Chapter 3

Current Rehabilitation Methods for Cerebral Palsy

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Additional information is available at the end of the chapter

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Abstract

In rehabilitation of children with cerebral palsy (CP), varying approaches and techniques are used, ranging from very conservative and conventional techniques, such as muscle strengthening, manual stretching, and massage, to more complex motor learning-based theories, such as neurodevelopmental treatment, conductive education, and several others. The motor disorders seen in CP are frequently accompanied by disturbances of sensation, cognition, communication, perception, and/or behavior disorders; thus, therapy approaches are arranged to meet the individual child's needs. The approaches can be divided into two groups as with equipment and without equipment. Examples for without equipment rehabilitation approaches are neurodevelopmental treatment, conductive education constraint-induced movement therapy, and task-oriented therapy, whereas robotic therapy, virtual reality, and horse-back riding therapy are the examples of rehabilitation approaches with equipment. CP is a prevalent, disabling condition. Application of evidence-based methods ensures maximum gains in children. The concept that intense, task-specific exercises capitalize on the potential plasticity of the CNS and thus improve motor recovery has led to the development of several successful interventions for children with CP. Also approaches that improve the patient's motivation and target the activities of daily living and participation are the most effective approaches for functional recovery of the children with CP.

Keywords: cerebral palsy, rehabilitation, physiotherapy, current, present

1. Introduction

Cerebral palsy (CP) applies to an insult of the developing brain that produces a disorder of movement and posture. Primary symptoms of cerebral palsy are problems with muscle tone, balance, selectivity, and strength. Rehabilitation of the children with CP aims to reach and maintain optimal physical, sensory, intellectual, psychological, and social function. It includes providing the tools an individual needs to gain and maintain independence and self-determination. Brain plasticity is important to the pathophysiology and treatment of CP throughout a patient's life. This feature has directed research into functional recovery, and rehabilitation therapies that aim to capitalize on neuroplasticity are being developed. Recent recommendations state that intensive rehabilitation improves motor function in children with CP by including motor learning theories. Repetitive, goal-directed movements that are associated with sensory feedback and an attractive environment are likely to promote reorganization of the neuronal pathways and motor development after brain injuries [1, 2]. Advances in neuroscience suggest that the central nervous system (CNS) has some plasticity and the potential to reorganize throughout the entire lifespan rather than merely during a short period of development. Activity-dependent plasticity takes place in the motor cortex. The concept that intense, task-specific exercises capitalize on the potential plasticity of the CNS and thus improve motor recovery has led to the development of several successful interventions. In general, techniques used in CP rehabilitation can be classified as (1) approaches without using any equipment and (2) approaches with using equipments. In the rehabilitation of CP, there have been several major therapeutic practices during past years, including the Bobath concept and sensory integration; these models of treatment have been adopted as good practice and accepted as conventional approaches to treatment. Additional, well-controlled, randomized trials are needed to establish efficacy and to define the most appropriate roles for new technologies in physical rehabilitation interventions for children with CP [3, 4].

2. Approaches without using any equipment

2.1. Bobath concept

The Bobath approach, also known as neurodevelopmental treatment (NDT), was developed by Dr. Karel Bobath and Berta Bobath in the 1940s. The concept was based on observations of how abnormal tone interfered with the child's ability to develop functional activity. The Bobaths developed a theoretical framework for practice based on the neurophysiological knowledge of the day [5]. The Bobath concept says that normal quality of tone is necessary for effective movement. In Bobath concept, therapists use specialized handling techniques that improve the quality of tone and facilitate the movement patterns in the execution of everyday tasks. Also, active participation of the child is emphasized throughout treatment with the specific aim and controlling the activity. The quality of tone has always been central to this concept [6]. The Bobaths emphasized the need for movement strategies learnt in treatment to be carried over into everyday life activities. When planning the most appropriate activity, therapists draw on an in-depth knowledge of normal motor development and the control of movement [7]. NDT aims to normalize the muscle tone, inhibit primitive and abnormal reflexes, and to facilitate normal movements [8]. The Bobath concept based on the systems approach to motor control, with neuroplasticity as the primary mechanism for neurological recovery [9, 10]. Bobath concept helps to improve postural alignment and inhibit abnormal reflexes with child's active participation and practice of functional skills. Using handlings, the therapist aims to facilitate the desired muscle action. Through these handlings, it is possible to conduct movements, influence muscle tone, and improve postural alignment and postural self-organization [11–13]. Self-organization facilitates posture and movement integration, allowing the use of postural control strategies contributing for motor learning and motor control improvement. Normal movements are facilitated, and abnormal patterns are inhibited to allow appropriate active reactions [14]. The therapist induces an expected motor response by means of the stimulation of sensory pathways, which are the gateways to motor control and motor learning [15, 16]. This approach also provides observation, analyzing a child's performance and finding his/her potential. The purpose of this approach is to correct abnormal postural tone and to facilitate more normal movement patterns for performing daily activities [17]. Despite the widespread use of NDT, studies of its effectiveness have reported conflicting or inconsistent findings. Thus, more accurate assessment tools are important for measuring the effectiveness of NDT in cerebral palsy (CP) rehabilitation [16].

2.2. Goal attainment therapy

The aim of this therapy for children with CP, as for most children with developmental disabilities, is to facilitate the child's participation in everyday life situations, e.g., to communicate with parents, siblings, and peers; to move from one place to another; to dress and undress; to eat; and to play. The choice of goals for therapy is dependent on many factors: the child's likings and the family's preferences, the society and environment in which the family lives, and the child's degree of disability [18, 19]. Gradually, a shift has occurred in therapy. Today the child is given the possibility to be more of an active problem solver (instead of, as previously, a passive recipient of treatment) in the context of the day-to-day environment. This treatment approach is referred to as 'task-oriented' approach and is built on theories of motor control. The development and learning of new skills occur in an interaction between the child, the task to be performed, and the particular environment in which the activity takes place [20–22]. This is the context in which the goals for therapy are set in close collaboration with the child's family and sometimes also the child. The goals and especially the grading of the goals in steps provide an individual plan for the child to learn the specific activity and reach the goal [23, 24]. Thus, it is important to integrate principles of motor learning in the treatment concept and adapt the principles to the prerequisites of each specific child. As CP is a very heterogeneous disorder, large differences exist between the children. Also from this viewpoint, the formulation of treatment goals offers an opportunity to an individualized treatment approach. The set goals should be specific, measurable, attainable, relevant, and timed (SMART) [25–31]. Functional training and practice of functional tasks are important parts of the rehabilitation management in CP. Achievement of functional goals was always the ultimate purpose of therapists [10]. Physiotherapists often identify a general aim in treatment of their patients, such as improving trunk balance or gait pattern. Such aims have general changes in the child's performance, they do not refer to a specific activity achievement. Setting a treatment goal involves identifying and formulating standards of motor activity, which are in advance of the child's current capacity. Previous studies on a group of quadriplegic children reported improved motor function after treatment using goal setting [32–35]. In randomized trials, the goal-directed therapy in real environment has been shown to be more effective than approaches focusing on impairments in quality of movement and muscle performance [35–38]. Collaborative goal setting and achieving meaningful, client-selected goals bring about effective therapy service [39, 40]. Effective listening and communication are strategies and fundamental components of successful interventions to establish a common goal [41, 42]. Treatment success was defined by Goal Attainment Scaling (GAS). GAS is an individualized criterion-referenced measurement that quantifies the achievement of treatment or intervention goals for different kinds of treatment issues [43, 44]. For each goal, client and therapist improved specific, observable, and quantifiable outcomes. Five outcome levels were identified, including expected level of performance (assigned 0), two levels of less favorable (assigned −2 or −1), and two levels of more favorable outcomes (assigned +1 or +2) [24].

2.3. Strength training programs

Enhancing muscular fitness and higher levels of muscular strength causes significantly better cardiometabolic risk factor profiles, lower risk of all-cause mortality, fewer cardiovascular disease events, and lower risk of developing functional limitations. In CP, muscle weakness is a primary impairment, and there is strong evidence showing that children with CP are significantly weaker than children with typical development [45–52]. In the past, strength training was considered to be contraindicated in children with CP because it was thought to increase muscles stiffness and result in an increase in spasticity. However, studies have found no change in spasticity during or after training, which supports the current belief that strength training for persons with spasticity is not contraindicated [53–55]. Muscle strength training studies have shown that training may strengthen muscles without adverse effects in children and adolescents with CP. The majority of participants were spastic diplegic or hemiplegic distribution. These trials are evidence for benefit of strength training programs that improve strength [56]. Also, there is an evidence that targeted strength training improves spasticity. Therefore, in conjunction with cardiorespiratory fitness, target muscle strengthening in children, adolescents, and adults with CP is imperative [57]. As for children with typical development, resistance training has observable benefits in strength among children, adolescents, and adults with CP [58]. There is inadequate evidence to show changes in activity or participating in everyday life. However, there are strong indications that strength training programs play an important role in the habilitation of individuals with CP [7]. Isokinetics has been used in testing and performance enhancement for over 30 years. In 1967, some authors introduced the concept of isokinetic exercise training and rehabilitation. Isokinetics are frequently chosen because of their inherent patient safety and objectivity. Isokinetic represents a match between mechanically imposed velocity and the subject movement that contacts against a controlled angular velocity. Therefore, through accommodating resistance, the muscle contracts at its maximal capability at all points throughout the range of motion [59]. Endurance exercises are considered as exercises that are done in a time limit of a person's ability to maintain either a specific force or power involving muscular contractions. Several studies have found out that endurance exercises can greatly increase strength in the muscles by adding specific weight training to their programs. Strength development through endurance training is important for the prevention and rehabilitation of injuries and for improving sport performance. Strength is also important for maintenance of functional capacity; with aging or injury, there is catabolic breakdown of the muscle connective tissue, resistance training presents the only natural method to offset such wasting conditions. Resistance exercise is a very common type of endurance training, which can improve the muscle strength and give a good balance to our bodies [60–65]. Strength training also increase the power of weak antagonist muscles and of the spastic agonists. Improvements with various modalities ranged from 19.6% with isokinetic strengthening to over 100% with training machines and free weights [66–70]. The nature of the relationship between strength and function is of considerable relevance to clinical practice. Task-oriented weight-bearing strength training for children with CP was effective in increasing strength and functional performance. Gains in strength improve functional motor performance, if strengthening exercises includes more functional closed kinetic chain exercises. In these exercises, the subject is weight bearing through the feet, and the body mass is raised and lowered over the feet by concentric and eccentric action of lower limb muscles, such as sit-to-stand and walking [71].

2.4. Conductive education

Conductive education (CE) is a combined educational and task-oriented approach for children with CP. Specially trained 'conductors' give education to homogeneous groups of children with motor disorders [72]. This approach has its origins in learning theory. The movement problems experienced by children with CP are thought of primary learning process problems. Training takes place in an educational setting. The conductor who is trained in all aspects of motor and cognitive development structures the activities, especially the self-care activities. Group work is important as a motivating factor, and there is a strong emphasis on the importance of anticipation, with forward planning of activities and volitional control in acquisition of new skills [73]. CE approach aims to educate people with physical disabilities to acquire new experiences in activities of daily living (ADLs). In this approach, the child is educated on how to use his/her abilities for performing active movements and generalizing this learning to different life situations. In this technique, children present activities in the form of a group, using music and rhythmic speech during activities. Paying attention to all aspect of child development, that is, the physical, intellectual, cognitive, and social approach, is important [74]. The CE approach is more effective in improving social interaction and relationships than the other approaches. Educational programs for parents can also improve the quality of life of children with CP in activities, such as eating, bowel, and urine control [75]. In Hungary, where this approach was pioneered, children tend to be in the educational setting all day. Frequently, group work and the use of specialized furniture are incorporated into more eclectic treatment programs [7]. Major differences in outcome between CE and another intensive rehabilitation program was not demonstrated [76]. A study comparing individual PT or OT with CE showed that CE improved coordinative hand functions and activities of daily living [77]. The emphasis of intervention is on independence in attaining goals rather than on quality of movement. CE is sometimes included in the group of complementary therapies for CP. It has been reported to be used by 21% of children with CP [6, 10, 78, 79].

2.5. Sensory Integration Training

Sensory integration therapy is based on the idea that some kids experience "sensory overload" and are oversensitive to certain types of stimulation. When children have sensory overload, their brains have trouble processing or filtering many sensations at once. Meanwhile, other children are undersensitive to some kinds of stimulation. Children who are undersensitive do not process sensory messages quickly or efficiently. These children may seem disconnected from their environment. In either case, children with sensory integration issues struggle to organize, understand, and respond to the information they take in from their surroundings. Sensory integration therapy exposes children to sensory stimulation in a structured, repetitive manner. The theory behind this treatment approach is that, over time, the brain will adapt and allow them to process and react to sensations more efficiently. CP has been treated with an emphasis on ameliorating motor impairments; however, more recently, the significant impact of concomitant sensory impairments has been acknowledged and targeted for evaluation and intervention. Sensory integration is developed by an occupational therapist, Jean Ayres, in the 1960s. In this concept, difficulties in planning and organizing behavior are attributed to problems of processing sensory inputs within the CNS, including vestibular, proprioceptive, tactile, visual, and auditory. Children with sensory integration dysfunction frequently use different sensory combination strategies. Treatment focuses on integration of neurological processing by facilitating the individual to process the type, quality, and intensity of sensation. Children with sensory integration problems often display inappropriate responses to sensory input. Some children show poor ability to register sensory information and therefore seek sensory input, and those who are hypersensitive to sensory stimuli require desensitizing. The processing of sensory information is fundamental for organizing behaviors. A significant number of children with CP have sensory impairments. Sensory integration may help processing and integration of this sensory information, thereby enhancing the child's acquisition of function [7, 80]. Programs of Sensory Integration Training in individuals and group treatments affect children with cerebral palsy. It was concluded that sensory integration training in children with cerebral palsy will be applied to combined programs and the relationship with individual and group treatments developed [81].

2.6. Constraint-induced movement therapy (CIMT)

Congenital hemiplegia is the most common form of unilateral CP, with a prevalence of 1 in 1300 live births. One side of the body has impairments in movement and/or sensation, which may cause difficulty with daily activities. The result of sensory and motor impairments often leads to "developmental disuse"—a phenomenon in which such children tend not to use the affected extremity, so it accordingly fails to develop [26, 82]. Constraint-induced movement therapy (CIMT) is specifically used to improve upper limb function in children with hemiplegia who account for approximately 30% of all children with CP [83]. CIMT aims to increase spontaneous use of the impaired arm by forcing the child to use it by restraining the other one. It is characterized by the following elements: restraining of the unaffected side, concentrated and intensive practice (over 2–3 treatment weeks for 6–7 days with the unaffected hand restrained 90% of the waking hours, followed by 10 days of a 6-hour intensive program), and shaping activities [84]. This protocol has been modified in a number of studies and more recent use with children with hemiplegia has featured a shorter duration of restraint (with none taking place at home) and the use of child-friendly treatment tasks [85]. One potential advantage of CIMT is that the restraint allows the therapist administering the intervention to focus solely on the more-affected arm [86]. Some clinical trials show that this modified CIMT significantly improves movement efficiency and bimanual arm use in hemiplegic children [87, 88]. A recent systematic review provides evidence of efficacy of CIMT for improving hand function. CIMT was initially used in adults with hemiparesis [89]. During the acute phase of stroke, the individual unable to use the upper limb effectively, which over time results in learned nonuse of the affected upper limb. Similar loss of function was found in children with hemiplegia [90–92]. During development, the children with hemiplegia frequently find that daily tasks are more effective and efficient using the nonaffected hand. CIMT increases functional ability in the affected upper limb with a concomitant cortical reorganization. In recent years, a variety of clinical trials bring out modified CIMT, where the unaffected limb is restrained for less than 3 hours a day. Restraint of the nonaffected limb may take several forms, including bivalved casts, a glove, or a sling. Activity programs involve selected tasks that are systematically increased in difficulty, this is often referred to as a shaping process. CIMT improves movement efficiency, performance, and perceived usage of the involved upper extremity hand and arm, the changes retains for 6 months. CIMT is efficacious in improving movement efficiency that was not age-dependent [88, 91–93]. CIMT is based on a concept that is not new but it is still experimental in hemiplegic CP. Further research is essential for its tolerability for children and families and to ensure that it is developmentally appropriate.

2.7. Bimanual training

The Bimanual training (BIT) provides bimanual training activities, which focus on improving the coordination of both arms using structured tasks in bimanual play and functional activities with intensive practice [94]. Historically, therapists have used a bimanual approach in the management of motor dysfunction in children with hemiplegia, but only recently has an intensive bimanual training program, the hand-arm bimanual intensive training (HABIT) been published to substantiate its effectiveness. This approach is based on motor learning theory (practice specificity, types of practice, and feedback), neuroplasticity (i.e., the potential of the brain to change by repetition, increasing movement complexity, motivation, and reward), and focuses on the equal use of both arms in bimanual tasks. Intensive BIT (e.g., HABIT), was developed with recognition that increased functional independence in the child's environment requires the combined use of both hands. BIT was developed in response to the limitations of CIMT, with a view to addressing bimanual coordination while maintaining the positive aspects of intensive training of the impaired arm. BIT also focuses on improving coordination of the two hands using structured task practice embedded in bimanual play and functional activities [86, 95, 96]. The lower extremity (LE) is generally less affected than the upper extremity (UE) in children with hemiplegic CP, normally allowing gait. However, impairments are observed in the involved LE ranging from isolated equines in the ankle to hip flexion and adduction with a fixed knee. In standing, children are unable to achieve postural symmetry, presenting an overload on one body side. This leads to limitations in walking abilities. In the past decade, intensive training techniques focusing on the UE (i.e., CIMT, intensive bimanual training) have shown tremendous promise in improving UE function. Hand-arm bimanual intensive therapy including lower extremities (HABIT-ILE) combines upper and lower bilateral extremity training [97, 98]. Frequently used bimanual tasks and activities are gross dexterity, manipulative games and tasks, functional tasks, arts and craft, and virtual reality (wii-fit, kinect). Frequently used bilateral lower extremity tasks are ball sitting, standing, balance board standing, virtual reality (wii-fit, kinect), walking/running, jumping, cycling, and making scooter. Bimanual activities that require trunk and LE postural adaptations are performed at a table of appropriate height (50% of the time) on unstable supports: sitting on fitness balls or standing on balance boards. Both the decreased time and the progressively increasing postural challenge represent the main difference from HABIT. Furthermore, 30% of the time is devoted to activities of daily living where standing and/or walking is required (dressing, brushing teeth, doing one's hair, transporting objects such as a tray, and household chores such as sweeping and washing dishes). Finally, the remaining time (20%) is spent in gross motor physical activities/play, such as bowling, ball playing, jumping rope, street hockey, use of wii-fit, balance bike (without pedals), scooter use, and wall climbing. These are performed in standing, walking, and running (or jumping) with the LE and simultaneously involving bimanual coordination. These activities are graded toward more demanding tasks for the LE [99].

2.8. Family-centered models

Family-centered care refers to how healthcare professionals interact and involve children's family in the care. A family-centered approach is characterized by therapist's practices that respect to families, where information is exchanged, where there is responsiveness to the family priorities and choices, and where family-therapist partnerships are fundamentally important. The family-centered practice has emphasis on child and family strengths rather than deficits. This approach facilitates family choice and control [100–103]. In this approach, effective intervention is based on collaborative decision making and respect for parents' understandings of their child's needs and appreciation of family and child worldviews, values, and preferences. Family-centered service promote the family's (including the child) self-determination, decision-making capabilities, and self-efficacy [104–107]. The principles underlying family-centered service include recognition of parents as the experts on their child's needs, the promotion of partnership, and support for the family's role in decision making for their child. There is evidence that family-centered care is related to physical or health benefits to children and psychosocial benefits for mothers [108]. Collaboration or a partnership between therapists and families has been endorsed as a best approach in the field of early intervention and pediatric rehabilitation [109–111]. Successful parent-therapist collaboration is characterized by the following therapist competencies: (1) ability to listen, share, and learn with families; (2) ability to foster the parental role and expertise; and (3) ability to facilitate parent-centered decision making about what is best for the child [42]. These abilities and behaviors, together, constitute the building blocks of family-centered service, effective help giving, and relationship-based practice [112, 113]. The "family-centred service" is built on three principles: (1) respect that parents know and want the best for their child, (2) every family is unique, and (3) optimal development occurs within a supportive family and a community context [18, 114, 115]. A family-centered service approach offers a perspective in which the child and biological aspects of the child are important but where the needs of the parents and the family are central to incorporate and support. The well-being of the family is essential to the well-being of the child. In many countries, (re)habilitation centers offer multiprofessional services to children with developmental disabilities, and a family-centered service approach is often an important basis in the work with families. Good team collaboration is needed to optimally coordinate services. Key features in this process are good organization and communication and a lucid process in the collaborative decision making when setting goals for therapy [116, 117].

3. Approaches with using equipments

3.1. Treadmill training

Approximately 41% of children with CP display limited walking ability. A typical form of gait training has been performed overground with assistive devices or parallel bars. The treadmill has recently gained more attention as an instrument for gait training and assessment with several advantages over conventional methods. The treadmill can help clinicians overcome space constraints, reduce physical demands, and establish a convenient set-up for gait evaluation [118]. Treadmill training is used for children with CP to help them to improve balance and build strength of their lower limbs so they could walk earlier and more efficiently than those children who did not receive treadmill training [65]. In recent years, there has been increasing interest in partial body weight-supported treadmill training (PBWSTT). In PBWSTT, the child is in a harness that supports their body weight, reducing some of the effort required for walking over the treadmill. The treadmill assists in production of steps while the child is supported in a safe environment. Recent studies have reported the benefits of gait training on a treadmill. Some studies showed that treadmill training helped children with cerebral palsy to walk about 101 days earlier than children who did not train by treadmill. A recent study, which looked at the effects of PBWSTT on endurance, functional gait, and balance, trained children for 30 minutes twice daily for 2 weeks, showed improvements in walking speed and energy efficiency. A recent systematic review of PBWSTT in young children with developmental disability (the majority of whom had CP) concluded that there was no definitive evidence that PBWSTT alone increases ambulatory ability. Although the systematic review did not support the effectiveness of the treatment, the evidence from some of the papers reviewed suggested some positive improvements [119, 120]. Positive effects of treadmill training were found in comparison with overground gait training on static and functional balance. The effects were found after 12 sessions of training at the aerobic threshold without body weight support. The benefits included an improvement in functional performance and greater independence in children with CP [121]. It is suggested that treadmill training may favor proprioceptive feedback, leading to adjustments for adequate postural balance and functional performance [122]. Also, backward walking (BW) training on the treadmill can improve the gross motor function measure, weight-bearing symmetry, and temporospatial gait parameters in individuals with spastic cerebral palsy. The muscles of the legs are active for a longer period during BW training when compared with forward (FW) training, and a longer period of muscle activity can result in greater muscle strength gain than with FW training. Furthermore, training in BW could require higher physiological and perceptual responses than FW at matched speed, as BW is the performance of a novel task for most children with CP. BW treadmill training helps children with spastic CP to improve walking capacity and decrease standing asymmetry of body weight distribution [123]. Treadmill gait training helps such children to repeat task-centered activities while walking; accordingly, they control velocity and develop a proper walking pattern by processing repeated sensory inputs obtained during walking. It is effective for increasing the muscular strength of the knee extensors and flexors as well as enhancing balance activities. Thus, it plays an important role in improving the functional activities of children with cerebral palsy. Enhanced muscular strength in the lower limbs causes adjusting the participants' posture, improving dynamic postural stability, and ultimately improving walking. Also, improved walking endurance and muscle strength leads to improved gait performance after treadmill training [124].

3.2. Robot-assisted therapy

Robot-assisted therapy (RAT) is conducted using robotic devices that enable the patients to perform specific limb movements. The main interest in using robots is to allow the patients to achieve a large amount of movement in a limited time. Additionally, the attractive human-machine interface has the capacity to motivate the child to perform his or her therapy through playful games, such as car races, or to perform exercises that mimic ADLs. Moreover, robotic devices allow the patient to receive visual, auditory, or sensory feedbacks. Finally, the robot gives performance-based assistance to the patients. This assistance can enhance the neuronal plasticity by enabling the patients to initiate and accomplish movements as actively as possible [125–132]. The strength of RAT is based on repetitive, goal-oriented, cognitive engaging tasks, which appear to be particularly interesting in the pediatric age, when the neuroplasticity is recognized to be at its maximum. Robotic therapy might increase functional strength and improve isolated movements. Because consistency of assistance can be maintained, intensity and difficulty can be set according to the patient's improvement. Several groups reported long-lasting improvements in standing and walking of children with CP. Also, parents and patients report improvements in terms of quality of life [133–135]. A device specifically developed for the locomotion training is the Lokomat (Hocoma, CH), made of two active orthoses, a weight-bearing system and a treadmill. This robotic rehabilitation has been proposed to improve walking and physical fitness [136]. It is reported that the muscular strength of ankle dorsi-flexion and plantarflexion increases in children with cerebral palsy who played a block break game and an airplane game using robotics in virtual reality three times per week for 12 weeks [137]. Robotic devices offer children fun and intensive rehabilitation that a human therapist cannot provide. These robots can be easily integrated as a relevant complement to therapy in the clinical setting. Studies have shown that combined passive and active training using a portable robot for children with CP is effective and feasible in a research laboratory and in a clinical setting. A repetitive, goal-directed, biofeedback training through motivating games in the laboratory and in the home environment is feasible. Robot-guided therapy can be an option for a home-based treatment program. The benefits of home-based robot-guided therapy are also similar to those of laboratory-based robot-guided therapy [138].

3.3. Virtual reality

Virtual reality has been defined as the use of interactive simulations created with computer to perform users in virtual environments that appear, sound, and feel similar to real-world objects and events [139, 140]. Users interact with virtual objects by moving and manipulating them. The therapeutic aims of virtual reality and interactive computer play are to provide users with more than just an entertaining experience [141]. The use of virtual reality in pediatric rehabilitation is based on its distinctive attributes that provide ecologically valid opportunities for active learning, which are enjoyable and motivating yet challenging and safe [142, 143]. Due to limitations in mobility and manual ability, children with CP may have fewer opportunities for free play. Without opportunities for self-initiated and spontaneous play, children can develop a learned helplessness and assume that they are unable to perform a task even though they may have the required physical abilities. In contrast to planned structured activities led by an adult, free play is characterized by children's spontaneous engagement in an activity that is intrinsically motivating and self-regulated [144]. Virtual reality can improve the patient's motivation and achievement in ADLs. Preliminary data suggest that this type of therapy also improves motor function in the upper and lower extremities that are caused by CP [127, 145]. The dynamic nature of stimulus increases the ability of cognitive and/or motor demands. The automated recording of task outcome enables clinicians to focus on child's performance within a virtual environment and to observe whether he or she is using effective strategies [146]. Clinicians can now design virtual environments to achieve a variety of therapeutic objectives by varying task complexity, type, and amount of feedback [147, 148]. The significance of virtual reality technology is related to the motivation it provides to perform multiple task-oriented repetitions [149]. Virtual reality is more important in children who are often not compliant in following a conventional exercise program because they find the exercises to be less interesting [150–153]. The technologies differ in both type and technical complexity. There are a variety of technologies that can be used to implement virtual environments. These include the use of standard desktop or laptop computer equipment, camera-based video capture gesture control devices (e.g., Microsoft's Kinect), Nintendo Wii Fit (http://wiifit.com/) head-mounted displays, haptic and other sensor- and/or actuator-based devices, and large screen immersive systems (e.g., Motek's CAREN http://www.motekmedical.com/) [153]. It is showed that children with a neurological gait disorder reported higher levels of motivation while gait training during a virtual reality soccer activity compared with training with therapy instruction [154, 155]. Participants' motivation levels were found to differ based on the type of virtual reality game played. Their motivation levels were less during a virtual reality navigation game than during conventional therapy and greater during virtual reality soccer than during conventional therapy. Finally, participants reported more fun and interest when doing dorsiflexion exercises in the context of GestureTek virtual reality games compared with completing exercises while sitting in a chair with therapist instruction. More specifically, 8 of 10 children increased their median energy expenditure significantly. Parents reported motivation-enabled performance, four participants self-reported feeling motivated, and volition levels were increased. Demonstration of the effectiveness of any virtual reality intervention depends on the degree to which the attained skills transfer to the "real world." Interactive computer play is one of the hottest areas in neurorehabilitation research, with much of the focus being on individuals with cerebral palsy [4, 156–158].

3.4. Cardiorespiratory endurance training

Many children, adolescents, and adults with CP have reduced cardiorespiratory endurance (the capacity of the body to perform physical activity that depends mainly on the aerobic or oxygen-requiring energy systems), muscle strength, and habitual physical activity participation [58]. Both reduced cardiorespiratory endurance and muscular weakness pose significant risks for negative health outcomes and early, cardiovascular, and all-cause mortality. Because people with CP have lower level muscle strength and cardiorespiratory endurance, they are at higher risk for developing cardiovascular diseases. This has been shown by increased cardiometabolic risk factors, including hypertension, cholesterol, HDL-C, visceral adipose tissue, and obesity in adults with CP [159–166]. Moreover, adults with CP, there were substantially increased estimates of chronic diseases, such as diabetes, asthma, hypertension and other cardiovascular conditions, stroke, joint pain, and arthritis [167]. In studies, the participants exercised at least two to four times per week for minimum 20 minutes and at a moderate intensity of about 60–75% maximum heart rate, 40–80% of heart rate reserve, or 50–65% peak oxygen uptake. The studies reported outcomes in aerobic performance, measured with an arm cranking/cycle test, and shuttle run test and in cardiorespiratory endurance [168–172].

Cardiorespiratory training can effectively increase cardiorespiratory endurance in children and young adults with CP. Exercise prescription for people with CP should include: (1) a minimum frequency of two to three times per week; (2) an intensity between 60 and 95% of peak heart rate, or between 40 and 80% of the HRR, or between 50 and 65% of VO2peak; and (3) a minimum time of 20 minutes per session, for at least 8 consecutive weeks, when training three times a week or for 16 consecutive weeks when training two times a week. Moreover, a pre-workout warm-up and cool-down could be added to reduce musculoskeletal injury [58]. A program of "functional exercises," combining aerobic and anaerobic capacity and strength training, in ambulatory children improves physical fitness and quality of life. Training programs on static bicycles or treadmill were beneficial for gait and gross motor development without enhancing spasticity and abnormal movement patterns [171, 173].

3.5. Hippotherapy

Hippotherapy is a rehabilitation strategy performed with a moving horse, which has demonstrated its potential to improve the mobility of children with CP. This therapy is designed to improve motor functioning and quality of movement in children with CP [174, 175]. The warmth and shape of the horse and the rhythmic, three-dimensional movement of horseback riding improve the flexibility, posture, balance, and mobility of the rider. Hippotherapy can be described as a low frequency, high repetition treatment strategy. Muscle contractions and postural adjustments are required to react to the horse's movements. A full-sized horse transfers about 110 multidimensional swinging motions to the rider each minute while walking. More specifically, in a 30-minute therapy session, a horse walking at a speed of 100 steps/minute will induce over 3000 steps. In order to maintain vertical alignment and react to these postural challenges, the child must engage their trunk muscles intensively. In most hippotherapy sessions, the child takes various positions (e.g., forward sitting, side sitting, and backward sitting). During the sessions, a therapist and a trained side walker provide support and movement possibilities for the child sitting on the horse. In addition, equine movement induces a scapular and pelvic dissociation in the rider, similar to what is observed in a normal gait pattern with asymmetric arm and pelvis movements [176, 177]. Horseback riding therapy reduces abnormal tone, promoting motor performance, creating symmetric alignment, and improving postural awareness, gait, and mobility. It is a walk practice for the upper body without the use of the legs. One systematic review and two meta-analyses provide evidence that hippotherapy positively affects postural control, balance, and muscle symmetry [178–180]. Session length ranged from 30 minutes to 1 hour with a frequency ranging from one to two sessions per week. According to a recent systematic review, a weekly 45-minute session of hippotherapy for 8–10 weeks was correlated with positive effects on gross motor function in children with CP [181]. The social functioning domain is influenced by various factors, such as education, socioeconomic status, cognition, communication abilities, and motor function [182]. The opportunity to use or practice communication, listening, and language skills during hippotherapy also results in the improvements in social functioning. Hippotherapy enhances the child's motivation and willingness for participation in an activity [183].

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References

[1] Sakzewski L, Ziviani J, Boyd R. Systematic review and meta-analysis of therapeutic management of upper-limb dysfunction in children with congenital hemiplegia. Pediatrics. 2009;123:1111-1122. DOI:10.1542/peds.2008-3335.

[2] Holt RL, Mikati MA. Care for child development: basic science rationale and effects of interventions. Pediatric Neurology. 2011;44:239-253. DOI:10.1016/j.pediatrneurol.2010.11.009.

[3] Aisen ML, Kerkovich D, Mast J, Mulroy S, Wren TA, Kay RM, Rethlefsen SA. Cerebral palsy: clinical care and neurological rehabilitation. Lancet Neurology. 2011;10:844-852. DOI:10.1016/S1474-4422(11)70176-4.

[4] Tatla SK, Sauve K, Virji-Babul N, Holsti L, Butler C, Van Der Loos HF. Evidence for outcomes of motivational rehabilitation interventions for children and adolescents with cerebral palsy: an American Academy for Cerebral Palsy and Developmental Medicine systematic review. Developmental Medicine & Child Neurology. 2013;55:593-601. DOI: 10.1111/dmcn.12147.

[5] Mayston MJ. Physiotherapy management in cerebral palsy: an update on treatment approaches. In: Scrutton D, Damiano D, Mayston M, editors. Management of the motor disorders of children with cerebral palsy. 2nd ed. London: MacKieth Press, 2004. p. 147–160. No. 161. Clinics in developmental medicine.

[6] Mayston MJ. Setting the scene. In: Edwards S, editor. Neurological physiotherapy—a problem solving approach, 2nd ed. Edinburgh: Churchill Livingstone, 2002. p. 3–19.

[7] Barber CE. A guide to physiotherapy in cerebral palsy. Paediatrics and Child Health. 2008;18:410–413.

[8] Bobath B. The very early treatment of cerebral palsy. Developmental Medicine & Child Neurology. 1967;9:373–390.

[9] Fetters L, Kluzik J. The effects of neurodevelopmental treatment versus practice on the reaching of children with spastic cerebral palsy. Physical Therapy. 1996;76:346–358.

[10] Papavasiliou AS. Management of motor problems in cerebral palsy: a critical update for the clinician. European Journal of Paediatric Neurolology. 2009;13:387-396. DOI: 10.1016/j.ejpn.2008.07.009.

[11] Mayston M. Bobath concept: Bobath@ 50: Mid-life crisis—What of the future? Physiotherapy Research International. 2008;13:131–136.

[12] Velickovic TD, Perat MV. Basic principles of the neurodevelopmental treatment. Medicina, 2005;42:112–120.

[13] Howle J M. Neuro-developmental treatment approach: Theoretical foundations and principles of clinical practice. Osseum Entertainment; 2002.

[14] Ju YH, Hwang IS, Cherng RJ. Postural adjustment of children with spastic diplegic cerebral palsy during seated hand reaching in different directions. Archives of Physical Medicine and Rehabilitation. 2012; 93: 471.

[15] Tsorlakis N, Evaggelinou C, Grouios G, Tsorbatzoudis C. Effect of intensive neurodevelopmental treatment in gross motor function of children with cerebral palsy. Developmental Medicine & Child Neurology. 2004;46:740–745.

[16] Grazziotin Dos Santos C, Pagnussat AS, Simon AS, Py R, Pinho AS, Wagner MB. Humeral external rotation handling by using the Bobath concept approach affects trunk

extensor muscles electromyography in children with cerebral palsy. Research in Developmental Disabilities. 2014; 20:134-141. DOI: 10.1016/j.ridd.2014.09.013.

[17] Case-Smith J. Occupational therapy for children. 5th ed. St. Louis, MO: Mosby.

[18] Bamm EL, Rosenbaum P. Family-centred theory: origins, development, barriers, and supports to implementation in rehabilitation medicine. Archives of Physical Medicine and Rehabilitation. 2008;89:1618-1624.

[19] Nijhuis BJ, Reinders-Messelink HA, de Blecourt AC, Boonstra AM, Calame EH, Groothoff JW, Nakken H, Potema KL. Goal setting in Dutch paediatric rehabilitation. Are the needs and principal problems of children with cerebral palsy integrated into their rehabilitation goals? Clinical Rehabilitation. 2008;22:348-363.

[20] Valvano J. Activity-focused motor interventions for children with neurological conditions. Physical & Occupational Therapy in Pediatrics. 2004;24:79-107.

[21] Darrah J, Wiart L, Magill-Evans J. Do therapists' goals and interventions for children with cerebral palsy reflect principles in contemporary literature? Pediatric Physical Therapy. 2008; 20:334-339.

[22] Shumway-Cook A, Woollacott MH. Motor control: translating research into clinical practice. 3rd ed. Lippincott Williams and Wilkins; 2006.

[23] O'Neill DL, Harris SR. Developing goals and objectives for handicapped children. Physical Therapy. 1982;62:295-298.

[24] Hurn J, Kneebone I, Cropley M. Goal setting as an outcome measure: A systematic review. Clinical Rehabilitation. 2006;20:756-772.

[25] Van Duijenvoorde AC, Zanolie K, Rombouts SA, Raijmakers ME, Crone EA. Evaluating the negative or valuing the positive? Neural mechanisms supporting feedback-based learning across development. Journal of Neuroscience. 2008; 28:9495-9503.

[26] Stanley F, Blair E, Alberman E. Cerebral palsies: Epidemiology and causal pathways. London: Mac Keith Press; 2000.

[27] Palisano R, Rosenbaum P, Walter S, Russel D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. Developmental Medicine & Child Neurology. 1997;39:214-223.

[28] Eliasson A, Rösblad B, Krumlinde-Sundholm L, Beckung E, Arner M, Ohrvall A, Rosenbaum P. Manual Ability Classification System (MACS) for children with cerebral palsy: scale development and evidence of validity and reliability. Developmental Medicine & Child Neurology. 2006;48:549-554.

[29] Law M, Darrah J, Pollock N, King G, Rosenbaum P, Russel D, Palisano R, Harris S, Armstrong R, Watt J. Family-centered functional therapy for children with cerebral palsy: An Emerging Practice Model. Physical & Occupational Therapy in Pediatrics. 1998;18:83-102.

[30] Siegert RJ, McPerson KM, Taylor WJ. Toward a cognitive-affective model of goal-setting in rehabilitation: is self-regulation theory a key step? Disability and Rehabilitation. 2004;26:1175-1183.

[31] Carlberg EB, Löwing K. Goal directed training in children with cerebral palsy. Turkish Journal of Medical Science, Pediatric Rehabilitation Special Issue. 2010;3:53-57.

[32] Bower E, Mc Lellan DL, Arney J, Campbell MJ. A randomised controlled trial of different intensities of physiotherapy and different goal-setting procedures in 44 children with cerebral palsy. Developmental Medicine & Child Neurology. 1996;38:226-237.

[33] Bower E. Goal setting and the measurement of change. In: Scrutton D, Damiano D, Mayston M, editors. Measurement of motor disorders in children with cerebral palsy. London: Mc Keith Press; 2004. p. 32-52.

[34] Bower E, Mc Lellan DL. Assessing motor skill acquisition in four centres for the treatment of children with cerebral palsy. Developmental Medicine & Child Neurology. 1994;36:902-909.

[35] Van den Broeck C, De Cat J, Molenaers G, Franki I, Himpens E, Severijns D, Desloovere K. The effect of individually defined physiotherapy in children with cerebral palsy (CP). European Journal of Paediatric Neurology. 2010;14:519-525. DOI:10.1016/j.ejpn.2010.03.004.

[36] Novak I, Cusick A, Lannin N. Occupational therapy home programs for cerebral palsy: double-blind, randomized, controlled trial. Pediatrics. 2009;124:e606–e614.

[37] Ketelaar M, Vermeer A, Hart H, van Petegem-van Beek E, Helders PJ. Effects of a functional therapy program on motor abilities of children with cerebral palsy. Physical Therapy. 2001;81:1534–1545.

[38] Salem Y, Godwin EM. Effects of task-oriented training on mobility function in children with cerebral palsy. NeuroRehabilitation. 2009;24:307–313.

[39] Levack WM, Taylor K, Siegert RJ, Dean SG, McPherson KM, Weatherall M. Is goal planning in rehabilitation effective? A systematic review. Clinical Rehabilitation. 2006;20:739–755.

[40] Mastos M, Miller K, Eliasson AC, Imms C. Goal-directed training: linking theories of treatment to clinical practice for improved functional activities in daily life. Clinical Rehabilitation. 2007;21:47–55.

[41] King G, Currie M, Bartlett DJ, Gilpin M, Willoughby C, Tucker MA, Strachan D, Baxter D. The development of expertise in pediatric rehabilitation therapists: changes in approach, self-knowledge, and use of enabling and customizing strategies. Developmental Neurorehabilitation. 2007;10:223–240.

[42] Palisano RJ, Chiarello LA, King GA, Novak I, Stoner T, Fiss A. Participation-based therapy for children with physical disabilities. Disability and Rehabilitation. 2012;34:1041-1052. DOI:10.3109/09638288.2011.628740.

[43] Kirusek TJ, Smith A, Cardillo JE. Goals attainment scaling: applications, theory and measurement. Hillsdale, New Jersey: Laurence Erlbaum Associates; 1994.

[44] Palisano RJ. Validity of goal attainment scaling in infants with motor delays. Physical Therapy. 1993;73:651-660.

[45] Wiley ME, Damiano DL. Lower-extremity strength profiles in spastic cerebral palsy. Developmental Medicine & Child Neurology. 1998;40: 100–107.

[46] Eek MN, Tranberg R, Beckung E. Muscle strength and kinetic gait pattern in children with bilateral spastic CP. Gait & Posture. 2011; 33: 333–337.

[47] Williams MA, Haskell WL, Ades PA, Amsterdam EA, Bittner V, Franklin BA, Gulanick M, Laing ST, Stewart KJ. Resistance exercise in individuals with and without cardiovascular disease: 2007 update: a scientific statement from the American Heart Association Council on Clinical Cardiology and Council on Nutrition, Physical Activity, and Metabolism. Circulation. 2007;116:572–584.

[48] Jurca R, Lamonte MJ, Church TS, Earnest CP, Fitzgerald SJ, Barlow CE, Jordan AN, Kampert JB, Blair SN. Associations of muscle strength and fitness with metabolic syndrome in men. Medicine & Science in Sports & Exercise. 2004; 36: 1301–1307.

[49] Jurca R, Lamonte MJ, Barlow CE, Kampert JB, Church TS, Blair SN. Association of muscular strength with incidence of metabolic syndrome in men. Medicine & Science in Sports & Exercise. 2005; 37:1849–1855.

[50] Peterson MD, Saltarelli WA, Visich PS, Gordon PM. Strength capacity and cardiometabolic risk clustering in adolescents. Pediatrics. 2014;133: e896–e903.

[51] Gale CR, Martyn CN, Cooper C, Sayer AA. Grip strength, body composition, and mortality. International Journal of Epidemiology 2007;36:228–235.

[52] Brill PA, Macera CA, Davis DR, Blair SN, Gordon N. Muscular strength and physical function. Medicine & Science in Sports & Exercise. 2000;32:412–416.

[53] Damiano DL, Vaughan CL, Abel MF. Muscle response to heavy resistance exercise in children with spastic cerebral palsy. Developmental Medicine & Child Neurology. 1995;37:731–739.

[54] Scholtes VA, Becher JG, Comuth A, Dekkers H, Van Dijk L, Dallmeijer AJ. Effectiveness of functional progressive resistance exercise strength training on muscle strength and mobility in children with cerebral palsy: a randomized controlled trial. Developmental Medicine & Child Neurology. 2010;52:e107–e113.

[55] Morton JF, Brownlee M, McFadyen AK. The effects of progressive resistance training for children with cerebral palsy. Clinical Rehabilitation. 2005;19 283–289.

[56] Dodd KJ, Taylor NF, Damiano DL. A systematic review of the effectiveness of strength training programs for people with cerebral palsy. Archives of Physical Medicine and Rehabilitation.2002; 83:1157–1164.

[57] Engsberg JR, Ross SA, Collins DR. Increasing ankle strength to improve gait and function in children with cerebral palsy: a pilot study. Pediatric Physical Therapy. 2006;18:266–275.

[58] Verschuren O, Peterson MD, Balemans AC, Hurvitz EA. Exercise and physical activity recommendations for people with cerebral palsy. Developmental Medicine & Child Neurology. 2016; 7. DOI: 10.1111/dmcn.13053.

[59] Davis B, Bull R, Roscoe Roscoe D. Physical education and the study of sport. 4th ed. Edinburgh: Mosby; 2000. p. l30–l150.

[60] Brandom R. Physical medicine and rehabilitation. 2nd ed. Philadelphia: Harcourt Health Science Company; 2000. p. 400–404.

[61] Mccall G, Byrnes W, Dickinson A, Pattany P, Fleck SJ. Muscle fiber hypertrophy, hyperplasia, and capillary density in college men after resistance training. Journal of Applied Physiology. 1996;81:2004–2010.

[62] Graham A, Reid A. Physical fitness of adults with an intellectual disability: A 13-year follow-up study. Research Quarterly for Exercise and Sport. 2000;71:152–161.

[63] Sutherland DH, Davis JR. Common abnormalities of the knee in cerebral palsy. Clinical Orthopaedics and Related Research. 1993;288:139–147.

[64] Carmeli E, Barchad S, Masharawi Y, Coleman R. Impact of a walking program in people with Down syndrome. Journal of Strength and Conditioning Research. 2004;18:180–184.

[65] Olama KA. Endurance exercises versus treadmill training in improving muscle strength and functional activities in hemiparetic cerebral palsy. Egyptian Journal of Medical Human Genetics. 2011;12:193-199.

[66] Damiano DL, Kelly LE, Vaughan CL. Effects of a quadriceps femoris strengthening programme on crouch gait in children with cerebral palsy. Physical Therapy. 1995;75:658–667.

[67] MacPhail HEA, Kramer JF. Effect of isokinetic strength training on functional ability and walking efficiency in adolescents with cerebral palsy. Developmental Medicine & Child Neurology. 1995;37:763–775.

[68] Damiano DL, Abel MF. Functional outcomes of strength training in spastic cerebral palsy. Archives of Physical Medicine and Rehabilitation.1998;79:119–125.

[69] Dodd KJ, Taylor NF, Graham HK. A randomized clinical trial of strength training in young people with cerebral palsy. Developmental Medicine & Child Neurology. 2003;45:652–657.

[70] Horvat M. Effects of a progressive resistance training program on an individual with spastic cerebral palsy. American Corrective Therapy Journal. 1987;41:7–11.

[71] Blundell SW, Shepherd RB, Dean CM, Adams RD. Functional strength training in cerebral palsy: a pilot study of a group circuit training class for children aged 4–8 years. Clinical Rehabilitation. 2003;17:48–57.

[72] Bairstow P, Cochrane R. Is conductive education transplantable? British Journal of Special Education. 1993;20:84–88.

[73] Medveczky E. Conductive education as an educational method of neurorehabilitation. Budapest: International Petö Institute; 2006.

[74] Hari M. The human principle in conductive education. Peto Magazine; 1996. p. 9–12.

[75] Dalvand H, Dehghan L, Feizy A, Amirsalai S, Bagheri H. Effect of the Bobath technique, conductive education and education to parents in activities of daily living in children with cerebral palsy in Iran. Hong Kong Journal of Occupational Therapy. 2009; 19:14-19.

[76] Odman PE, Oberg BE. Effectiveness and expectations of intensive training: a comparison between child and youth rehabilitation and conductive education. Disability and Rehabilitation. 2006; 28:561–570.

[77] Blank R, von Kries R, Hesse S, von Voss H. Conductive education for children with cerebral palsy: effects on hand motor functions relevant to activities of daily living. Archives of Physical Medicine and Rehabilitation. 2008;89:251–259.

[78] Parkes J, Donnelly M, Dolk H, Hill N. Use of physiotherapy and alternatives by children with cerebral palsy: a population study. Child Care Health & Development. 2002;28:469–477.

[79] Liptak GS. Complementary and alternative therapies for cerebral palsy. Mental Retardation and Developmental Disabilities Research Reviews. 2005;11:156–163.

[80] Spitzer S, Roley SS. Sensory integration revisited. In: Roley SS, Blanche EI, Schaaf RC, editors. Understanding the nature of sensory integration with diverse populations. Therapy Skills Builders; 2001. p. 3–27.

[81] Bumin G, Kayihan H. Effectiveness of two different sensory-integration programmes for children with spastic diplegic cerebral palsy. Disability and Rehabilitation. 2001;23:394-399.

[82] Charles J, Gordon AM. A critical review of constraint-induced movement therapy and forced use in children with hemiplegia. Neural Plasticity. 2005;12:245–261.

[83] Hagberg B, Hagberg G, Beckung E, Uverbrant P. Changing panorama of cerebral palsy in Sweden VIII. Prevalence and origin in the birth year period 1991–1994. Acta Paediatrica. 2001; 90: 271–277.

[84] Taub E, Wolf SL. Constraint induction techniques to facilitate upper extremity use in stroke patients. Topics in Stroke Rehabilitation. 1997;3:1–24.

[85] Gordon AM, Charles JR, Wolf SL. Methods of constraint induced movement therapy for children with hemiplegic cerebral palsy: Development of a child-friendly intervention for improving upper-extremity function. Archives of Physical Medicine and Rehabilitation. 2005;86:837–844.

[86] 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. Developmental Neurorehabilitation. 2013;16:133-143. DOI: 10.3109/17518423.2012.702136.

[87] Eliasson AC, Sundholm LK, Shaw K, Wang C. Effects of constraint-induced movement therapy in young children with hemiplegic cerebral palsy: An adapted model. Developmental Medicine & Child Neurology. 2005;47:266–275.

[88] Charles JR, Wolf SL, Schneider JA, Gordon AM. Efficacy of a child-friendly form of constraint-induced movement therapy in hemiplegic cerebral palsy: A randomized control trial. Developmental Medicine & Child Neurology. 2006;48:635–642.

[89] Novak I, McIntyre S, Morgan C, Campbell L, Dark L, Morton N, Stumbles E, Wilson SA, Goldsmith S. A systematic review of interventions for children with cerebral palsy: State of the evidence. Developmental Medicine & Child Neurology. 2013; 55:885–910.

[90] Taub E. Somatosensory deafferentation research with monkeys: implications for rehabilitation medicine. In: Ince LP, editor. Behavioural psychorehabilitation medicine; clinical applications. Philadelphia: Williams and Wilkins; 1980. p. 371–401.

[91] Deluca SC, Echols K, Law CR, Ramey SL. Intensive paediatric constraint-induced therapy for children with cerebral palsy: randomized, controlled, crossover trial. Journal of Child Neurology. 2006;21:931–938.

[92] Hoare B, Imms C, Carey L, Wasiak J. Constraint induced movement therapy in the treatment of the upper limb in children with hemiplegic cerebral palsy: a cochrane systematic review. Clinical Rehabilitation. 2007;21:675–685.

[93] Gordon AM, Charles J, Wolf SL. Efficacy of constraint-induced movement therapy on involved upper-extremity use in children with hemiplegic cerebral palsy is not age-dependent. Pediatrics. 2006;117:363–373.

[94] Gordon AM, Schneider JA, Chinnan A, Charles JR. Efficacy of a hand-arm bimanual intensive therapy (HABIT) in children with hemiplegic cerebral palsy: A randomized control trial. Developmental Medicine & Child Neurology. 2007;49:830–838.

[95] Nudo RJ. Adaptive plasticity in motor cortex: Implications for rehabilitation after brain injury. Journal of Rehabilitation Medicine. 2003;41:7–10.

[96] Kleim JA, Hogg TM, VandenBerg PM, Cooper NR, Bruneau R, Remple M. Cortical synaptogenesis and motor map reorganization occur during late, but not early, phase of motor skill learning. Journal of Neuroscience 2004;24:628–633.

[97] Caty GD, Arnould C, Thonnard JL, Lejeune TM. ABILOCO-Kids: A Rasch-built 10-item questionnaire for assessing locomotion ability in children with cerebral palsy. Journal of Rehabilitation Medicine. 2008;40:823–830.

[98] Domagalska ME, Szopa AJ, Lembert DT. A descriptive analysis of abnormal postural patterns in children with hemiplegic cerebral palsy. Medical Science Monitor. 2011;17: CR110–CR116.

[99] Bleyenheuft Y, Gordon AM. Hand-arm bimanual intensive therapy including lower extremities (HABIT-ILE) for children with cerebral palsy. Physical and Occupational Therapy in Pediatrics. 2014;34:390-403. DOI: 10.3109/01942638.2014.932884.

[100] Dunst CJ, Trivette CM. Meta-analytic structural equation modeling of the influences of family-centered care on parent and child psychological health. International Journal of Pediatrics. 2009;2009:1-9.

[101] Dunst CJ, Trivette CM, Hamby DW. Meta-analysis of family-centered help-giving practices research. Mental Retardation and Developmental Disabilities Research Reviews. 2007;13:370-378.

[102] Chiarello L. Family-centered care. In: Effgen S, editor. Meeting the physical therapy needs of children. 2nd ed. Philadelphia, PA: F.A. Davis; 2013.p.153-180.

[103] King G, Chiarello L. Family-centered care for children with cerebral palsy: conceptual and practical considerations to advance care and practice. Journal of Child Neurology. 2014;29:1046-1054. DOI: 10.1177/0883073814533009.

[104] Wampold BE. The great psychotherapy debate: Models, methods, and findings. Mahwah, NJ: Lawrence Erlbaum; 2001.

[105] Franck LS, Callery P. Re-thinking family-centred care across the continuum of children's healthcare. Child Care Health and Development. 2004;30:265–277.

[106] Rosenbaum P, King S, Law M, King G, Evans J. Family-centred service: A conceptual framework and research review. Physical and Occupational Therapy in Pediatrics. 1998;18:1–20.

[107] Johns N, Harvey C. Training for work with parents: Strategies for engaging practitioners who are uninterested or resistant. Infants & Young Children. 1993;5:52–57.

[108] King S, Teplicky R, King G, Rosenbaum P. Family-centered service for children with cerebral palsy and their families: a review of the literature. Seminars in Pediatric Neurology. 2004;11:78–86.

[109] Moore TG, Larkin H. "More than my child's disability": A comprehensive review of family-centred practice and family experiences of early childhood intervention services. Melbourne: Scope (Vic) Inc.; 2006.

[110] Bailey DB Jr, Buysse V, Edmondson R, Smith TM. Creating family-centered services in early intervention: perceptions of professionals in four states. Exceptional Children. 1992;58:298–309.

[111] Kalmanson B, Seligman S. Family-provider relationships: The basis of all interventions. Infants & Young Children. 1992;4:46–52.

[112] Dunst CJ, Trivette CM. Empowerment, effective help-giving practices and family-centered care. Pediatric Nursing. 1996;22:334–337

[113] King G, King SM, Rosenbaum PL. Interpersonal aspects of care-giving and client outcomes: A review of the literature. Ambulatory Children Health. 1996;2:151–160.

[114] Rosenbaum P. Families and service providers: Forging effective connections, and why it matters. In: Scrutton D, Damiano D, Mayston M, editors. Management of the motor disorders of children with cerebral palsy. 2nd ed. Clinics In Developmental Medicine No. 161. London: Mac Keith Press; 2004. p.22-31.

[115] Wiart L, Ray L, Darrah J, Magill-Evans J. Parents' perspectives on occupational therapy and physical therapy goals for children with cerebral palsy. Disability and Rehabilitation. 2010;32:248–258.

[116] Preston KM. A team approach to rehabilitation. Home Healthcare Nurse. 1990;8:17-23.

[117] Nijhuis BJ, Reinders-Messelink HA, de Blécourt AC, Hitters WM, Groothoff JW, Nakken H, Postema K. Family-centred care in family-specific teams. Clinical Rehabilitation. 2007;21:660-671.

[118] Jung T, Kim Y, Kelly LE, Abel MF. Biomechanical and perceived differences between overground and treadmill walking in children with cerebral palsy. Gait & Posture. 2016;45:1-6. DOI: 10.1016/j.gaitpost.2015.12.004.

[119] Provost B, Dieruf K, Burtner PA, Phillips JP, Bernitsky-Beddingfield A, Sullivan KJ, Bowen CA, Toser L. Endurance and gait in children with cerebral palsy after intensive body weight-supported treadmill training. Pediatric Physical Therapy. 2007;19:2–10.

[120] Laforme Fiss AC, Effgen SK. Outcomes for young children with disabilities associated with the use of partial, body-weight supported, treadmill training: an evidence-based review. Physical Therapy Reviews. 2006;11:179–189.

[121] 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. Brazilian journal of physical therapy. 2013;17:17–23.

[122] Marchese R, Diverio M, Zucchi F, Lentino C, Abbruzzese G. The role of sensory cues in the rehabilitation of parkinsonian patients: a comparison of two physical therapy protocols. Movement Disorders. 2000;15:879–883.

[123] Kim SG, Ryu YU, Je HD, Jeong JH, Kim HD. Backward walking treadmill therapy can improve walking ability in children with spastic cerebral palsy: a pilot study. International Journal of Rehabilitation Research. 2013;36:246-252. DOI: 10.1097/MRR.0b013e32835dd620.

[124] Cho C, Hwang W, Hwang S, Chung Y. Treadmill training with virtual reality improves gait, balance, and muscle strength in children with cerebral palsy. The Tohoku Journal of Experimental Medicine. 2016;238:213-218. DOI: 10.1620/tjem.238.213.

[125] Fasoli SE, Fragala-Pinkham M, Hughes R, Hogan N, Krebs HI, Stein J. Upper limb robotic therapy for children with hemiplegia. American Journal of Physical Medicine and Rehabilitation. 2008;87:929-936.

[126] Fasoli SE, Ladenheim B, Mast J, Krebs HI. New horizons for robot-assisted therapy in pediatrics. American Journal of Physical Medicine and Rehabilitation. 2012;91:280-289.

[127] Fluet GG, Qiu Q, Kelly D, Parikh HD, Ramirez D, Saleh S, Adamovich SV. Interfacing a haptic robotic system with complex virtual environments to treat impaired upper extremity motor function in children with cerebral palsy. Developmental Neurorehabilitation. 2010;13:335-345. DOI: 10.3109/17518423.2010.501362.

[128] Frascarelli F, Masia L, Di Rosa G, Cappa P, Petrarca M, Castelli E, Krebs HI. The impact of robotic rehabilitation in children with acquired or congenital movement disorders. European Journal of Physical and Rehabilitation Medicine. 2009;45:135-141.

[129] Pignolo L. Robotics in neuro-rehabilitation. Journal of Rehabilitation Medicine. 2009;41:955-960.

[130] Krebs HI, Palazzolo JJ, Dipietro L. Rehabilitation robotics: performance-based progressive robot-assisted therapy. Autonomous Robots. 2003;15:7-20.

[131] Sapin J. Conception d'un robot interactif pour la re-education des membres supérieurs de patients cérébrolésés [thesis]. Louvain-la-Neuve, Belgium: Université catholique de Louvain; 2010.

[132] Gilliaux M, Renders A, Dispa D, Holvoet D, Sapin J, Dehez B, Detrembleur C,Lejeune TM, Stoquart G. Upper limb robot-assisted therapy in cerebral palsy: a single-blind randomized controlled trial. Neurorehabilitation and Neural Repair. 2015;29:183-192. DOI: 10.1177/1545968314541172.

[133] Meyer-Heim A, Ammann-Reiffer C, Schmartz A, Schafer J, Sennhauser FH, Heinen F, Knecht B, Dabrowski E, Borggraefe I. Improvement of walking abilities after robotic-assisted locomotion training in children with cerebral palsy. Archives of Disease in Childhood. 2009;94(8):615-620. DOI: 10.1136/adc.2008.145458.

[134] Borggraefe I, Kiwull L, Schaefer JS, Koerte I, Blaschek A, Meyer-Heim A, Heinen F. Sustainability of motor performance after robotic-assisted treadmill therapy in children: An open, non-randomized baseline-treatment study. European Journal of Physical Rehabilitation and Medicine. 2010;46:125-131.

[135] Borggraefe I, Schaefer JS, Klaiber M, Dabrowski E, Ammann-Reiffer C, Knecht B, Berweck S, Heinen F, Meyer-Heim A. Robotic-assisted treadmill therapy improves walking and standing performance in children and adolescents with cerebral palsy. European Journal of Paediatric Neurology. 2010;14:496-502.

[136] Peri E, Biffi E, Maghini C, Marzorati M, Diella E, Pedrocchi A, Turconi AC,Reni G. An ecological evaluation of the metabolic benefits due to robot-assisted gait training. Annual International Conference of the IEEE Engineering in Medicine and Biology Society. 2015;2015:3590-3593. DOI:10.1109/EMBC.2015.7319169.

[137] Burdea GC, Cioi D, Kale A, Janes WE, Ross SA, Engsberg JR. Robotics and gaming to improve ankle strength, motor control, and function in children with cerebral palsy: a case study series. IEEE Transactions on Neural Systems and Rehabilitation Engineering. 2013;21:165-173.

[138] Chen K, Wu YN, Ren Y, Liu L, Gaebler-Spira D, Tankard K, Lee J, Song W, Wang M, Zhang LQ. Home-based versus laboratory-based robotic ankle training for children with cerebral palsy: A pilot randomized comparative trial. Archives of Physical Medicine and Rehabilitation. 2016 Feb 19. PII: S0003-9993(16)00104-0. DOI: 10.1016/j.apmr.2016.01.029.

[139] Rizzo AA. Virtual reality and disability: emergence and challenge. Disability and Rehabilitation. 2002;24:567-569.

[140] Sandlund M, McDonough S, Hager-Ross C. Interactive computer play in rehabilitation of children with sensorimotor disorders: a systematic review. Developmental Medicine & Child Neurology. 2009;51:173-179.

[141] Weiss PL, Tirosh E, Fehlings D. Role of virtual reality for cerebral palsy management. Journal of Child Neurology. 2014;29:1119-1124.DOI: 10.1177/0883073814533007.

[142] Schultheis MT, Rizzo AA. The application of virtual reality technology for rehabilitation. Rehabilitation Psychology. 2001;46:296-311.

[143] Lange B, Flynn SM, Rizzo AA. Game-based tele-rehabilitation. European Journal of Physical Rehabilitation Medicine. 2009;45:143-151.

[144] Rios-Rincon AM, Adams K, Magill-Evans J, Cook A. Playfulness in children with limited motor abilities when using a robot. Physical and Occupational Therapy in Pediatrics. 2015;13:1-15.

[145] Wu YN, Hwang M, Ren Y, Gaebler-Spira D, Zhang LQ. Combined passive stretching and active movement rehabilitation of lower-limb impairments in children with

cerebral palsy using a portable robot. Neurorehabilitation and Neural Repair. 2011; 25:378–385.

[146] Snider L, Majnemer A. Virtual reality as a therapeutic modality for children with cerebral palsy. Developmental Neurorehabilitation. 2010;13:120-128.

[147] Kizony R, Weiss PL, Rand D. Designing and adapting VR technology and VEs for rehabilitation: a multidisciplinary approach. In: Cobb S, Lange B, editors. Virtual reality technologies for health and clinical applications, Vol. 4: Design, technologies, tools, methodologies & analysis. New York: Springer. In press.

[148] Levin ML, Deutsch J, Kafri M, et al. Validity of virtual reality environments for motor rehabilitation. In: Weiss PL, Keshner EA, Levin MF, eds. Virtual reality technologies for health and clinical applications, Vol. 1: Applying virtual reality technologies to motor rehabilitation. New York: Springer. In press.

[149] Page SJ, Levine P, Sisto S, Bond Q, Johnston MV. Stroke patients' and therapists' opinions of constraint-induced movement therapy. Clinical Rehabilitation. 2002;16:55-60.

[150] Rizzo AA, Kim G. A SWOT analysis of the field of virtual rehabilitation and therapy. Presence. 2005;14:1-28.

[151] Laufer Y, Weiss PL. Virtual reality in the assessment and treatment of children with motor impairment: a systematic review. Journal of Physical Therapy Education. 2011;25:59-71.

[152] Saposnik G, Levin MF. Virtual reality in stroke rehabilitation: a meta-analysis and implications for clinicians. Stroke. 2011;42:1380-1386.

[153] Weiss PL, Weintraub N, Laufer Y. Virtual reality therapy in pediatric rehabilitation. In: Chau T, editor. Pediatric rehabilitation engineering: From disability to possibility, London: Taylor & Francis; 2011.p.291-328.

[154] Brutsch K, Koenig A, Zimmerli L, Mérillat-Koeneke S, Riener R, Jäncke L, van Hedel HJA, Meyer-Heim A. Virtual reality for enhancement of robot-assisted gait training in children with central gait disorders. Journal of Rehabilitation Medicine. 2011;43:493–499.

[155] Brütsch K, Schuler T, Koenig A, Zimmerli L, Koeneke SM, Lünenburger L, Riener R, Jäncke L, Meyer-Heim A. Influence of virtual reality soccer game on walking performance in robotic assisted gait training for children. Journal of Neuroengineering and Rehabilitation. 2010;7:15.

[156] Sandlund M, Waterworth EL, Hager C. Using motion interactive games to promote physical activity and enhance motor performance in children with cerebral palsy. Developmental Neurorehabilitation. 2011;14:15–21.

[157] Jannink MJ, van der Wilden GJ, Navis DW, Visser G, Gussinklo J, Ijzerman M. A low-cost video game applied for training of upper extremity function in children with cerebral palsy: a pilot study. Cyberpsychology & Behavior. 2008;11:27-32

[158] Harris K, Reid D. The influence of virtual reality play on children's motivation. Canadian Journal of Occupational Therapy. 2005;72:21–29.

[159] Myers J, Prakash M, Froelicher VF, Do D, Partington S, Atwood JE. Exercise capacity and mortality among men referred for exercise testing. The New England Journal of Medicine. 2002;346:793–801.

[160] Blair SN, Cheng Y, Holder JS. Is physical activity or physical fitness more important in defining health benefits? Medicine and Science in Sports and Exercise. 2001;33:379–399.

[161] Artero EG, Lee DC, Ruiz JR, Sui X, Ortega FB, Church TS, Lavie CJ, Castillo MJ, Blair SN. A prospective study of muscular strength and all-cause mortality in men with hypertension. Journal of the American College of Cardiology. 2011;57:1831–1837.

[162] Ortega FB, Silventoinen K, Tynelius P, Rasmussen F. Muscular strength in male adolescents and premature death: cohort study of one million participants. BMJ. 2012;345:e7279.

[163] Peterson M, Zhang P, Haapala H, Wang S, Hurvitz E. Greater adipose tissue distribution and diminished spinal musculoskeletal density in adults with cerebral palsy. Archives of Physical Medicine and Rehabilitation. 2015;96:1828–1833.

[164] Peterson MD, Haapala HJ, Hurvitz EA. Predictors of cardiometabolic risk among adults with cerebral palsy. Archives Physical Medicine and Rehabilitation. 2012;93:816–821.

[165] van der Slot WM, Roebroeck ME, Nieuwenhuijsen C, Bergen MP, Stam HJ, Burdorf A, van den Berg-Emons RJ, Move Fit and Lifespan Research Group. Cardiovascular disease risk in adults with spastic bilateral cerebral palsy. Journal of Rehabilitation Medicine. 2013;45:866–872.

[166] Ryan JM, Crowley VE, Hensey O, McGahey A, Gormley J. Waist circumference provides an indication of numerous cardiometabolic risk factors in adults with cerebral palsy. Archives of Physical Medicine and Rehabilitation. 2014;95:1540–1546.

[167] Peterson MD, Ryan JM, Hurvitz EA, Mahmoudi E. Chronic conditions in adults with cerebral palsy. JAMA. 2015;314:2303–2305.

[168] Nsenga AL, Shephard RJ, Ahmaidi S. Aerobic training in children with cerebral palsy. International Journal of Sports Medicine. 2013;34:533–537.

[169] Unnithan VB, Katsimanis G, Evangelinou C, Kosmas C, Kandrali I, Kellis E. Effect of strength and aerobic training in children with cerebral palsy. Medicine and Science in Sports and Exercise. 2007;39:1902–1909.

[170] van den Berg-Emons RJ, van Baak MA, Speth L, Saris WH. Physical training of school children with spastic cerebral palsy: effects on daily activity, fat mass and fitness. International Journal of Rehabilitation Research. 1998;21:179–194.

[171] Verschuren O, Ketelaar M, Gorter JW, Helders PJ, Uiterwaal CS, Takken T. Exercise training program in children and adolescents with cerebral palsy: a randomized controlled trial. Archives of Pediatrics & Adolescent Medicine. 2007;161:1075–1081.

[172] Slaman J, Roebroeck M, van der Slot W, Twisk J, Wensink A, Stam H, van den Berg-Emons R. LEARN 2 MOVE Research Group. Can a lifestyle intervention improve physical fitness in adolescents and young adults with spastic cerebral palsy? A randomized controlled trial. Archives of Physical Medicine and Rehabilitation. 2014;95:1646–1655.

[173] Williams H, Pountney T. Effects of a static bicycling programme on the functional ability of young people with cerebral palsy who are non-ambulant. Developmental Medicine and Child Neurology. 2007;49:522–527.

[174] Kavanagh J, Barrett R, Morrison S. Age-related differences in head and trunk coordination during walking. Human Movement Science, 2005;24,574–587.

[175] Noble JJ, Charles-Edwards GD, Keevil SF, Lewis AP, Gough M, Shortland AP. Intramuscular fat in ambulant young adults with bilateral spastic cerebral palsy. BMC Musculoskeletal Disorders, 2014;15: 236.

[176] Snider L, Korner-Bitensky N, Kammann C, Warner S, Saleh M. Horseback riding as therapy for children with cerebral palsy: Is there evidence of its effectiveness? Physical and Occupational Therapy in Pediatrics. 2007;27:5–23.

[177] Champagne D, Corriveau H, Dugas C. Effect of hippotherapy on motor proficiency and function in children with cerebral palsy who walk. Physical and Occupational Therapy in Pediatrics. 2016;1:1-13.

[178] Strauss, I. Hippotherapy: Neurophysiological therapy on the horse. Toronto, Ontario: Therapeutic Riding Association; 1995.

[179] Van Roon D, Steenbergen B, Meulenbroek RG. Trunk recruitment during spoon use in tetraparetic cerebral palsy. Experimental Brain Research. 2004;155:186–195.

[180] Wuang YP, Su CY. Reliability and responsiveness of the Bruininks–Oseretsky Test of Motor Proficiency—In children with intellectual disability. Research in Developmental Disabilities. 2009;30:847–855.

[181] Park ES, Rha DW, Shin JS, Kim S, Jung S. Effects of hippotherapy on gross motor function and functional performance of children with cerebral palsy. Yonsei Medical Journal. 2014;55:1736-1742. DOI: 10.3349/ymj.2014.55.6.1736.

[182] Kwon TG, Yi SH, Kim TW, Chang HJ, Kwon JY. Relationship between gross motor function and daily functional skill in children with cerebral palsy. Annals of Rehabilitation Medicine. 2013;37:41-49.

[183] Casady RL, Nichols-Larsen DS. The effect of hippotherapy on ten children with cerebral palsy. Pediatric Physical Therapy. 2004;16:165-172.