able to exercise and gain the effect of exercising by increase muscle strength, leading to able to improve movement and AROM of the joint. The result showed that the AROM of knee extensions has no significant difference in both legs of the EG and the CG between pre-and post-test, and between groups, due to the pre-test value for both groups were the normal range value or full AROM. Moreover, in the CG, the data demonstrated that the AROM of ankle dorsiflexion of both legs were significantly increased compared to pre-test, but then less than normal ROM, which might result from a prolonged muscle stretching, that subjects were standing on a tilt table for 30 minutes, once a week, increasing muscle length especially the calf muscles, resulting in improving AROM of ankle dorsiflexion. For the EC, it was found that both AROM of ankle dorsiflexion and plantarflexion were significantly increased compared to pre-test and were within the normal range[19]. However, the result shown that only ankle dorsiflexion was significant differences as compared to the control group. This may be due to the effect of stretching the calf muscles and the exercise.

Previous study suggested the starting position at outer range of lower extremity like the optimal joint range of motion and sarcomere, the maximum number of crossbridges can form and shown maximum force of muscle[20], which is consistent with the exercise program in this study, the participants began in standing with hip and knee flexed at least 90° and then extended hip and knee maximally, and returned to starting position. In this exercise position was shown highly effective improve strength of hip extensors, hip flexors, knee flexors and ankle dorsiflexors as found the significant difference of AROM of the EG when compared with CG. Even though the AROM of the hip flexion and ankle dorsiflexion were found the significant different in weaker leg, it might be possible that the pre-test value of the weaker leg was lower than the strong leg, causing the differences after exercise to be more different, and it was indicated that this intervention can help restore muscle function, especially in muscles with severe weakness. These results were consistent with Park et al. which suggest that functional training using the sliding rehabilitation machine may have some effect on the mobility of ankle joint and balance in children with CP and reported that the ROM of the ankle dorsiflexion was significantly increased to the normal range after the functional training using the sliding rehabilitation machine and there were significant differences between the pre- and post-test in the pediatric balance scale (PBS) and GMFM[17]. It was indicated that ROM of lower extremities of children with spastic CP correlates with alignment in the upright position and walking[21-23]. The improvements in AROM of lower extremity could be explained by the effects of strength training program on muscle strength. Subsequently, an increase in muscle strength and optimize tone might leads to an increase in functional mobility of lower extremity[11,20,21] and lead to an improve in the AROM of joints with abnormalities. Active exercise in form of dynamic stretching might be another explanation for these discrepancies. Previous study reported that stretching muscles may prevent contractures and promote muscle growth[24,25]. Slow and continuous stretching which lasts for 30 minutes to 2 hours could decrease spasticity[26]. It may be possible that prolonged stretching can improve muscle length and joint mobility of lower extremity, such as the results found in the CG.

This study's strengths included a lower extremity strength training program that safe and easily deployed for whole muscles group of lower extremity. It would be useful for physical therapists, professional health care, teachers as well as parents to promote range of motion for children with CP. Limitations of this study was the progressive program provide by take the sand weight bag on a vest, which may be inaccurate and requires many materials.

Conclusion

A lower extremity strength training program by using a sliding rehabilitation machine was effective to improve the AROM of the lower extremity and useful for promoting AROM of the lower extremity in children with spastic CP. Further studies are needed to study the relationship between the AROM of lower extremity and gross motor abilities of lower extremity after receiving strength training program.

Take home messages

Research findings indicate that a lower extremity strength training program using a sliding rehabilitation machine was effective to improve and promote active range of motion (AROM) of lower extremity in spastic CP. Results showed that AROM of the lower extremity in the exercise group improved significantly as compared with control group (p-value < 0.05).

Conflicts of interest

The authors declare no conflict of interest.

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