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Strengthening (progressive resistive exercise) for individuals with Cerebral Palsy age 4-20 years who demonstrate muscle weakness¹

Clinical Question

- P** (population/problem): Among individuals with cerebral palsy age 4-20 years does
I (intervention): strength training
C (comparison)
O (outcome): improve functional skills?

Target Population: children, adolescents and young adults with cerebral palsy age 4-20 years

Inclusions:

- Individuals with cerebral palsy whose muscular weakness impairs functional mobility
- Individuals able to generate sufficient volitional movement in the muscles to be trained

Exclusions:

- Individuals unable to follow directions necessary to initiate voluntary movement in muscles to be trained on command
- Individuals who have undergone orthopedic surgery or neurosurgery within the past 12 months who have not received specific clearance from the surgeon to participate in a progressive resistance exercise program
- Individuals with medical conditions that preclude participation in a progressive resistive exercise program

Recommendation(s): (See Table of Recommendation Strength following references)

1. It is recommended that a program of strengthening exercises be considered for inclusion as part of the comprehensive therapy management of children with cerebral palsy who demonstrate muscular weakness and functional limitations (*Anttila 2008a [1a], Mockford 2008 [1a], Verschuren 2008 [1a], Dodd 2002 [1a], Rimmer 2001 [4a], Damiano 1995a [4a], Damiano 1995b [4a], McCambridge 2008 [5], Olney 2006 [5], Mayston 2004 [5]*).

Note: An individualized exercise program may include a progressive strengthening program following the principles proposed by DeLorme (*Delorme 1948 [5]*) as follows:

1. “perform a small number of repetitions until fatigue
2. allow sufficient rest between exercises for recovery, and
3. increase the resistance as the ability to generate force increases”

(*Taylor 2005 [1a]*).

2. It is recommended that strength training be task-specific (*Salem 2009 [2a], Schmidt 2005 [5]*).
3. It is recommended that a program of strength training targeting the lower extremity muscle groups be considered for:

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- children whose goal is standing or improved ambulation (*Anttila 2008a [1a], Mockford 2008 [1a], Verschuren 2008 [1a], Dodd 2002 [1a]*).
- ambulatory individuals with hemiplegic CP who demonstrate greater than a 10% asymmetry in strength between the lower extremity muscle groups of the affected side and the non-affected side (*Mayston 2004 [5], Scrutton 2000 [5]*).

4. It is recommended that a program of strength training targeting upper extremity muscle groups be considered for children who could benefit from increased upper body strength, particularly those who utilize manual wheelchairs for mobility (*McCubbin 1985 [2a]*).

5. It is recommended that for children age 4 to 6 years, the following methods of strengthening be considered:

- free weights (*Morton 2005 [4a], Damiano 1998 [4a], Damiano 1995a [4a]*);
- resistance devices (elastic bands) (*Unger 2006 [2a]*);
- task-specific functionally-based, weight-bearing activities with body weight providing resistance (*Liao 2007 [2a]*);
- task-specific, functionally-based, exercises such as treadmill walking, step-ups, sit-to-stands and leg presses (*Liao 2007 [2a], Blundell 2003 [4b]*).

6. It is recommended that the following methods for strengthening be considered for persons age 6 and older:

- a. free weights (*Unger 2006 [2a], Morton 2005 [4a], Damiano 1998 [4a], Damiano 1995a [4a], Damiano 1995b [4a]*)
- b. resistance devices (elastic bands) (*Unger 2006 [2a]*)
- c. task specific-circuit training (*Unger 2006 [2a]*)
- d. task-specific functionally-based, weight-bearing activities with body weight providing resistance or with a load providing resistance (*Liao 2007 [2a], Katz-Leurer 2009 [2b], Blundell 2003 [4b]*)
- e. isokinetic training (*McCubbin 1985 [2a], MacPhail 1995 [4a]*)
- f. static exercise bicycle (*Williams 2005 [4a]*)

Note: Ambulatory and non-ambulatory individuals with severe CP have demonstrated improvement in standing skills for transfers or assisted ambulation after participation in a strengthening program utilizing a static exercise bicycle. (*Williams 2005 [4a]*)

7. It is recommended that the exercise sequence include:

- a. 5 minutes of warm up activity
- b. 5 minutes of flexibility exercise
- c. 20 to 40 min of progressive resistance exercise (PRE)
- d. 5 minutes of “warm down” activity
- e. 5 minutes of flexibility exercises
(*Lillegard 1997 [2a]*)

8. It is recommended that an individualized progressive strengthening program include exercises of sufficient specificity, intensity, frequency, training weight or load, and duration be performed to increase muscle force (*Olney 2006 [5]*).

- a. Specificity: exercises target large muscle groups responsible for the desired task (*Blundell 2003 [4b]*).
- b. Intensity: approximately 3-8 exercises (*Anttila 2008a [1a], Anttila 2008b [1a], Mockford 2008 [1a], Verschuren 2008 [1a], Dodd 2002 [1a], Katz-Leurer 2009 [2b], Campbell 2006 [5]*).
- c. Frequency: 2-3X per week (*Anttila 2008a [1a], Anttila 2008b [1a], Mockford 2008 [1a], Verschuren 2008 [1a], Dodd 2002 [1a], Olney 2006 [5]*).
- d. Training weight (TW) or load: The initial training weight may be 65% of maximum isometric muscle strength (*Damiano 1995b [4a]*).

Note: For example, repetitions may be increased from 3 sets of 5-10 repetitions, to 4 sets of 5-10 repetitions to 3 sets of 10-12 repetitions as the strength improves. Maximum strength should be re-assessed every 2 weeks and the training weight reset to 65% of the maximal strength after each 2 week interval (*Mockford 2008 [1a]*).

- e. Duration: 6-10 weeks (*Anttila 2008a [1a]*, *Anttila 2008b [1a]*, *Mockford 2008 [1a]*, *Verschuren 2008 [1a]*).

Note: Minimum recommended duration of training programs is 6 weeks. Individuals, who demonstrate smaller strength deficits at pre-training, including those with hemiplegia, may benefit from a longer training period (i.e. 10 weeks) (*Damiano 1998 [4a]*).

- f. Setting: clinic (*Anttila 2008a [1a]*, *Anttila 2008b [1a]*, *Mockford 2008 [1a]*, *Verschuren 2008 [1a]*, *Dodd 2002 [1a]*, *Katz-Leurer 2009 [2b]*), home (*Katz-Leurer 2009 [2b]*), community (*Blundell 2003 [4b]*).

9. It is recommended that strength training be repeated 1-2 times yearly to counteract the decline in strength that begins to occur 3 months post training (*Damiano 1995b [4a]*, *MacPhail 1995 [4a]*).

Discussion/summary of evidence

Individuals with cerebral palsy present with multiple physical impairments including decreased muscle strength, fatigue, in-coordination and spasticity that may restrict daily activities and limit their full participation in life roles (*Pountney 2007 [5]*, *Olney 2006 [5]*, *Scrutton 2000 [5]*). Most children with cerebral palsy demonstrate significant muscle weakness compared with non-affected peers (*Damiano 1995a [4a]*, *Damiano 1995b [4a]*, *Kramer 1994 [4a]*). Weakness in lower extremity musculature accounts for 50% of the variance of walking speed in children with diplegic and hemiplegic CP (*Damiano 1995a [4a]*). Damiano et al found that even ambulatory children with diplegic CP demonstrate marked quadriceps weakness when compared to unaffected peers (*Damiano 1995b [4a]*). Although most children with hemiplegic CP become independent community ambulators, they often demonstrate persistent asymmetry due to muscle weakness and decreased efficiency in gait which may restrict daily activities and limit full participation (*Scrutton 2000 [5]*). Children with hemiplegic CP demonstrate significant asymmetry in strength between the involved side and less involved side of the body. In orthopedic patients a 10% asymmetry in strength has significant impact on function (*Nunn 1988 [5]*).

Contemporary evidence supports that muscular weakness in CP may contribute more to the individual's degree of impairment than spasticity (*Fry 2004 [4a]*, *Shortland 2002 [4a]*, *Wiley 1998 [4a]*). In the past, it was feared that strength training might exacerbate abnormal muscle tone and movement abnormalities. Studies since that time, have demonstrated that this concern is unfounded (*Andersson 2003 [5]*) further, current evidence indicates that strength training increases muscle force production without increasing spasticity and may improve functional skills of persons with cerebral palsy (*Anttila 2008a [1a]*, *Mockford 2008 [1a]*, *Verschuren 2008 [1a]*, *Dodd 2002 [1a]*, *Darrah 1997 [1b]*). The early work of McCubbin and Shasby (1985) demonstrated that resistance training in persons with CP age 10-20 years resulted in strength gains similar to non-affected peers; and that progressive resistance was a necessary component to realize improved strength (*McCubbin 1985 [2a]*). Studying the effects of strength training in children ages 9-14 yrs, Lillegard, et al 1997, found that a 12 week program of strength training with children of this age group could improve strength and motor performance (*Lillegard 1997 [2a]*). Kramer and MacPhail established a relationship between knee extensor strength and gross motor skills and gait efficiency (*Kramer 1994 [4a]*); and later determined that isokinetic strengthening of the knee flexors and extensors improved both walking efficiency and functional ability in independently ambulatory adolescents with mild spastic CP (*MacPhail 1995 [4a]*).

Strength training has been demonstrated to increase strength (force production) in persons with cerebral palsy aged 4 years and older (*Pippenger 2004 [1a]*, *Dodd 2002 [1a]*, *Damiano 1998 [4a]*, *MacPhail 1995 [4a]*, *Damiano 2002 [5]*). However the ideal mode, frequency, intensity, and duration of strength training required to improve functional outcomes in this population has not been definitively determined (*Anttila 2008a [1a]*, *Mockford 2008 [1a]*, *Verschuren 2008 [1a]*, *Dodd 2002 [1a]*). Contemporary evidence supports that children with CP as young as 4 years of age can benefit from resisted strengthening exercises (*Dodd 2002 [1a]*). Strength training with an isokinetic dynamometer has been studied in adolescents with CP and improvement reported (*MacPhail 1995 [4a]*). In a muscle strengthening study of 11 children with CP, a decrease in the asymmetry in lower extremity strength between the affected and stronger side, improved some parameters of gait in children with hemiplegic CP (i.e. maximal speed and cadence increased) (*Damiano 1998 [4a]*). Five children with hemiplegic CP increased strength in targeted lower extremity muscle groups (20% increase in

strength) to a lesser degree than 6 children with spastic diplegia (increased strength by 69%) after a 6 week strength training program. Although the 20% strength improvement in children with hemiplegia was statistically significant, a 24% asymmetry persisted. Since weaker muscles respond more quickly to training, they propose that children with hemiplegia may benefit further from a strengthening program greater than 6 weeks duration (*Damiano 1998 [4a]*).

Persons with diplegia, quadriplegia and hemiplegia can benefit from a strength training program. “Strength training is now one of the most well-studied therapy approaches in cerebral palsy”(*Damiano 2009 [5]*).

Health Benefits, Side Effects and Risks

In a 2008 policy statement, Strength Training by Children and Adolescents, the American Academy of Pediatrics summarizes the benefits of strength training as follows: “Recent studies have shown some benefit to increased strength, overall function, and mental well-being in children with cerebral palsy” (*McCambridge 2008 [5]*).

Other references indicate that the benefits of strength training include improved muscle strength and functional abilities such as standing, walking speed and running in children, adolescents and young adults with cerebral palsy (*Anttila 2008a [1a]*, *Anttila 2008b [1a]*, *Mockford 2008 [1a]*, *Verschuren 2008 [1a]*, *Dodd 2002 [1a]*, *Darrah 1997 [1b]*) with no adverse effect on spasticity (*Anttila 2008a [1a]*).

Reported side effects include some transient muscle and joint soreness that did not, however, preclude further exercise (*Mockford 2008 [1a]*). Also, two investigators have hypothesized that children who had received hamstring lengthening surgery prior to strength training may be at risk for developing hyperextension at the knee (*Mockford 2008 [1a]*).

Future Research Agenda

Rimmer, et al identified the need for longitudinal study of the efficacy of exercise for persons with CP and studies that include a longer follow up period of up to 12 months to more precisely determine the exercise schedule needed to maintain gains and counter the decline in physical mobility associated with advancement of age in this population (*Rimmer 2001 [4a]*).

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Note: Full tables of evidence grading system available in separate document:

- Table of Evidence Levels of Individual Studies by Domain, Study Design, & Quality (abbreviated table below)
<http://groups.ce/NewEBC/EBCFiles/Table-EvidenceLevels.pdf>
- Grading a Body of Evidence to Answer a Clinical Question
<http://groups.ce/NewEBC/EBCFiles/GradingBodyOfEvidence.pdf>
- Judging the Strength of a Recommendation (abbreviated table below)
<http://groups.ce/NewEBC/Judgingthestrengthofarecommendation.pdf>

Table of Evidence Levels (see note above)

<i>Quality level</i>	<i>Definition</i>
1a† or 1b†	Systematic review, meta-analysis, or meta-synthesis of multiple studies
2a or 2b	Best study design for domain
3a or 3b	Fair study design for domain
4a or 4b	Weak study design for domain
5	Other: General review, expert opinion, case report, consensus report, or guideline

†a = good quality study; b = lesser quality study

Table of Recommendation Strength (see note above)

<i>Strength</i>	<i>Definition</i>
“Strongly recommended”	There is consensus that benefits clearly outweigh risks and burdens (or visa-versa for negative recommendations).
“Recommended”	There is consensus that benefits are closely balanced with risks and burdens.
No recommendation made	There is lack of consensus to direct development of a recommendation.
<p><i>Dimensions:</i> In determining the strength of a recommendation, the development group makes a considered judgment in a consensus process that incorporates critically appraised evidence, clinical experience, and other dimensions as listed below.</p> <ol style="list-style-type: none"> 1. Grade of the Body of Evidence (see note above) 2. Safety / Harm 3. Health benefit to patient (<i>direct benefit</i>) 4. Burden to patient of adherence to recommendation (<i>cost, hassle, discomfort, pain, motivation, ability to adhere, time</i>) 5. Cost-effectiveness to healthcare system (<i>balance of cost / savings of resources, staff time, and supplies based on published studies or onsite analysis</i>) 6. Directness (<i>the extent to which the body of evidence directly answers the clinical question [population/problem, intervention, comparison, outcome]</i>) 7. Impact on morbidity/mortality or quality of life 	

Supporting information

Introductory/background information

A growing body of contemporary evidence indicates that strength training increases muscle force production without increasing spasticity and may improve functional skills of persons with cerebral palsy (*Anttila 2008a [1a], Mockford 2008 [1a], Verschuren 2008 [1a], Dodd 2002 [1a], Darrah 1997 [1b]*). Taylor et al. 2005 (1a) suggests the term "progressive resistance exercise" be used as a more specific description than "strengthening" when describing "exercise programs that are designed to increase muscle force production and that follow the principles of (1) performing a small number of repetitions (8-12) until fatigue, (2) allowing sufficient rest between exercises for recovery, and (3) increasing the resistance as the ability to generate muscle force develops" (*Taylor 2005 [1a]*).

The majority of children with hemiplegic CP will walk by age 2 or earlier barring major comorbidities such as an intractable seizure disorder or profound developmental delay (*Scrutton 2000 [5]*). Although most become independent community ambulators, they often demonstrate persistent asymmetry due to muscle weakness and decreased efficiency in gait which may restrict daily activities and limit full participation (*Scrutton 2000 [5]*). Children with

hemiplegic CP demonstrate significant asymmetry in strength between the involved side and less involved side of the body. In orthopedic patients a 10% asymmetry in strength has significant impact on function (Nunn 1988 [5]).

No studies investigating resisted strengthening exercise with children younger than 4 years of age were identified. In infancy, generalized strengthening of musculature and development of functional skills is fostered by providing the child with a variety of appropriate positions to practice voluntary movement against gravity and age appropriate sensorimotor experiences (Olney 2006 [5]). During the preschool years, practice of more challenging transitional and functional skills against gravity such as stair climbing provides opportunity for improving eccentric and concentric muscle activity (Olney 2006 [5]).

Reported methods of strength training include free weights (Morton 2005 [4a], Damiano 1998 [4a]) and training of task-specific, functionally-based activities (Blundell 2003 [4b]). Use of isokinetic devices has also been studied (MacPhail 1995 [4a]). Post-training, improvements in strength and function can be maintained, with usual activity levels, for up to 3 months. However, improvement begins to decline 3 months after cessation of the training program. This suggests that maintenance of, or further improvement in strength and function may require another strengthening program after several months of detraining (MacPhail 1995 [4a]).

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Search strategy

1. Databases

OVID MEDLINE
OVID CINAHL

Search dates: June 15, 2009. Date range: 1966-May 30, 2009.

Search Terms: cerebral palsy, strength training, strengthening, exercise, neuromotor dysfunction, muscle strength

2. Limits and Filters: English, humans

3. Additional articles: from reference lists

Known conflicts of interest:

Conflict of interest declarations were completed by members of the BESt development team and none were found.

Copies of this Best Evidence Statement (BESt) are available online and may be distributed by any organization for the global purpose of improving child health outcomes. Website address: <http://www.cincinnatichildrens.org/svc/alpha/h/health-policy/ev-based/default.htm>

Examples of approved uses of the BESt include the following:

- copies may be provided to anyone involved in the organization's process for developing and implementing evidence based care;
- hyperlinks to the CCHMC website may be placed on the organization's website;
- the BESt may be adopted or adapted for use within the organization, provided that CCHMC receives appropriate attribution on all written or electronic documents; and
- copies may be provided to patients and the clinicians who manage their care.

Notification of CCHMC at HPCEInfo@cchmc.org for any BESt adopted, adapted, implemented or hyperlinked by the organization is appreciated.

Additionally for more information about CCHMC Best Evidence Statements and the development process, contact the Health Policy & Clinical Effectiveness office at: 513-636-2501 or HPCEInfo@chmcc.org.

This Best Evidence Statement addresses only key points of care for the target population; it is not intended to be a comprehensive practice guideline. These recommendations result from review of literature and practices current at the time of their formulation. This Best Evidence Statement does not preclude using care modalities proven efficacious in studies published subsequent to the current revision of this document. This document is not intended to impose standards of care preventing selective variances from the recommendations to meet the specific and unique requirements of individual patients. Adherence to this Statement is voluntary. The clinician in light of the individual circumstances presented by the patient must make the ultimate judgment regarding the priority of any specific procedure.