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PEDALING EXERCISE AS A REHABILITATION FOR CHILDREN WITH CEREBRAL PALSY (A REVIEW ARTICLE)

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ABSTRACT

Cerebral palsy (CP) is a common cause of disability during childhood. It is a neuromuscular development disorder that is caused by a non-progressive impairment to the fetal brain. There are many neuromuscular, musculoskeletal and developmental impairments associated with CP, including spasticity, dystonia, contractures, abnormal bone marrow development, balance disturbances, selective loss of motor control, and weakness. Recently. There has been increased focus on participation in physical activity in children with CP. Exercises that help people with spasticity include cycling, strengthening exercises and treadmill training**.** The cycle ergometer can be used in cases with CP to improve cardiovascular fitness, balance, gait and upper limbs function. The goal of this review was to present cycling as rehabilitation tool and its effect in children with CP.

Key Words: Cerebral palsy, Cycling, Physical activity, Rehabilitation.

INTRODUCTION

Cerebral Palsy: Definition and Classification

Cerebral palsy (CP) describes a group of disorders of the development of movement and posture caused by a brain injury occurring early in life **(Bax *et al*., 2005 and Colver *et al*., 2014)**. It is a group of permanent and non-progressive neurological disorders occurring in the fetus and the developing child brain, causing mainly motor impairment, which directly affects movements and posture **(Goyal *et al*., 2017 and Sadowska *et al*., 2020)**.

It is a common cause of disability during childhood. Disorders result from various insults to different areas within the developing nervous system, which explains the variability in the clinical findings **(Hoon and Vasconcellos, 2010).** Both primary and secondary impairments present in various degrees of severity, influencing the performance of functional activities such as gait **(Gage, 2004).** Usually it accompanied by sensory, perceptual, cognitive, and communicative changes, behavioral disorders, and reduced cardiorespiratory fitness **(Rosenbaum *et al*., 2007).**

The prevalence of CP for all live births ranges from 1.5 to 3 per 1000 live births, with variation between high income and low to middle income countries and geographic region **(Johnston, 2020).** Cerebral palsy is described using different classifications primarily motor type, topography, and motor severity. Numerous classifications and sub-classifications of CP have been proposed. The most common classifications include muscle tone disturbance and motor dysfunction **(Rosenbaum *et al*., 2007).**

The four major subtypes of CP are spastic, athetoid, ataxic, and mixed CP, with spastic forms being the most common form **(Ghai, 2004).** In spastic type, the most problems in children with spastic CP are spasticity in extremity muscles; hypotonia in trunk muscles, insufficiency in protective and equilibrium reactions, stereotype movement patterns, slow and firm movements combined reactions, joint deformities due to muscle strength inequality, posture and gait disorders **(Olney and Wright, 2000).** While, in athetoid type the main problems include fluctuations in muscle tone, involuntary extremity and trunk movements, insufficiency of stabilization of the trunk and extremities, insufficiency of muscle co-contraction, and insufficiency of correction, equilibrium and protective reactions **(Sellier *et al*., 2016).** The ataxic type, is generally presented with hypotonia, weak co-contraction, postural stabilization insufficiency, dissymmetry and coordination disorders of movement **(Beckung *et al*., 2008).** Mixed type represented when it is a mixed CP form, i.e. spasticity with ataxia and/or dyskinesia, the child should be classified according to the dominant clinical feature **(Cans *et al*., 2007).**

The spastic subtype, which is characterized by persistent increased muscle tone in one or more limbs, is the most common subtype that accounting 70%–90% of cases in children **(Yim *et al*., 2017).** According to **Shevell and Bodensteiner, (2004)** spastic CP is described by which parts of the body are affected: Spastic diplegia, Spastic hemiplegia and Spastic quadriplegia. In spastic diplegia, there is a motor impairment in the extremities, marked weakness in the trunk and hypertonia of the extremities**.** Spasticity is mainly in the legs, with the arms less affected or not affected at all. People with spastic diplegia might have difficulty in walking because tight hip and leg muscles cause their legs to pull together, turn inward, and cross at the knees **(Platt *et al*., 2009).** While in spastic hemiplegia only one side of the body is affected, where the arm is more affected than the leg**.** Spastic quadriplegia is the most severe form of spastic CP and affects all four limbs, the trunk, and the face. People with spastic quadriplegia usually cannot walk and often have other developmental disabilities such as intellectual disability, seizures, or problems with vision, hearing or speech **(Shevell and Bodensteiner, 2004).**

Spasticity: Definition and Management

Spasticity is a major clinical feature of over 75% of cases with CP **(Olney and Wright, 2000).**The main motor disorders arising from this disease are muscle hypertonia followed by reduced muscle strength and decreased selective control of movement **(Nooijen *et al*., 2014).**

Spasticity can be regarded as one of the positive features of the upper motor neuron syndrome (UMNS) and should not be confused with other positive features like clonus, automatic movement, etc. Every manifestation of UMNS may be independent of another finding of UMNS **(Canning *et al*., 2000).** Spasticity is a chronic condition defined as “disordered sensory-motor control, resulting from an upper motor neuron lesion, presenting as intermittent or sustained involuntary activation of muscles” with postural limb changes **(Burridge *et al*., 2005).** It is not a static phenomenon but changes continuously throughout the day, even during sleep, depending on the presence of pain or other irritants such as inflammation, urinary stones, or infection, as well as general factors such as emotional states or a woman’s menstrual period **(Petropoulou, 2017).**

Spasticity is generally defined as “a velocity-dependent increase in tonic stretch reflexes with exaggerated tendon jerks, resulting from hyperexcitability of the stretch reflex, as one component of the UMNS” **(Scholtes *et al*., 2006).** Spasticity presents various clinical signs of motor impairments including loss of voluntary muscle activation, abnormal involuntary muscle activation, and delay in gross motor function, also pain may be associated with hip dislocation and contracture **(Westbom *et al*., 2017)** For this reason, spasticity is thought to cause changes in muscle morphology and structure, causing deformity, and impaired muscle growth **(Sees and Miller, 2013).**

Neurorehabilitation comprises four main categories of spasticity management targets: **The first category** involves nursing care: (a) Preventing or treating deformation contractures, (b) preventing or treating a tendency to slump over, (c) proper positioning of the body on the bed/wheelchair, (d) easy catheterization of the bladder, (e) easy fitting of mechanical aids, such as a brace, (f) facilitating caregiver work, (g) pain relief, and (h) improving sleep. **The second category** centers on improving movement: (a) The unmasking of voluntary movements previously covered by significant spasticity in cases of incomplete lesions, (b) accelerating the “spontaneous” recovery process, (c) modifying the “immature” motor pattern, (d) using new recovery techniques to guide and encourage retraining of existing neural circuits, e.g. such as robotic, mechanized aids, and (e) a new functional pattern in moving and walking. **The third category** includes daily life activities: transfers, getting around, dressing, personal hygiene, driving, etc. **The fourth category** is about quality of life: (a) independent living, and (b) social and professional reintegration **(Gracies *et al*., 1997).**

Physical Activity and Cerebral Palsy

Physical inactivity causes chronic health problems, and physically inactive children with CP are at risk of long term consequences like coronary artery disease, hypertension, diabetes, obesity and mortality **(Verschuren *et al*., 2016).** Persons with CP have lower levels of health-related fitness (muscle strength and cardiorespiratory endurance) and reduced levels of physical activity (PA), so they are at higher risk for developing metabolic and cardiovascular diseases. This has been shown by increased cardio metabolic risk factors, including hypertension, cholesterol, high density lipoprotein test (HDL-C), visceral adipose tissue and obesity in adults with CP **(Peterson *et al*., 2015).** It is important to consider the early use of therapeutic interventions that focus on the control of muscle tone and prevention of muscle contracture is important for children with spastic CP **(Lee *et al*., 2019).**

Physical activity is a parameter that needs increased developing and encouraged in the care for young CP patients. It has been established that these children have a daily PA level below the international threshold recommended by the World Health Organization (WHO) for 5-17 year old **(Damiano, 2006)**.

Physical activity is described as any body movements generated by skeletal muscles resulting in energy expenditure **(WHO, 2010).** Recently, there has been increased focus on participation in PA in children with CP **(Majnemer *et al*., 2008).** Physical activity is necessary for the optimal physical, emotional, and psychosocial development of all children **(Verschuren *et al*., 2016).** Peripheral physiological benefits (such as increased muscle blood flow) can occur in the trained muscle **(Ballaz *et al*., 2007).**

Aerobic exercise training can lead to significant increases in cardiorespiratory endurance among individuals with CP **(Slaman *et al*., 2014).** Exercises that help people with spasticity include cycling, strengthening exercises and treadmill training **(Hesse, 2008).**

Cycling Exercise

Cycling is an effective rehabilitation tool that can be added to the physical therapy program to promote high speed of movement by improving muscle control more than other daily activities performed by most of CP children. This rehabilitation tool often used by physical therapists to improve strength and cardiorespiratory fitness **(Gregor and Fowler, 1996).** Recumbent stationary cycling has been proposed as a safe, enjoyable, and practical exercise modality for children with CP that lack the postural control and strength necessary for upright exercises **(Siebert *et al*., 2010).** The cycle ergometer, a stationary device that allows cyclic rotations in passive, active, and endurance modes, may be considered one such possibility, promoting an activity that is safe and fully adaptable to the disabilities of this population **(dos Santos *et al*., 2015).**

Individuals with CP have impairments such as agonist-antagonist co-contraction and abnormal muscle tone **(Johnston *et al*., 2007),** which may lead to irregular, halted progression of revolutions during cycling **(Kaplan, 1995),** thus affecting the rhythmicity and smoothness of cycling. Cycling with poor smoothness, e.g., arrested progression of revolutions and poor rhythmicity may result in inefficient cycling and reduced intensity of the exercise, and thereby, lead to reduced efficacy. Cycling with maladaptation will further lead to reinforcement of atypical movement patterns. Thus, it is critical to evaluate the motor control of cycling to train correct neuromuscular strategies for more optimal benefits from cycling, although cycling performance has been previously evaluated in terms of muscle activation, kinematics and kinetics **(Johnston *et al*., 2007).**

The primary motor cortex activation was positively correlated with the rate of the active cycling movements. It is suggested that higher motor centers, including the primary and supplementary motor cortices and the cerebellum, take an active part in the generation and control of rhythmic motor tasks such as cycling. These spinal and supraspinal motor control mechanisms might be activated by pedaling and help to restore well-coordinated selective muscle activities **(Fujiwara *et al*., 2003).**

Cycling Exercise in Lower Limb

Ergometers are type of equipment used for upper and lower extremity training. They have been widely used for subjects with CP **(García *et al*., 2016).** Ergometer exercises are easy to perform and quantify the amount of load, making them suitable for upper and lower extremity exercise programs. In addition, long-term ergometer exercise in people with CP has been reported to improve motor function **(Williams and Pountney, 2007).**

The beneficial effects of lower limb ergometer exercise depend on the involvement of reciprocal inhibition, which enhances reduction of muscle tonus **(Li and Francisco, 2015).** One factor that can increase spasticity in CP is a general increase in muscle spindle sensitivity and imbalance in the descending inhibitory and facilitatory regulatory mechanisms acting on spinal stretch reflexes secondary to cortical disinhibition. Repeated pedaling exercise can reduce the hypersensitivity of the muscle spindle, leading to decrease spasticity **(Pyndt *et al*., 2003).** Also, repeated pedaling exercise may activate upper motor neurons, leading to recovery of the balance between activation and inhibition of spinal reflexes **(Fujimoto *et al*., 2021)**. Because pedaling facilitates selective muscle activation with less co-contraction of antagonists, it can potentially be an effective mode of muscle reeducation **(Fujiwara *et al*., 2003).**

Studies on the effect of lower limb cycling exercise found a reducing in spasticity and increasing in the range of knee extension motion in children with CP **(Fujimoto *et al*., 2021),** also an improvement in the antigravity muscles strength and lower limb joints range of motion and the decrease in lower limb spasticity especially calf and hamstring muscles was reported **(Ghani *et al*., 2021). Verschuren *et al*. (2016)** reported that parents of youth with CP who had participated in a physical training program noticed progress in their child's motor skills and independence.

Similar to reciprocal stepping, bipedal cycling can provide the opportunity for subjects to practice accuracy in timing and movement of lower limbs as well as to learn the effective muscle usage of the affected leg during exercise **(Brown and Kautz, 1998).** The positron emission tomography study during cycling movement showed that active cycling significantly activated areas bilaterally in the primary sensory cortex, primary motor cortex, and supplementary motor cortex and in the anterior part of the cerebellum **(Christensen *et al*., 2000).**

Pedaling has been promoted as an appropriate exercise to improve fitness for persons with CP **(Rimmer, 2001)**. Cycling training has been found to facilitate lower limb coordination or improve reciprocal muscle activity **(Hornby *et al*., 2012).** Pedaling is a highly efficient task to promote bilateral use of the lower limbs **(Handa *et al*., 2004).** Lower limb ergometer exercises are easy to perform and quantify the amount of load, making them suitable for lower extremity exercise programs **(Williams and Pountney, 2007).** Cycling may induce positive speed related changes in neuromotor control and muscle physiology by promoting higher speeds of movement than are possible during daily activities of most children with CP although cycling has been recommended as an appropriate **(Rimmer, 2001).**

Pedaling helps to improve strength of the lower limb muscles without the need to load the muscles in an isolated joint range as the muscles work together in harmony in an alternative pattern of flexion and extension out of the pathological pattern. Pedaling helps children to move their legs in a speed that is not possible during ordinary daily living activities which have a positive influence on muscle physiology and neuromotor control **(Fowler *et al*., 2010 and Hornby *et al*., 2012).**

Fowler *et al*., (2010) demonstrated that cycling has a positive effect on the locomotor endurance of children with CP by observing a significant improvement in this parameter following training on a static bicycle. Thus, being an equipment that is easy to handle and transport, as well as supporting the literature regarding its benefits, the cycle ergometer can be an important tool in the rehabilitation of individuals beginning in the acute phase post-stroke. Although it is already well described that the use of the cycle ergometer improves cardiovascular function **(Jin *et al*., 2013)**, gait and balance **(Lund *et al*., 2017)**, and upper limbs function **(Diserens *et al*., 2007).**

Cycling Exercise in Upper Limb and Trunk

Trunk and extremity motor impairments in CP lead these children to remain long periods without physical or aerobic activities, or harming their cardiopulmonary capacity, stability, muscle strength, and agility. To overcome this issue, in the rehabilitation of CP, there have been several major therapeutic practices during past years, including models of treatment that 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 **(Tatla *et al*., 2013).**

Shoulder and elbow functional movements result in trunk muscles activation which include trunk flexors and extensors, along with quadriceps, gastrocnemius and tibialis anterior muscles. Through repetition, the infant acquires and refines the coordination or movement patterns necessary to achieve the functional action goal. Arm ergometry or arm cycling involves sitting upright in a seat and “pedaling” with the arms. An important advantage of ergometer training over conventional physiotherapy is that patients who are motivated to continue training, can do so themselves, which is an alternative to hand-to-hand therapy, often limited by budget constraints. Though arm ergometry is one of the means of upper limb movement **(Priyabrata *et al*., 2017 and Ojha *et al*., 2017).**

Muscle activities of the trunk during upper limb movements are thought to be important for maintaining postural stability. Hence, upper limb movement training should be carried out in the context of the task demands (alternate arm movements) and may be essential for the implicit engagement of the underlying neural conventional networks for integration of the different mechanical, sensory, motor and goal oriented systems that contribute to arm function and postural regulation **(Priyabrata *et al*., 2017).**

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 **(Braendvik *et al*., 2013).**

Franki *et al*., (2012) reported that individuals with CP need consistent upper extremity training because CP can lead to muscle contractures and functional disturbance. Considering that the poor muscle strength in children with CP in one of the most important factors affecting motor function, so increasing muscle strength is a fundamental treatment for motor performance. **Kim, and Park (2011) ; Kim *et al*., (2012)** recommended strength training with intensive repetitions that develop upper extremity exercise capacity as rehabilitation treatment in children with CP**.**

In hemiplegic CP children the impaired arm usually swings with decreased amplitude on the involved side whereas the arm swing amplitude of the non-hemiplegic arm exceeds that of healthy participants **(Meyns *et al*., 2012a)**. This increase in non-hemiplegic arm swing was found to counteract an increased angular momentum generated by the legs suggesting it is aimed to control total body angular momentum, so arm swing is utilized in order to balance the rotational motion of the body **(Bruijn *et al*., 2011).** Asymmetry in arm swing behavior contributes to reduction in bilateral arm coordination **(Huang *et al*., 2012).**

During gait, the affected upper extremity posture in children with hemiplegia typically includes an abducted, internally rotated shoulder, elbow flexion, wrist flexion, and thumb adduction that so called ‘guard position’ **(Galli *et al*., 2011)**. The role of arm movements in children with hemiplegic CP is to maintain stability in walking. Guard positions in children with CP have been suggested to be a compensatory strategy to maintain balance. Such guard position is useful when preparing for a fall and in regaining balance after a perturbation **(Meyns *et al*., 2012a).**

Arm swing may minimize energy consumption and decrease vertical ground reaction moment during gait, since a smaller ground reaction moment needs to be generated by the leg muscles **(Pontzer *et al*., 2009).** Still swinging the arms would cost more energy than the reduced energy demands of the legs **(Bruijn *et al*., 2011).**

Regular passive arm exercise led to an increase in the range of motion in the affected arm **(Shin *et al*., 2012). Hussein *et al*., (2014)** suggested that the arm cycling exercises may have significant improvements in the involved upper extremity angular displacements of hemiplegic children. It also had a positive impact on leg angular displacements in these patients.

Usage of arm cycling could improve shoulder and elbow joint angular displacement, which might improve coordinated movements between the two sides, as arm cycle provides bimanual motor performance (flexion on the one side and extension on the other side) which may reduce the associated reactions. The associated reactions are involuntary changes in muscle tone that arise from excessive effort needed for a voluntary mirror movement, that is due to unintended symmetrical irradiations of motor activity to the contralateral side during a unimanual motor performance, such reactions are found in children with hemiplegic CP **(Kubo *et al*., 2004).**

The significant improvement ($P < 0.05$) in angular displacements of hip, knee and ankle joints that was associated with a concomitant improvement of the arm swing can be explained by inter limb coordination, as coordinated upper limb exercise by using arm cycling may improve coordination between upper and lower limbs **(Meyns *et al*., 2012b).**

Improvement in the lower limb angular displacement might be due to the usage of arm cycling, as arm cycling exercises may allow children to reciprocally swing the arms while walking at a faster speed than they were normally able to achieve **(Barzi and Zehr, 2008).** As **Huang and Ferris (2009)** found that upper limb movement influences the recruitment of lower limb motor neurons during locomotors-like rhythmic activity on a recumbent stepper.

On its arm cycling form, the cycle ergometer may be able to increase muscular strength and range of motion in chronic post-stroke patients **(Diserens *et al*., 2007).** The cycle ergometer exercise improves several parameters, such as strength and endurance, along with torso control in sitting position **(Sandberg *et al*., 2016; Ojha *et al*., 2017).** In the exercise training protocols, the duration of training programs ranged from 3 to 5 weeks. Improvements in motor control, trunk stability and cognition were reported following this type of exercise training **(Brenner, 2017).**

For typically developing persons who are deconditioned, the WHO recommendation is to include light- to moderate-intensity exercise, and moderate and vigorous intensity. The guidelines recommend a frequency of 5 days/week of moderate exercise or 3 days/week of vigorous exercise. The recommendation is 20–60 min of continuous and rhythmic moderate or vigorous exercises that involve major muscle groups **(Verschuren *et al*., 2016).**

CONCLUSION

Physical activity is necessary for the optimal physical, emotional, and psychosocial development of all children. Children with CP have a daily PA level below the international threshold recommended by the WHO for 5- 17 year old. Cycling is an effective rehabilitation tool that can be added to the physical therapy program. Studies found that lower limb cycling exercise reducing spasticity and increasing in the range of knee extension motion in children with CP. Also arm cycling exercises may allow children to reciprocally swing the arms while walking at a faster speed than they were normally able to achieve and muscle activities of the trunk during upper limb cycling are thought to be important for maintaining postural stability.

Conflict of interest

The authors have declared no conflict of interest.

Compliance with Ethics Requirements

This article does not contain any studies with human or animal subjects.

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تمرين العجله لتأهيل حالات الأطفال المصابين بالشلل الدماغى
(مقالة مرجعية)

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الشلل الدماغى هو سبب شائع للاعاقه خلال فترة الطفوله. إنه اضطراب تطويرى عصبى_عضلى ينجم عن إعاقه غير تقدمية فى دماغ الجنين. هناك العديد من الاعاقات العصبية–عضليه والعضليه_الهيكليه والتنمويه المرتبطه بالشلل الدماغى بما فى ذلك التشنج؛ والتشوه الحركى والانقباضات وتطوير النخاع العظمى غير الطبيعى واضطرابات التوازن وفقدان انتقائى للتحكم الحركى والضعف. فى الآونه الاخيرة كان هناك تركيز متزايد على المشاركه فى النشاط البدنى للاطفال الذى يعانون من الشلل الدماغى. تشمل التمارين التى تساعد الاشخاص ذوى التشنج العضلى ركوب الدراجات وتمارين تقوية العضلات وتدريب المشاية. يمكن استخدام الدراجة فى حالات شلل الدماغ لتحسين اللياقة القلبية والتوازن والمشى ووظيفة الاطراف العلوية. كان الهدف من هذه المراجعة هو تقديم تبديل الدراجة كأداة للتأهيل وتأثيرها على الاطفال الذى يعنون من الشلل الدماغى.

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