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EFFECTS OF EXERCISE TRAINING ON PERFORMANCE AND FUNCTION IN INDIVIDUALS WITH CEREBRAL PALSY: A CRITICAL REVIEW

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ABSTRACT

This critical review article describes the exercise performance capabilities, and the effect of exercise training interventions, in individuals with cerebral palsy (CP). A literature search was conducted using PubMed, Medline, Embase, Scopus, Web of Science, Science Direct and Google Scholar databases from the earliest possible date to December 2014. Large impairments in exercise performance have been reported in individuals with CP, as well as large improvements following the implementation of training interventions. The physiology underlying the functional and physical impairments in CP were also reviewed, and grouped into categories, namely: motor impairments, central impairment, skeletal muscle morphology and physical inactivity. Although much research exists on individuals with CP, there is conflicting evidence for the benefits of exercise training in these individuals. This is due to the use of sedentary, paediatric populations and varied methodologies. Investigating individuals who have undergone high-volume exercise training from a young age might result in a better understanding of functional and physical performance in individuals with CP.

***Key words*:** Disability; Physical activity; Rehabilitation; Physiology.

INTRODUCTION

Origins of and definitions for cerebral palsy

Cerebral palsy (CP) was first termed "Little's Disease" after Dr. William John Little (1810-1894), who was the first to study infantile malformation, and the first to characterise spastic diplegic CP, attributing the condition to trauma at birth. Sir William Osler (1849-1928) later introduced the term "cerebral palsy" during his extensive clinical research on children with CP. Sigmund Freud (1865-1939), although not recognised for many years, contributed significantly

to the area of CP research by identifying pre-natal causes of the condition, as well as grouping the different forms of CP under the umbrella term "infantile cerebral palsies" (Osler.W., 1889; Longo & Ashwal, 1993). Cerebral Palsy, defined by Bax in 1964 as "a disorder of posture and movement due to a defect or lesion of the immature brain" (Bax, 1964:295) has an estimated incidence of 2.5 per every 1000 live births (Rosen & Dickinson, 1992). The definition has since been expanded to include a group of movement disorders caused by damage to the immature brain before, during, or directly after birth. The damage occurs in one or more of three main areas in the brain controlling movement, namely the motor cortex, cerebellum and basal ganglia (Bialik & Givon, 2009). Hypertonic CP is the most common form of CP, with athetoid, ataxic and mixed CP being less common (Reddihough & Collins, 2003). Limb distribution of the impairment is present in three main categories, namely hemiplegic, diplegic and quadriplegic impairment (Rosenbaum *et al.*, 2010).

Cerebral palsy and sport participation

Participation in competitive sport by individuals with disabilities is a relatively new phenomenon, with the first organised sports competition for disabled individuals held in 1948 for World War II veterans with spinal cord injuries. Between 1948 and 1960, the International Stoke Mandeville Games grew in size and eligible impairment types, until the first Paralympic Games were held in Rome in 1960. The Paralympic movement has grown over the years, with more than four thousand athletes from 164 countries competing in the 2012 London Paralympic Games, a significant increase from the 2008 Beijing Paralympic Games which hosted 3951 athletes from 146 countries (Anon, 2014). Athletes with CP compete in many sports, but predominantly athletics, football, swimming and boccia.

Research in cerebral palsy

With the growth of both clinical and sporting populations with CP over the last century, research in CP has been carried out, predominantly addressing the need for improved quality of life. Many interventions have aimed to address quality of life, exercise therapy being an example. The use of exercise in the treatment and management of individuals with CP has yielded positive results from both traditional and alternative methods (Damiano & Abel, 1998; Zadnikar & Kastrin, 2011).

The majority of these studies, however, have focused on quality of life within severely affected paediatric patients, and not exercise performance capacity in athletic adults, due in part to the relative urgency for research within highly affected populations. Although exercise performance measures are often reported in these studies, no studies to date have definitively described exercise and performance capacities of children and adults with CP from a sports performance perspective. Moreover, there is neither consistent nor longitudinal evidence for the use of exercise training to improve sport performance in this patient population.

PURPOSE OF STUDY

To provide consistency on this clinical condition, the present review summarises the current literature on the exercise and performance capacities of individuals with CP, describing: (1) the effect of CP on specific aspects of exercise performance; (2) the response to exercise training and results of interventions aimed at improving these aspects; and (3) how the physiology

underlying the functional or physical impairments present in CP can be better understood. For a complete summary of the intervention studies included in this review, see Table 1 later.

METHODOLOGY

A literature search was conducted using PubMed, Medline, Embase, Scopus, Web of Science, Science Direct and Google Scholar databases from the earliest possible date to December 2014. The medical subject heading (MeSH) terms included *cerebral palsy, brain injury, spasticity* and related terms. The search terms, matched with the MeSH included *classification, adult, athlete, exercise training, strength, aerobic, anaerobic, agility, speed, flexibility, electromyography, muscle morphology, physical inactivity* and related terms. Abstracts were screened, and individual articles were selected based on quality and focus of the studies. Furthermore, the reference lists of articles were also searched for further studies. Only studies published and available in the English language were included.

This review primarily investigated individuals with CP, and excluded individuals with traumatic brain injury or other neurological disorders causing movement abnormalities. For clinical purposes within research, the functional abilities of individuals with CP have been classified into five discernible groups within the Gross Motor Function Classification System (GMFCS) (Palisano *et al.*, 1997). The system is scored from minimally affected (level I, unaided ambulation) to severely affected (level V, permanent wheelchair use) individuals with CP. For the purpose of this review, only studies using individuals in the GMFCS levels I and II were reviewed (Rosenbaum *et al.*, 2008). This ensured an appropriate comparison of functional performance between individuals with truly ambulant CP and typically-developed able-bodied individuals, as GMFCS classifications beyond level II infer the use of assistive devices or wheelchairs, which would not enable close functional matching.

Also, due to the scarcity of literature in athletic adult samples, studies using paediatric samples have been reviewed. Any literature identified in adults or athletes in GMFCS levels I and II were included.

RESULTS

Strength

Weakness in individuals with CP has been widely demonstrated, with strength impairments ranging from 30 to 73% in children (Elder *et al.*, 2003; Stackhouse *et al.*, 2005; Reid *et al.*, 2010) and 12 to 52% in adults (Van Meeteren *et al.*, 2007; De Groot *et al.*, 2012; Hussain *et al.*, 2014). Only one of these studies (De Groot *et al.*, 2012) used an athletic adult sample of cycling and soccer athletes. They reported an isometric knee extension strength impairment ranging between 31 and 47% in elite soccer players and cyclists with CP, compared to able-bodied soccer players and cyclists (De Groot *et al.*, 2012). Interestingly, a study examining jump performance in elite soccer players with CP found similar vertical ground reaction forces in the athletes with CP, compared to previous results in athletes without CP with 1.92 body weight for athletes with CP versus 1.51 body weight for able-bodied athletes (Camara *et al.*, 2013).

The most compelling studies that support the benefits of strength training in individuals with CP have found improvements of between 13 (Reid *et al.*, 2010) and 69% (Damiano & Abel, 1998) from six weeks of traditional strength training in hemiplegic and diplegic children in GMFCS levels I and II. This large range is the likely result of variation in methodology, differences between the size of muscle groups trained (smaller upper muscle group and improvement vs. larger lower limb muscle group and improvement), as well as normal inter-individual variations in response to training. Studies conducted on adults show similar results in strength gains, but with longer intervention periods (10 to12 weeks) (Andersson *et al.*, 2003; Ahlborg *et al.*, 2006; Johnston & Wainwright, 2011).

With the upper limit of strength improvement in clinical studies being 69%, it is an intriguing question to ask whether individuals with CP can train strength to within the "normal" range of able-bodied individuals. There is no literature which definitively answers this question, but the investigation of athletes with CP, who have undergone high loads of strength training may provide clarity on this issue.

Of particular interest is the effect of strength training on the asymmetry between the affected and non-affected sides after training. This asymmetry has been found to be reduced, though not eliminated, by strength gains in hemiplegic individuals, suggesting a larger potential for strength gains on the affected side. In a study conducted by Damiano and Abel (1998), a 24% asymmetry was measured after the six week strength training intervention, and while this was a reduction from a pre-training asymmetry of 42%, the authors did not speculate whether a longer training intervention would further minimise this difference (Damiano & Abel, 1998). Their finding does, however, invite this possibility.

Aerobic capacity

The aerobic capacity of children with CP has long been recognised as limited compared to that of typically developing children (Verschuren & Takken, 2010). Reductions in VO_2 peak ranging from 15 to 42% compared to healthy controls indicate a compromised aerobic capacity in paediatric studies (Rieckert *et al.*, 1977; Hoofwijk *et al.*, 1995; Maltais *et al.*, 2005; Verschuren & Takken, 2010). These findings have been supported by 23 to 45% and 21 to 61% impairments in VO_2 peak in adult men and women, respectively (Fernandez *et al.*, 1990; Nieuwenhuijsen *et al.*, 2011).

Comparing able-bodied controls to aerobically trained athletic adults with CP, VO_2 peak was found to be 0.3 and 21% lower VO_2 peak for athletes in GMFCS levels I and II, respectively. This is significantly closer to age-matched controls compared to other studies conducted on sedentary individuals with CP (De Groot *et al.*, 2012), and suggests a potential benefit of exercise training.

Aerobic exercise interventions have been implemented in children as young as two years old (Mattern-Baxter *et al.*, 2009). Although existing intervention studies differ in terms of samples studied, testing methods, intervention structure and outcome measures, the general finding is that exercise training improves aerobic capacity significantly (Damiano & DeJong, 2009).

Self-selected walking speed, often used as an outcome measure for aerobic capacity in young children with CP in a clinical setting, increased after training interventions, along with energy

efficiency (Blundell *et al.*, 2003; Chan *et al.*, 2004; Phillips *et al.*, 2007; Provost *et al.*, 2007; Gorter *et al.*, 2009; Chrysagis *et al.*, 2012). A more rigorous testing method using the lactate threshold to determine exercise intensity has reported a 20% increase in aerobic capacity in children and a 12% increase in aerobic capacity in adults, using a similar protocol (Pitetti *et al.*, 1991; Shinohara *et al.*, 2002). Of interest in these studies was that arm ergometry power output was unchanged as a result of the exercise intervention, whereas leg ergometry power output improved significantly, indicating larger aerobic capacity when training larger muscle groups, as proposed previously (Shinohara *et al.*, 2002).

Anaerobic capacity and agility

Anaerobic performance of children with CP, assessed using the 30-second Wingate test, has been found to be two to four standard deviations lower than in typically developing children. Other studies report a 27 to 46% impairment in peak power output in children with CP using a 20 second Wingate test (Bar-Or, 1986; Parker *et al.*, 1992; Verschuren *et al.*, 2010; Balemans *et al.*, 2013).

Comparisons of agility between CP and control groups are limited. From the available literature, we found that the average time to complete a repeat sprint agility task was 39% longer in children with CP. Indeed, some participants with CP took over 60 seconds to complete a task that took only 19.5 seconds for the able-bodied participants to complete (Verschuren *et al.*, 2010).

There is also limited research on the potential to increase anaerobic capacity and agility with training in individuals with CP. In the only study found, Verschuren *et al.* (2007) reported a 25 and 15% increase in anaerobic capacity and agility, respectively, following an eight month intervention targeting these variables (Verschuren *et al.*, 2007). This intervention is one of the longest duration interventions in individuals with CP, and also included a four-month follow-up after completion of the study. This follow-up, during which time no supervised training or encouragement to train was provided, revealed a 9 and 4% reduction in anaerobic capacity and agility from peak values achieved at the end of the 8-month programme.

Flexibility

Although lack of flexibility and the presence of contractures has been well documented in individuals with CP, it has not yet been concluded whether training interventions can successfully improve flexibility. Some interventions have found improved dynamic flexibility, muscle tone and reduced hypertonia with the use of stretching interventions (McPherson *et al.*, 1984; Dickin *et al.*, 2013), while other studies found no change in flexibility, despite positive changes in other parameters, like hypertonia and functional ability (O'Dwyer *et al.*, 1994; Darrah *et al.*, 1999; Low *et al.*, 2003). The differences in these studies may be explained, again, by the age of the participants. The one study that reported only positive change in flexibility was conducted by McPherson *et al.* (1984) in children with CP, while the other studies that reported varying or inconclusive results were conducted on adolescents or adults with CP.

Table 1. SUMMARY OF INTERVENTION STUDIES INCLUDED IN REVIEW

Study	Participants	Intervention			Outcomes	Results
		Type	Duration	Frequency		
Strength						
Ahlborg *et al*., 2006	Training group with CP: n=7 (21-41 years) Control group with CP: n=7 (21-41 years)	Training group: Whole body vibration therapy Control group: Strength training			• Spasticity • Isokinetic strength • 6 minute walk test • Timed up and go test • Gross motor function test	*Training group*: Significantly decreased in knee extensors *Training group*: Significant improvement at 30º/s *Control group*: Significant improvement at 30 º/s and 90ºs *Training group*: NS *Control group*: NS *Training group*: NS *Control group*: NS Training group: Improved significantly
Andersson *et al*., 2003	Training group with CP: N=10 (23-44 years) Control group with CP: N=7 (25-47 years)	Strength training	10 weeks	2 days/week	• Spasticity • Range of movement • Isometric strength • Concentric strength • Eccentric strength • Gross motor function measure	NS NS *Training group*: Significant improvement (hip extensors, hip flexors) *Control group*: NS *Training group*: significant improvement at 30º/s and 90ºs in knee extensors *Control group*: NS NS *Training group*: Significant difference *Control group*: NS

					• 6 minute walk test • Timed up and go	*Training group*: Significant improvement (walking distance, walking velocity) *Control group*: NS *Training group*: Significant difference *Control group*: NS
Damiano & Abel, 1998	CP: N=11 (6-12 years) Diplegic group: N=6 Hemiplegic group: N=5	Strength training	6 weeks	3 days/week	• Isometric strength • 3D gait analysis • Gross motor function measure	*Diplegic group*: ↑ 69% *Hemiplegic group*: ↑ 20.3% in affected leg *Unaffected leg*: NS 24% asymmetry across sides maintained Asymmetry improved Improved
Healy *et al*., 1958	CP: N=5 (8-16 years)	Concentric and isometric strength training	8 weeks	3 days/week	• Concentric strength • Isometric strength • Knee ROM	Significant improvement Significant improvement NS
Johnston *et al*., 2011	CP: N=1 (49 years)	Cycling with superimposed electrical stimulation	12 weeks	3 days/week	• Spasticity • 6 minute walk test • Timed up and go test • Concentric strength • Gait parameters • Medical outcomes study 36-item health survey • International classification of functioning, disability and health	NS NS Significantly improved by 24.4% Hip flexor ↑ 22.2% Hip extensor ↑ 18.5% NS Significantly improved Significantly improved

MacPhail & Kramer, 1995	CP: N=17 (12-20 years)	Eccentric, isometric, concentric strength training	8 weeks	3 days/week	• Peak torque • Peak work • Spasticity • Efficiency	Strength ↑ 21-25% NS NS
Reid *et al*., 2010	CP: N=14 (9-15 years) Con: N=14 (9-15 years)	Progressive eccentric strength program	6 weeks	3 days/week	• Peak torque to body mass (T/BM) • Work to body mass (W/BM) • Angle at peak torque • Curve width • EMG activation	Concentric task: ↑ 13% Eccentric task: ↑ 25% NS NS ↓ to normal amplitude
Toner *et al*., 1998	CP: N=6 (4-7 years)	Strength training with use of biofeedback	6 weeks	7 days/week	• Strength • Toe tapping ability	NS Improved
Aerobic capacity						
Chan *et al*., 2004	CP: N=12 (4-11 years)	Treadmill training and electrical stimulation	4 weeks	3 days/week	• 3D gait analysis • Ankle moment quotient Ankle power quotient • Gross motor function measure	NS NS NS Significant improvement
Chrysagis *et al*., 2012	Training group with CP: N=11 Control group with CP: N=11	Training group: Treadmill without body weight support Control group: Traditional physiotherapy	12 weeks	3 days/week	• Spasticity • Self-selected walking speed • Gross motor function measure	NS *Training gro*up: Significant improvement *Control group*: NS *Training group*: Significantly improved *Control group*: NS

Mattern-Baxter *et al*., 2009	CP: N=6 (2.5-3.9 years)	Treadmill training	4 weeks	3 days/week	• Gross motor function measure • Paediatric evaluation of disability inventory • 10m walk test 6 minute walk test	Significant improvement Significant improvement Over-ground walking speed and distance covered ↑
Phillips *et al*., 2007	CP: N= (6-14 years)	Body weight supported treadmill training	2 weeks	2 times/day 6 days/week	• fMRI activation • 10 m walk test 6 minute walk test	fMRI activation increased Over-ground walking speed and distance covered ↑
Provost *et al*., 2007	CP: N= (6-14 years)	Body weight supported treadmill training	2 weeks	2 times/day 6 days/week	• Energy expenditure • 10 m walk test 6 minute walk test • Single leg balance test • Gross motor function measure	Significant improvement in energy expenditure Over-ground walking speed and distance covered ↑ NS Significant difference
Shinohara *et al*., 2002	CP: N=11 Leg group: N=6 (13.3-15.8 years) Arm group: N=5 (11.8-16.3)	Anaerobic threshold training Leg group: cycle ergometer Arm group: arm ergometer	20 weeks	2 days/week	• VO_2 at anaerobic threshold • Self-reported endurance capacity	Leg group: VO_2 ↑ 20% Arm group: NS Children reported a perception of increased endurance capacity in only the leg group
Anaerobic capacity and agility						
Verschuren *et al*., 2007	CP: N=86 (7-18 years)	Aerobic and anaerobic circuit training	8 months	2 days/week	• Muscle power sprint test • 10 x 5m Sprint test	Anaerobic capacity ↑ 25% Agility ↑ 15%

Flexibility						
Darrah *et al*., 1999	CP: N=23 (11-20 years)	Active stretching for lower extremities	10 weeks	3 days/week	• Spasticity of triceps surae • Sit-and reach (hamstring flexibility) • Adductor flexibility	NS NS NS
Dickin *et al*., 2013	CP: N=8 (20-51 years)	Individualised whole body vibration therapy	2 sessions	-	• Spasticity • Range of movement • 3D gait analysis	NS Dynamic ankle range: Significantly improved Walking speed, stride length: Significantly improved
McPherson *et al*., 1984	CP: N=4 (10-18 years)	Year 1: static stretching Year 2: standing posture devices	2 years	Year 1: 5 days/week Year 2: 7 days/week	• Knee extensor range of movement • Muscle tone	Knee ROM ↑ 4-9º Year 2: Decreased muscle tone
O'Dwyer *et al*., 1994	CP: N=15 (6-19 years)	Passive stretching	42 days	3 days/week	• Ankle range of movement • Contracture of triceps surae	NS Significant decrease

PROPOSED FACTORS LIMITING PERFORMANCE

Motor impairments and functional performance

One of the explanations for decreased strength, speed and aerobic capacity is the combination of motor impairments present in the complex condition of CP. These include centrally-mediated muscular weakness, incoordination, hypertonia, contracture and co-activation. Incoordination, hypertonia, contracture and co-contraction are all observed in individuals where the central nervous system is disturbed or damaged in some way. Incoordination is the inability of the central nervous system to correctly utilise the proposed pathway to recruit motor units in the correct synchronicity to enable fluid movement (Neptune & Kautz, 2001). Hypertonia and muscle contractures are among the most prominent features in CP, and result in muscles that have increased resting and dynamic tone, rigidity and decreased range of movement. These muscle irregularities are a result of dysfunction, in part, of the stretch reflex found at the third level of the motor control hierarchy (Damiano *et al.*, 2001; Iqbal, 2011).

Movement can be severely affected, as a result of these irregularities. Co-activation is the simultaneous contraction of antagonist muscles during contraction of the agonist muscle, and is usually seen in typically developing individuals in small amounts during everyday activities and increased amounts only when a need for increased joint stability is required, such as when walking over highly unstable surfaces (Osternig *et al.*, 1984). However, co-activation during normal tasks in CP has been highlighted as one of the factors causing impaired performance, by activating both agonist and antagonist muscles to the extent that fluid movement is counteracted due to highly opposing forces on the joints (Damiano *et al.*, 2002). The combination of motor impairments seen in individuals with CP would thus result in abnormal gait patterns, increased energy requirements for the same task, as well as increased time needed to complete the task (Lundberg, 1978; Lundberg, 1984; Damiano *et al.*, 2000). These impairments have been attributed to several large contributing factors, described below briefly.

Central impairment

Stackhouse *et al.* (2005) superimposed electrical stimulation during a maximum voluntary contraction, in order to examine the possible central contribution to impaired performance, and discovered that voluntary muscle activation was 33% and 49% lower in the quadriceps and triceps surae, respectively, compared to able-bodied individuals (Stackhouse *et al.*, 2005).

This demonstrates a substantial impairment in the brain's ability to recruit muscle, which is consistent with other research (Elder *et al.*, 2003). However, the number of motor units available to be used was similar, as measured by M-wave amplitudes, and this suggests under-activation of muscle due to central inhibition (Frontera *et al.*, 1997; Rose & McGill, 2005), rather than an impairment at the level of the muscle or motor neuron junction. This occurs along with co-activation of antagonist muscles (Stackhouse *et al.*, 2005), leading to the theory that muscular impairments observed in individuals with CP are the result of a combination of muscular under-activation (Reid *et al.*, 2010), decreased central input to the muscle due to damage to the supraspinal centres (Leonard *et al.*, 1990) and co-activation of antagonist muscles (Myklebust *et al.*, 1982; Reid *et al.*, 2010).

Skeletal muscle morphology

Several authors have attributed muscular weakness to an identified increase in Type I muscle fibres in lower extremity muscles in children with CP (Rose *et al.*, 1994; Ito *et al.*, 1996; Stackhouse *et al.*, 2005). In addition to Type I muscle fibre predominance, increased intramuscular fat, atrophy and decreased muscle size in the paretic limbs have also been identified as an outcome of CP. These changes have been consistently attributed to sustained low-frequency muscle fibre firing, caused by hypertonia and altered central drive in muscle affected by CP (Castle *et al.*, 1979; Rose *et al.*, 1994; Ito *et al.*, 1996; Rose & McGill, 2005; Stackhouse *et al.*, 2005; Hussain *et al.*, 2014) and these findings indicate changes at both central and peripheral levels in individuals with CP.

Physical inactivity

It is widely accepted that children with CP engage in less physical activity than their typically developing peers, with almost exclusively negative consequences (Maher *et al.*, 2007; van Eck *et al.*, 2008; Verschuren & Takken, 2010). Durstine *et al.* (2000) proposed a circular mechanism for physical inactivity in disabled populations, whereby individuals with a disability engage in less physical activity, which results in deconditioning which further decreases their level of functioning and thus volitional engagement in physical activity (Durstine *et al.*, 2000). Most of the studies in the area of CP, whether in children or adults, attribute some level of poor performance to a relative lack of exercise training when compared to control groups. Engaging in physical activity, however, has been observed to be one of the most important factors for the successful maintenance of function in this population (Conchar *et al.*, 2014). Therefore, the participation of those with CP in exercise programmes is particularly important, maybe even more so than their typically developing peers, for proper physiological development (Gorter *et al.*, 2009).

CONCLUSIONS

Research on individuals with CP has focused mainly on improving quality of life for severely affected and sedentary children, with little research on exercise performance capacity in adults and athletes with CP. It has been established that individuals with CP: (1) present with a large range of impairments in exercise performance; and (2) improve significantly with participation in exercise training of different modalities. However, most of the studies have been short in duration and predominantly investigated sedentary individuals.

Through reviewing the existing literature on exercise performance impairments in individuals with CP, as well as investigating the possible mechanisms responsible for these impairments, it has become clear that, although CP has been extensively researched, there is conflicting evidence and no solid consensus regarding the effect of CP on human physiology and physical function. This is mainly due to the use of paediatric samples, physical inactivity in the samples investigated, and the relatively short interventions administered. It must also be acknowledged that the grouping of clinical studies and sporting performance studies in this review can make the reporting of results difficult, as these two groups of research prioritise different aspects of physiology. Clinical studies generally prioritise health-related outcomes whereas sporting performance studies prioritise sporting performance and physiology. However, due to paucity

of research in the sporting category, the categories have been grouped in an effort to understand the overall effect of CP on human physiology.

To be able to definitively describe the effect of long-term exercise training on individuals with CP, it is suggested that researchers investigate individuals where the confounding factors of low activity status and age have been eliminated as far as is possible. That is, studying individuals who have participated in high-level training over a long period of time would enable better identification and understanding of the physiological effect of CP on the body. In-depth investigation into an athletic sample would also give insight into the effect of long-term exercise training on the impairments observed in CP. Studying this population may provide further evidence for the use of exercise as a rehabilitation and management tool in CP, possibly providing improved management for both severely affected and ambulant individuals with CP of all ages.

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