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Motor-based priming: isokinetic outcomes of aerobic exercise in children with spastic diplegia

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Abstract

Introduction. Priming is a behavioural change generated by preceding stimuli. Priming physical activities with aerobic exercise could improve performance and function. The study aimed to investigate the effect of aerobic exercise before a rehabilitation program on quadriceps peak torque in children with cerebral palsy of spastic diplegia.
Methods. Overall, 32 patients participated in this study; they were randomly assigned to 2 groups. Patients in the control group (A) engaged in a selected physical therapy program, while those in the experimental group (B) performed aerobic exercise by using a bicycle ergometer followed by application of the same selected physical therapy program as received by group A. The treatment programs were conducted 3 times per week for 12 successive weeks. Measurements obtained included concentric peak torque of quadriceps muscle at 30° as well as 90°. These measures were recorded 2 times: before and after the application of the treatment program.
Results. There were statistically significant differences when comparing pre- and post-treatment mean values in each group. Also, there was a significant difference in favour of group B with regard to post-treatment mean values.
Conclusions. In accordance with the applied procedures, aerobic exercise is effective in improving quadriceps peak torque in children with cerebral palsy of spastic diplegia when applied before a physical therapy rehabilitation program.
Key words: diplegia, motor-based priming, aerobic exercise, isokinetic outcomes

Introduction

Cerebral palsy (CP) is a group of disorders of movement and posture, often characterized by impairments such as muscle weakness, spasticity, and abnormal patterns of co-contraction [1]. CP involves several non-progressive neurodevelopmental disorders of posture and motor impairment. 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 [2].

Spastic diplegia is a common term applied to the variation of spastic quadriplegia in which the upper extremities are less affected than the lower ones [3]. It is a motor impairment in the extremities; also, marked weakness in the trunk and hypertonia of the extremities were identified [4].

Crouch gait pattern, one of the most frequent gait pathologies in patients with CP [5], is characterized by increased knee flexion throughout the stance phase and often increased hip flexion and internal rotation, which exaggerate knee extensor weakness [6].

Aerobic exercise is defined as ‘planned, structured repetitive physical activity for extended periods and at sufficient intensity to improve or maintain physical fitness’ [7, p. 2].

The priming theory presumes that the brain will become more responsive to motor training due to increased neural activity if it is activated by using an intervention delivered before the motor learning intervention. This ‘therapeutic window’ may result from the modulation of long-term potentiation [8–10]. Motor priming has several forms, including unilateral or bilateral, repetitive or continuous movements, and aerobic training [11]. Cycling is a rehabilitation method often applied by clinicians as a form of aerobic exercises to improve strength, as well as cardiorespiratory fitness [12].

Data concerning the effects of an early physical therapy intervention on CP strongly suggest the benefits of a multidisciplinary approach. The type and frequency of an intervention must be determined because of the wide variability in the practices [13].

The main objective of this study is to investigate the effect of aerobic exercise in a form of cycling before a physical therapy program on quadriceps concentric peak torque in children with CP of spastic diplegia.

Subjects and methods

Study design and sampling

A randomized controlled trial was conducted. On the basis of the study design, the participants were randomly assigned to 2 groups.

The Windows version of G*Power 3.1.9.4 software was used for sample size determination and power testing as follows: a comparison of 2 independent means (2 tails) was assumed, with an effect size of 1.1. Adopting the value of $\alpha = 0.05$, a sample size of 32 participants was required and the power was 85%.

Inclusion and exclusion criteria

The participants were recruited from the outpatient clinic, Faculty of Physical Therapy, Cairo University. Children of both sexes aged 6–8 years were selected. They were diagnosed with CP of spastic diplegia. The degree of spasticity

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ranged between 1 and 1^+ in accordance with the modified Ashworth scale. The individuals were able to stand alone with heels on the ground without support. They were cognitively competent and able to understand and follow instructions. Excluded were children with fixed deformities of upper or lower limbs, as well as one who had significant perceptual, cognitive, visual, and auditory disorders.

Randomization

On the basis of the equal number, equal gender distribution, and equal distribution of spasticity degree (1:1) in both groups, randomization was allocated to avoid bias in variation in results. Stratification was performed through categorizing participants into categories following the initial assessment; then, each category took the same block number to ensure equal distribution of these numbers between the groups.

The children were assigned to 2 groups: the control group (A) and the experimental group (B). Each group consisted of 16 participants. Group A engaged in a rehabilitation program based on the selected physical therapy training program. Group B underwent aerobic training followed by the same program as received by group A participants, with a break of 5–10 minutes in between. Each patient received 36 hours of rehabilitation training as the session lasted 1 hour and was conducted 3 times per week for 12 successive weeks.

Evaluation procedure

Peak torque is the maximal torque (newton-meters, N · m) generated by the child during a concentric movement. Concentric peak torque of quadriceps muscles was measured bilaterally with an isokinetic dynamometer at 2 different angle speeds (30°/s, 90°/s). The isokinetic strength test in individuals with CP is reliable both at 30°/s [14] and at 90°/s [15, 16].

The child was positioned sitting with their back against a backrest and their hips in 90° flexion. The arms were crossed over the chest, and the pelvis and thighs were secured with straps. The resistance pad of the dynamometer was positioned over the distal part of the lower leg and secured with a strap. After a 5-minute submaximal warm-up on a stationary cycle and 2–3 submaximal and maximal familiarization repetitions, each participant performed 3 maximal-effort isometric contractions of the knee extension muscle group, minimizing the error of measurement and equalizing the ankle position with a 10-second rest between concentric and eccentric work and at least 20-second rest between the trials. Each child started at an angular velocity of 30°/s. Verbal encouragement to perform at maximal effort was given.

All test data acquisition was performed by using the Biodex Advantage Software package for Windows.

Treatment procedure

Aerobic exercise (bicycle ergometer)

A stationary bicycle (Monark Rehab Trainer model 88IE) was used as it involves a semi-recumbent design with a wide padded seat and seat belt, back support, and foot straps attached to the pedals to provide complete fixation of the child's foot on the ergometer pedal. It provided resistance to the lower extremities during cycling by standard cycling. The bicycle seat location was adjusted to ensure a knee joint angle of 15–20° flexion when the knee was maximally extended during cycling; then, it was locked in place. Power was read in watts at 50–100 pedal revolutions/minute. Comfort and safety tips were considered.

Each child received stretching exercises for bilateral hip flexors, knee flexors, and ankle plantar flexor muscles as 5–10-minute warm-up before cycling. Lower extremity resistance training began with the attachment of one tensioning cord. Once cycling was in a smooth pattern without difficulty for 10 complete pedalling revolutions, a second tensioning cord would be engaged, increasing the resistance to 20 pounds. This protocol was repeated until either the participant was unable to cycle at the next higher cord increment or the cycling pattern was not smooth. The resistance level was recorded as the maximum cord level for the session. During subsequent sessions, each child began with a minimum of 20 revolutions at cord levels below the previous session maximum. During each session, the minimum, as well as the maximum number of tensioning cords and the corresponding number of revolutions were recorded. The total duration of the training session was approximately 10–15 minutes.

Selected physical therapy program

The program was applied to all participants. It included facilitation of normal movement patterns (head, trunk, and extremities), inhibition of released primitive reflexes, as well as facilitation of postural reactions (righting, equilibrium, and protective reactions). Proprioceptive training using weight-bearing from different positions was applied. Gait was trained through closed and open environment protocols. Climbing up and going down were parts of the rehabilitation program.

Statistical analysis

Data analyses were performed with the GraphPad Prism 8 software for Windows. The collected data of demographic and other baseline characteristics were statistically treated to show the mean and standard deviation of the measured parameters. A chi-square test and independent t-test were used to compare baseline characteristics.

A parametric statistical test in the form of repeated measures 2-way analysis of variance (ANOVA) was performed to compare changes in quadriceps concentric peak torque resulting from the applied rehabilitation programs. To compare results between the groups after each assessment, an unpaired t-test was used. The value of $p < 0.05$ was considered statistically significant.

Ethical approval

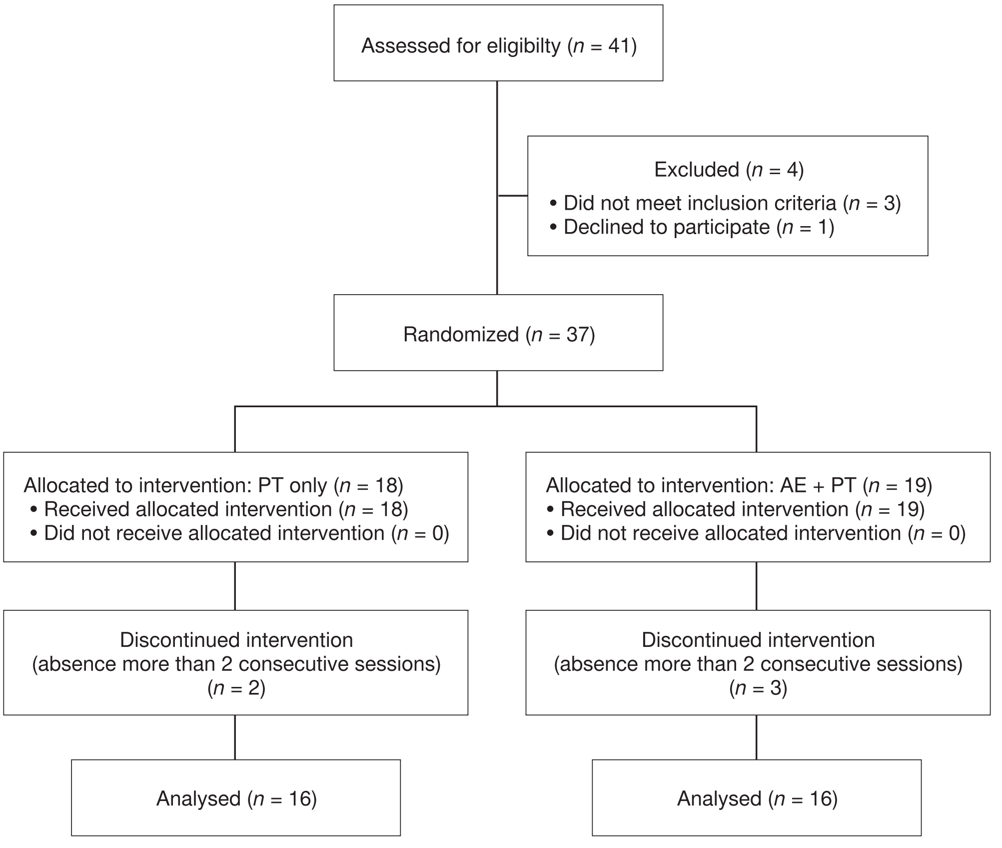
The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ethical Committee of the Faculty of Physical Therapy, Cairo University [approval No.: P.T.REC/012/002736 of May 17, 2020].

Informed consent

Informed consent has been obtained from the legal guardians of all individuals included in this study.

Results

A total of 32 participants were randomly allocated to the control and the experimental groups. The control group (n = 18) was programmed for physical therapy, whereas the



PT – selected physical therapy program, AE – aerobic exercise

Figure 1. The study flowchart

experimental group (n = 19) received aerobic exercise in addition to the treatment program applied in the control group. Of the 18 participants allocated to the control group, 2 withdrew from the study (owing to absence from more than 2 consecutive sessions), compared with 3 patients from the experimental group (Figure 1).

Table 1 presents a summary of demographic and other baseline characteristics at entry, including age, weight, and height. There were no significant differences between the groups ($p > 0.05$).

Table 1. Demographic and baseline characteristics

Item	Control group (Mean ± *SD*)	Experimental group (Mean ± *SD*)
Age (years)	7.15 ± 0.84	7.41 ± 0.65
Weight (kg)	15.68 ± 2.93	15.83 ± 3.05
Height (m)	1.13 ± 0.18	1.08 ± 0.25

When comparing pre-treatment mean values between the groups, no significant difference was noted in the measured variables ($p > 0.05$).

Statistically significant differences were observed in concentric peak torque of quadriceps at either 30° or 90° when comparing pre- and post-treatment mean values on both sides in group A, as well as in group B ($p < 0.05$), as shown in Table 2.

When comparing post-treatment mean values between the groups, significant differences were revealed in concentric peak torque of quadriceps either at 30° or at 90° of both sides in favour of group B ($p < 0.05$). The interaction between all variables was studied and there was no significant difference.

Discussion

Neuromotor disorders associated with CP interfere with both posture and motor function. Most of these deficits include neuromuscular origin problems, which dramatically

Table 2. Comparison of mean values of quadriceps concentric peak torque at 30° and 90° for both sides in both groups

Quadriceps concentric peak torque		Control group		Experimental group	
		Before	After	Before	After
At 30°	Right side	16.67 ± 0.72	19.93 ± 1.01*	16.11 ± 0.74	25.53 ± 1.91*#
	Left side	16.4 ± 0.61	18.53 ± 0.9*	15.97 ± 0.98	24.47 ± 2.05*#
At 90°	Right side	15.78 ± 1.31	18.96 ± 1.44*	16.1 ± 0.99	26.4 ± 1.54*#
	Left side	14.2 ± 1.8	17.39 ± 1.49*	15.73 ± 0.96	23.89 ± 2.2*#

* significant difference between pre- and post-treatment mean values, # significant difference between post-treatment means values

affect growth and development of these children. Children with diplegia experience several motor problems, such as a limited range of motion, especially during walking, in addition to abnormal forms of co-contraction [17]. In such cases, an unequal muscle pull leads to a further propagation of deformities in the form of flexion, adduction, and internal rotation at the hips, flexion at the knees, and shortened Achilles tendons [18].

Abnormal stereotyping during physical activity is the main factor of deformational changes due to muscle weakness, as well as abnormal muscular activities, like anomalous patterns of co-contraction, resulting in an exaggeration of deformities in both posture and gait in addition to irregularities in the maturation processes [19].

At present, aerobic training has been added to physical therapy programs for children with CP as it focuses on improving muscle strength and cardiovascular fitness [20]. The current study was designed to investigate the effect of priming aerobic exercise to a physical therapy program on quadriceps peak torque in children with CP of spastic diplegia. The participants' age ranged between 6 and 8 years owing to delayed independent standing (which may be delayed for up to 5 years).

The isokinetic dynamometer provides a reliable means of assessing knee strength, with excellent test-retest reliability for isokinetic knee extension. A learning effect occurred when evaluating isometric torque, which indicates the importance of habituation for this measure [21].

The results of the current study revealed significant differences in concentric peak torque of quadriceps either at 30° or at 90° on both sides in both groups. Also, significance was apparent when comparing post-treatment results of all measured variables in both groups in favour of group B, which practised bicycle ergometer exercise before the physical therapy program.

An increasing body of evidence confirms that many children with CP demonstrate muscular weakness and may benefit from programs designed to increase strength [22–24]. This comes in agreement with the results of the present study, which revealed an increase of strength (peak torque) of the quadriceps muscle after the designed rehabilitation programs.

It is not surprising that alternative approaches to management arise and attract attention because of a lack of definitive treatment [25]. According to the priming theory, aerobic exercise can improve neuroplasticity and even motor function [26]. Aerobic exercise increases neurotrophin concentration and blood supply to the brain, and therefore could improve other outcomes, such as relearning of complex skills [27–29].

Recently, it has been demonstrated that aerobic exercise on a bicycle ergometer improves the sensorimotor function [12]. Currently, there is more evidence supporting aerobic exercise as a method of priming lower limb motor recovery [30, 31].

Limitations

Our study was limited to one type of CP in addition to a limited range of age. It was difficult to follow up all participants for investigating long-term effects. The inclusion criteria and randomization method were developed to avoid variation in results.

Conclusions

According to the reports and results achieved in the present study, it could be concluded that priming aerobic exercise on a bicycle ergometer to a physical therapy program improves quadriceps concentric peak torque in children with CP of spastic diplegia.

Future research

Future studies are required for different types of CP, larger sample sizes, longer time, different age groups, as well as various assessment tools. Also, the long-term effect has to be investigated.

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Disclosure statement

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Conflict of interest

The author states no conflict of interest.

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