The effects of progressive functional training on lower limb muscle architecture and motor function in children with spastic cerebral palsy

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Abstract. [Purpose] To investigate the effects of progressive functional training on lower limb muscle architecture and motor function of children with spastic cerebral palsy (CP). [Subjects] The subjects of this study were 26 children with spastic CP. [Methods] Thirteen subjects in the experimental group performed general neurodevelopmental treatment (NDT) and additional progressive functional trainings and 13 subjects in the control group performed only general NDT 3 times a week for 6 weeks. Ultrasonography, gross motor function measurement (GMFM) and the mobility questionnaire (MobQue) were evaluated. [Results] After the intervention, the muscle thickness of the quadriceps femoris (QF), cross-sectional area of the rectus femoris (RF), pennation angle of the gastrocnemius (GCM) and the MobQue score of the experimental group were significantly greater than those of the control group. The muscle thickness of QF correlated with the cross-sectional area (CSA) of RF and the pennation angle of GCM, and GMFM score correlated with the pennation angle of GCM. [Conclusion] Progressive functional training can increase muscle thickness, CSA, and the pennation angle of the lower limb muscles, and improve the mobility of spastic CP children making it useful as a practical adjunct to rehabilitation therapy.

Key words: Cerebral palsy, Function, Ultrasonography

INTRODUCTION

Cerebral palsy (CP) is not a progressive diseases, but movement problems and musculoskeletal disorders in CP may change over time1). In order to lessen the movement problems and musculoskeletal disorders of cerebral palsy, progressive functional training is used2–4). In a previous study, progressive functional training significantly improved muscle strength. However, walking ability and anaerobic muscle power did not change. In addition, spasticity and range of motion remained unchanged2). Thus, investigation of muscles architecture changes are required to assess cerebral palsy treatments.

Clinically, many measures of cerebral palsy are difficult to use in objective and quantitative analysis, because they are qualitative assessments of performance and dysfunction degree. Therefore, magnetic resonance imaging or ultrasound imaging are needed for the assessment of muscular architecture, e.g. muscle thickness, cross-sectional area, and pennation angle5, 6). So far, few studies have investigated the effectiveness of interventions using quantitative analysis of muscular architecture changes in CP. Therefore, the purpose of this study was to evaluate the effectiveness of the progressive functional training using ultrasonography of lower limb muscular architecture and motor function of spastic CP children.

SUBJECTS AND METHODS

We enrolled 26 spastic CP children. The inclusion criteria were an age between 5 and 10 years, the ability to follow verbal instructions, and the ability to walk independently indoors with or without walking aids (Gross Motor Function Classification; GMFCS levels I–III). The exclusion criteria were unstable seizures, any treatment for spasticity or surgical procedures in the 6 months before the study, any change in medication expected during the study period, of any other disease that would have interfered with physical activity.

This study lasted for 6 weeks and had a single-blind randomized controlled design. The purpose of the study was explained to the participants or caregivers, and their informed consent was obtained. The study protocol was approved by the institutional review board of Sahmyook University, Seoul.

The control group received 30 minutes general neurodevelopmental treatment (NDT), 3 sessions a week for 6 weeks.
The experimental group received the same 30 minutes general NDT with an additional progressive functional training program, 3 sessions a week for 6 weeks. The progressive functional training program consisted of warm-up exercise using range of motion and stretching for 3 minutes, followed by three functional training items: loaded sit-to-stand for 5 minutes, loaded lateral step-up and half knee-rise for 10 minutes, and unloaded lateral step-up and half knee-rise for 10 minutes. To finish the program, a 2-minute cool-down exercise using a tension-relaxation was used. The training load was initially set to 5% of subjects’ body weights and progressively increased, based on repeated estimation of the eight-repetition maximum. After performing each training item, a break of 1–2 minutes was provided.

Ultrasoundography (US), gross motor function measurement (GMFM), and the mobility questionnaire (MobQue) were evaluated before and after the intervention. An ultrasoundography system (Medison Myosone, U5, Samsung, Korea) with a 6–12-MHz, 2D B-mode linear transducer was used to obtain images of the quadriceps femoris (QF), rectus femoris (RF), and gastrocnemius (GCM). The right side muscle thickness of QF, cross-sectional area (CSA) of RF, and the muscle thickness and pennation angle of GCM were measured. The US measurements were carried out by one examiner who had 5 years experience in musculoskeletal US. The average values of three measures were calculated and used in the analysis.

In order to assess the motor function of subjects, the Gross Motor Function Measurement-88 (GMFM-88) was conducted by one pediatric physical therapist who had 3 years of experience in GMFM-88. Subjectively reported mobility was assessed with the MobQue which consists of 47 questions assessing caregiver-reported mobility limitations.

SPSS ver. 18.0 statistical software was used for statistical analyses. The Kolmogorov-Smirnov test was used to examine the normality of the data, which were found to be normally distributed. The χ2 test and independent t-test were used to assess the homogeneity of the groups. The paired t-test was used to test the significance of differences in the pre- and post-intervention values of each group. The independent t-test was implemented to test the significance of differences between the control and experimental groups after the intervention. Finally, the Pearson correlation coefficient was used to investigate the relationships between each muscles’ architecture items and motor function in the two groups. Significance was accepted at p < 0.05.

**RESULTS**

The general characteristics of both groups are shown in Table 1. After the intervention, the thickness of QF, CSA of RF, and the pennation angle of GCM showed significant increases in the experimental group (p<0.05) (Table 2). The MobQue score of the progressive functional training group showed a significant improvement compared to the control group (p<0.05). The GMFM score of the experimental group increased more than that of the control group, but was not significantly different (Table 3). Pearson correlation coefficients show that the thickness of QF correlated with the CSA

### Table 1. The general characteristics of the subjects

| Parameter     | Groups             |
|---------------|--------------------|
|               | Experimental group | Control group     |
|               | (n=13)             | (n=13)            |
| Gender        |                    |
| Male/Female (%) | 8/5 (61.5/38.5)    | 5/8 (38.5/61.5)   |
| Age, years    | 6.1 (2.7)          | 6.9 (2.5)         |
| Height, cm    | 107.2 (21.8)       | 118.0 (27.6)      |
| Weight, kg    | 19.1 (8.2)         | 25.8 (16.4)       |
| BMI, kg/m²    | 16.3 (1.9)         | 17.1 (3.6)        |

Values are n (%) or mean (SD). There was no significant differences between the groups.

BMI: body mass index

### Table 2. Comparison of muscle architecture of the lower limb between groups, and before and after intervention

| Parameter     | Groups             |
|---------------|--------------------|
|               | Experimental group | Control group     |
|               | (n=13)             | (n=13)            |
| QF thickness  |                    |
| (cm)          | Pre 1.6 (0.2)      | 1.8 (0.2)         |
|               | Post 1.9 (0.2)**   | 1.7 (0.3)         |
|               | Change 0.3 (0.2)** | −0.1 (0.3)        |
| RF CSA thickness | Pre 1.2 (0.5)    | 1.7 (0.6)         |
| (cm²)         | Post 2.1 (0.7)**   | 1.6 (0.5)         |
|               | Change 0.9 (0.7)** | −0.1 (0.7)        |
| GCM thickness |                    |
| (cm)          | Pre 0.7 (0.1)      | 0.8 (0.2)         |
|               | Post 1.0 (0.1)**   | 1.0 (0.2)         |
|               | Change 0.3 (0.2)   | 0.2 (0.4)         |
| GCM pennation angle (°) | Pre 14.9 (6.2) | 17.8 (8.2)        |
|               | Post 17.9 (3.5)**  | 15.6 (3.4)        |
|               | Change 3.0 (4.6)** | −2.2 (6.4)        |

Values are mean (SD); *indicates significant difference, p<0.05; **indicates significant difference, p<0.01.

QF: Quadriceps femoris; RF: rectus femoris; CSA: cross-sectional area; GCM: gastrocnemius

### Table 3. Comparison of GMFM and MobQue scores between groups and before and after intervention

| Parameter     | Groups             |
|---------------|--------------------|
|               | Experimental group | Control group     |
|               | (n=13)             | (n=13)            |
| GMFM (score)  |                    |
| Pre           | 78.0 (19.1)        | 79.1 (14.7)       |
| Post          | 81.9 (16.1)**      | 81.3 (14.3)**     |
| Change        | 3.9 (4.0)          | 2.1 (1.9)         |
| MobQue (score)|                    |
| Pre           | 55.7 (29.9)        | 48.3 (26.9)       |
| Post          | 66.9 (26.7)**      | 51.5 (25.7)       |
| Change        | 11.2 (8.8)**       | 3.2 (10.6)        |

Values are mean (SD); *indicates significant difference, p<0.05; **indicates significant difference, p<0.01.

GMFM: Gross Motor Function Measurement; MobQue: Mobility Questionnaire
In the correlation coefficient analysis, the GMFM score increased after the intervention in the experimental group. CSA of RF, and the pennation angle of GCM significantly increased with functional level. The function of CP children has long been recognized as primary clinical features of CP. Our results show that the progressive functional training improved the muscle architecture items of muscle thickness, CSA, and the pennation angles of CP children who had pathological problems with their muscle function. These fine structural muscle changes may lead to improvement in function.

The findings of this study demonstrate that progressive functional training can increase muscle thickness, cross-sectional area, and the pennation angles of lower limb muscles, and improve the mobility of spastic CP, and can be used as a practical adjunct to rehabilitation therapy. A limitation of this study was that we could not divide the CP subjects into hemiplegia and diplegia groups due to the small number of subjects. We suggest further study implementing various individual treatments and using measurements of muscle architecture.

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| Table 4. Pearson correlation coefficient among muscle architectures and mobility function |
|----------------|----------------|----------------|----------------|----------------|----------------|
| Parameter      | QF thickness (cm) | RF CSA (cm²) | GCM thickness (cm) | GCM pennation angle (°) | GMFM (score) | MobQue (score) |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| QF thickness (cm) | 1             |                |                |                |                |                |
| RF CSA (cm²)    | 0.763**       | 1              |                |                |                |                |
| GCM thickness (cm) | 0.383         | 0.519**        | 1              |                |                |                |
| GCM pennation angle (°) | 0.452*         | 0.537**        | 0.521**        | 1              |                |                |
| GMFM (score)    | 0.076          | 0.188          | 0.361          | 0.585**        | 1              |                |
| MobQue (score)  | 0.112          | 0.175          | −0.093         | 0.136          | 0.112          | 1              |

Values are r (Pearson’s coefficient). *indicates significant correlation at p<0.05, **indicates significant correlation at p<0.01.

QF: quadriceps femoris; RF: rectus femoris; CSA: cross sectional area; GCM: gastrocnemius; GMFM: Gross Motor Function Measurement; MobQue: Mobility Questionnaire.

...and GCM, and the pennation angle of GCM.

Muscle weakness and changes in muscle architecture have long been recognized as primary clinical features of CP. Our results show that the progressive functional training improved the muscle architecture items of muscle thickness, CSA, and the pennation angles of CP children who had pathological problems with their muscle function. These fine structural muscle changes may lead to improvement in function.

In our study of muscle architectures, the thickness of QF, CSA of RF, and the pennation angle of GCM significantly increased after the intervention in the experimental group. In the correlation coefficient analysis, the GMFM score significantly correlated with the muscle thicknesses of QF and GCM, and the pennation angle of GCM.

...and improve the mobility of spastic CP...
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