CLINICAL REVIEW

Cerebral Palsy: an Overview

Indexing Metadata/Description

› **Title/condition:** Cerebral Palsy: an Overview
› **Synonyms:** Palsy, cerebral: an overview
› **Anatomical location/body part affected:** Central nervous and musculoskeletal systems
› **Area(s) of specialty:** Neurological Rehabilitation, Orthopedic Rehabilitation, Pediatric Rehabilitation
› **Description**
- Cerebral palsy (CP) is a disorder characterized by abnormal tone, posture, and movement patterns that is caused by a static (i.e., nonprogressive) lesion in the developing brain in the prenatal through neonatal period(1)
- The incidence of CP is 2–3 per 1,000 live births(1)
- Anatomical classification of CP
  - Diplegia – lower extremities are more involved than upper extremities
    - For additional information on diplegia, see *Clinical Review…Cerebral Palsy: Spastic Diplegia;* CINAHL Topic ID Number: T708898
  - Hemiplegia – one side of the body is affected by CP; injury to brain located principally in one hemisphere(1)
    - For additional information on hemiplegia, see *Clinical Review…Cerebral Palsy: Spastic Hemiplegia;* CINAHL Topic ID Number: T708899
  - Quadriplegia/tetraplegia – all extremities are affected similarly(2)
  - Triplegia – the lower extremities and one upper extremity are affected; very rare(3)

› **ICD-10 codes**
- G80 cerebral palsy
  - G80.0 spastic quadriplegic cerebral palsy
  - G80.1 spastic diplegic cerebral palsy
  - G80.2 spastic hemiplegic cerebral palsy
  - G80.3 dyskinetic cerebral palsy
  - G80.4 ataxic cerebral palsy
  - G80.8 other cerebral palsy
  - G80.9 cerebral palsy, unspecified

› (ICD codes are provided for the reader's reference, not for billing purposes)
- **Reimbursement:** There are government programs that provide economic assistance to families in need. These may include public assistance, access to affordable healthcare options, food and nutrition supplements, and tax credits. Individuals who may require assistance are encouraged to apply for programs through their state and local government agencies(107)
- **Presentation/signs and symptoms:** Classifications of physiological types of CP vary; the types listed below are from United Cerebral Palsy (UCP). UCP is an international nonprofit organization consisting of a network of affiliates. Signs and symptoms as well as certain secondary impairments are listed from various references. The clinician should recognize that although the lesion is static, the secondary conditions (e.g., muscle weakness) can worsen over time(1)

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- General signs and symptoms of CP
  - Atypical muscle tone[1]
  - Atypical deep tendon reflexes[1]
  - Pain may be present as a result of arthritis, overuse syndromes, or musculoskeletal deformities[1]
  - Secondary musculoskeletal complications, including scoliosis, joint contractures, cervical instability, hip subluxation, foot/ankle deformities such as equinus and calcaneus deformity, osteophytes, and cervical spinal stenosis, may be observed as the patient ages[1]
  - Muscle weakness and limited range of motion (ROM)[1]
  - Difficulty with motor control, coordination, and isolating muscle groups for movement
  - Cognitive impairments ranging from mild to severe[1]
  - Dyspraxia and other speech and language disorders[7]
  - Seizures[7]
  - Hearing loss[7]
  - Feeding difficulties[7]
  - Incontinence[7]
  - Visual impairments[7]
- Spastic CP
  - Approximately 70–80% of CP cases[8]
  - Initially may present with hypotonia in infancy[8]
  - Hyperreflexia
  - Difficulty with motor control, coordination, and isolating muscle groups for movement
  - Delayed developmental motor milestones
  - Decreased ROM
  - Severe musculoskeletal deformities may develop as a result of prolonged spasticity[5]
    - Thoracolumbar scoliosis with pelvic obliquity is most prevalent; marked lordosis is typical in these patients; the scoliosis is often a C-shapedcurve (no compensatory curve)[5]
    - Hip dislocation may occur[5]
    - Muscle and joint contractures may develop[5]
    - Calcaneal varus, usually with a plantar flexion bias[5]
    - Dynamic equinus is a frequent finding in patients with lower extremity spasticity[9]
- Ataxic CP
  - Rare form; ~5–10% of CP cases[8]
  - Damage to the cerebellum due to sequelae of a tumor removal[14]
  - Affects primarily balance, coordination, depth perception, gait, and rapid alternating movements[8]
  - Gait is characterized by a wide base of support and unsteadiness
  - Tremor on intention may be observed[8]
  - Hypotonia; athetoid movements may be detected in the antigravity position[14]
  - Developmental delay in motor milestones[14]
  - Deficits with language skills[14]
- Dyskinetic CP
  - Approximately 10–20% of CP cases[8]
  - Dyskinesia is an umbrella term for various movement disorders, including chorea, athetosis, and dystonia
    - Chorea: abrupt, jerky distal movements
    - Athetosis: slow, writhing, persistent movements in the proximal extremities and trunk
    - Dystonia: writhing movements leading to sustained atypical postures
  - Abnormal involuntary movement patterns

- Postural tone fluctuates and is typically hypotonic[14]
- Postural instability[14]
- Impaired co-contraction of muscle groups[14]
- Hypermobility present in most joints

–For more information regarding CP, see *Clinical Review…Cerebral Palsy: Spastic Hemiplegia*; CINAHL Topic ID Number: T708899; *Clinical Review…Cerebral Palsy: Spastic Diplegia*; CINAHL Topic ID Number: T708898;*Clinical Review…Cerebral Palsy: Botulinum Toxin Type A Injections and Nonstandard Treatment Interventions*; CINAHL Topic ID Number:T708990;*Clinical Review…Cerebral Palsy: Speech Therapy*; CINAHL Topic ID Number:T708777; and *Clinical Review…Dysphagia: Cerebral Palsy (Children)*; CINAHL Topic ID Number: T708945

Causes, Pathogenesis, & Risk Factors

› **Causes**

- Congenital CP – occurs as a result of injury to the child's brain prior to or during birth[8]
- Acquired CP – occurs as a result of injury to the brain after birth, or during the first few years of life (typically by age 2 years). It can be the result of an infection, traumatic brain injury (TBI), anoxia, or ischemia[3,8]

  –approximately 10% of cases of CP are acquired[8]
- Approximately 20% of cases of CP are associated with known risk factors
- Current evidence does not support that perinatal asphyxia is a major cause of CP[90]

› **Pathogenesis**

- An injury occurs in a region or multiple regions in the brain, resulting in permanent damage to brain tissue during the period of infant brain development[8]
- A review of the literature on brain imaging patterns in children with CP published during 1995–2012 indicates that brain abnormalities were observed in 86% of neuroimaging scans. White-matter injury was the most common imaging finding, but with high heterogeneity. Grey-matter injury, malformations, focal vascular insults, and miscellaneous findings (in descending order) were also observed[80]

› **Risk factors (prenatal)**

- Gestational age (<= 33 weeks' gestation)[10]
- Nuchal cord[10]
- Low birth weight (i.e., < 5.5 pounds or 2 ½ kg)[7]
- Multiple birth
- Menkes syndrome—copper cannot be absorbed by the GI tract[2]
- TORCH (**t**oxoplasmosis, **o**ther infections [e.g., syphilis], **r**ubella, **c**ytomegalovirus, **h**erpes) syndrome
- Intraventricular hemorrhage[3]
- Maternal infection[8]
- Chorioamnionitis[12]—the membranes that cover the fetus become inflamed[2]
- In vitro fertilization (IVF)[10]
- Mother and infant blood-type incompatibility[8]
- Placenta complications[8]
- Intrauterine growth retardation[6]
- Intracranial hemorrhage[6]
- Periventricular leukomalacia (PVL)[1]

› Risk factors (postnatal)

- Severe jaundice[8]
- Bacterial meningitis[7]
- Viral encephalitis[7]
- Falls[7]

Overall Contraindications/Precautions

› New clinicians may require training on how to address the emotional needs of the parents of a child with CP
› Patients with CP have an increased risk for fractures[124,125]
  • Critical periods of bone health (CPBH) differ for individuals with CP compared to the general population
    – Males with CP have greater relative fracture risk across the lifespan (2.9–5.6 times higher) and increased rate of fractures (14 times higher) compared to age-matched peers without CP
    – For females with CP fracture risk is increased at set points:between ages 18 and 21, perimenopausal, and postmenopausal
  • Patients with CP are at increased risk for osteoporosis secondary to osteopenia from decreased weight-bearing[108]
  • Immobility often leads to osteoporosis, predisposing the patient to fractures
  • 41% of fractures occur after surgery and during physical therapy treatments
  • Common fractures occur in the long bones such as the distal femur[108]
  • Patients with CP who are ambulatory have an increased risk of traumatic and stress fractures
› Seizures are common in children with CP.[7,66] During a seizure:[66]
  • Stay with the patient
  • Comfort the individual and speak calmly
  • Clear sharp or hard objects
  • Do not hold down extremities
  • Use aspiration precautions: rotate head to side, assess airway, and wait for tonic-clonic activity to pass before administering artificial respiration if indicated
› Clinicians should be aware of any feeding tubes and take appropriate precautions during examination and treatment
› A patient with oral motor dysfunction may not be able to safely manage liquids/foods and may be at risk for aspiration. Consult with family, nurse, and/or speech-language pathologist (SLP) for restrictions
› Consult with family/healthcare providers for restrictions/healthcare plan related to a diagnosis of gastroesophageal reflux disease (GERD). Try to schedule therapy sessions either before meals or several hours after
› In patients with shunts, monitor for signs/symptoms of shunt malfunction (e.g., seizures, irritability, headaches, vomiting)[14]
› See specific **Contraindications/precautions** under **Assessment/Plan of Care**

Examination

› **History**
  • **History of present illness/injury**
    – **Etiology of illness**
      - What type of CP does the patient have?
      - If known, where is the lesion located in the brain?
      - What was the birth history?
    – **Course of treatment**
      - **Medical management**
        - Orthopedic surgery may be indicated for:[66]
          - Significant contractures
          - Joint subluxation/dislocation
          - Curvature of the spine affecting (or potential to affect) overall function and/or respiration
          - Difficulty with hygiene and/pain due to musculoskeletal deviations and/or spasticity
        - The patient's medical team needs to carefully decide how (and if) to treat spasticity in patients with CP. Generally a reduction in spasticity is useful to the patient; however, in some instances spasticity can facilitate function in otherwise weak muscles. To avoid inadvertent loss of function, the entire clinical picture should be evaluated prior to implementing any treatment strategies to reduce spasticity[16]
        - Children may require gastrostomy due to significant feeding/swallowing impairments. Based on a 2014 systematic review, evidence for the effectiveness of surgical interventions (such as gastrostomy tube, jejunostomy tube and fundoplication) for feeding difficulties is low. Studies of gastrostomy typically demonstrate significant improvements in weight gain[87]

- Spasticity management may consist of the following (Note: The level of investigation into the efficacy of various treatment methods varies):[16]
  - Physical therapy and/or orthotic management
  - Oral medications (e.g., diazepam)
  - Chemodenervation – botulinum toxin, phenol, or alcohol injections
  - Dorsal rhizotomy
  - Intrathecal baclofen
  - Orthopedic surgery
- Document other aspects of medical management,including respiratory function and growth and nutrition

- **Medications for current illness/injury**
  - Determine what medications clinician has prescribed, if any; are they being taken? Do they effectively control symptoms?
  - Botulinum toxin, intrathecal baclofen, and diazepam may be used for spasticity; pamidronate to increase bone mineral density; and glycopyrrolate to reduce drooling
  - Antiseizure medications may be prescribed as indicated[17]
  - Dopamine receptor blockers may be prescribed to decrease involuntary movements
  - Patients may also be treated with medications for pain management, bowel and bladder dysfunction, and behavioral problems (e.g., anxiety, ADHD)
- **Diagnostic tests completed:** Testing may consist of:
  - MRI to assess location and size of brain injury[1]
  - Cranial ultrasound[18]
  - X-ray to assess for orthopedic concerns such as scoliosis, femoral anteversion, hip dysplasia
  - EEG assessment may be completed[17]
- **Home remedies/alternative therapies:** Document any use of home remedies (e.g., ice or heating pack) or alternative therapies (e.g., acupuncture, Brain Gym, hyperbaric chamber treatment) and whether they help
  - In a 2019 systematic review and meta-analysisinvolving 12 studies, researchers in South Korea investigated the impact of hippotherapy (therapeutic horseback riding) on function, gait, and balance of children with CP. Researchers found that hippotherapy had a significant effect on gait but not on function and balance measures[67]
  - In a follow-up randomized controlled study conducted by the same South Korean researchers, hippotherapy positively affected gross motor function and balance in 91 children with CP presenting at various Gross Motor Function Measure (GMFM) levels (I–IV). The GMFM-88, GMFM-66, and Pediatric Balance Scale (PBS) were used as outcome measures[91]
  - In an RCT conducted in Japan, researchers investigated the impact of long-term hippotherapy on walking ability of 24 children with CP and QOL of their caregivers[53]
    - Children were equally divided into two groups, hippotherapy and standard recreation (control group)
    - Participants in each group received a 30-minuteprogram one time per week for 48 consecutive weeks. All participants continued with normal daily routines the rest of the week and did not receive any physical therapy during study period
    - Outcome measures used were the 5MWT, GMFM-66,GMFM dimensionE (GMFM-E) and caregiver QOL using a brief version of the WHO Quality of Life self-assessment questionnaire (WHOQOL-BREF). Each outcome measure was assessed at baseline, post intervention, and 3- month follow-up
    - Researchers foundthat hippotherapy resulted in significant improvements in GMFM-66 and GMFM-Escores, gait efficiency, stability, and QOL measures compared to the control group
  - Please see *Clinical Review…Hippotherapy*; CINAHL Topic ID Number: T901881 for more information on this topic
- **Previous therapy:** Document whether patient has had occupational and/or physical therapy for this or other conditions and what specific treatments were helpful or not helpful. How long did the patient receive rehabilitation services?

– **Aggravating/easing factors** (and length of time each item is performed before the symptoms come on or are eased)
– **Body chart:** Use body chart to document location and nature of symptoms
– **Nature of symptoms:** Document nature of symptoms (constant vs. intermittent, sharp, dull, aching, burning, numbness, tingling). Pain may be caused by medical and/or surgical procedures; physical, occupational and/or speech therapy

treatments; and/or gastrointestinal, orthopedic and/or neuromuscular disorders.[19] The specific cause of pain may be difficult to isolate

– **Rating of symptoms**
  - Use a visual analog scale (VAS) or 0–10 scale to assess symptoms at their best, at their worst, and at the moment (specifically address if pain is present now and how much)
    - Pain is highly prevalentin patients with CP[73]
    - Musculoskeletal pain experienced by children with CP can have a significant negative impact on health-related QOL.[54] Parents of children with CP do not always understand the impact of this pain on the child's well-being and mental health; hence, a self-reported measure of QOL should be administered whenever possible to best meet the needs of the patient[54]
  - The Oucher scale, a self-report pain VAS, may be used with children aged 3.3 years and older.[20] FLACC scale for younger or nonverbal patients
– **Pattern of symptoms:** Document changes in symptoms throughout the day and night, if any (A.M., mid-day, P.M., night); also document changes in symptoms due to weather or other external variables
– **Sleep disturbance:** Document number of wakings/night, if any
  - Children with CP may have difficulty staying asleep for various reasons, including pain, seizures, gastrointestinal problems, and/or respiratory problems such as sleep hypoventilation, central sleep apnea, and obstructive sleep apnea
– **Other symptoms:** Document other symptoms patient may be experiencing that could exacerbate the condition and/or symptoms that could be indicative of a need to refer to physician (e.g., dizziness, bowel/bladder dysfunction, saddle anesthesia). In children with shunts, the clinician should monitor for signs and symptoms of shunt malfunction (e.g., irritability, headaches, vision problems, vomiting, redness along shunt tract)
– **Respiratory status:** Document if the patient has received or is receiving respiratory therapy or oxygen. Obtain results of pulmonary function tests (PFTs) where available
– **Barriers to learning**
  - **Are there any barriers to learning? Yes__ No__**
  - **If Yes, describe _____**

• **Medical history**
– **Past medical history**
  - **General inquiry**
    - What is the reason for present evaluation?
    - What is patient's age and adjusted age for prematurity? (When performing standardized tests, typically adjust for prematurity until age 24 months, but this varies regionally and based on testing purpose)
    - At what age was CP diagnosed in the patient?
    - Any hospitalizations? If so, how long was the patient hospitalized?
    - Who is on the patient's medical team?
    - Any recent X-rays?
    - Does the child require a feeding tube? If so, for what percentage of total nutrition?
    - Has the patient undergone any surgical procedures, specifically orthopedic surgeries?
    - Any spasticity management interventions, botulinum toxin, phenol, baclofen pump, etc.?
    - If relevant (e.g., depending on patient's age), inquire about pregnancy and birth history. Note pertinent findings such as Apgar scores, gestational age, adjusted age, birth weight, need for ventilation, manner of delivery, need for forceps or vacuum, nuchal cord complications, NICU stay, and fetal exposure to alcohol or drugs
  - **Comorbid diagnoses:** Ask patient/caregiver about other problems, including diabetes, obesity, epilepsy, sensory integration disorder,[7] GERD, cancer, autism spectrum disorder (ASD),heart disease, psychiatric disorders, and orthopedic disorders
    - Adults with CP have increased rates of depression and anxiety compared to age-matchedcontrols[88]
      - Based on the results of a retrospective longitudinal cohort study conducted in the United Kingdom that evaluated data from 1987 through 2015 concerning 1705 adults 18 years or older with CP and 5115 matched adults without CP
  - **Medications previously prescribed:** Obtain a comprehensive list of medications prescribed and/or being taken (including OTC drugs and herbal supplements)
  - **Other symptoms:** Ask patient/caregiver about other symptoms the patient may be experiencing that are inhibiting their motor development

- **Social/occupational history**
  - **Patient's goals:** Document what the patient and caregiver hope to accomplish with therapy and in general
    - Does the family feel they have necessary support in place?
  - **Vocation/avocation and associated repetitive behaviors, if any**
    - What is child's grade level if school-aged?
    - Does the child travel to school?
    - Is the child in an integrated classroom?
    - Can the child access the classroom in a timely manner?
    - What therapeutic services does the child receive through the school district?
    - Is the child involved in any additional activities, hobbies, and/or sports?
    - How much daily physical activity does the patient typically get?
      - Physical Activity Scale for Individuals with Physical Disabilities can be used to determine self-reported level of activity
      - Children and young adults with CP participate in significantly lower levels of habitual physical activity than their typically developing peers[68]
    - Is the older patient living independently, working, and driving?
    - How is the patient's endurance throughout the day?
  - **Functional limitations/assistance with ADLs/adaptive equipment**
    - What is the patient's primary means of mobility (indoor/outdoor)?
    - Does the patient utilize any assistive or adaptive devices for ADLs?
    - How does the child manage bowel and bladder function?
  - **Living environment**
    - Inquire about stairs, number of floors in the home, with whom patient lives (e.g., caregivers, family members). Identify if there are barriers to independence in the home
    - Is the patient able to safely negotiate all environments (home, school, work setting)?
    - What is the child's primary mode of mobility within the home/school?
    - Are any modifications necessary to access the home or within the home?

› **Relevant tests and measures: (While tests and measures are listed in alphabetical order, sequencing should be appropriate to patient medical condition, functional status, and setting.) May be age and setting specific; recommendations are a guide and should be implemented as appropriate for each unique patient**

- **Anthropometric characteristics**
  - Is there a functional/true leg-length discrepancy present?
  - Note height and weight and calculate BMI. Compare to age- and sex-matched growth curves
- **Arousal, attention, cognition (including memory, problem solving)**
  - Assess orientation to name, place, date, and time (as age appropriate)
  - Assess ability to follow simple commands. How many steps?
  - The Neonatal Behavioral Assessment Scale may be used for newborns
  - Note any adaptive communication devices used by child/family
- **Assistive and adaptive devices**
  - What devices does the patient have? Assess safety and fit of current devices, as well as need for additional devices
  - The Family Impact of Assistive Technology Scale is designed to rate the effect assistive technology (e.g., postural control devices) has on a child with disability and their family. The test is geared toward children who cannot sit independently. Further testing needs to be completed to fully assess validity and reliability of this new instrument[21]
- **Balance**
  - Assess static and dynamic balance reactions in developmentally appropriate postures
  - The PBS can be used on patients older than age 5 years
  - The Timed Up and Go (TUG) test can be used as an objective measure of balance and mobility
  - The TUG is considered the best predictor of walking ability in adults with CP
  - The Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) assesses higher-level balance skills in patients aged 4–21 years
  - Fivetimes sit-to-stand-test (FTSTS) has been found to be a reliable measure for assessment of functional balance ability and lower-limb strength in children with mild to moderate CP[59]

- Based on a 2014 systematic review, the Pediatric Reach Test (PRT), Sitting Assessment for Children with Neuromotor Dysfunction (SACND), Segmental Assessment of Trunk Control (SATCo), and Trunk Control Measurement Scale (TCMS) are recommended for use in clinical practice to assess sitting balance in children and adolescents with CP[82]

• **Cardiorespiratory function and endurance**
- Document vital signs at rest and during mobility
- Document distance patient can safely propel wheelchair
  - The 6-minute push test (6MPT) and the one-stroke push test (1SPT) are reproducible functional tests for children and adolescents with CP who self-propel a wheelchair[75]
- Six-minute walk for distance test (6MWT) or TUG test may be used in ambulatory population
- An accelerometer can be used to measure habitual physical activity in ambulant children with CP[92]
  - The ActiGraphGT3X+ accelerometer has been found to be reliable under controlled walking and stepping conditions, as well as in a community environment, to measure physical activity in independently ambulating children and adolescents with CP[92]
- Note respiratory rate, use of diaphragm and accessory muscles, atypical breathing patterns, and color changes in lips, skin, and fingers
- In a study in the Netherlands that involved 70 children with CP and 31 typically developing children, researchers found that children with CP had decreased aerobic and anaerobic exercise responses compared with typically developing children[65]
- Results of a study conducted in South Korea indicate that children with spastic diplegic CP and hemiplegic CP have lower respiratory function in terms of maximum inspiratory and expiratory pressures (MIP and MEP), forced vital capacity (FVC), and forced expiratory volume in 1 second (FEV1) compared to children with normal development.[93]

  No significant differences were found between children with spastic diplegic CP and hemiplegic CP[93]

• **Circulation**
- Assess pedal pulses
- Note capillary refill time
- Note temperature and color of skin

• **Ergonomics/body mechanics**
- Body mechanics are often impaired; the clinician should document compensatory strategies

• **Functional mobility** (including transfers, etc.)
- WeeFIM for overall functional assessment
- Quick functional assessment tests that can be used for adolescents with CP
  - GMFM[89]
  - Timed Up and Down Stairs (TUDS) test
  - TUG test
  - Sit-to-Stand (STS) test
  - Lateral Step-Up (LSU) test
  - 1-minute walk test
  - 10-meter walk test

• **Gait/locomotion**
- Assess child's gait and document any gait abnormalities and/or asymmetries
- Common atypical gait patterns include decreased and/or absent heel strike, increased stance phase, increased hip/knee flexion in all phases of gait, increased hip internal rotation with adduction, decreased trunk/pelvic disassociation[22]
- Common gait deviations in CP can be grouped into gait patterns of spastic hemiplegia and spastic diplegia. Clinical gait analysis (CGA) is used to identify, quantify, and understand how gait deviationsimpair function. CGA uses video, kinematic and kinetic measurements, electromyography, and plantar pressure data
- Formal gait analysis, ideally at a computerized motion analysis laboratory, is beneficial prior to surgical intervention to properly identify abnormal gait biomechanics due to spastic muscle patterns
  - Three-Dimensional Gait Analysis (3-DGA) is used to evaluate gait in an objective manner and is reported to have high intrarater reliability[23]
- Children with CP have difficulty activating plantar flexors, which impairs the push-off phase of gait. Gait training improves gait symmetry and facilitates push-off in children with CP[24]

- Sixteen children with CP and 14 typically developing children (4–15 years) were recruited
- Ground reaction force at push-off (dPF) was calculated from foot pressure measurements from insoles and gait kinematics were recorded by a three-dimensional video analysis during treadmill and over-ground walking
- Measurements were taken at baseline and after 4 weeks of 30 minutes daily inclined treadmill training

– In a 2018 systematic review and meta-analysis including 41 studies that investigated the effects of functional gait training on walking ability in children and young adults with CP, researchers found strong evidence that functional gait training results in clinically important benefits including improved walking speed. Weaker evidence was found that functional gait training improved walking endurance and gait-related gross motor function [41]

– In a study with 209 children and adolescents with CP conducted in the United States, researchers found that in order to reliably measure the stepping activity of children and adolescents with CP, it is necessary to monitor walking activity over a period of:[52]

- at least 8days for individuals aged 2 to 5 years who are at GMFCS level I (walking without restrictions), 6 days for those at level II (walking without assistive devices but some assistance and limitations for stairs/community walking), and 2 days for those at level III (walking only with assistive devices)
- at least 6days for individuals aged 6 to 14 years at GMFCS levelI, 5 days for those at level II, and 4 days for those at level III

• **Joint integrity and mobility**

– High risk for developing joint contractures in children with spasticity since full ROM is not achieved; document any joint contractures

– Assess upper and lower extremities for joint crepitus

– Document joint hypermobility using Beighton Hypermobility Scale[106]

– Assess hip joint integrity via Galeazzi sign and/or Ortolani maneuver

• **Motor function (motor control/tone/learning)**

– Assess upper and lower extremities and trunk for coordination, hypertonicity, hypotonicity, and dystonia

– Assess spasticity using Modified Ashworth Scale or Tardieu Scale

- The Tardieu Scale was found to have good to excellent intrarater and interrater reliability when assessing ankle plantar flexors or elbow flexors in children with CP in a study comprising 6 examiners; reliability was significantly increased following 1 day of training[25]

– Assess for ankle clonus and indicate number of beats, if present

– Assess movement pattern during age-appropriate functional and/or play activities (e.g., ball handling, jumping, kicking, running)

- Observe quality of movement patterns and the ability to isolate muscle groups (such as hip abductors and hip extensors when rolling)
- Indicate any abnormal patterns, reflexes, or tone observed with specific activity

– Refer for assessment for adaptive play and leisure equipment when appropriate; adaptive bicycles and other adaptive equipment can allow children with CP to experience and participate in play and leisure activities with their able-bodied peers[56]

• **Muscle strength**

– Use manual muscle testing (MMT) and/or handheld dynamometry as indicated. MMT is not valid in the presence of abnormal tone. It is appropriate for children aged 4–5 years and above who can follow directions for testing. Assess trunk strength for flexion and extension and isolate upper and lower trunk rotation.[13]Document the patient's ability to isolate muscle groups against gravity (i.e., hip abductors in side-lying, hip extensors in prone)

– Handheld dynamometry has been found to have acceptable reliability in children with CP for testing hip flexors, hip extensors (in supine), knee flexors and extensors, and ankle dorsiflexors (with stabilization). To analyze changes in muscle strength in children in relation to an intervention or maturation, strength should be reported relative to body weight or as a torque measurement (relative to lever length). Measurement error varies across more impaired and less impaired limbs

– Use the Selective Control Assessment of the Lower Extremity (SCALE) to determine extent of selective (isolated) motor control available[76]

– Assess strength through function in the younger population and in those who are unable to follow verbal commands due to cognitive deficits

- Fourteen children from the Netherlands with hemiplegic (n = 6) or diplegic (n = 8) CP had their lower extremity strength measured via a handheld dynamometer[30]
  - The authors concluded that evaluating strength via handheld dynamometers can be reliable in assessing changes in isometric muscle strength when using the mean of at least two trials

• **Neuromotor development:** Use one of the following functional tests to assess developmental skills:
- Test of Infant Motor Performance (TIMP)
  - Clinical tool designed to assess motor performance in infants 34 weeks postconceptional age to 4 months post-term[26]
  - Can be used to document progress in postural and motor control[27]
  - Reported to have excellent test-retest and rater reliability (in clinicians with proper instruction on use of TIMP)[26]
  - Sensitivity is 92% and specificity is 76% for predicting motor performance at 1 year[26]
  - For additional information on the TIMP, see *Clinical Review…Test of Infant Motor Performance (TIMP)*; CINAHL Topic ID Number: T902532
- The WeeFIM is a clinically useful tool for assessing self-care, sphincter control, transfers and locomotion, and communication and social cognition[28]
  - The WeeFIM is most useful in children aged 2–5years[28]
  - The WeeFIM has been studied in various countries and found to be valid in gross domain assessment[28]
- The Functional Walking Test (FWT) measures a child's ability to kneel, stand from kneeling position, stand, walk, and climb stairs[29]
- The Peabody Developmental Motor Scales, Second Edition (PDMS-2) has good test-retest reliability[13]
- The GMFM and the Pediatric Evaluation of Disability Inventory (PEDI) are appropriate outcome measures [13]
  - The GMFM is an outcome measure that classifies children with CP based on their level of independence with gross motor skills[18]
    - Can be used to track progress (or regression) in gross motor skills, as it is sensitive to motor change
    - The original GMFM had 88 items (GMFM-88); the latest version has 66 items (GMFM-66). Based on a 2014 systematic review, both versions of the GMFM are effective in measuring change in gross motor function in children with CP[78]
  - PEDI[18]
    - Developed for use with infants and children (aged 6 months to 7.5 years)
    - Can be used to track progress (or regression) in domains of self-care, mobility, and social function
  - Results from a 2014 systematic review indicate that the PEDI has the strongest psychometric properties in school-aged children[79]
- The Manual Ability Classification System (MACS) is a classification system designed to categorize children 4 to 18 years of age with CP based on the use of their hands for functional activities[77,102]
  - Level 1: Children are able to handle most objects easily and successfully on their own
  - Level II: Children are able to handle most objects on their own but with minimal decreased ability and/or speed
  - Level III: Children are able to handle objects but with difficulty and require help in preparing and/or modifying activities
  - Level IV: Children are able to handle a limited selection of easily managed objects in adapted situations
  - Level V: Children cannot handle objects and have severely limited ability to perform simple actions
  - Results of a 2014 Swedish study that included 1,267 children with CP suggest MACS levels are stable over time and the classification system has excellent predictive value[77]

• **Observation/inspection/palpation** (including skin assessment)
- Assess skin integrity and monitor tolerance to orthotics, if in use; document wearing schedule
- Note redness, ability to blanch, any breakdown in skin; measure and stage any wounds and notify MD

• **Oral mechanism exam and related tests**
- Screen patient for oral motor dysfunction/feeding problems that may compromise nutritional/health status. Examine for signs of weak suck, delayed/absent tongue lateralization, tongue thrust, weak lip closure, uncoordinated swallowing mechanism, tonic bite, hyperactive gag reflex, and poor seating/posture during feeding secondary to unstable trunk[13]

- **Posture**
  - Assess posture in sitting and standing, with and without braces
  - Assess posture in wheelchair as indicated
  - Observe for signs of scoliosis (rib hump, shoulder elevation, pelvic asymmetry)[11]
    - Twenty to twenty five percent of individuals with CP develop scoliosis
    - The course of scoliosis in CP varies from idiopathic curves. In CP the curve can progress after skeletal maturity
    - For additional information on scoliosis, see *Clinical Review…Scoliosis*; CINAHL Topic ID Number: T708447
- **Range of motion**
  - Assess passive and active ROM for upper and lower extremities; use goniometry
  - In the younger population, ROM can be assessed though functional movement if patient is resistant to hands-onassessment
  - Flexibility assessments should include the following tests:[13]
    - Hip abduction with knees flexed (adductor magnus, brevis, and longus muscles)
    - Hip extension in the Thomas test position with the knee extended (iliopsoas muscle) and flexed (rectus femoris muscle)
    - Knee extension with hip flexion (popliteal angle –hamstring muscles)
    - Ankle dorsiflexion with knee flexed (soleus muscle) and knee extended (gastrocnemius muscle)
- **Reflex testing/protective reactions**
  - Assess for anterior, posterior, and lateral protective reactions in sitting, prone, and standing
  - Assess for primitive reflexes (e.g., Moro, asymmetrical tonic neck, parachute), which may be abnormally absent or persistent
  - Assess deep tendon reflexes bilaterally for C5, C6, C7, L4, and S1; hyperreflexia often elicited
- **Self-care/activities of daily living** (objective testing)
  - Evaluate or inquire about ADLs; note any assistive devices used
  - The Canadian Occupational Performance Measure (COPM) may be used to assess function in the domains of self-care,leisure, and productivity[31]
  - The Assessment of Life Habits (LIFE-H) tool may be used to evaluate ADLs in children aged 5–13 years
  - Results of a 2014 systematic review suggest that the Assessment of Motor and Process Skills (AMPS) is the most effective measure to evaluate ADL performance or capacity and is suitable for children and adolescents, but further research should examine the reliability of the AMPS over time in children and adolescents with CP[79]
- **Sensory testing**
  - Stereognosis, joint position sense, and two-pointdiscrimination are often impaired in children with CP[32]
    - Assess tactile sensation using Semmes Weinstein monofilaments[32]
    - Assess two-point discrimination using paper clips[32]
    - Use the Sensory Integration and Praxis Test (SIPT) to assess stereognosis and graphanesthesia[32]

Assessment/Plan of Care

› **Contraindications/precautions**

- **Patients with this diagnosis are at risk for falls;[71] follow facility protocols for fall prevention and post fall-preventioninstructions at bedside, if inpatient. Ensure that patient and family/caregivers are aware of the potential for falls and educated about fall-prevention strategies. Discharge criteria should include independence with fall-preventionstrategies**
  - Adults with CP often experience mobility decline in early to middle adulthood, with reduced balance and increased fall risk[63]
- Only those contraindications/precautions applicable to this diagnosis are mentioned below, including with regard to modalities. Rehabilitation professionals should always use their professional judgment and knowledge of best-practice evidence
- Clinicians should include the family/caregivers in the treatment sessions, explain and demonstrate therapeutic treatment interventions, and provide oral and written instructions for a home program as indicated. Whenever possible, interventions for patients with CP should be family-centered and function-focused[72]

- Clinicians should follow the guidelines of their clinic/hospital and what is ordered by the patient's physician. The summary listed below is meant to serve as a guide, not to replace orders from a physician or a clinic's specific protocols
- **Cryotherapy** contraindications[33]
  - Raynaud's syndrome
  - Cold urticaria
  - Paroxysmal cold hemoglobinuria
  - Impaired circulation
- **Cryotherapy** precautions[33]
  - Hypertension – cold can lead to an increase in blood pressure
  - Hypersensitivity to cold
  - Avoid aggressive treatment with cold modalities over an acute wound
  - Avoid placement over superficial nerves for extended periods (> 1 hour)
  - Cold may be counterproductive if being used to facilitate muscle relaxation and reduce in pain in patients who do not tolerate the modality
- **Thermotherapy** contraindications[33]
  - Decreased circulation
  - Decreased sensation
  - Acute/subacute traumatic and inflammatory conditions
  - Skin infections
  - Impaired cognition or language barrier
  - Malignant tumors
  - Tendency for hemorrhage or edema
  - Heat rubs

› **Diagnosis/need for treatment:** Most children with CP will require periodic courses of physical therapy throughout their lifespan, with the degree/intensity of physical therapy varying depending on the child's needs. Intervention should be tailored to meet the needs of the child/family at each particular stage of development as well as recovery from postsurgical procedures. The goals of physical therapy are numerous but generally include prevention of musculoskeletal deformity, maximization of mobility and age-appropriate functional skills, and patient/family education

- It is important to note that although early diagnosis is key to initiating rehabilitative services, up to 50% of children with CP diagnosed before the age of 2 years have spontaneous resolution of symptoms and, therefore, CP may have been inaccurately diagnosed[4]

› **Rule out**

- Progressive neurologic disorder
- Idiopathic toe-walking
- Pelizaeus-Merzbacher disease: X-linked genetic disorder, slowly progressive, begins in infancy

› **Prognosis**

- In an observational cohort study conducted in the United States involving 80 children with CP ages 2 through 6, researchers found that the ability to transfer from sit to stand and stand to sit predicted independent walking[34]
- Canadian researchers found that of 258 children and adolescents with CP, 53.2% of children and 57.5% of adolescents attended regular schools; however, 41% of these children and adolescents required special education resources[85]
  - The remainder of the children and adolescents in the study attended special schools and 84.6%of all children and adolescents were receiving at least one rehabilitative service, with physical therapy and occupational therapy the most common services provided
  - Services were primarily one time a week and conducted in the school setting for both children and adolescents, but for the adolescents services were more frequently consultations rather than direct weekly therapies
  - Children with lower IQ, greater motor impairments, and greater activity limitations were significantly more likely to receive occupational therapy, physical therapy, speech-language therapy, or special education
- The TUG test is a reliable and responsive measure of mobility and balance in children with CP[35]
  - Based on a prospective observational study of children ages 3 to 10 years with CP in GMFCS levels I–III
  - Researchers used minimal detectable change (MDC) using baseline data and minimal clinically important difference (MCID) values based on the GMFCS levels

  - MDC values ranged from 1.40 to 8.74 seconds and MCID estimates ranged from 0.22 to 5.31 seconds, both of which were of statistical significance
- Factors associated with lower physical activity in children aged 8–17years with CP include decreased participation in the home and community, female sex, older age (adolescents), and decreased performance on the 6MWT[94]
  - Older age and reduced community participation were associated with high inactivity
  - GMFM–Section E (walking, running, jumping) score is also an important predictor of daily physical activity[95]
- Survival[109]
  - Approximately 80% of individuals with no severe impairments survive beyond 58 years
  - For those individuals with severe or multiple impairments, mortality increases with severity of impairment
  - Approximately 80% of individuals with severe impairments (4 or more disabilities) survive to age 20
- Authors of a cross-sectional register study conducted in Sweden of 3545 individuals with CP aged 4–18 years using data collected from 2017 to 2018 assessed pain in this population[36]
  - Overall prevalence of pain was 44%
  - Older age and female sex were associated with increased risk of pain
  - Pain was most common in the lower extremities
  - Pain intensity was higher at older ages and higher GMFCS levels
  - Approximately two-thirds of all children and adolescents with CP reported pain that disturbed ADLs and one-third reported pain that disrupted sleep

› **Referral to other disciplines**

- Surgeon (including neurosurgeon and orthopedic surgeon): The typical goal of surgery in this population is to improve ROM and manipulate musculoskeletal deformities with the aim of improving overall function[15]
- Counselors, therapists, social workers, and neuropsychologists: Many anecdotal reports of psychosocial issues were reported in the literature as parents and children cope with the effects of CP. A referral to a specialist may be warranted, and each case should be evaluated on an individual basis. The clinician needs to avoid generalizations based on level of impairment and assess the needs of each family separately
- SLP: If feeding or speech concerns are present, a speech therapy evaluation is indicated
  - Researchers in the United Kingdom reported that in a population of adolescents with spastic diplegic CP (n = 346), 63% had impaired speech of varying severity; 32% of the 346 reported being provided with 1 or more types of augmentative and alternative communication (AAC), but 75% of these adolescents reported that AAC was only for use at school and for communication assistance[84]
- Occupational therapy as indicated for feeding and fine-motor deficits

› **Other considerations**

- There are numerous assessment tools available to assist in monitoring various domains related to patient/family QOL; examples include:[13]
  - Pediatric Quality of Life Inventory
  - Lifestyle Assessment Questionnaire
  - Family Support Scale
  - Health Utilities Index
  - Strengths and Difficulties Questionnaire
- School setting
  - Children with CP may have difficulty with executive functioning and working memory, increasing risk for learning disabilities. Additionally,due to motor impairments children with CP may have difficulty with school engagement (e.g., following school routines and participating in school activities)[37]
    - Researchers in Portugal conducteda nine-weeknarrative-based educational intervention program (Story-tool) to promote self-regulation and executive functioning (EF) stimulation in children with CP
    - 15 children age range 8 to 12 years with cognitive performance level on the WISC-III above medium-lowparticipated in the study. Participants received 18 sessions, 60 minutes each of the Story-toolintervention to foster self-regulation and EF skills to promote school engagement
    - Outcome measures included pre and post intervention neuropsychological assessment and self-reportquestionnaire
    - Researchers found that the intervention significantly improved three dimensions of school engagement: behavioral, emotional, and cognitive

› **Treatment summary**

• Strength training

– Based on a 2016 review of the literature on exercise and physical activity guidelines for persons with CP conducted in the Netherlands, the following recommendations were made:[38]

- Cardiovascular exercise a minimum of 2–3 times/week, at an intensity between 60 and 90% of peak heart rate or between 50 and 65% of VO_2 peak
- Exercise duration minimum of 20 minutes per session for atleast 8 consecutive weeks when training 3 times per week, or for 16 consecutive weeks if training only 2 times per week
- Pre-workout warmup and cooldown are recommended to prevent musculoskeletal injury

› Guidelines of the Cincinnati Children's Hospital Medical Center recommend including a progressive strength-training exercise program as part of comprehensive physical therapy management for individuals with CP aged 4 to 20 years[74]

• Strength training may improve muscle strength, balance, gait speed, and gross motor function without increasing spasticity in children and adolescents with spastic CP[112]

– Based on the results of a 2021 systematic review and meta-analysis conducted in Spain of 27 RCTs involving 847 patients age range 0 to 22 years
– Meta-analysis demonstrated significant differences in favor of strength training compared to standard physical therapy interventions and untreated control group

• Lower limb strength training with resistance bands may improve gross motor function in children with CP[40]

– Based on the results of an experimental study conducted in India involving 12 children with CP between ages 4 and 10 years with baseline GMFCS level I and II
– The children received strength training with resistance bands 3 times per week for 6 weeks. Strengthening exercises included 3 sets of 10 repetitions of hip flexion, extension, abduction, adduction, knee extension, knee flexion, and ankle plantarflexion and dorsiflexion
– Outcome measures included pre and post assessment of GMFM scale
– Results showed significant improvements in pre and post score of the components D (standing) and E (walking, running, and jumping) of the GMFM, 9.49% and 6.39%, respectively

• Results of a related study conducted in Spain suggest that the use of strengthening with resistive bands may improve motor function in children with CP[110]

– Based on a 2019 systematic review and meta-analysis of 15 studies (12 RCTs, 3 non RCT), authors found that resistance therapy intervention significantly improved motor function as measured by the GMFM, Lateral Step Up (LSU), TUG, and Mobility Questionnaire

• Functional progressive resistive exercise (FPRE) may improve muscle tone, dynamic balance, and functional ability in children with spastic CP[111]

– Based on a 2020 RCT conducted in Korea involving 25 children age range 6 to 13 years with spastic diplegic CP divided into 2 groups, FPRE group (n = 13) and control group (N = 12)
– The FPRE group exercised 30 minutes, 3 times per week for 6 weeks. FPRE protocol consisted of ROM exercise, stretching, sit to stand, half kneeling, side-step up, and standing exercises. The control group received conventional therapy (FES, standing frame, and mat activities) for the same duration and frequency
– Knee extensor strength, ultrasound imaging of the quadricep muscle, muscle tone, dynamic balance, and functional ability scored using the GMFM-88 were measured pre and post intervention
– Results showed significant improvements on all outcome measures in the FPRE group compared to the control group

• Progressive resistive exercises performed using circuit training to increase trunk and lower extremity strength may improve overall strength, balance, and function[86]

– Based on an RCT with 60 children with spastic diplegic CP conducted in Saudi Arabia
– Children in the experimental group participated in a 6-weeksupervised circuit strengthening program in conjunction with traditional physical therapy; the control group participated solely in traditional physical therapy. Strength training sessions were 3 times a week. Six to 10 repetitions per exercise were completed and repetitions progressed to a higher weight when the subject could perform 3 sets of 12 repetitions
– Balance, strength, and functional ability improved significantly compared to the control group as measured by the PBS, handheld dynamometer, and the GMFM
– Results of a feasibility study conducted in Australia suggest that a community-based, low-dose group exercise program can improve balance and strength in children with CP[96]

  - Ten children with CP, aged 8–15 years, participated in an 8-week program in a community gym using simple equipment
  - Strength of elbow flexors, hip abductors, ankle dorsiflexors, and ankle plantar flexors improved. Functional strength as measured by seated throw, distance jump, and lateral step-upand balance as measured by the Movement Assessment Battery for Children (MABC), the lateral and forward reach tests, and the BOT also showed improvement
  - The researchers noted that this study demonstrates that results of strength and balance training studies conducted in clinical research settings with specialized equipment translate into clinical practice in a low-cost, low-dosecommunity program
- Strength training combined with botulinum toxin type A treatments might lead to greater reductions of spasticity in children with CP[60]
  - Based on a study with 15 children with spastic diplegic CP conducted in Australia[60]
  - Children were receiving bilateral lower-limb botulinum toxin type A treatments from their physicians[60]
  - The strength training was done 3 times per week for 10 weeks and was coordinated and progressed by a physical therapist every 2 weeks
  - Lower limbs were targeted for the strength-training exercises and each program was individualized to the specific study participant's needs
  - Researchers found that over the course of the study period the injections appeared to reduce spasticity and the strength training did not increase it; strength and functional gains were found in all muscles that were both trained and treated with injections
- Functional training
  - Static upper limb weight-bearing exercises may improve body alignment in individuals with spastic hemiparetic CP[4]
    - Based on the results of an RCT including 11 participants with CP divided into intervention group (IG; n = 6) and control group (CG; n = 5). Individuals in the IG performed stretching exercises of the major muscle groups of upper and lower limbs and weight-bearing exercises in prone and sitting, 40 minutes, 2 times per week for 12 weeks. CG did not perform any type of motor therapy for duration of study
    - Outcome measures included GMFM-88, Pediatric Berg Balance Scale, Trunk Impairment Scale (TIS), 6MWT, 10MWT, TUG, and Edinburgh Visual Gait Scale (EVGS) and were assessed pre and post intervention
    - Results showed the IG demonstrated significant improvements on the 6MWT, TUG, TIS, and Pediatric Berg Balance Scale. Authors concluded that the intervention was effective in improving static and dynamic balance, increasing gait speed, and improving weight shift to the affected side
  - Goal-directed functional therapy (GDT) was reported to be more effective than activity-focused therapy (AT) for children with CP, leading to improved abilities in self-careand mobility[51]
    - Based on a nonrandomized, comparative study conducted in Sweden
    - Forty-four children with CP participated in the study
    - The children were divided into 2 groups and received 1 of 2 interventions
      - Group 1 – GDT; group session 1x/week; daily practice; 12 weeks duration
      - Group 2 – AT; individual session 1x/week; daily practice; 12 weeks duration
    - GDT is different from AT in that GDT
      - Identifies individually tailored treatment goals
      - Implements regular group meetings for therapy
      - Incorporates specific parental education at the beginning of therapy
    - Results
      - Preintervention – Scores on the PEDI caregiver assistance in self-care scale were significantly higher in group 2
      - Postintervention – The between-group comparison revealed that group 1 experienced significantly greater improvements in mobility and self-care
- Gait training
  - Functional gait training may be more effective in improving walking speed than conventional physical therapy interventions[41]
    - Based on a 2017 systematic review and meta-analysisof 41 studies including 11 RCTs that investigated the effects of functional gait training on walking ability in children and young adults with CP
    - Functional gait training included both over-groundtraining and/or treadmill-based gait training, and use of partial weight support systems
    - Virtual reality and biofeedback were used to increase patient engagement

- Treadmill gait training might be more effective for improving functional balance in children with CP as compared to over-ground gait training[70]
  - Based on an RCT conducted in Brazil with 15 children with CP (7 randomized to experimental/treadmill training group and 8 to the control/over-ground gait training)
  - Treadmill training protocol consisted of two 30-minute sessions per week for 7 weeks; the child was instructed to walk at 60% of maximal speed for the first and final 5 minutes of each session and 80% of maximal for the 20 minutes in between
  - Although both the treadmill and over-ground gait training protocols led to within-group improvements in functional balance, the mean increase on the Berg Balance Scale score in the treadmill group was 14.7 points whereas the mean increase for the control group was 3.2 points
- Researchers in Germany found a high degree of variability in responses to robot-enhanced repetitive treadmill training in patients with early-developed movement disorders that included CP[97]
  - Eighty-three patients aged 4–18 years participated in treadmill walking for a mean total of 7.2 hours
  - Determinants of inter-individual variability in treatment responses included gross motor abilities at baseline and age

• Postural control techniques
- Water-based exercise may improve postural control in children with spastic CP[42]
  - Based on a quasi-experimental design conducted in Korea of 20 preschoolers with spastic CP who participated in water-based exercises
  - Participants performed 3 different types of leg exercises for flexor, extensor, and abductor muscles of the lower leg, one 40-minute session per week for 8 weeks
  - Trunk control was measured via the Korean-trunkcontrol measurement scale (K-TCMS) before and after the intervention
  - Results showed improvements post intervention on the K-TCMS in the domains of static sitting, dynamic sitting, and dynamic reaching
- Balance training using the Biodex balance system is more effective than traditional physical therapy in improving balance in children with CP[81]
  - Based on an RCT in Egypt
  - Thirty children with spastic diplegic CP were randomly selected to participate in traditional physical therapy only or traditional physical therapy in conjunction with Biodex balance training for 30 minutes a day, 3 days a week, for 3 months
    - Both groups had significant improvement in balance parameters at the end of 3 months; however, the Biodex training group had greater improvement in balance and stability compared to the control group
    - Outcome measures were the PBS, fall-riskbalance testing on the Biodex, static and dynamic balance stability on the Biodex, and directional control on the Biodex

• Neurodevelopmental treatment (NDT)
- NDT may improve gross motor function in children with CP
  - Researchers from a study in Iran concluded that children being treated with NDT techniques may show improvements in lying and rolling, sitting, crawling, kneeling, and standing[43]

• Electrotherapeutic modalities
- Functional electrical stimulation in combination with standard physical therapy may improve motor activity in children with CP[44]
- Neuromuscular electrical stimulation (NMES) may improve gross motor function in children with CP[45]
  - Based on the results of a meta-analysis conducted in Brazil of 6 RCTs involving 174 participants that investigated the effect of NMES combined with other therapies on gross motor function assessed by the GMFM scale
  - Researchers found that NMES combined with other therapies (e.g., treadmill walking and strengthening) resulted in greater improvements in gross motor function compared to standard physical therapy or neurodevelopmental treatment
- NMES may improve gait in children with spastic CP[46]
  - Based on a 2019 systematic review of 18 studies involving 212 participants that investigated gait-specific NMES for children with CP
  - Results showed that single-channel gait-specific NMES improved ankle motion in the swing phase of gait, but did not improve more complex gait issues common in CP such as flexed knee and stiff knee gait

• Prescription, application of devices and equipment

– Ankle-foot orthosis (AFO)
  - There is substantial evidence that AFOs that control the foot and ankle in stance and swing phases can improve gait efficiency in ambulant children with CP (GMFCS levels I–III). Use of AFOs may reduce the energy cost of gait[98]
    - AFOs are typically used to optimize gait dynamics through application of a mechanical constraint to the ankle that controls motion
  - AFOs might improve plantar flexor tone in the lower extremities of patients with CP[98]
    - Based on a cross-sectional population-basedstudy of 2200 children age range 0–19 years with GMFCS levels ranging from I to V conducted in Sweden
    - Researchers found that AFOs were used in 51% of the children to improve ankle function and increase ROM. Of the children who wore AFOs 70% were at GMFCS IV–V levels, with the highest use among 5-year-olds
    - Furthermore, treatment goals (e.g., increased ROM) were achieved in almost 75% of the AFO users
– Seating/positioning interventions
  - Adaptive seating is recommended for individuals with CP to develop and maintain optimum posture and functional use of upper extremities[47]
    - Based on a prospective study conducted in Turkey involving 20 children with spastic CP GMFCS levels III–V that investigated the effectiveness of different seating adaptations for maximal postural alignment and function
    - Postural control and function were measured with the Seated Postural Control Measure Sitting Assessment Scale, and taken in three different systems: standard chair, adjustable seating system, and custom-made orthosis
    - Researchers found significant differences between the standard chair and adjustable seating system in regards to foot control, arm control, and total seating assessment scale scores, with no significant differences noted between the adjustable seating system and custom-madeorthosis
    - Researchers concluded that both the adjustable seating system which is adaptable as a patient grows and thecustom-made orthosis (lower cost) are beneficial
  - Adaptive seating systems in children with severe CP may improve postural control, upper extremity function, self-care, and play behavior at hom[48]
    - Based on the results of a 2015 systematic review conducted in the Netherlands that investigated the effect of adaptive seating on young persons less than 19 years with severe CP in regards to outcomes across all domains of the International Classification of Functioning, Disability and Health for Children and Youth version(ICF-CY)
– Environmental modifications (e.g., handrails, car wheelchair hoists, portable ramps) improve mobility, social function, and self-care in children with CP[49]
– In a review of the literature investigating the effect of wheelchair positioning on upper extremity function in children with CP, an investigator compiled the following recommendations:[50]
  - The child's pelvis should be held in neutral
  - A functional sitting position (FSO) is recommended to facilitate the use of the child's upper extremities
    - FSO – hip belt, abduction orthosis, a cutout tray, footrests, and orientation in space of 0–15º. Also included was a forward sloped seat of 0–15º
  - The child's head, shoulders, and trunk should be slightly anterior to the ischial tuberosities
– Early use of powered mobility can have a positive impact on the psychosocial and play skills of children with CP or orthopedic disabilities[57]
  - Based on a study conducted in the United States of 23 children with CP or another type of disability aged 18 months to 6 years[57]
  - Significant increases in both parental perception of positive social skills and the number of mobility activities during free play (although no increase in the interaction with toys and objects was seen)[57]

• Passive stretching
– Researchers from a study in the United Kingdom found that passive stretching can increase overall muscle length immediately post-stretch in children with CP. Passive stretching is suitable for short-term gain in increasing muscle length, which may lead to long-termchanges[39]

• Constraint-induced movement therapy
– Constraint-induced movement therapy can improve grasping ability, daily function, and temporal/spatiotemporal control of reaching in children with unilateral CP[55]

- Based on an RCT conducted in Taiwan with 24 children with CP receiving constraint-induced therapy and 23 children with CP receiving traditional rehabilitation; children were 6 to 12 years of age and had unilateral spastic CP[55]
- Both groups received individualized therapist-basedinterventions at home for 3.5–4 hours per day, 2 days per week for 4 weeks[55]
- In the experimental group, the participants wore an elastic bandage and restraint mitt that limited both finger and wrist movement in the less affected arm; therapy sessions involved function tasks (reaching, grasping, manipulating household items) with the more affected arm[55]
- At the conclusion of the 4 weeks of the study, the children in the experimental group demonstrated significantly greater improvement on outcome measures[55]
  - Improved grasping ability measured by the PDMS-2
  - Improved functional use of affected arm measured by the Pediatric Motor Activity Log
  - Improved temporal and spatiotemporal efficiency of reaching as measured by reaction time, movement time, and peak velocity

– Modified constraint-induced movement therapy can improve hand dexterity and grip strength in children with CP[61]
- Based on a small RCT conducted in South Korea[61]
- Twenty subjects with CP total; 10 received traditional rehabilitation and 10 participated in a modified constraint-induced movement therapy program[61]
- All participants participated in 30-minutetraditional sessions that took place semi-weekly;the experimental group additionally received 60-minute constraint-induced movement therapy sessions with the nonaffected arm restrained by a string and splint.During these sessions participants were guided through 13 functional activities with the un-constrained hand[61]
- At the conclusion of the study, the children in constraint-induced movement therapy group showed significantly greater improvement in the following measures: block and box test (hand dexterity test), grip strength, and WeeFIM[61]

– A combination of constraint-induced movement therapy and bimanual training might produce the best outcomes for children with CP[64]
- Based on a systematic review that included 7 studies; authors of the review found that both constraint-induced movement therapy and bimanual therapy produced similar improvements in the abilities of the affected arm as well as overall functional performance. Because constraint-inducedmovement therapy appears to yield more improvements in unimanual tasks with the impaired arm and bimanual training is more effective for improving performance of bimanual and functional tasks, authors recommended considering an approach to therapy that includes both types of training[64]

– Results of an RCT conducted in Israel suggest that both modified constraint-induced movement therapy and bimanual therapy provided in a school-based setting can lead to improvements in bimanual skill and quality of movement patterns[99]
- Twelve children with hemiplegic CP were randomized to receive modified constraint-induced movement therapy or hand-arm bimanual intensive therapy for 2 hours per day, 6 days per week in a special education preschool/kindergarten
- After 8 weeks of intervention, both groups demonstrated comparable improvement on the Assisting Hand Assessment and the Quality of Upper Extremity Skills Test

– In a pilot study conducted in Taiwan, researchers found that group constraint-induced movement therapy could be a feasible and effective alternative to individual, one-on-oneconstraint-induced movement therapy in clinical practice[69]

• Vibration treatment

– In an RCT conducted in Croatia with 89 children with CP, researchers found that the addition of sound-based vibration treatment significantly reduced spasticity and increased motor function as compared to traditional physical therapy interventions alone[58]
- Intervention period was 12 weeks, during which time all subjects received three 40-minute sessions per week; children in the intervention group received the addition of sound-based vibration treatment twice per week
  - Vibration treatment was delivered using a vibroacoustic bedpad; children were placed on the bedpad in supine position for 20 minutes
- At the conclusion of the study, the children in the experimental group showed a significantly greater reduction in spasticity (as measured by the Modified Ashworth Scale) and a significantly greater increase in gross motor function (as measured by the GMFM) than the group that received traditional physical therapy interventions only

- Researchers emphasized that vibration treatment should be used as a complement to traditional physical therapy interventions and should not replace active therapist-based intervention

– A trunk-targeted intervention combined with vibration can improve posture and gait in children with CP[62]

- Based on a study conducted in South Africa with 27 children with CP aged 6 to 13 years[62]
- Intervention consisted of selective trunk-targetedexercises to activate and strengthen abdominal muscles; all exercises were performed on a vibrating platform; therapy program was 4 weeks long, with 2 sessions in the first week, 3 sessions in the second, and 3 to 4 sessions in the third and fourth weeks[62]
- Significant improvements were seen in gait speed, sitting posture, standing posture, and abdominal strength[62]

– Whole-body vibration (WBV) may improve strength and balance in children with CP[83]

- Based on an RCT conducted in Egypt with 30 children with spastic diplegic CP. All children received traditional physical therapy 1 hour a day, 5 days a week for 3 months. In addition to traditional therapy, the experimental group received WBV training for 9 minutes a day, 5 days per week for the 3 months
- Using the Biodex balance system, the children in the WBV group showed a significant improvement in knee extensor peak torque at 60°/sec and 90°/sec and overall stability index compared to the control group

– WBV training can improve joint sense and gait in children with CP[105]

- Based on an RCT conducted in Korea with 24 children with CP
- The children were randomized to either the conventional PT group (n = 12) or WBV with physical therapy group (n = 12)
- Both groups received physical therapy twice a week for 3 weeks that included passive stretching of the lower limbs and techniques to reduce spasticity and facilitate normal movement patterns. However, the WBV group also performed their specific intervention and were asked to stand on the platform with knees slightly flexed to 30°. The platform moved in a side-to-side pattern with a frequency of 20-24Hz and an amplitude of 1–2mm. The duration was set at 3 minutes of vibration followed by 3 minutes of rest for 3 sets
- The WBV training group showed significant improvements in gait speed and step width as well as joint proprioception compared to the control group

– For additional information on WBV training, see *Clinical Review…Whole-Body Vibration Training: an Overview;* CINAHL Topic ID Number: T709253

• Children with spastic cerebral palsy may improve gross motor functions and functional ambulation when using Adeli suit therapy (AST)[103]

– Based on a case series study from Korea involving two patients with spastic CP
– The Adeli suit uses a series of "elastic bands and pulleys that create artificial force" that works to prevent muscle atrophy and is used for the maintenance of muscle tone. The suit uses hooks, rings, and bungee-like cords that allow the physical therapist to mimic flexor and extensor patterns of major muscle groups in order to reposition limbs and correct for abnormal muscle alignment
– Both participants applied the AST for 60 minutes, 5x/week for 4 weeks

Problem	Goal	Intervention	Expected Progression	Home Program
Gross motor delay	Maximize age-appropriate gross motor function	**NDT, functional training, GDT** Referral to adaptive physical education programs as indicated (See *Treatment summary*)	Progress each patient as indicated and appropriate	Implement a home program that incorporates activities that foster carryover of newly acquired skills Ensure patient and parent/caregiver receive proper education on home program

Gait deviations with decreased independence	Improve gait with increased independence, improved energy efficiency, and appropriate use of adaptive equipment as indicated	**Gait training, ankle strengthening, GDT, balance training** (See *Treatment summary*) **Prescription, application of devices and equipment** Assess need for assistive devices and adaptive equipment and implement as indicated (See *Treatment summary*)	Progress each patient as indicated and appropriate	Implement a home program that incorporates activities that foster carryover of newly acquired skills
Decreased functional capacity/impaired ability to perform ADLs and leisure activities	Increase independence with ADLs and leisure activities, including mobility on/off playground equipment	**Functional training, strength training** Referral to adaptive physical education programs **Prescription, application of devices and equipment** Assess need for assistive devices and adaptive equipment, and implement as indicated Constraint-induced therapy (See *Treatment summary*)	Progress each patient as indicated and appropriate	Implement a home program that incorporates activities that foster carryover of newly acquired skills

Contractures of muscle and joint tissue Decreased bone mineral density (osteopenia/ osteoporosis)[8]	Prevent secondary complications such as contractures, decreased bone mineral density, pain, and orthopedic deformities as able	**Functional training** ROM, stretching, and positioning programs as indicated Assess need for orthotics (See *Treatment summary*)	Progress each patient as indicated and appropriate	Implement a home program that incorporates maintenance of functional ROM
Musculoskeletal deformities such as scoliosis and hip dysplasia. Hip dysplasia can lead to hip subluxation/ dislocation	Independent with orthotic management	**Prescription, application of devices and equipment** Assess need for assistive devices and adaptive equipment, and implement as indicated Referral to an orthotist as indicated (See *Treatment summary*)	Progress each patient as indicated and appropriate	Home program should incorporate orthotic management
Decreased strength, muscle imbalances, and atrophy	Improve strength Improve muscle balance Reduce/prevent atrophy	**Functional training** Therapeutic exercise can be implemented to strengthen weakened muscles[16] For the younger child, strengthening can be accomplished through play and functional/ developmental activities (See *Treatment summary*)	Progress patient as appropriate	Provide patient and family/ caregivers with written instructions regarding functional activities that can be performed at home as indicated

Decreased endurance	Improve endurance Increase daily physical activity	**Functional training, aerobic training, gait training** (See *Treatment summary*)	Progress as indicated	Implement a home program that incorporates endurance activities
Muscle tone abnormalities Abnormal postural tone Persistent neonatal reflexes	Normalize muscle tone as able Improve postural alignment	**Interventions to normalize muscle tone** Stretching may serve to decrease hypertonicity for brief periods (e.g., hours)[16] Therapeutic exercise should be implemented to strengthen weakened muscles[16] Teach caregiver/patient tone management techniques (See *Treatment summary*)	N/A	Implement a home program that incorporates tone management techniques
Decreased coordination Decreased balance reactions Decreased protective reactions	Improve coordination Improve balance reactions Improve protective reactions	**Functional training** Incorporate strategies to improve the patient's balance (See *Treatment summary*)	Progress as indicated	Balance activities may be added to the patient's home exercise program as indicated. Ensure the caregivers can safely carry out the prescribed interventions
Skin breakdown due to impaired sensation	Prevent skin breakdown Increase awareness of sensory limitations/ pressure-relieving strategies	**Integumentary repair and protection techniques** Instruct the patient and family how to perform pressure-relieving techniques in the wheelchair or in bed Any wounds should be staged and monitored closely	N/A	Home program should include the care/ prevention of wounds as indicated

Poor alignment in wheelchair	Improve alignment in wheelchair	**Prescription, application of devices and equipment** Complete a wheelchair assessment as appropriate and indicated Inquire about primary use of wheelchair (e.g., home, community, school, all settings) Clinicians must recognize the diverse needs of children with CP and the importance of a custom-built wheelchair. Ensure there is room for growth as funding may be limited (See *Treatment summary*)	N/A	Home program should incorporate positioning strategies
Nutritional deficits due to feeding difficulties/oral motor dysfunction[8]	Reduce nutritional deficits	**Therapeutic intervention** Refer to appropriate specialists as indicated	N/A	N/A

Desired Outcomes/Outcome Measures

› Desired outcomes/Outcome measures

- Attainment of gross motor milestones
  - PDMS-2, BOT-2, TIMP, PEDI, MACS
- Improved gait pattern with increased independence
- Appropriate use of adaptive equipment
  - Use of assistive/adaptive devices
- Increased independence with ADLs and leisure activities
  - Independence during functional activities
  - GMFM, TIMP, WeeFIM, PDMS-2, PEDI, BOT-2, PBS, COPM, MACS, AMPS
- Restored or maintained ROM
  - Goniometric measurement of ROM
- Prevention of secondary complications such as contractures, decreased bone mineral density, pain, skin breakdown, and orthopedic deformities as able
  - Skin integrity
- Independence with orthotic management

- Improved strength, reduced/prevention of atrophy
  - MMT, handheld dynamometry
- Improved endurance
  - Measures of endurance (e.g., 6MWT)
- Normalized muscle tone as able
  - Modified Ashworth Scale, Tardieu Scale
- Improved postural alignment, improved alignment in wheelchair
- Improved coordination
  - MACS
- Improved balance and protective reactions
  - BOT-2, PBS
- Increased awareness of sensory limitations/pressure-relievingstrategies
- Increased daily physical activity
  - Accelerometry, self-reported physical activity

Maintenance or Prevention

› Children and adolescents with CP are less likely to participate in sports, clubs, and organized activities compared to peers without CP or developmental disabilities[88]

› Adults with CP have been shown to participate in lower levels of physical activity and spend increased time in sedentary behavior[100]

› Results of an RCT conducted in the Netherlands indicate that a lifestyle intervention program designed to increase physical activity in adolescents and young adults with spastic CP was not effective [101]

- Fifty-seven patients with spastic CP aged 16 to 25 years completed the study
- A 6-month lifestyle intervention consisting of fitness training and counseling on physical behavior and sports participation was implemented
- Physical activity was measured objectively using activity monitor and subjectively using self-reported Physical Activity Scale for Individuals with Disabilities
- The intervention was ineffective at eliciting behavioral change

› Healthcare services to manage the needs of adults with CP are often inadequate.[91]Children and adolescents with CP would benefit from more proactive planning for the transition to adult health care to continue to receive optimal intervention

› Home exercise program should be implemented with a focus on:
- preventing ROM loss
- preventing pressure sores
- orthotic wearing schedule
- exercises/activities to maintain strength and function

› Researchers who examined the use of therapeutic video games for patients with CP found that these games encourage children to be more compliant with their home exercise program[104]

- The game system uses an LED pencil that the patient moves to “follow the road until the final destination”
- Two rehabilitation games were developed to simulate upper extremity movements including flexion, extension, pronation, and supination. The games were designed with different difficulty levels that can be increased or decreased depending on the patient’s progress in the game

Patient Education

› National Institute of Neurological Disorders and Stroke, https://www.ninds.nih.gov/Disorders/Patient-Caregiver-Education/Hope-Through-Research/Cerebral-Palsy-Hope-Through-Researc

› United Cerebral Palsy, https://www.ucp.org/

Coding Matrix

References are rated using the following codes, listed in order of strength:

M	Published meta-analysis	**RV**	Published review of the literature	**PP**	Policies, procedures, protocols
SR	Published systematic or integrative literature review	**RU**	Published research utilization report	**X**	Practice exemplars, stories, opinions
RCT	Published research (randomized controlled trial)	**QI**	Published quality improvement report	**GI**	General or background information/texts/reports
R	Published research (not randomized controlled trial)	**L**	Legislation	**U**	Unpublished research, reviews, poster presentations or other such materials
C	Case histories, case studies	**PGR**	Published government report		
G	Published guidelines	**PFR**	Published funded report	**CP**	Conference proceedings, abstracts, presentation

References

1. Patel DR, Neelakantan M, Pandher K, Merrick J. Cerebral palsy in children: A clinical overview. *Translational Pediatrics*. 2020;9(Suppl 1):S125-S135. doi:10.21037/tp.2020.01.01. **(RV)**
2. Venes D, ed. *Taber's Cyclopedic Medical Dictionary*. 22nd ed. Philadelphia, PA: FA Davis Company; 2013. **(GI)**
3. Niedzwecki CM, Roge DL, Schwabe AL. Cerebral Palsy. In: Braddom RL, ed. *Physical Medicine and Rehabilitation*. 5th ed. Philadelphia, PA: Elsevier Saunders; 2016:1053-1071. **(GI)**
4. De Oliveira EAR, Moraes LD, dos Santos JF, Ozu MHU, Misao MH, Narumia LC. Upper limb weight-bearing effect on the body alignment of individuals with cerebral palsy who have spastic hemiparesis: A randomized clinical trial. *Fisioter Mov*. 2019;32:e003216. **(RCT)**
5. Spastic Cerebral Palsy. Cerebral Palsy Alliance Web site. https://cerebralpalsy.org.au/our-research/about-cerebral-palsy/what-is-cerebral-palsy/types-of-cerebral-palsy/spastic-cerebral-palsy updated 2018. Published November 18, 2015. **(GI)**
6. Kurjak A, Predojevic M, Stanojevic M, et al. Intrauterine growth restriction and cerebral palsy. *Acta Inform Med*. 2010;18(2):64-82. **(RV)**
7. Cerebral Palsy. Symptoms and Causes. Mayo Clinic Web site. http://www.mayoclinic.org/diseases-conditions/cerebral-palsy/symptoms-causes/dxc-20236552. Published September 1, 2021. **(GI)**
8. UCP: United Cerebral Palsy Web site. http://www.ucp.org. Accessed January 25, 2015. **(GI)**
9. Gill H, Bajaj A, Singh J, Sareen A. To study the efficacy of electromyographic biofeedback training on dynamic equinus deformity and gait in children with spastic cerebral palsy. *IOSR-JSPE*. 2014;1(3):35-39. **(RV)**
10. MacLennan AH, Thompson SC, Gecz J. Cerebral palsy: causes, pathways, and the role of genetic variants. *Am J Obstet Gynecol*. 2015;213(6):779-788. doi:https://doi.org/10.1016/j.ajog.2015.05.034. **(RV)**
11. Hagglund G, Pettersson K, Czuba T, Persson-Bunke M, Rodby-Bousquet E. Incidence of scoliosis in cerebral palsy. *Acta Orthop*. 2018;89(4):443-447. doi:https://doi.org/10.1080/17453674.2018.1450091. **(R)**
12. Tita ATN, Andrews WW. Diagnosis and management of clinical chorioamnionitis. *Clin Perinatol*. 2010;37(2):339-354. **(RV)**
13. Akba# AM. Assessments and outcome measures of cerebral palsy. *Cerebral Palsy - Current Steps. IntechOpen*. 2016. https://www.intechopen.com/chapters/51622. doi:https://doi.org/10.5772/64254. **(RV)**
14. Senesac CR. Management of clinical problems of children with cerebral palsy. Umphred DA, Burton GU, Lazaro RT, Roller ML, eds. *Neurologic Rehabilitation*. 7th ed. St. Louis, MO: Mosby; 2019. **(GI)**
15. Cloake T, Gardner A. The management of scoliosis in children with cerebral palsy: A review. *J Spine Surg*. 2016;2(4):299-309. doi:https://doi.org/10.21037/jss.2016.09.05. **(RV)**
16. Sadowska M, Sarecka-Hujar B, Kopyta I. Cerebral palsy: Current opinions on definition, epidemiology, risk factors, classification and treatment options. *Neuropsychiatric Disease and Treatment*. 2020;16:1505-1518. doi:10.2147/NDT.S235165. **(RV)**
17. Cerebral palsy: Hope through research. National Institute of Neurological Disorders and Stroke, National Institutes of Health Web site. https://www.ninds.nih.gov/Disorders/Patient-Caregiver-Education/Hope-Through-Research/Cerebral-Palsy-Hope-Through-Research. Published 2021. **(GI)**
18. Tecklin JS. *Pediatric Physical Therapy*. 5th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2015. **(GI)**
19. Swiggum M, Hamilton ML, Gleeson P, Roddey T. Pain in children with cerebral palsy: implications for pediatric physical therapy. *Pediatr Phys Ther*. 2010;22(1):86-92. doi:10.1097/PEP.0b013e3181cd18a7. **(RV)**
20. Oucher scale. Measuring pain in children. University of Arizona College of Medicine Phoenix Web site. https://nasemso.org/wp-content/uploads/PFD-Pain-Assessment-CE-Gross.pdf. **(GI)**
21. Delarosa E, Horner S, Eisenberg C, Ball L, Renzoni AM, Ryan SE. Family impact of assistive technology scale: development of a measurement scale for parents of children with complex communication needs. *Augment Altern Commun*. 2012;28(3):171-80. **(RV)**
22. Tugui RD, Antonescu D. Cerebral palsy gait, clinical importance. *Maedica*. 2013;8(4):388-393. **(RV)**
23. Van den Noort JC, Ferrari A, Cutti AG, Becher JG, Harlaar J. Gait analysis in children with cerebral palsy via inertial and magnetic sensors. *Med Biol Eng Comput*. 2013;51(4):377-386. **(RV)**
24. Lorentzen J, Frisk R, Willerslev-Olsen M, Bouyer L, Farmer SF, Nielsen JB. Gait training facilitates push-off and improves gait symmetry in children with cerebral palsy. *Hum Mov Sci*. 2020;69:102565. doi:https://doi.org/10.1016/j.humov.2019.102565. **(R)**
25. Gracies JM, Burke K, Clegg NJ, et al. Reliability of the Tardieu Scale for assessing spasticity in children with cerebral palsy. *Arch Phys Med Rehabil*. 2010;91(3):421-428. doi:10.1016/j.apmr.2009.11.017. **(R)**
26. The Test of Infant Motor Performance and the Harris Infant Neuromotor Test. Web site. http://thetimp.com/. Accessed January 25, 2015. **(GI)**
27. Richards CL, Malouin F. Cerebral palsy: definition, assessment and rehabilitation. *Handb Clin Neurol*. 2013;111:183-195. **(RV)**
28. Maddux AB, Cox-Martin M, Dichiaro M, Bennett TD. The association between the Functional Status Scale and the Pediatric Functional Independence Measure in children who survive traumatic brain injury. *Pediatr Crit Care Med*. 2018;19(11):1046-1053. doi:https://doi.org/10.1097/PCC.0000000000001710. **(R)**
29. Quinn A, O'Regan M, Horgan F. Psychometric evaluation of the functional walking test for children with cerebral palsy. *Disabil Rehabil*. 2011;33(25-26):2397-2403. **(R)**
30. Willemse K, Brehm MA, Scholtes VA, Jansen L, Woudenberg-Vos H, Dallmeijer AJ. Reliability of isometric lower-extremity muscle strength measurements in children with cerebral palsy: implications for measurement design. *Phys Ther*. 2013;93(7):935-941. doi:10.2522/ptj.20120079. **(RV)**
31. Pendleton HM, Schultz-Krohn W. *Pedretti's Occupational Therapy: Practice Skills for Physical Dysfunction*. 7th ed. St. Louis, MO: Mosby Elsevier; 2013. **(GI)**
32. Auld ML, Johnston LM. Perspectives on tactile intervention for children with cerebral palsy: a framework to guide clinical reasoning and future research. *Disabil Rehabil*. 2018;40(15):1894-1854. doi:https://doi.org/10.1080/09638288.2017.1312571. **(R)**
33. Michlovitz SL, Bellew JW, Nolan TP. *Michlovitz's Modalities for Therapeutic Intervention*. 6th ed. Philadelphia, PA: FA Davis; 2016. **(GI)**
34. Begnoche DM, Chiarello LA, Palisano RJ, Gracely EJ, McCoy SW, Orlin MN. Predictors of independent walking in young children with cerebral palsy. *Phys Ther*. 2016;96(2):183-192. doi:https://doi.org/10.2522/ptj.20140315. **(R)**
35. Carey H, Martin K, Combs-Miller S, Heathcock JC. Reliability and responsiveness of the timed up and go test in children with cerebral palsy. *Pediatr Phys Ther*. 2016;28(4):401-408. doi:https://doi.org/10.1097/PEP.0000000000000301. **(R)**

36. Eriksson E, Hägglund G, Alriksson-Schmidt AI. Pain in children and adolescents with cerebral palsy – a cross-sectional register study of 3545 individuals. *BMC Neurol*. 2020;20(10):15. doi:https://doi.org/10.1186/s12883-019-1597-7. **(R)**
37. Periera A, Rosario P, Lopes S, et al. Promoting school engagement in children with cerebral palsy: a narrative based program. *Int J Environ Res Public Health*. 2019;16(19):3634. doi:https://doi.org/10.3390/ijerph16193634. **(R)**
38. Verschuren O, Peterson MD, Balemans A, Hurvitz E. Exercise and physical activity recommendations for people with cerebral palsy. *Dev Med Child Neurol*. 2016;58(8):798-808. doi:https://doi.org/10.1111/dmcn.13053. **(RV)**
39. Theis N, Korff T, Kairon H, Mohaghegi AA. Does acute passive stretching increase muscle length in children with cerebral palsy? *Clin Biomech*. 2013;28:1061-1067. **(RV)**
40. Shah VS, Shaikh S, Udani V, Khandare S, Modi A. Effects of lower limb strength training on gross motor functions in children with cerebral palsy. *Int J Contemp Pediatr*. 2018;5(5):1923-1927. doi:https://doi.org/10.18203/2349-3291.ijcp20183532. **(R)**
41. Booth ATC, Buizer AI, Meyns P, Oude Lansink ILB, Steenbrink F, van der Krogt MM. The efficacy of functional gait training in children and young adults with cerebral palsy: a systematic review and meta-analysis. *Dev Med Child Neurol*. 2018;60(9):866-883. doi:https://doi.org/10.1111/dmcn.13708. **(M)**
42. Kim HK, Shin HK. The effects of water-based exercise on postural control in children with spastic cerebral palsy. *Phys Ther Rehabil Sci*. 2017;6(2):77-82. doi:https://doi.org/10.14474/ptrs.2017.6.2.77. **(R)**
43. Labaf S, Shamsoddini A, Hollisaz MT, Sobhani V, Shakibaee A. Effects of neurodevelopmental therapy on gross motor function in children with cerebral palsy. *Iran J Child Neurol*. 2015;9(2):36-41. **(RV)**
44. Mukhopadhyay R, Mahadevappa M, Lenka PK, Biswas A. Therapeutic effects of functional electrical stimulation on motor cortex in children with spastic cerebral palsy. *Conf Proc IEEE Eng Med Biol Soc*. 2015;2015:3432-3435. **(RV)**
45. Salazar AP, Pagnussat AS, Pereira GA, Scopel G, Lukrafka JL. Neuromuscular electrical stimulation to improve gross motor function in children with cerebral palsy: a meta-analysis. *Braz J Phys Ther*. 2019;23(5):378-386. doi:10.1016/j.bjpt.2019.01.00. **(M)**
46. Mooney JA, Rose J. A scoping review of neuromuscular electrical stimulation to improve gait in cerebral palsy: The arc of progress and future strategies. *Front Neurol*. 2019;10:887. doi:https://doi.org/10.3389/fneur.2019.00887. **(SR)**
47. Sahinoglu D, Coskun G, Bek N. Effects of different seating equipment on postural control and upper extremity function in children with cerebral palsy. *Prosthet Orthot Int*. 2017;41(4):85-94. doi:https://doi.org/10.1177/0309364616637490. **(R)**
48. Angsupaisal M, Maathuis CGB, Hadders-Algra M. Adaptive seating systems in children with severe cerebral palsy across International Classification of Functioning, Disability and Health for Children and Youth version domains: a systematic review. *Dev Med Child Neurol*. 2015;57(10):919-931. doi:https://doi.org/10.1111/dmcn.12762. **(SR)**
49. Home modifications. My Child at Cerebral Palsy Web site. http://www.cerebralpalsy.org/resources/government-resources/housing/home-modifications. Accessed February 21, 2017. **(GI)**
50. Stavness C. The effect of positioning for children with cerebral palsy on upper-extremity function: a review of the evidence. *Phys Occup Ther Pediatr*. 2006;26(3):39-53. **(SR)**
51. Löwing K, Bexelius A, Brogren Carlberg E. Activity focused and goal directed therapy for children with cerebral palsy - do goals make a difference?. *Disabil Rehabil*. 2009;31(22):1808-1816. **(R)**
52. Ishikawa S, Kang M, Bjornson KF, Song K. Reliably measuring ambulatory activity levels of children and adolescents with cerebral palsy. *Arch Phys Med Rehabil*. 2013;94(1):132-137. doi:10.1016/j.apmr.2012.07.027. **(R)**
53. Mutoh T, Tsubone H, Takada M, et al. Impact of long-term hippotherapy on the walking ability of children with cerebral palsy and quality of life of their caregivers. *Front Neurol*. 2019;10:834. doi:https://doi.org/10.3389/fneur.2019.00834. **(R)**
54. Ramstad K, Jahnsen R, Skjeldal OH, Diseth TH. Mental health, health related quality of life and recurrent musculoskeletal pain in children with cerebral palsy 8-18 years old. *Disabil Rehabil*. 2012;34(19):1589-1595. doi:10.3109/09638288.2012.656794. **(R)**
55. Chen CL, Kang LJ, Hong WH, Chen FC, Chen HC, Wu CY. Effect of therapist-based constraint-inducted therapy at home on motor control, motor performance and daily function in children with cerebral palsy: a randomized controlled study. *Clin Rehabil*. 2013;27(3):236-245. doi:10.1177/0269215512455652. **(RCT)**
56. Pickering DM, Horrocks L, Visser K, Todd G. Adapted bikes: what children and young people with cerebral palsy told us about their participation in adapted dynamic cycling. *Disabil Rehabil Assist Technol*. 2013;8(1):30-37. doi:10.3109/17483107.2012.680942. **(R)**
57. Guerette P, Furumasu J, Tefft D. The positive effects of early powered mobility on children's psychosocial and play skills. *Assist Technol*. 2013;25(1):39-48. **(R)**
58. Katusic A, Alimovic S, Mejaski-Bosnjak V. The effect of vibration therapy on spasticity and motor function in children with cerebral palsy: a randomized controlled trial. *NeuroRehabilitation*. 2013;32(1):1-8. doi:10.3233/NRE-130817. **(RCT)**
59. Kumban W, Amatachaya S, Emasithi A, Siritaratiwat W. Five-times-sit-to-stand test in children with cerebral palsy: reliability and concurrent validity. *NeuroRehabilitation*. 2013;32(1):9-15. doi:10.3233/NRE-130818. **(R)**
60. Williams SA, Elliott C, Valentine J, Gubbay A, Shipman P, Reid S. Combining strength training and botulinum neurotoxin intervention in children with cerebral palsy: the impact on muscle morphology and strength. *Disabil Rehabil*. 2013;35(7):596-605. doi:10.3109/09638288.2012.711898. **(R)**
61. Yu J, Kang H, Jung J. Effects of modified constraint-induced movement therapy on hand dexterity, grip strength and activities of daily living of children with cerebral palsy: a randomized control trial. *J Phys Ther Sci*. 2012;24(10):1029-1031. **(RCT)**
62. Unger M, Jelsma J, Stark C. Effect of a trunk-targeted intervention using vibration on posture and gait in children with spastic type cerebral palsy: A randomized control trial. *Dev Neurorehabil*. 2013;16(2):79-88. doi:10.3109/17518423.2012.715313. **(RCT)**
63. Morgan P, McGinley J. Performance of adults with cerebral palsy related to falls, balance and function: a preliminary report. *Dev Neurorehabil*. 2013;16(2):113-120. doi:10.3109/17518423.2012.725107. **(R)**
64. Dong VA, Tung IH, Siu HW, Fong KN. Studies comparing the efficacy of constraint-induced movement therapy and bimanual training in children with unilateral cerebral palsy: a systematic review. *Dev Neurorehabil*. 2013;16(2):133-143. doi:10.3109/17518423.2012.702136. **(SR)**
65. Balemans AC, Van ely L, De Heer SJ, et al. Maximal aerobic and anaerobic exercise responses in children with cerebral palsy. *Med Sci Sports Exerc*. 2013;45(3):561-568. doi:10.1249/MSS.0b013e3182732b2f. **(R)**
66. Chin EM, Gwynn HE, Robinson S, Hoon AH, Jr. Principles of medical and surgical treatment of cerebral palsy. *Neurol Clin*. 2020;38(2):397-416. doi:https://doi.org/10.1016/j.ncl.2020.01.009. **(R)**
67. Kim HK, Shin HK. The effects of water-based exercise on postural control in children with spastic cerebral palsy. *Phys Ther Rehabil Sci*. 2017;6(2):77-82. doi:https://doi.org/10.14474/ptrs.2017.6.2.77. **(R)**
68. Carlon SL, Taylor NF, Dodd KJ, Shields N. Differences in habitual physical activity levels of young people with cerebral palsy and their typically developing peers: a systematic review. *Disabil Rehabil*. 2013;358(8):647-655. doi:10.3109/09638288.2012.715721. **(SR)**
69. Wu WC, Hung JW, Tseng CY, Huang YC. Group constraint-induced movement therapy for children with hemiplegic cerebral palsy: a pilot study. *Am J Occup Ther*. 2013;67(2):201-208. doi:10.5014/ajot.2013.004374. **(R)**
70. Grecco LA, Tomita SM, Christovão TC, Pasini H, Sampaio LM, Oliveira CS. Effect of treadmill gait training on static and functional balance in children with cerebral palsy: a randomized controlled trial. *Braz J Phys Ther*. 2013;17(1):17-23. **(RCT)**
71. Morgan P, McGinley J. Performance of adults with cerebral palsy related to falls, balance and function: a preliminary report. *Dev Neurorehabil*. 2013;16(2):113-120. doi:10.3109/17518423.2012.725107. **(R)**
72. Aydin R, Nur H. Family-centered approach in the management of children with cerebral palsy. *Turkish J Phys Med Rehabil*. 2012;58(3):229-235. **(RV)**
73. Parkinson KN, Dickinson HO, Arnaud C, Lyons A, Colver A; SPARCLE group. Pain in young people aged 13 to 17 years with cerebral palsy: cross-sectional, multicentre European study. *Arch Dis Child*. 2013;98(6):434-440. doi:10.1136/archdischild-2012-303482. **(R)**
74. Best evidence statement (BESt). Strengthening (progressive resistive exercise) for individuals with cerebral palsy age 4-20 years who demonstrate muscle weakness. Cincinnati (OH): Cincinnati Children's Hospital Medical Center. *Cincinnati Children's Hospital Medical Center*. July 26, 2010;9p. **(G)**

75. Verschuren O, Ketelaar M, De Groot J, Vila Nova F, Takken T. Reproducibility of two functional field exercise tests for children with cerebral palsy who self-propel a manual wheelchair. *Dev Med Child Neurol*. 2013;55(2):185-190. doi:10.1111/dmcn.12052. **(R)**
76. Fowler EG, Staudt LA, Greenberg MB, Oppenheim WL. Selective Control Assessment of the Lower Extremity (SCALE): development, validation, and interrater reliability of a clinical tool for patients with cerebral palsy. *Dev Med Child Neurol*. 2009;51(8):607-614. doi:10.1111/j.1469-8749.2008.03186.x. **(R)**
77. Ohrvall AM, Krumlinde-Sundholm L, Eliasson AC. The stability of the Manual Ability Classification System over time. *Dev Med Child Neurol*. 2014;56(2):185-189. doi:10.1111/dmcn.12348. **(R)**
78. Alotaibi M, Long T, Kennedy E, Bavishi S. The efficacy of GMFM-88 and GMFM-66 to detect changes in gross motor function in children with cerebral palsy (CP): a literature review. *Disability & Rehabil*. 2014;36(8):617-627. doi:10.3109/09638288.2013.805820. **(SR)**
79. James S, Ziviani J, Boyd R. A systematic review of activities of daily living measures for children and adolescents with cerebral palsy. *Dev Med Child Neurol*. 2014;56(3):233-244. doi:10.1111/dmcn.12226. **(SR)**
80. Reid SM, Dagia CD, Ditchfield MR, Carlin JB, Reddihough DS. Population-based studies of brain imaging patterns in cerebral palsy. *Dev Med Child Neurol*. 2014;56(3):222-232. doi:10.1111/dmcn.12228. **(RV)**
81. El-Shamy SM, Abd El Kafy EM. Effect of balance training on postural balance control and risk of fall in children with diplegic cerebral palsy. *Disability & Rehabil*. 2014;36(14):1176-1183. doi:10.3109/09638288.2013.833312. **(RCT)**
82. Banas BB, Gorgon EJR. Clinimetric properties of sitting balance measures for children with cerebral palsy: a systematic review. *Phys Occup Ther Pediatr*. 2014;34(4):313-334. doi:10.3109/01942638.2014.881952. **(SR)**
83. El-Shamy SM. Effect of whole-body vibration on muscle strength and balance in diplegic cerebral palsy. *Am J Phys Med Rehabil*. 2014;93(2):114-121. doi:10.1097/PHM.0b013e3182a541a4. **(RCT)**
84. Cockerill H, Elbourne D, Allen E, et al. Speech, communication and use of augmentative communication in young people with cerebral palsy: the SH&PE population study. *Child Care Health Dev*. March 2014;40(2):149-157. doi:10.1111/cch.12066. **(R)**
85. Majnemer A, Shikako-Thomas K, Lach L, Shevell M, Law M, Poulin C. Rehabilitation service utilization in children and youth with cerebral palsy. *Child Care Health Dev*. 2014;40(2):275-282. doi:10.1111/cch.12026. **(R)**
86. Tedla JS. Strength training effects on balance in spastic diplegia subjects: a randomized controlled trial. *J Pediatric Neuro*. 2014;12(1):15-28. doi:10.3233/JPN-140634. **(RCT)**
87. Ferluga ED, Sathe NA, Krishnaswami S, Mcpheeters ML. Surgical intervention for feeding and nutrition difficulties in cerebral palsy: a systematic review. *Dev Med Child Neurol*. 2014;56(1):31-43. doi:10.1111/dmcn.12170. **(SR)**
88. Smith KJ, Peterson MD, O'Connell NE, et al. Risk of depression and anxiety in adults with cerebral palsy. *JAMA Neurol*. 2019;76(3):294-300. doi:https://doi.org/10.1001/jamaneurol.2018.4147. **(R)**
89. Chrysagis N, Skordilis EK, Koutsouki D. Validity and clinical utility of functional assessments in children with cerebral palsy. *Arch Phys Med Rehabil*. 2014;95(2):369-374. doi:10.1016/j.apmr.2013.10.025. **(R)**
90. Ellenberg JH, Nelson KB. The association of cerebral palsy with birth asphyxia: a definitional quagmire. *Dev Med Child Neurol*. March 2013;55(3):210-6. doi:10.1111/dmcn.12016. **(SR)**
91. Kwon JY, Chang HJ, Yi SH, Shin HY, Kim YH. Effect of hippotherapy on gross motor function in children with cerebral palsy: a randomized controlled trial. *J Alt Compl Med*. 2015;21(1):15-21. doi:10.1089/acm.2014.0021. **(RCT)**
92. Mitchell LE, Ziviani J, Boyd RN. Variability in measuring physical activity in children with cerebral palsy. *Med Sci Sports Exercise*. 2015;47(1):194-200. doi:10.1249/MSS.0000000000000374. **(R)**
93. Kwon YH, Lee HY. Differences in respiratory pressure and pulmonary function among children with spastic diplegic and hemiplegic cerebral palsy in comparison with normal controls. *J Phys Ther Sci*. 2015;27(2):401-403. doi:10.1589/jpts.27.401. **(R)**
94. Mitchell LE, Ziviani J, Boyd RN. Characteristics associated with physical activity among independently ambulant children and adolescents with unilateral cerebral palsy. *Dev Med Child Neurol*. 2015;57(2):167-174. doi:10.1111/dmcn.12560. **(R)**
95. Bania TA, Taylor NF, Baker RJ, Graham HK, Karimi L, Dodd KJ. Gross motor function is an important predictor of daily physical activity in young people with bilateral spastic cerebral palsy. *Dev Med Child Neurol*. 2014;56(12):1163-1171. doi:10.1111/dmcn.12548. **(R)**
96. Auld ML, Johnston LM. 'Strong and steady': a community-based strength and balance exercise group for children with cerebral palsy. *Disabil Rehabil*. 2014;36(24):2065-2071. doi:10.3109/09638288.2014.891054. **(R)**
97. Schroeder AS, Von Kries R, Riedel C, et al. Patient-specific determinants of responsiveness to robot-enhanced treadmill therapy in children and adolescents with cerebral palsy. *Dev Med Child Neurol*. 2014;56(12):1172-1179. doi:10.1111/dmcn.12564. **(R)**
98. Wingstrand M, Hagglund G, Rodgy-Bousquet E. Ankle-foot orthoses in children with cerebral palsy: a cross sectional population-based study of 2200 children. *BMC Musculoskelet Disord*. 2014;15:327. doi:https://doi.org/10.1186/1471-2474-15-327. **(G)**
99. Gelkop N, Burshtein DG, Lahav A, et al. Efficacy of constraint-induced movement therapy and bimanual training in children with hemiplegic cerebral palsy in an educational setting. *Phys Occup Ther Peds*. 2015;35(1):24-39. doi:10.3109/01942638.2014.925027. **(R)**
100. Ryan JM, Crowley VE, Hensey O, Broderick JM, McGaney A, Gormley J. Habitual physical activity and cardiometabolic risk factors in adults with cerebral palsy. *Res Dev Disabil*. 2014;35(9):1995-2002. doi:10.1016/j.ridd.2014.03.051. **(R)**
101. Slaman J, Roebroek M, Dallmijer A, Twisk J, Stam H, Van Den Berg-Emons R. Can a lifestyle intervention programme improve physical activity behavior among adolescents and young adults with spastic cerebral palsy? A randomized controlled trial. *Dev Med Child Neurol*. 2015;57(2):159-166. doi:10.1111/dmcn.12602. **(RCT)**
102. Jeevanantham D, Dyszuk E, Bartlett D. The Manual Ability Classification System: A scoping review. *Pediatr Phys Ther*. 2015;27(3):236-241. doi:10.1097/PEP.0000000000000151. **(SR)**
103. Lee BH. Clinical usefulness of Adeli suit therapy for improving gait function in children with spastic cerebral palsy: a case study. *J Phys Ther Sci*. 2016;28(6):1949-1952. **(C)**
104. Lee WC, Reyes-Fernandez MC, Posada-Gomez R, Juarez-Martinez U, Martinez-Slbaja A, Alor-Hernandez G. Using health games for rehabilitation of patients with infantile cerebral palsy. *J Phys Ther Sci*. 2016;28(8):2293-2298. **(R)**
105. Ko MS, Sim YJ, Kim DH, Jeon HS. Effects of three weeks of whole-body vibration training on joint-position sense, balance, and gait in children with cerebral palsy: a randomized controlled study. *Physiother Can*. 2016;68(2):99-105. **(RCT)**
106. Malek S, Reinhold EJ, Pearce GS. The Beighton Score as a measure of generalized joint hypermobility. *Rheumatol Int*. 41(10):1707-1726. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8390395/. **(SR)**
107. Government resources. My Child at CerebralPalsy.org Web site. http://www.cerebralpalsy.org/resources/government-resources. Accessed February 21, 2017. **(GI)**
108. American Academy for Cerebral Palsy and Developmental Medicine (AACPDM). Osteoporosis in cerebral palsy. https://www.aacpdm.org/publications/care-pathways/osteoporosis-in-cerebral-palsy. Published 2016. **(G)**
109. Blair E, Langdon K, McIntyre S, Lawerence D, Watson L. Survival and mortality in cerebral palsy: observations to the sixth decade from a data linkage study of a total population register and National Death Index. *BMC Neurol*. 2019;19(1):11. doi:https://doi.org/10.1186/s12883-019-1343-1. **(R)**
110. Collado-Garrido L, Paras-Bravo P, Calvo-Martin P, Santibanez-Marguello M. Impact of resistance therapy on motor function in children with cerebral palsy: a systematic review and meta-analysis. *Int J Environ Res Public Health*. 2019;16(22):4513. doi:https://doi.org/10.3390/ijerph16224513. **(SR)**
111. Cho H-J, Lee B-H. Effect of functional progressive resistance exercise on lower extremity structure, muscle tone, dynamic balance and functional ability in children with spastic cerebral palsy. *Children*. 2020;7(8):85. doi:https://doi.org/10.3390/children7080085. **(R)**
112. Merino-Andrés J, García de Mateos-López A, Damiano DL, Sánchez-Sierra A. Effect of muscle strength training in children and adolescents with spastic cerebral palsy: A systematic review and meta-analysis. *Clin Rehabil*. 2022;36(1):4-14. doi:https://doi.org/10.1177/02692155211040199. **(SR)**