Functional strength training in child with cerebral palsy
GMFCS IV: Case report

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Abstract:
Objective: To evaluate the effectiveness of a functional strength training.
Case report: A nine-year-old child with Cerebral Palsy (CP) classified as level IV according to Gross Motor Function Classification System participated in the study. Assessments were at baseline, five weeks and 10 weeks post-intervention. Lower-extremity muscles strength was evaluated with an isokinetic dynamometer. Also, Gross Motor Function Measure (GMFM-88) and Timed up & Go (TUG) tests were assessed. A functional strength training protocol, four sessions a week, for 10 weeks was applied.
Results: Following functional strength training, it improvements were found in hip, knee and ankle muscles strength, as well as increase in GMFM-88 score and decrease in time for TUG test performance. Positives outcomes from functional strength training were obtained beyond improvements in strength, since improvements in functional motor performance were also achieved.
Conclusion: Therefore, individualized, specific and functional strength training seems to be an alternative to rehabilitation of children with CP with high level of functional disability.

Keywords: Cerebral Palsy, exercises, rehabilitation, motor activity, strength

Introduction
Children with Cerebral Palsy (CP) present multiple impairments, including muscle weakness, spasticity and deficits in coordination [1]. Muscle weakness has been recognized as a primary limiting factor in CP [2], and it has been associated to limitations in motor activity performance [3]. Several studies have been conducted to evaluate strength training in children with CP. Increases in muscle strength and functional enhancement after strength training were reported in children with CP [3]. However, recent reviews about this topic have shown poor evidence for the effectiveness of strength training in increased function in children with CP [4, 5].

Scholtes et al. [6] proposed that the possible explanations for these results could be related with short training periods, diversity in strength training protocols and insufficient training resistance or progression. Taking into account these factors, the authors studied the effectiveness of protocols including functional activities such as exercises associated with overload principle for 12 weeks in children with CP. They concluded that although these functional progressive resistance training seems to be effective in increasing muscle strength, it did not result in increased functionality, evaluated by walking ability.

One explanation for the lack of effectiveness of those strength protocols in functionality could be the fact that functional activities, as walking and sit-to-stand movement, present a non-linear relationship with muscle strength. In this relationship, increases in muscle strength will culminate in increases in functional performance only in individual with a pronounced weakness [7–9]. Previous studies suggested that walking ability requires only a lower amount of muscle strength [10, 11]; therefore, it is possible that strength training would be more effective in children who are more impaired, for example, classified as level III or IV according to GMFCS; as well as for children who had surgery [12].
Thompson et al. [13] found a progressive reduction in strength in all muscles group with increasing walking difficulty from GMFCS levels I to III in children with diplegic CP.

Over the past years there have been several studies regarding strength training in children with CP. However, one of the many gaps is the evidence on response for strength training of children with CP who have more severe limitations in mobility. Therefore, we aimed to evaluate the effects of functional strength training on improvements in isokinetic lower extremity strength and gross motor function in a child with CP classified at GMFCS level IV.

**Case description**

**History**

KMT was a nine-year-old girl with spastic diplegic CP, classified as level IV according to GMFCS. One year before the study, KMT received botulinum toxin injections to gastrocnemius muscles on both sides; pelvic osteotomy; left femoral derotation and adductor tendon lengthening. The child was not able to walk before the surgery.

At baseline assessment, the child was able to ambulate in some indoors settings with assistive device (anterior rolling walker) and ankle-foot orthoses. She needed assistance from an adult to steer the walker only to avoid obstacles. KMT required the use of a wheelchair to get around the community, and was not able to propel it independently. Moreover, she required assistance in most posture transfers and was not totally able to sit and stand unsupported. KMT stated that her goals were to safely sit independently, ambulate at school, indoors and outdoors; decreasing her reliance on others. Moreover, the child was able to follow commands and directions. She attended to school in regular education, and was able to write and read.

Physical examination was performed and we observed muscle weakness (Kendal scale) and spasticity (Ashworth scale) predominantly in lower limb and trunk; decreased range of motion and deficits in postural control, especially in sitting posture (Table I).

KMT participated in rehabilitation programme, in clinical settings, since she was three years old, two times a week, with 60 minutes duration for each session. The rehabilitation was based on the Bobath concept and included functional exercises training.

During clinical observation, we observed that KMT presented muscle weakness and impairments in functional performance, especially decreased gait velocity, poor alignment during functional tasks, difficulties in sitting unsupported and to perform lateral walk. Furthermore, she was submitted to multi-level orthopedic surgeries and botulinum toxin injections, which contribute to muscle weakness. Therefore, a strength training programme seemed to be an appropriate rehabilitation alternative for KMT.

**Assessment**

The Ethics Committee for Human Research of Federal University of São Carlos approved the study, which is in agreement with the Declaration of Helsinki and the resolution 196/96 from National Health Council. The child was admitted in the study following informed written parental consent.

Independent researches, who were physical therapists experienced in administering pediatric outcomes, performed each of the tests, but the same test was performed by only one examiner. Assessments were at baseline, five weeks of intervention and ten weeks of intervention. First, Gross Motor Function Measure (GMFM-88) and Timed Up & Go (TUG) evaluation were conducted. Then, muscles strength was evaluated with an isokinetic dynamometer.

GMFM is a valid, reliable and sensitive test, especially developed for children with CP. It measures gross motor function improvements over time or as a result of intervention [14]. GMFM was applied according to manual guidelines. The whole procedure was recorded. The intra-rater agreement was 92%.

TUG is a practical and quick test which has been widely used to verify ambulatory mobility [15]. In this study, the child was sat on a bench with her knees and hips at 90° of flexion and her feet resting on the floor. Initially, instructions and explanations were delivered to the child. One trial was allowed to practice.

TUG was performed according to Williams et al.’s [15] description. In this study, the child performed sit-to-stand movement with support and walked with

<table>
<thead>
<tr>
<th>Muscle tone</th>
<th>Muscle strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trunk extensors</td>
<td>1</td>
</tr>
<tr>
<td>Abdominal</td>
<td>1</td>
</tr>
<tr>
<td>Hip internal rotators</td>
<td>2</td>
</tr>
<tr>
<td>Hip external rotators</td>
<td>1</td>
</tr>
<tr>
<td>Hip flexors</td>
<td>1</td>
</tr>
<tr>
<td>Hip extensors</td>
<td>1</td>
</tr>
<tr>
<td>Hip adductors</td>
<td>2</td>
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<tr>
<td>Hip abductors</td>
<td>1</td>
</tr>
<tr>
<td>Knee flexors</td>
<td>2</td>
</tr>
<tr>
<td>Knee extensors</td>
<td>1</td>
</tr>
<tr>
<td>Ankle plantarflexors</td>
<td>2</td>
</tr>
<tr>
<td>Ankle dorsiflexors</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes: "Ashworth scale. 
"Kendal scale.
assistive device (anterior roller walker). Time in seconds was recorded from the “go” cue to when the child sat down on the bench. One trial was considered for analysis. In this sense, the shorter the time of execution, better dynamic balance control was obtained by the child. The intra-rater agreement was 92%.

Isokinetic evaluation was performed with the Biodex System-3 pro computerized isokinetic machine (Biodex Medical System, Shirley, NY). Hip adductors/adductors, knee flexors/extensors and ankle dorsiflexors/plantarflexors muscles were evaluated. Peak torque/body weight (N-M) was considered for analysis.

Hip: the child was placed in side-lying position. The dynamometer axis was aligned with the intersection point of the posterior superior iliac spine and the greater trochanter. The lever arm was attached below inferior patella border. The hip was rotated from 0° to 30° of hip adduction [16].

Knee: the child was placed in sitting position with hip flexed at 90°. The knee joint axis was aligned with the centre of the Biodex lever arm. The lever arm was placed two inches above the lateral malleolus. The knee was rotated from 90° of knee flexion to 20° of knee extension [17].

Ankle: the child was placed in the sitting position with hip and knee maintained in 70° and 30° of flexion, respectively. The ankle axis was aligned with the centre of the lever arm. The ankle was rotated from maximal active dorsiflexion to maximal active plantarflexion [18].

The 30°/s angular velocity and the concentric isokinetic mode were chosen. The passive mode protocol was chosen since the child was unable to produce enough active torque to self initiate movement of the lever arm and do not have enough strength to move the lever arm against gravity [18]. In the passive mode test, the individual performs a maximal effort and, at the same time, the dynamometer produces movement at a constant preset velocity [19]. Therefore this test is called an active-assisted test. Initially, five sub-maximal contractions were carried out for child familiarization. After two minutes, five maximal contractions for each joint were required.

Intervention description

At the first session, the physical therapist taught the exercises without resistance. Once the exercise technique was mastered, the training load was determined. The load should be such that the child could only complete ten repetitions of each exercise before fatigue sets in. The training load was adjusted by adding free weights around body segments. The child was evaluated every week to adjust training load. A physical therapist experienced in administering pediatric rehabilitation protocols carried out the intervention. Each session lasted between 60 and 90 minutes. The child executed four sessions a week for ten weeks. All exercises were performed in three sets of ten repetitions, with 90-second interval between sets [12].

A warm-up period was applied. The intervention was established according to child’s needs. Therefore, hip adductors/adductors, knee flexors/extensors and ankle plantarflexors/dorsiflexors strengthening were emphasized. In addition, exercises for trunk-stabilizer muscles were included [20]. Details of the warm-up and exercises are reported in Table II. A cool-down period was applied and included relaxation sessions and stretch exercises of the lower limbs. During strength training period, the child stopped her previous treatments. At all exercises, neoprene straps were utilized for promoting adequate biomechanical alignment, preventing hip internal rotation and thigh external rotation.

Results

Peak torque/body weight increased after intervention, except for left knee muscles. Moreover, GMFM score increased, especially in dimensions D and E, and TUG score decreased after the strength training (Table III). The child did not report any pain or discomfort during evaluation or exercises performance, as well as did not have injuries.

Regarding GMFM test, we found the greater improvements in the following items: rolling to sit, sit on a bench from the floor, kneeling on the floor, sit-to-stand with support of upper limbs, stand to sit, sit to stand without arms, kneeling to standing, lateral walking with support, stepping forward with support and stair climbing. During training the load was adjusted according to child’s improvement in muscle strength. The description of load progression is presented in Table IV.

Discussion

The purpose was to investigate the effects of functional strength training in a child with CP and with severe motor function disability. Improvements were found in lower-extremity muscle strength and motor activities performance. Although studies reported similar results to ours, it remains unclear whether strength training can improve functionality [3]. Therefore, we suggest that some factors can be associated with the positive outcomes found in this case report.
### Table II. Exercises description.

<table>
<thead>
<tr>
<th>Muscle groups</th>
<th>Warm-up</th>
<th>Trunk-stabilizer</th>
<th>Hip flexor and ankle dorsiflexor</th>
<th>Knee extensor</th>
<th>Knee flexor and ankle plantiflexor</th>
<th>Hip adductor and abductor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday/Wednesday</td>
<td>Treadmill walking - 10 minutes</td>
<td>Bridging: In the hook-lying position, pressing the upper back and feet into the mat, the child should raise her pelvis of the floor, hold this position for 30 seconds and then back to initial position. The resistance was applied by free loads strapped around pelvis and proximal thigh.</td>
<td>Step forward: In an upright position with parallel bars support, the child was motivated to step forward, flexing the hip and dorsal flexing the foot. The resistance was applied on proximal thigh and foot.</td>
<td>Sit-to-stand: The child was seated in a bench adjusted to her leg length - knee and hip joints flexed at 90°. The child was motivated to get the upright position, even with upper extremity support. The resistance was applied with free loads around pelvis and proximal thigh.</td>
<td>Step backward: In upright position (parallel bars), the child was motivated to step backward, extending the hip and plantar flexing the foot. The resistance was applied on foot and distal shank.</td>
<td>Lateral walk: In an upright position (parallel bars), the child was stimulated to execute lateral walk. The resistance was applied on proximal thigh and distal shank.</td>
</tr>
<tr>
<td>Tuesday/Friday</td>
<td>Adaptive Tricycle - 10 minutes</td>
<td>High-kneeling: The child was positioned in kneeling, sitting on heels and then returned to sitting on heels. The resistance was applied with free loads around pelvis and proximal thigh.</td>
<td>Stair-climbing-A: with upper-extremity support. For hip flexion and foot dorsal flexion, it was prioritize the first phase of this skill (single stance), which is from the lift off of the target foot in the swing phase to its placement on the step. The resistance was applied on proximal thigh and foot.</td>
<td>Stair-climbing-B: exercise was executed with upper extremity support. For knee extension and foot elevation, it was prioritize the second phase of this skill (double stance), which lasts from the contact of one foot on the step to lift off of the target foot from the ground. The resistance was applied on proximal thigh and foot.</td>
<td>Down stair: Walking down stair exercise was executed with upper extremity support. The child was motivated to walk backward down the step. The resistance was applied on distal shank and foot for executing knee flexion and foot dorsal flexion.</td>
<td></td>
</tr>
</tbody>
</table>
**Table IV. Load progression.**

<table>
<thead>
<tr>
<th></th>
<th>Weeks 1 and 2</th>
<th>Weeks 3 and 4</th>
<th>Weeks 5 and 6</th>
<th>Weeks 7 and 8</th>
<th>Weeks 9 and 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridging</td>
<td>Pelvis: 0 kg</td>
<td>Pelvis: 0.5 kg</td>
<td>Pelvis: 0.5 kg</td>
<td>Pelvis: 1 kg</td>
<td>Pelvis: 1 kg</td>
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<tr>
<td></td>
<td>Thigh R: 0.5 kg Thigh L: 0.5 kg</td>
<td>Thigh R: 1 kg Thigh L: 1 kg</td>
<td>Thigh R: 1 kg Thigh L: 1 kg</td>
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<tr>
<td>High-kneeling</td>
<td>Pelvis: 0.5 kg Thigh R: 0.5 kg Thigh L: 0.5 kg</td>
<td>Pelvis: 0.5 kg Thigh R: 1 kg Thigh L: 1 kg</td>
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<tr>
<td></td>
<td>Thigh R: 0.5 kg Thigh L: 0.5 kg</td>
<td>Thigh R: 1 kg Thigh L: 1 kg</td>
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<tr>
<td>Step forward</td>
<td>Thigh R: 0.5 kg Thigh L: 0.5 kg</td>
<td>Thigh R: 1 kg Thigh L: 1 kg</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Foot R: 0 kg Foot L: 0 kg</td>
<td>Foot R: 0.5 kg Foot L: 0.5 kg</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Stair-climbing A</td>
<td>Thigh R: 0.5 kg Thigh L: 0.5 kg</td>
<td>Thigh R: 1 kg Thigh L: 1 kg</td>
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<tr>
<td></td>
<td>Foot R: 0 kg Foot L: 0 kg</td>
<td>Foot R: 0.5 kg Foot L: 0.5 kg</td>
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<tr>
<td>Sit-to-stand</td>
<td>Pelvis: 1 kg Pelvis: 1 kg</td>
<td>Pelvis: 1.5 kg Pelvis: 1.5 kg</td>
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<tr>
<td></td>
<td>Thigh R: 0.5 kg Thigh L: 0.5 kg</td>
<td>Thigh R: 1 kg Thigh L: 1 kg</td>
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<tr>
<td>Stair-climbing B</td>
<td>Thigh R: 0.5 kg Thigh L: 0.5 kg</td>
<td>Thigh R: 1 kg Thigh L: 1 kg</td>
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<tr>
<td></td>
<td>Foot R: 0 kg Foot L: 0 kg</td>
<td>Foot R: 0.5 kg Foot L: 0.5 kg</td>
<td></td>
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<tr>
<td>Step backward</td>
<td>Shank R: 0.5 kg Shank L: 0.5 kg</td>
<td>Shank R: 1 kg Shank L: 1 kg</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Foot R: 0 kg Foot L: 0 kg</td>
<td>Foot R: 0.5 kg Foot L: 0.5 kg</td>
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</tr>
<tr>
<td>Down stair</td>
<td>Shank R: 0.5 kg Shank L: 0.5 kg</td>
<td>Shank R: 1 kg Shank L: 1 kg</td>
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<tr>
<td></td>
<td>Foot R: 0 kg Foot L: 0 kg</td>
<td>Foot R: 0.5 kg Foot L: 0.5 kg</td>
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<tr>
<td>Lateral walk</td>
<td>Thigh R: 0.5 kg Thigh L: 0.5 kg</td>
<td>Thigh R: 1 kg Thigh L: 1 kg</td>
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<tr>
<td></td>
<td>Foot R: 0 kg Foot L: 0 kg</td>
<td>Foot R: 0.5 kg Foot L: 0.5 kg</td>
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</tbody>
</table>

Note: R = right; L = left.
First, the current study approaches to progressive overload principle. It considers that training load should increase progressively, so muscle metabolic capacity can always be challenged. Consequently, morphological and metabolic muscle adaptations occur, resulting in increased muscle strength [21]. In this study, the load was adjusted every week and training load progressively increased over weeks. Furthermore, the proposed training was based on task-oriented practice. It shows greater improvements in activities performance, since it enables the refinement of neural control commands besides increases in strength [22]. Therefore, we suggest that improvements in muscle strength and functional performance could be associated with muscle morphological and metabolic adaptations as well as neural refinement and motor learning.

Second, we should consider the principle of specificity of training, which attest that improvements in motor performance are only achieved when training narrowly mimics the desired performance [23]. For that, our training programme was very similar to randomized controlled trials studies with CP, which applied multi-joint exercises; however all exercises with support such as sit-to-stand movement with support from Liao et al. [24], front step-ups from Dodd et al. [25] and lateral step-ups and walking up and down stairs from Lee et al. [26]. In addition, our protocol involved more multi-joint exercises not included in others studies, such as high-kneeling and lateral walking.

We found improvements in GMFM scores, with major increases in dimensions D and E, which represent, respectively, “standing” and “walking, running and jumping” items. These items are related to the exercises proposed during intervention, such as sit-to-stand movement and stair-climbing. Therefore, we suggest that strength improvements found in this study occurred in activities that closely reflected the way in which exercises were performed.

Third, increases in muscle strength are accompanying to decreases in TUG time. TUG test requires a sophisticated postural control and dynamic balance, since it requires a process of planning, initiation and execution of complex activities such as rising from chair, walking, changing direction and sitting. For that, decreasing TUG time means that child improved in agility and postural control, since that minor time in the TUG test is associated with low risk and high gait speed [15].

However, most previous studies reported no changes in walking speed after strength training [27]. Our study is in agreement with Buchner et al. [7] that reported a non-linear relationship between strength and walking speed. The authors showed that small changes in physiological capacity may have large effect on activity performance in severe disability persons while little or no effect is found in mild cases. Therefore, we believe that the difference between the present study and previous ones could be explained based on the level of motor function, since the child evaluated in the present study showed severe motor function disability, while children from previous studies showed mild disability (levels I–II GMFCS).

Additionally, one important observation was that no improvements were found in muscle strength at knee extensors/flexors left side, which was submitted to orthopedic surgical procedures. Seniorou et al. [28] evidenced that muscle weakness persisted around one year after orthopedic surgeries, even when the child was submitted to strength training. In this instance, we propose that strength training should be of longer duration, in cases where orthopedic surgeries occurred. Besides, the muscles that failed were the weakest that the child initially presented. Based on this, we may conclude that applied functional exercises may not be efficient for very weak muscles. Additionally, Verschuren et al. [12] concern that resistance training involving only multi-joint exercises is of limited effectiveness in strengthening very weak muscles because alterations in task performance may occur to compensate for very weak muscles. For that, future protocols should compare single-joint muscle strengthening to multi-joint exercises in very weak muscles in training protocols, especially in children with GMFCS IV.

A major limitation of this study is the fact that this is a case report, therefore we cannot conclude whether this intervention is effective for children with CP who have more severe limitations in mobility. However, we believe that this protocol is feasible to conduct with a child and it informs a possible design for future studies. Moreover, we believe that future studies should also include single-joint exercises, especially for very weak muscles.

In conclusion, we believe that an individualized, specific, progressive overload and task-oriented strength training is associated with the positive outcomes found in this study. Medical history and data from initial assessment are important to determine whether strength training can be applied for each child. Moreover, the exercises should be designed according to child’s need, so improvements in muscle strength as well as in motor function can be achieved.

**Declaration of interest:** The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.
References


