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Strength Training in People with Cerebral Palsy

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Abstract

Disorders affecting muscle strength in children with cerebral palsy (CP) are indicated among the main reasons of the motor performance disorder. Muscle weakness is a common disorder in children with CP and is associated with insufficient or reduced motor unit discharge, inadequate coactivation of antagonist muscles, secondary myopathy, and impaired muscle physiology. Studies have shown the usefulness of strength training in children with CP and revealed the relationship of muscle strength with activity. Strength exercises increase muscle strength, flexibility, posture, and balance in CP. They also increase the level of activity in daily life and develop functional activities.

Keywords: cerebral palsy, muscle strength, strength training, treatment outcome, assessment

1. Introduction

Cerebral palsy (CP) affects activity and social participation in children and is an umbrella term that encompasses permanent and nonprogressive disorders that develop during the prenatal, perinatal, or postnatal period following various effects on the brain that has not yet fully developed [1–7]. This effect on the central nervous system causes disturbances in the neuromuscular, musculoskeletal, and sensory systems of the children, leading to problems related to inadequate posture and motility [8]. These problems then result in decreased independence and physical activity, leading to a sedentary lifestyle and a negative effect on the child's physical development. The spasticity and loss of strength in comparison with their healthy peers in children with CP end in gait disorders and increased energy consumption [9, 10]. The muscle weakness in the trunk and lower extremity is especially important for ambulation and requires strength training [11, 12]. Studies have revealed the positive effects of strength

training and the relationship of muscle power with activity in children with CP [5]. Strength training in CP patients leads to increased muscle power, flexibility, posture, and balance. It also increases the activity level during daily living and improves functional activities such as walking and running [6].

We will analyze the factors causing the muscle weakness seen in children with CP in this section. We will also discuss the strength training methods used in the literature, together with the body structure and function in children, activity limitation and participation problems, within the framework of the International Classification of Functioning, Disability and Health: Children & Youth Version (ICF).

2. Definition of pathophysiology of strength inefficiency

Studies have revealed strength loss in the affected extremities of children with CP compared to their peers, even when the child with CP is at a high functional level, and the strength loss increases in correlation with the significance of the neurological effect [13]. The weakness in children with CP can be due to both the disturbed neural mechanisms and the muscle tissue changes. Most investigators believe that the low power production is related to the inadequate coactivation of antagonist muscles, decreased or inadequate motor unit discharge, secondary myopathy and disturbed muscle physiology [5].

2.1. The neurologic basis of weakness

Many neurological factors contribute to the weakness seen in children with CP. Normal neural development is related to progressive strength increase, increased contraction speed, and increased isometric maximum voluntary contraction power. Muscle activity is controlled by the central nervous system via the peripheral nerves. The repetition of normal movement leads to stronger neural networks in the nervous system in healthy children. A normally developing child voluntarily repeats normal activities many times, while a child with CP will repeat abnormal movement patterns, causing strengthening of the abnormal neural networks [14].

The central input that stimulates the motor neurons is decreased in these children due to pyramidal tract damage. The motor neuron pool therefore becomes inadequate in the management of the agonist muscle. The muscle's contraction power is increased both by increasing the number of active motor units and by the firing rate of the already active motor units. This is especially the result of a regular summation pattern of the motor unit, and this arrangement is specific to each muscle. However, motor units work in an inadequate, irregular, and slower than normal manner following upper motor neuron (UMN) damage. The muscle therefore cannot be activated [14, 15].

There is a specific balance between the firing rate and motor unit summation of each muscle during power production. The muscle strength usually develops with the summation of motor units due to the disturbance in the firing rate modulation in spastic muscles. The normal pairing between the motor unit firing rate and the mechanical features of the muscle fibers is

also disturbed. This leads to inadequate power production of the muscle and early fatigue [16]. Inadequate firing of motor units leads to strength loss in the early stage, while the decreased motor response adaptation ability limits selective motor control and strength production ability [2]. It has been shown that children with CP are unable to activate the high-threshold motor unit groups necessary for maximum voluntary contraction and are also unable to change the firing rate of the low-threshold motor units [17].

A voluntary movement develops in the agonist muscle, while the antagonist muscle relaxes thanks to the reciprocal inhibitory pathways. The disturbance in the inhibitory pathways leads to abnormal cocontraction. Normal movement requires the prevention of abnormal cocontraction between the agonist and antagonist. The cocontraction seen in children with CP is at a much higher level than in normal children of the same age. These cocontractions especially develop during rapid reciprocal movements [18, 19].

The sensory and motor innervation of the muscle spindle is complicated. The muscle spindle structure is very sensitive to the length of the muscle. The stimulation threshold of the sensory fibers of the muscle spindle can lead to a response of zero in the chronically shortened spastic muscle, while, in contrast, it can cause abnormal relaxation length and decreased control of upper centers via the afferent fibers of the muscle spindle in the chronically elongated muscle. There is marked agonist weakness in children with CP due to prolonged spastic antagonist muscle activity [14].

In short, the neural factors that cause muscle weakness in children with CP are decreased motor management, stronger abnormal neural networks, disturbed firing pattern, reciprocal inhibition, and disturbance in the adjustment within the muscle spindle. The neurophysiological abnormalities in children with CP cause persistent and permanent problems when passing into adulthood. These abnormalities limit the ability of children with CP to grow so that he/she can become stronger in the normal manner [14].

2.2. The muscular basis of weakness

In the past, it was believed that muscle tissue histology would not change in a subject with a brain lesion. Recent studies have revealed that the disturbances in the morphological structure of the skeletal muscle in children with CP cause muscular weakness [14]. Sinkjaer et al. [20] have demonstrated that the muscle tissue can show histopathological changes after an UMN lesion. The muscle tissue changes vary according to the child's age and ambulatory level. The age of cerebral damage can also affect the histology [21].

2.2.1. The changes seen in the muscle fiber types

It has been reported that motor unit types can change following an UMN lesion. The activity and size of the motor neuron largely determines the number of muscle fibers in a motor unit and the type of myosin within these fibers. Myosin production is modulated with hormonal and mechanical activity. There are various ratios of type I and type II motor units in most muscles used in movement, and these ratios vary according to the basic function of the muscle. For example, M. Soleus mostly contains slow contracting type I fibers and supports posture

M. Gastrocnemius mostly has fast contracting type II fibers and therefore provides the pushing power for walking and running. The neural input that is disturbed because of cerebral damage affects the differentiation of these fiber types. With growth, adult myosin forms take the place of the embryonic and neonatal forms, changing the muscle. This change takes place from childhood to adulthood. The muscle is modeled according to the activity level, environmental effects, and especially mechanical tension. The disturbed activity level and ability to transfer load affect myosin development [14, 21].

Muscle spindle development and synthesis of acetylcholine receptors depend on the neural activation pattern in the prenatal period. Neural lesions developing in the prenatal period can disturb the development of fetal muscle cells, muscle spindles, and neurotransmission. The child can therefore be born with inadequately differentiated muscle tissue and possible structural abnormalities in the muscle spindle and acetylcholine receptors. The first weeks of the postnatal period where there are marked changes in the neuromuscular and terminal connections are critical for muscle physiology and development. Delayed maturation in postnatal muscle fiber development has been shown in 21 low birthweight children with an UMN lesion. The changes in the muscle contractile features in children with CP are characterized by predominant type I and selective type II (a) and (b) atrophy. An increase in the number of type I fibers in these children leads to low power in the elongated muscle without the ability to produce contractions that rapidly produce a high degree of power [14].

2.2.2. Changes in muscle fiber length

Maximum power depends on the optimum interaction of actin and myosin filaments, and muscle power is related to the number of sarcomeres and the length of each sarcomere [22]. Fiber growth is a response to bone growth and loading. The tension in children with CP that develops due to the elongated sarcomeres decreases the interaction between the actin and myosin filaments, limiting the number of cross-bridges that develop and the force production ability [14].

Studies on children with CP have found sarcomere lengths to be abnormally long compared to a control group without spasticity. It has been reported that only 40% of the normal power can be produced with elongated sarcomeres [14, 23].

2.2.3. Changes in the total muscle length

The fascicle length is shorter in children with CP than in healthy peers. This may be due to the disturbance in volume, fibril atrophy, decreased pennation angle, and shortening of the intramuscular aponeurosis. Malaiya et al. [24] have compared the medial M. Gastrocnemius in 16 preadolescent spastic hemiparetic and 15 healthy children. They have only found that the hemiparetic side muscle fascicle length was 10% shorter than in healthy children during the ankle resting phase. Besides the most bulging part of the muscle being shorter, the musculotendinous unit tendon was longer than normal. Shorter muscles contain less sarcomeres and therefore have less cross-bridges to produce power. A longer tendon decreases the biomechanical benefit [14].

Although the spastic muscle tries to produce maximum power over the length-tension curve, the functional capacity is decreased. The reason is that the spastic muscle cannot work for prolonged periods at the optimum length needed to produce muscle function [14]. Increased power production during the push-off phase has been shown following M. Gastrocnemius fascia lengthening surgery in children with CP. This is because the lengthened spastic muscle works mostly from the middle point instead of the endpoint or the longer muscle is less sensitive to the reflex response at the early stage of the movement. The person can therefore produce voluntary contraction during the push-off phase [25].

The spastic muscle is short, and the antagonist muscle is therefore chronically in the rest position. A muscle in the rest position has a biomechanical disadvantage as it cannot shorten adequately to produce the necessary functional movement and create effective power [14].

2.2.4. Changes in muscle cross-sectional area

The capacity of the muscle to produce power is directly related to its cross-sectional area. Every unit of the cross-sectional area takes its expected adult form with growth, approximately after puberty. Strength training results can therefore be affected by the child's age [14]. Marbini et al. [26] have shown that children with CP have a decrease in the M. Triceps surae and adductor muscle cross-sectional area and pennation angle. The volume of the M. Gastrocnemius medialis with a decreased pennation angle is 30% less than normal [14]. The muscle fiber may never develop in premature children compared to a term child, and the cross-sectional area is therefore lower than normal and maximum contraction is limited. Studies have shown that muscle volume is lower in children with CP; cross-sectional area and intramuscular adipose tissue are increased compared to normal peers [14].

2.2.5. Changes in the passive features of the muscles

The amount of collagen is increased in the muscles of children with CP. The collagen amount is increased in relation to an increased degree of disturbance. This is responsible for contracture development. The muscle's passive viscoelastic features are affected by the collagen type, amount, collagen connections, and structural organization of the collagen fibers. This influences the internal resistance during viscoelastic contraction and the passive resistance during elongation in contraction in the opposite direction that the muscle has to put up with. A weak agonist muscle may not allow full lengthening of the spastic antagonist and may lead to contracture development. Increased passive tension therefore leads to muscle weakness [14].

In short, the muscular factors that cause the muscle weakness in children with CP are the disturbance in myosin production, structural abnormalities in the perinatal period, decreased muscle fascicle length, increased sarcomere length, decreased muscle volume, and decreased physiological section area [14].

3. The assessment of muscle strength in people with cerebral palsy

The assessment of muscle strength in children with CP has become standard in clinical application and research. The muscle power has a different distribution in many children and adolescents with CP, and this can lead to difficulties in the realization of daily functional activities [27]. Recent studies have shown that children with CP can benefit from strength training programs [12, 28–31]. Clinicians and investigators interested in the effect of strength training programs should therefore have adequate knowledge on the psychometric features of strength measurements in these children [27].

There are three different muscle strength measurements used in children and adolescents with CP in general: isometric, isokinetic, and functional strength test. The isometric-based test measures the power production ability of a muscle group without causing a change in the general muscle-tendon length. A maximal isometric contraction is only an indicator of the power production capacity in that particular condition and with the current muscle length and does not cause any difference in the muscle length during the task. Other factors accompanying muscle weakness such as excessive cocontraction and selective motor control disturbance can inhibit the ability to produce agonist power. However, the measured strength in many children with CP can significantly increase not only with repeated exercise but also with strength training. This is a major factor in evaluating weakness in CP and makes the validity of testing strength in CP or other spastic disorders doubtful. Isokinetic, the other measurement type, means 'same speed' and indicates tests performed at a predefined constant speed [27].

There are some administrative difficulties related to measuring strength in children with CP. The person being evaluated should be able to understand what he/she needs to do to produce maximum effort and conform with this repeatedly. The test positions require some modification in these individuals due to the short muscles, and the examining person needs to be careful not to applying counter force at the joint contracture point. Test positions that promote or inhibit the use of flexion or extension synergies can also have various effects on the power values from CP patients. Poor selective control in some muscle groups can prevent an individual from performing a task. Motor control limitations are probably not an important factor in the ability to generate power in CP children, as they are of lower intensity. As an example, when evaluating the lower extremity power in children with mild or moderate spastic diplegia or hemiplegia that have been tested in many muscle groups, what was understood from the task of selective control was the test position and the ankle dorsiflexors as a single muscle group and these were tested only in 2 of the 30 participants during knee extension [11]. However, motor control disorders can hinder a comprehensive strength test and training in those with more prominent neurological involvement [27].

3.1. Manual muscle testing—portable manual dynamometry

Muscle strength is usually evaluated with methods bases on isometric resistance in clinical practice [32]. Two methods used to evaluate muscle power are the manual muscle test (MMT) and manual dynamometry. MMT uses the 6-point (0–5) Medical Research Council (MRC) scale. However, the ability to determine muscle power changes with MMT is especially poor

in grades 4 and 5 [33, 34]. MMT is a simple manual instrument that has a small internal load cell that can measure muscle strength (in Newton) [27]. Portable manual dynamometry (PMD) has been shown to be a reliable and easy-to-use method to measure muscle strength in clinical practice. PMD enables the measurement of isometric contraction [35]. Two types of measurement methods have been defined [32]. In the make test, the examiner keeps the dynamometer in a fixed position, while the subject pushes against the dynamometer. In the break test, the examiner pushes the dynamometer against the subject's limb until the maximal effort of the subject is overcome and the joint cannot resist [35]. The make test has been shown to be more reliable than the break test. Testing arm muscles is more reliable than testing leg muscles and the affected side values are higher than the unaffected side in hemiparesis patients. It is very important for the examiner to have adequate muscle strength to hold the PMD stable [32].

3.2. Isokinetic dynamometry

Isokinetic dynamometry is usually performed in a laboratory setting, and a computer-controlled device is used to measure the muscle power created during a controlled movement. Isometric resistance is used to determine the strength of a muscle group around a joint with limited range of motion (ROM) but does not provide detailed information on the dynamic qualities of muscle strength during full ROM. This information can be obtained with dynamic instruments such as isokinetic machines. Isokinetic devices enable full and reliable monitorization of individual muscle development during a training program even when the muscle power is very limited. Isokinetic muscle training had a certain advantage to other types of strength training as the largest rotational moment is created throughout the full ROM. Isokinetic dynamometers are also relatively more reliable as resistance is adjusted according to participant effort with a measurement device. The resistance is therefore decreased immediately and the risk of injury minimized when limiting factors such as pain or discomfort are suddenly experienced. The isokinetic instrument shows the strength curves throughout ROM and provides visual feedback to the administrator. This feature is valuable in the motor development of children with minor disability and also in those with normal intelligence. There is only limited information on the reliability of isokinetic tests in subjects with neurological disorders. The reliability of isokinetic strength measurements at higher angular speeds has also not been determined. High angular speeds are typical of daily and sports activities and should therefore be included for follow-up and motivation purposes in the exercise protocols of children with CP who frequently display proprioceptive or attentive disorders. The main point in selecting a measurement method is reliability [36]. The reliability in testing the isokinetic power of knee flexors and extensors has mostly been shown for adult participants without CP in the literature. It has been reported that the test procedures are highly reliable at a great many angular speeds for the concentric contraction of knee extensors and flexors [37]. Molnar et al. [38] have discussed the reliability of the isokinetic tests of many muscle groups in the upper and lower extremities in children aged 7–15 years. They concluded that performing isokinetic tests was simple and highly reliable in children with a low-grade learning disability, as much as those with normal intelligence, who were typically developing children.

3.3. Functional strength testing

Functional strength tests: It is important to use functional exercises to test functional performance in the large muscle groups that are essential for standing and walking in children with CP. The following are three closed kinetic chain exercises [27, 39]:

The Lateral Step Test (on a 20-cm bench): This test is used to evaluate lower extremity muscle performance. The subject is asked to stand on the tested extremity with the feet parallel and the shoulders separated. The proper lateral step technique is defined as achieving a position within knee extension for the tested extremity during the test's extension phase. The number of times the untested foot's heel or toes touch the ground is counted. The test-retest reliability has been found to be excellent in young and healthy adult subjects. This protocol has not been previously evaluated in patients with CP [27, 40].

Sit-stand up (from 90°knee and hip flexion to the standing position): This is a functional test and the child must be able to stand up without using his hands. The child is put on a small bench and sits down with the feet on the ground and the knees flexed 90°. The child has to be able to stand up without using the hands and without any help from the bench with the arms or body during the transition. The repetitions where the child's legs and hips are within 15° of the extension position are counted [27, 39].

Attain stand thought half knell without using the arms: This is a functional test and the child must be able to stand up without using his arms. The child is put on a pillow in the high kneeling position, leaving the hands free. This means the weight is supported by one knee and the foot of the other side and that the alignment can change as long as the hips are away from the area below the legs and/or the weight-bearing surface. The child is told to stand up without any external support from a piece of furniture or the floor. The repetitions are counted every time the child succeeds in attaining the standing position, and both legs and hips were within 15° of the extension position [27, 39].

4. Strength training in people with cerebral palsy

Strength training was not at the forefront for children with CP until recently because it was believed it would increase spasticity. However, this has not been supported by the previously uncontrolled studies showing that strength training can increase lower extremity muscle power without increasing spasticity in these children [41, 42]. Several studies have provided adequate evidence for its effect on muscle power, but these effects have probably been overestimated due to the lower methodological quality of these studies [30, 43]. A few uncontrolled studies on the effect of strength training on motility results in children with CP have reported a limited effect [28, 41]. Three randomized clinical reviews published recently have evaluated both muscle power and motility in CP children, but conflicting results have been reported [44–46]. One of the explanations for these conflicting results could be the significant differences in training characteristics such as the type, intensity, and duration. The training should be customized for it to be successful and should stimulate more than the increase obtained with intensity as it does not include it [47].

4.1. Isokinetic training

Isokinetic resistance training has been made possible with mechanical devices such as Cybex II that keep extremity movement at a predefined constant speed. The resistance from the isokinetic device is produced in proportion to the applied force. Increased speed is therefore met by increased resistance. The maximum voluntary effort is met by the maximum resistance within the range of motion. More markedly, isokinetic resistance exercises have been found to be an excellent and safe training type to increase both the strength and power in reciprocal movement templates [48]. The measurements made with the Cybex II, the device used in this study, have also been found to be very reliable. Resistance training is used by athletes with cerebral palsy. The athletes are trained to compete in lifting weights at the cerebral palsy games, an approved activity. However, advocates of the specified treatment approach feel that weight training could be detrimental for persons with cerebral palsy. The potential harmful effects include increased resting muscle tonus, increased abnormal standing position, and decreased range of motion. Studies have shown that subjects with cerebral palsy experience increased strength with systematic resistance exercises. However, there is no study on the effect of systematic resistance exercises on movement function in these subjects. Increased motor function can also be gained through repetitive attempts without any resistance. Training results in more effective muscle activity as shown in electromyography records following a series of training attempts. All the repeated training attempts have been performed with normal subjects, and there are no studies on subjects with cerebral palsy. The merging of developments seen in nerve-muscle performance after repeated exercises without any resistance in unrelated persons with the known nerve-muscle problems in CP indicates a need for experimental research in this area [30, 45, 47–49].

It is recommended that for children with cerebral palsy, the following methods of strengthening be considered
Isokinetic training
Progressive resistance exercise
Bicycle and treadmill exercises
Weight training
Upper extremity strengthening
Aquatic training
Sports and recreation
Electrotherapy

4.2. Progressive resistance exercise

Progressive resistance exercise (PRE) training is a well-established strength training method where intensity is gradually increased. This stimulates more strength gain than related to typical growth and development [50].

The main elements of PRE are as follows: Providing enough resistance so that a low number of repetitions [usually 8–12] can be completed before fatigue starts, increasing the amount of resistance progressively as the strength increases and continuing the training program for an adequate duration so that its benefits are seen [50].

There have been recommendations to avoid strength training in children with CP in the past because it would increase spasticity, decrease ROM, and increase problems with walking. Systematic reviews have provided increasing evidence that strength training in children with CP increases muscle power without any side effects related to spasticity or ROM [30, 51, 52]. However, a recent review's authors concluded that strength training is not effective in children with CP [5]. It has also not been possible to make a decision on whether strength training is effective in improving functions such as the ability to walk. As expected, muscle strength decreases 6 weeks after the conclusion of the training and this has also been observed in healthy children [53]. Surprisingly, this effect has not been observed in a few comparable studies (mostly uncontrolled) with follow-up evaluations in children with CP [14, 41, 45]. Based on the results of controlled studies, it can be recommended to include strengthening in a regular exercise routine to enable increased strength levels [54].

Daily activities only need a specific amount of muscle power (i.e., the lowest threshold). There may be increases in these lowest threshold levels and movements, but there may also be increased strength that does not provide an additional advantage for movement improvement (i.e., the highest threshold) [55]. Strength training will therefore not be the appropriate treatment option if the aim is to improve mobility. Other components such as balance and coordination may affect the improvement in motility more than muscle power by itself [56].

The 12-week functional PRE strength training has been shown to be effective in increasing the strength of the knee extensors and hip abductor by 11–12% and the six-repetition maximum leg strength by 14%. However, this strength increase does not result in increased motility. In conclusion, functional PRE is said to be effective in increasing leg muscle strength in children with CP. PRE can also be included in a more intensive treatment regime or can be used as a target treatment after waiting for temporary muscle weakness as seen before or after botulinum toxin A or surgical treatment [56]. A typical PRE program for individuals with CP consisted of 2–4 exercises where isokinetic dynamometers, weight machines, or free weights were used. The participants typically completed three or four sets with 5–10 repeats of each exercise with 50–65% training intensity of one-repetition maximum. They were usually trained for three times a week for a duration ranging from 6 to 10 weeks. Studies vary greatly on the types of participants and have included children and adults aged 4–47 years with spastic hemiplegia, diplegia or quadriplegia alone or in combination and also a few patients with ataxia or dystonia [57].

4.3. Bicycle and treadmill exercises

Children with CP suffer from weakness and low endurance [11, 18]. The size of the effect for strength changes has varied greatly between studies. This variability in results could be due to the method-related differences in intervention intensity, frequency, and duration [58]. Bicycle riding is a rehabilitation tool commonly used in physiotherapy to improve power and

cardiovascular form and is recommended to individuals with CP as an appropriate exercise to keep in shape [59]. Stationary bicycle programs can provide resistance exercises for lower extremity muscles [58]. More studies are needed on stationary bicycle interventions for children with CP, but they have the potential to improve strength and cardiovascular form with minimum conditions for balance and motor control.

Treadmill training with partial body weight support (TTPBWS) is becoming more popular in the rehabilitation of children with CP. The literature on TTPBWS in CP mainly consists of case reports and small nonrandomized studies without a control group. Three separate reviews of TTPBWS in children with CP and also one on TTPBWS in pediatric rehabilitation have been published recently. Two reviews have concluded that TTPBWS can be safe and effective in increasing walking speed, while one review has stated that it could be useful to improve gross motor skills [60]. On the other hand, another review has concluded that there is not enough evidence to determine whether TTPBWS leads to an improvement in children with CP, that the evidence is for results in children with CP is weak, and that randomized studies are required to evaluate issues such as efficacy and dose [61]. These reviews have recommended more definite studies to determine the effectiveness of TTPBWS for children with CP. TTPBWS has also been reported to lead to changes in gait spatiotemporal parameters [62, 63].

The use of a mechanical treadmill can improve walking in children with CP skills [60]. Walking on a treadmill provides an opportunity for repeated training in the total gait cycle, facilitates the advanced gait model, and decreases the effect of poor balance on the child's ability to lift weights during walking when a body weight-supporting system is used [60, 61, 64].

Some preliminary studies have reported that TTPBWS is possible in children with CP as young as 15 months and that it can even be used in children who cannot yet walk independently [65]. Developing the gait has the potential to increase mobility and have a positive effect on the home, school, and wider community social participation of children with CP.

Treadmill training seems to be effective in the improvement of general gross motor skills. Different studies have evaluated the effects of treadmill training on gross motor skills. They have all reported important changes in the gross motor function measurement (GMFM) dimension (walking, running, jumping) after finding a major effect in the two groups skills [60].

According to a study has evaluated the effect of treadmill training on the energy consumption (EC), which evaluates the energy cost of walking. A large effect size for change was found in the EC when the progress in all participants was recorded [62].

4.4. Weight training

Although strength training seems to be safe for children of all ages when performed appropriately, loads should not be over the maximum before physical growth is completed for protect harmful effects on musculoskeletal tissues. Other safety issues include a more progressive accumulation of resistance, especially in weak children, that does not permit lifting weights by a child without supervision or hanging a weight from an extremity without muscular effort or external support. The child should not train on the same muscle groups on

consecutive days. The protocol needs to be changed if there is excessive or continuing pain due to the strengthening program or if muscle stiffness increased [66].

4.5. Upper extremity strengthening

Upper extremity muscle weakness is clinically important in children with CP as it is related to function. There is also evidence that upper extremity muscle weakness decreases the ability to perform daily living activities in children with CP [14, 67–69].

Muscle strengthening in individuals with CP is a general treatment intervention to increase strength and function, and it can be presented as a separate training or combined with other intervention types such as electrical stimulation, botulinum toxin A (BoNTA), aerobic training, or motor training [47, 70, 71]. Scianni et al. [5] and Franki et al. [72] have reported that muscle strengthening in CP will not increase muscle spasticity in their review. This has also been demonstrated in studies on upper extremity strengthening. Individuals with CP need consistent upper extremity training because CP can lead to muscle contractures and functional disturbance [73]. Considering that the poor muscle strength in children with CP in one of the most important factors affecting motor function, increasing muscle strength is a fundamental treatment for motor performance [30]. However, the number of studies on improving upper extremity functions through active physical training of the upper extremities in CP is limited [74]. These studies have recommended strength training with intensive repetitions that develop upper extremity exercise capacity as rehabilitation treatment in children with CP.

4.6. Aquatic training

The special characteristics of water provide a desired environment for children and adolescents with CP [75, 76]. For example, the weight lifting conditions are better in water with decreased body control amount, joint load, and effect of gravity. In conclusion, the aquatic physical activity protects joint integrity more than conditions outside [77]. Studies have shown that performing motor skills in the water will probably increase confidence and needs less resistance to try difficult tasks when compared with training on land [77]. Activities in water can also be more fun and different for children, possibly increasing motivation and interest. Aquatic physical activity can be significantly beneficial for persons with higher gross motor function classification system (GMFCS) levels and marked movement limitations who may have more difficulty and be more restricted in performing physical activities outside water [75]. It must be noted that there are only a limited number of programs outside water for this population [78].

The presence of aquatic facilities and the high degree of acceptance by the general public have led to significant interest by children and adolescents with CP in aquatic programs [79]. In 2010, Brunton and Bartlett described the participation of adolescents with CP in exercise programs. They reported swimming as one of the activities most liked by the participants; it was the second and third most common activity for GMFCS levels I, II and III and more significantly, the most common activity for the higher GMFCS levels of IV and V [80]. Similarly, Zwier et al. [81] reported that swimming was the second most common activity for children

with CP aged five to seven years and that 71% of these children were involved in swimming. In short, aquatic activities can be lifelong beneficial exercises and physical activities in these subjects. There is also evidence that this population with physical and cognitive skills already participates in aquatic activities [75].

However, aquatic activity programs for this population are few in number and the effects of these interventions have not therefore been effectively evaluated in subjects with CP. Kelly and Darrah have reported in 2005 that aquatic exercise has many observed benefits on flexibility, respiratory function, muscle power, and gross motor function, but there are very few studies on its effects. The authors have included three articles in their review, but the information is limited by the poor methodological quality. They concluded that 'More evidence is needed on the effect of aquatic exercises on keeping children with CP in shape and on their place in physical management programs' [75].

4.7. Sports and recreation

Childhood and adolescence are important period when disabled youngsters develop self-confidence and their attitudes and behaviors to transfer to adulthood [82]. Play, recreation, and sports participation have important effects on general development and are essential elements for childhood and adolescence [83, 84].

Sports and recreation have many physiological benefits thanks to regular participation in physical activities during childhood and adolescence, in addition to their psychosocial benefits. These include the increased muscle density and fat-free muscle tissue in adulthood, better management of body weight, low risk for high blood pressure and decreased feelings of depression and social isolation [85].

Despite physiological and psychosocial benefits, the rate of physical inactivity among disabled children is much higher than those without a disability and many specialists believe that this can eventually lead to health problems in adulthood [86–88].

4.8. Electrotherapy

Those who advocate electrotherapy applications state that electrical stimulation (ES) increases strength and motor function and is an attractive alternative for strengthening children with CP with poor selective motor control [89]. Although there are instances where ES can be used for its positive effect, it is usually included in rehabilitation approaches as a complementary element [90].

ES can be used in children with CP and adolescents to increase muscle power, improve functional capacity, and to teach the muscle its new function and strengthen it following orthopedic interventions. Neuromuscular electrical stimulation (NMES) and threshold electrical stimulation (TES) are commonly used variations [89]. NMES is application of an electrical stimulus to the lower motor neuron or terminal branches to cause depolarization and finally muscle contraction [91]. The strength increase in NMES develops with two mechanisms. The first one is the loading principle; the muscle's strength is increased with

increased cross-sectional area of the muscle. In the second mechanism, selective development of type II fibers enables synaptic activity development in the muscle [92].

The use of neuromuscular stimulation for a functional target is also known as functional electrical stimulation (FES) [92]. FES can be defined as the electrical stimulation of the nerve or muscle to produce the desired joint movement when a motor task is being realized and can also be used to improve the underlying motor control by increasing the specific task motion repetition [93, 94].

NMES-type currents administered to the agonist muscle have been proven to both strengthen the motor unit and increase contractile proteins, resulting in muscle hypertrophy and thus contributing to a stronger muscle [92]. FES can affect the potential of interneurons and motor neurons to be stimulated and provide sensory input at the same time and therefore contribute to individuals producing more power than they could voluntarily [95, 96]. Children with CP have been demonstrated to show beneficial development in muscle power and muscle cross-sectional area following NMES administration [97, 98].

Alternatively, TES is the administration of a low-intensity (2–10 mA) and long-duration (8–12 h) electrical current to the muscles during sleep. It does not cause visible muscle contractions. It basically increases local blood flow and enables vascularization of atrophic muscles, increasing muscle mass, and endurance [99]. Results evaluating the effect of TES on muscle power and function have emphasized that there is no gain in function or muscle power or muscle cross section in children who underwent TES treatment [100–102].

ES parameters used in children with CP reveals the following: frequencies were generally in the range 30 to 45 Hz, pulse durations 100–300 μs, and the time taken to reach the desired intensity (ramp up) ranged from 0.5 to 2 sec. Some variation existed in the contraction/relaxation times for the activation of the muscles. The TES on: off times were generally equal; however, with NMES, some authors used equal times and others ensured that the 'off' time was at least double the 'on' time. The intensity of stimulation and duration of treatment depended on whether TES or NMES was employed, with TES tending to be applied for a minimum of 30 h per week for 6–17 months. NMES was most commonly applied for 15–20 min per week in a task-orientated therapy setting or for up to 1 h daily for 2 months when applied at home [89].

5. Strength training within the framework of ICF

The positive and negative results of strength training have been evaluated with the use of the International Classification of Functioning, Disability and Health that provides a framework for the definition of health [30]. It is possible to define the disorder in the person according to impairment, activity restriction, and participation limitations in this scope. According to the ICF definition, impairment is deviation or losses of body function or structure, activity restrictions are difficulties in performing tasks or actions, and participation limitations are problems related to life conditions. A person's functionality and disability is thought to be a

dynamic interaction between contextual factors such as the environment and the person's health condition [30].

5.1. Impairment

There is no evidence that strength training increases spasticity and contractures in individuals with CP. Some clinicians have postulated that spastic CP individuals are not weak and that the disturbed performance of functional activities that is observed is actually a result of the spasticity [103]. Depending on clinical observations, it has been said that the increased effort related to strength training can increase spasticity in patients with a neurological disorder and that this can lead to increased muscle and joint contractures and decreased motor function [30]. However, this opinion has not been supported by the literature. Studies on the effect on strength training on spasticity have either found no effect or have even shown it could potentially decrease spasticity. Similarly, there is no evidence that strengthening programs will decrease ROM in individuals with CP; evidence even suggests that strength training can increase ROM, especially in the lower extremities [30].

5.2. Activity

A strengthening program planned to increase muscle strength could be expected to have less effect on the measurement of muscle power than on activity measurements as other factors such as sensory function, coordination, and even psychological factors contribute to motor performance [30]. Significant increases in the D and E dimensions of the GMFM have been found following a strengthening program aimed at lower extremity muscles [31]. These parts of the GMFM activities measure for example standing on one leg, standing up from a sitting position, walking, running, kicking, jumping, and walking up and down the steps [28] In relation to gait speed, a study has found a positive effect after strengthening, while another has found no change. This indicates that strengthening programs that have been developed into a form suitable for individual requirements can provide better functional results than less customized programs [31, 104]. Upper extremity strengthening exercises can also increase the endurance of children with CP using a wheelchair [30].

5.3. Participation

There are only a few studies evaluating the effect of strength training on the social participation of individuals with CP. However, it has anecdotally been reported that some participants have felt confident enough to join a regular community exercise program after the training was completed [105, 106].

5.4. Contextual factors

Contextual factors are an important point in evaluating the effects of strengthening programs. Clinicians need information on the effects of various environmental and personal contextual factors so that they can administer the best program. Despite the importance of these contextual factors, the information in the included articles is inadequate to obtain a meaningful result [30].

6. Conclusion

Since muscle weakness is a common disorder in children with CP, muscle strength may influence motor performance which affects activity in daily life and develop functional activities. Muscle weakness might resulted by the neurologic or the muscular basis. Muscle strength can measure with several clinical tests included isometric, isokinetic, and functional strength test. Strength interventions include different ways such as isokinetic training, progressive resistance exercise, bicycle and treadmill exercises, weight training, upper extremity strengthening, aquatic training, sports and recreation and electrotherapy. Strength training in CP has beneficial effects on body structure and function, activity limitation, and participation problems according to ICF in children with CP. In the literature, more studies needed for improved evidence-based clinical interventions.

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