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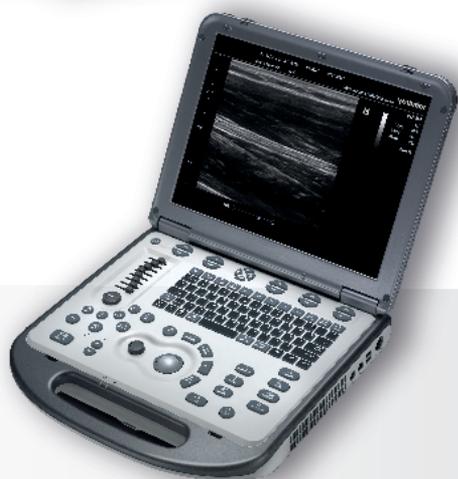
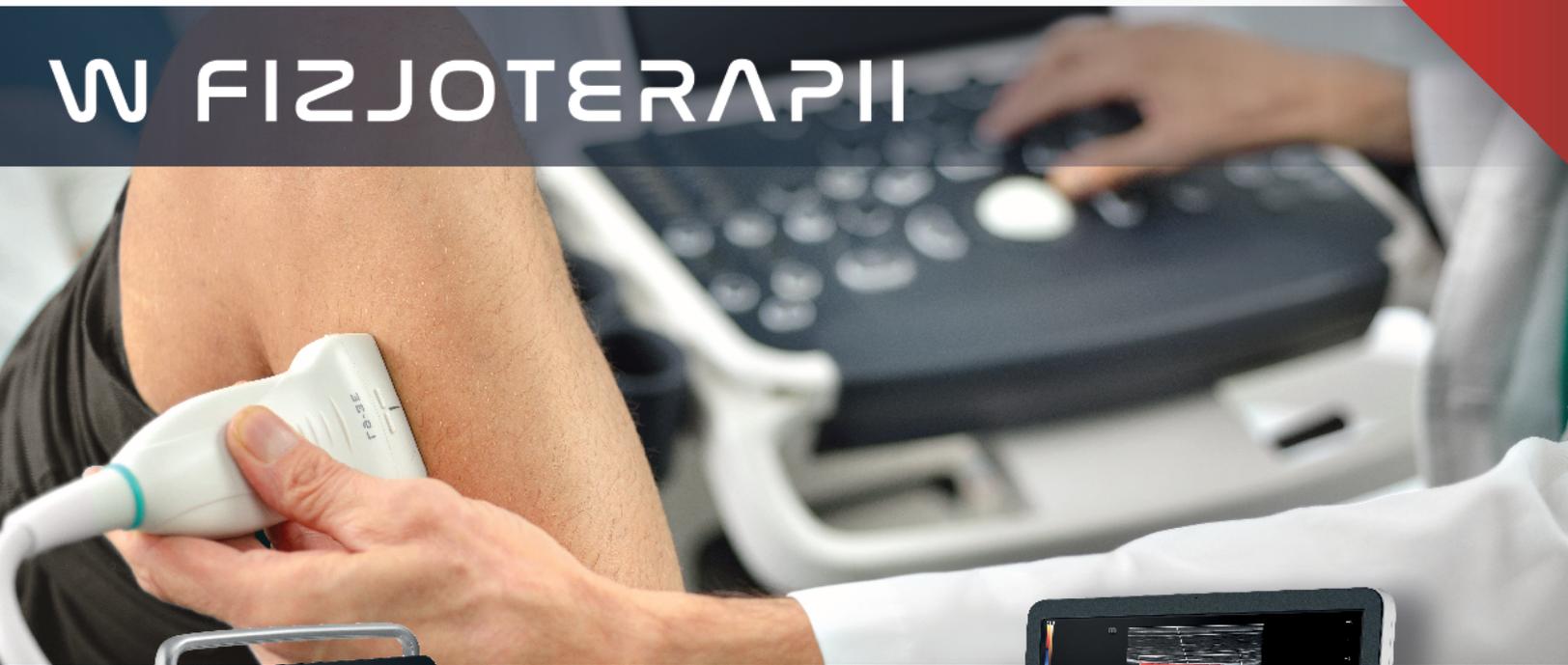
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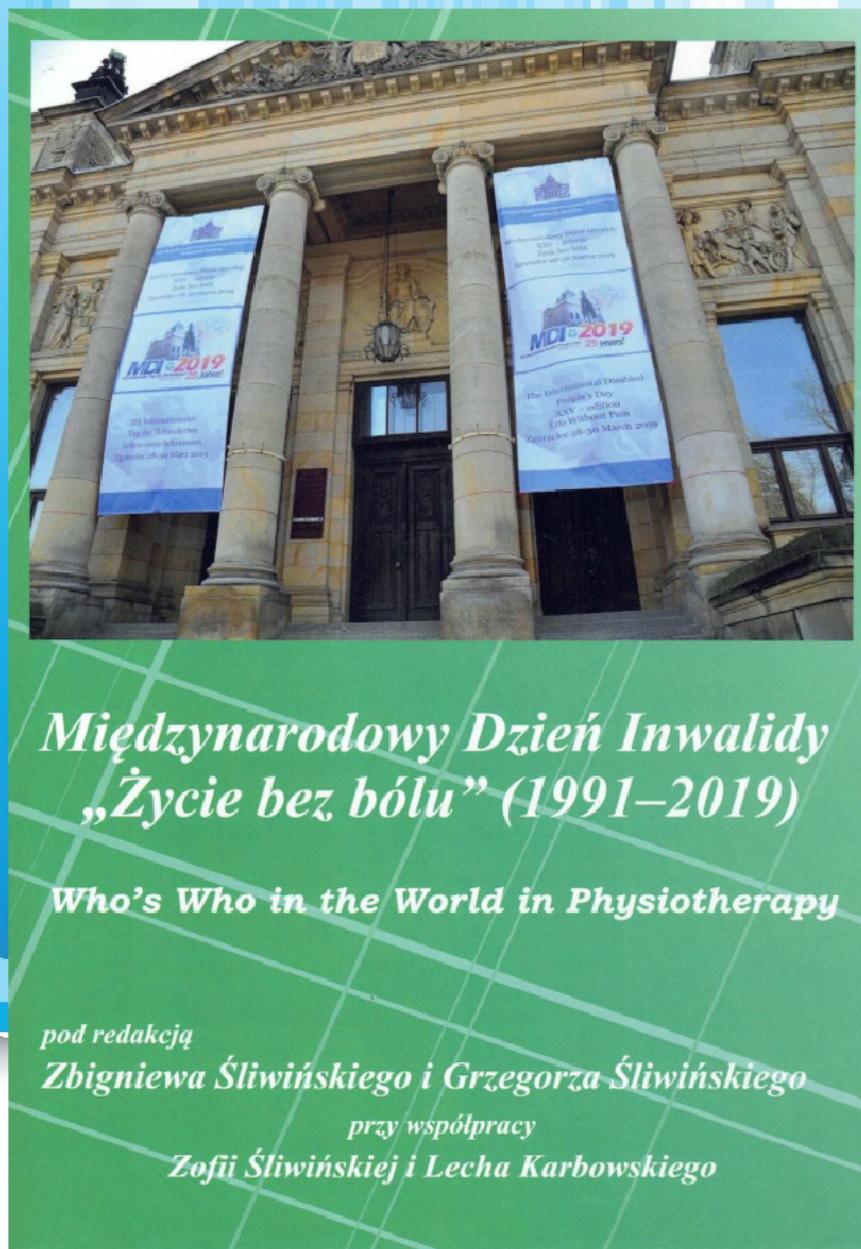
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Influence of biofeedback training time on muscle torque and knee excursion following semitendinosus release in spastic quadriplegic children with cerebral palsy: A randomized controlled trial

Wpływ czasu treningu z biofeedbackiem na moment obrotowy mięśni i ruch kolanowy po uwolnieniu półścięgna u dzieci ze spastycznym porażeniem czterokończynowym z porażeniem mózgowym: randomizowana, kontrolowana próba

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Abstract

Background. Medial hamstring shortening represents a serious common complication in children suffering from spastic quadriplegic cerebral palsy. Objective. The purpose of the study was to examine the efficacy of biofeedback training timing following tendon release in spastic quadriplegic cerebral palsied children. Design. a prospective, single-blind, randomized controlled trial. Setting: several hospitals across Giza and Cairo, where children were operated. Methods. Thirty spastic quadriplegic cerebral palsied children of both genders, with their ages ranged from 7 to 9 years ($\bar{x} = 8.2 \pm 0.86$ yr) were randomly assigned into two equal groups (A and B). The control group (A) was trained using electromyographic biofeedback daily for two weeks after removal of plaster cast, in addition to an hour/ day of a designed physical therapy program, while the study group (B) was trained by electromyographic biofeedback during the immobilization period and for two weeks after removal of the cast along with the same physical therapy program as the group (A). The knee extensors' peak torque and knee excursion angle were measured immediately and two weeks following cast removal by MERAC isokinetic system and electrogoniometer, respectively. Results. The findings exhibited a significant increase ($P < 0.05$) in the peak torque of knee extensors and an increase in knee excursion in the group (B) immediately and after two weeks of the cast removal when compared with the results of the group (A) after the same period. Conclusion. Applying electromyographic biofeedback training at the two-week immobilization period resulted in a strengthening of the quadriceps and maintaining the obtained range of knee extension following semitendinosus muscle release in spastic quadriplegic children with cerebral palsy.

Key words:

cerebral palsy, spastic quadriplegia, biofeedback, dynamometer

Streszczenie

Wstęp. Skrócenie przyśrodkowej części ścięgna podkolanowego stanowi poważne częste powikłanie u dzieci cierpiących na spastyczne czterokończynowe porażenie mózgowie. Cel. Celem badania było zbadanie skuteczności synchronizacji czasu treningu biofeedbacku po uwolnieniu ścięgna u dzieci z porażeniem mózgowym spastycznym z porażeniem czterokończynowym. Projekt. prospektywne, randomizowane, kontrolowane badanie z pojedynczą ślepą próbą. Miejsce: szpitale w Gizie i Kairze, w których operowano dzieci. Metody. Trzydzieści spastycznych dzieci z czterokończynowym porażeniem mózgowym obu płci w wieku od 7 do 9 lat (średnia = $8,2 \pm 0,86$ lat) zostało losowo przydzielonych do dwóch równych grup (A i B). Grupa kontrolna (A) ćwiczyła z wykorzystaniem elektromiograficznego biofeedbacku codziennie przez dwa tygodnie po zdjęciu opatrunku gipsowego, dodatkowo godzinę dziennie zaplanowanego programu fizjoterapii, podczas gdy grupa badana B ćwiczyła za pomocą elektromiograficznego biofeedbacku podczas unieruchomienia okres i przez dwa tygodnie po zdjęciu opatrunku gipsowego wraz z takim samym programem fizjoterapii jak grupa A. Szczytowy moment obrotowy prostowników kolana i kąt wychylenia kolana mierzono natychmiast i dwa tygodnie po zdjęciu odlewu za pomocą systemu izokinetycznego MERAC i elektrogoniometru. Wyniki. Wyniki wykazały istotny wzrost ($P < 0,05$) szczytowego momentu obrotowego prostowników kolana oraz wzrost ruchu kolana w grupie (B) bezpośrednio i po dwóch tygodniach od zdjęcia gipsu w porównaniu z wynikami grupy (A), po tym samym okresie. Wniosek. Zastosowanie treningu elektromiograficznego biofeedback w dwutygodniowym okresie unieruchomienia spowodowało wzmocnienie mięśnia czworogłowego i utrzymanie uzyskanego zakresu wyprostu kolana po rozluźnieniu mięśnia półścięgniastego u spastycznych dzieci z porażeniem czterokończynowym z mózgowym porażeniem dziecięcym.

Słowa kluczowe

porażenie mózgowie, czterokończyn spastyczny, biofeedback, dynamometr

Introduction

Muscle fiber development and growth depend on neuronal, nutritional, and hormonal factors, also initial and continuous patterns of muscle using [1]. Common movement disorders in children suffering from cerebral palsy (CP) involves abnormal muscle tone, the existence of primary reflex patterns, or their build-up involuntary movements, body-consciousness, and body schema disorders caused by deficient sensory information [2].

To adjust for the changing mechanical loads combined with movement in the normal milieu, the extremity muscles of the quadriplegic child perform a range of movements. So, some muscles may be predicted to function differently from others even during steady-speed gait. The reason for this is the differences in the muscle-tendon junction; for example, medial hamstring shortening that may occur due to muscle imbalance in spastic quadriplegic CP manifests in weakness in anti-gravity muscles (quadriceps) [3].

Motor function in subjects with spastic paresis is affected due to the neural injury that causes the paresis and results in a decrease in the voluntary motor unit recruitment. Motor function is also influenced by immobilization of the paretic limb following the neural injury that leads to muscles shortening, joint contracture, and chronic disuse of the paretic limb [4].

Knee flexion deformity, limited knee extension or hamstring contracture muscles is the most common problem at knee joint, which, if left untreated in some patients, causes fixed knee flexion contracture [5]. Knee contractures in CP children are treated by casting, bracing, stretching, or by surgical hamstring tendons lengthening [6].

Tendon lengthening affects knee joint performance due to the change in length-tension relationships of the quadriceps muscle [7]. Distal hamstring lengthening, which is a part of single-event multilevel surgery, is considered the ideal surgical technique for treating knee flexion deformity in CP children [8, 9].

A shortening in muscle length of semitendinosus after surgical lengthening indicates a reduction in the length range of the muscle's active force exertion, while a decrease in the muscle cross-sectional area indicates a reduction in its force production capacity. Following hamstring lengthening, the strength of knee flexor muscles decreases firstly, and then it reaches the pre-surgical strength level nine months following lengthening. This indicates that other knee extensor and hip flexor muscles may compensate for the reduction in cross-sectional area of semitendinosus [10].

Biofeedback is considered a valuable treatment tool; it functions to increase the myoelectric signals and it provides the subject with visual and/or auditory cues regarding their muscles [11]. Since the early 1970s, this technique has been used to help patients with different deficits as it can improve upper limb function, upper extremity nerve lesions, gait, as well as swallowing [12]. As it allows a patient to control his/her muscle activity, so it is considered as an effective tool for post-stroke rehabilitation [13, 14].

Biofeedback training has been applied for more than 50 years in rehabilitation to regain normal motion following injuries [15]. This procedure encourages the perfection of accuracy

during the rehabilitation process; it allows the patient to actively participate in their rehabilitation activities and minimize the healthcare professional supervision during the treatment program. Thus, biofeedback can be combined with different physical therapy modalities to improve their efficacy [16].

Electromyographic biofeedback is a technique that provides feedback about the electrical activity of the muscles and that way helping the subject to modify the tension developed in the muscle. As this technique is not associated with any adverse effects, it can be applied for a longer period in the rehabilitation session. Different disorders have been treated using biofeedback devices. Of them, the effectiveness of biofeedback training has been assessed mostly in knee disorders in orthopedic and sports medicine [17].

Yet, there is a gap in research regarding the best timing to apply biofeedback training following muscle release surgery. Therefore, this paper aimed to detect the effect of electromyography feedback training timing on both knee extension peak torque and knee angle of excursion following medial hamstring lengthening in spastic quadriplegic children with cerebral palsy.

Materials and methods

The study was conducted as a prospective, single-blinded, randomized controlled trial, with its proposal was accepted by the Research Ethical Committee of Faculty of Physical Therapy, Cairo University, Egypt, (No: P.T.REC/012/002487) on 29/9/2019. The trial was also registered at Pan African Clinical Trial Registry (PACTR201911806294013), following the Helsinki Declaration guideline for conducting medical research upon humans. The study lasted for 6 months, starting from February 2020 till August 2020. Before commencing the study, informed consent was obtained from each child's parents, notifying them that they can discontinue at any time.

Randomization / blinding

A computer-generated randomized table was the method used to implement the randomization using the SPSS program (version 16 for Windows; SPSS Inc., Chicago, Illinois, USA). Each child had an identification number, which would be assigned into one of two groups equal in number ($n = 15$). Sequentially numbered index cards were secured in opaque envelopes. An independent blinded researcher opened the sealed envelope and allocated each child to groups. After randomization, none of the recruited children dropped out of the study.

Subjects

A convenience sample of fifty children of both genders with spastic quadriplegic cerebral palsy was initially selected from various Cairo and Giza hospitals, where they were operated, following medial hamstring lengthening surgery. They were first screened for eligibility criteria and readiness to participate then children who met the inclusion criteria contributed to the study, as seen in the flow chart (Fig. 1). Children inclusion was achieved if their age ranged from 7 to 9 years and they were ambulant using walking aids. Children with a spasticity degree of +1 to 2 (indicated by modified Ashworth scale), those having a certain amount of gross motor function arrangement (le-

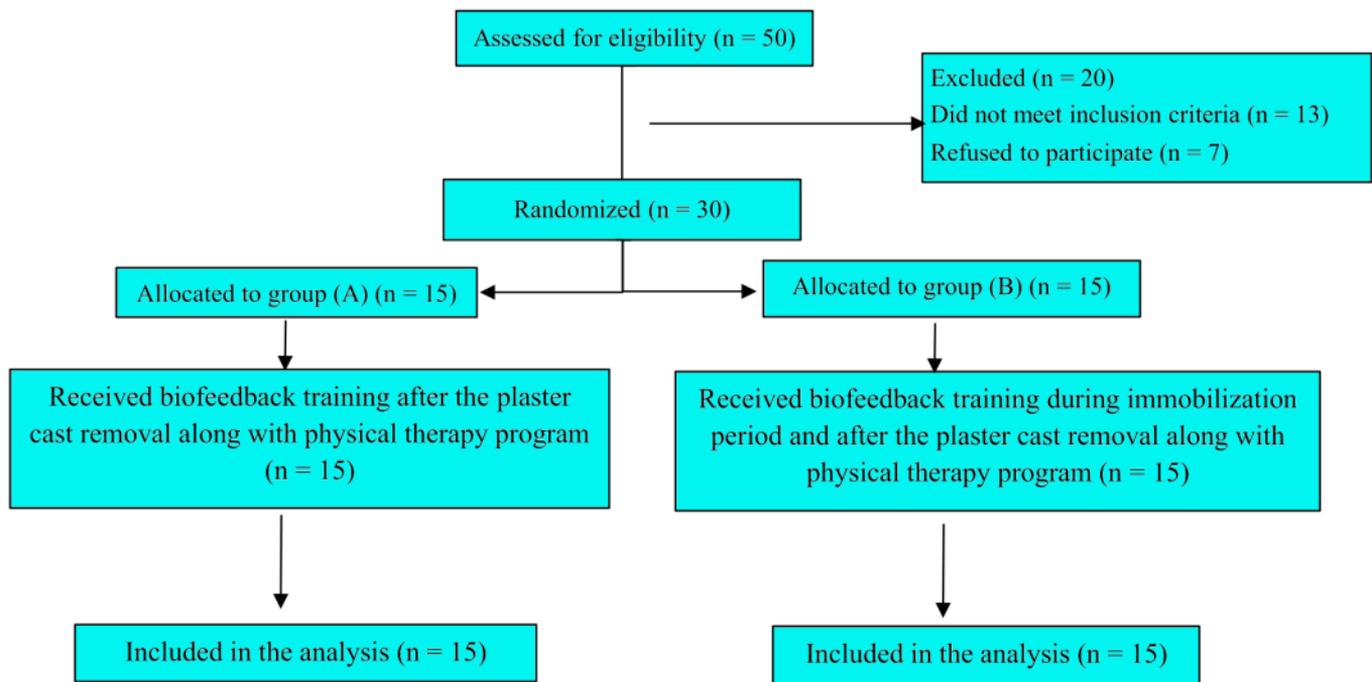


Figure 1. A flow chart for children included in the study across each trial stage

vel II and III), and those having IQ level over 80 according to Stanford Binet scale (able to understand verbal commands) were also included. Children were excluded if they had any other orthopedic deformity, neurological problem, or other syndromes causing the same tightness.

Intervention

Thirty selected children were randomly divided into two equal groups (A and B). Children of the group (A) were trained by electromyographic biofeedback for two weeks to pick up the quadriceps muscle’s signals following plaster cast removal, in addition to a physical therapy program that included neuro-developmental techniques and positioning for one hour /day.

As a preparation for the biofeedback training session, the area to be treated was cleaned and wiped with alcohol to decrease skin resistance. To pick muscle signals, adhesive surface electrodes were used. For recording the signals of vastus medialis oblique muscle, two electrodes were placed 4 cm superior and 3 cm medial to the superomedial border of the patella, while to record rectus femoris muscle’s signals, other electrodes were placed at the junction of the middle and lower third of the thigh, slightly downward and medially angled. The two active electrodes from each channel were placed as close together as possible along with the directions of the fibers of each muscle, and the reference electrode was placed below the tibial tubercle [18].

For biofeedback training, Automove AM 706 biofeedback device, consisting of one cable connected to the machine via a specific plug and three electrodes was used. The therapist explained the procedure to the children and asked them to notice the muscle contraction and try to increase the signals of vastus medialis oblique and rectus femoris muscles while performing exercises. Beforehand of each training session, the

child was instructed to maximally contract knee extensors three times. The average muscle activity of the three trials monitored by the electromyographic biofeedback device was then reduced by around 20% and the new value was determined as their threshold degree [18].

The training protocol involved different biofeedback–facilitated exercises and generally, children were instructed to contract vastus medialis oblique and rectus femoris muscles above their threshold level and maintain that audible signal for 5 seconds. The contraction was held for 5 seconds, followed by relaxation for 10 seconds. Every movement was done for 10 repetitions as one set and a total of three sets of each exercise were given for 5 days/ week over two weeks [18].

For delivering the physical therapy neurodevelopmental techniques, various tumble forms (e.g., wedges, balls, and rollers) were used. Neurodevelopmental techniques have focused mainly on lowering spasticity and promoting more normal movement patterns, all of which were preceded by passive stretching of the muscles of the lower extremity while improving motor functioning [19].

The session began with the children trying to maintain their position on the forearm and hand, progressing to other positions as sitting and semi-kneeling then standing, supported by the therapist, aiming to achieve reduced tone. As soon as the children had been able to maintain the exercise positions, the medical balls, rollers, and wedges were used to produce corrective reactions and train balance, followed by gait training according to the child’s motor developmental degree [20].

Children in the group (B) received electromyography biofeedback training during the immobilization period (two weeks) through windows within the cast and continued training after the removal of the plaster cast for another two weeks along with the same physical therapy program as the group (A).

Assessment of outcome measures

The primary outcomes for this study were knee extension peak torque and knee excursion improvement post-surgical. Children evaluation was carried out in a warm, well-ventilated, and lightened private room. Evaluation of the quadriceps muscle’s peak torque and the knee excursion range was performed by an independent well-experienced blinded assessor immediately following cast removal and two weeks after.

Quadriceps muscle’s peak torque

An isokinetic system, MERAC type was utilized to determine knee extensors peak torque, as it has been seen as the golden standard for measuring muscle performance [21]. It consists of a dynamometer, bench, and a computer unit that allows for data entry, recording as well as providing a printed report. It helps the therapist control the test parameters like speed, torque, and time. The isokinetic system was proved to be valid and reliable, as it has high reliability ranging from a good to an excellent degree in measuring knee extension with an intraclass correlation coefficient (ICC) of 0.89 to 0.98, and ICC of 0.86 to 0.98 for measuring knee flexion, for 95% of the CI [22].

The tested child was positioned in the setting, with knee joints right-angled at the edge of the device bench. Good alignment of body parts was maintained by straps. The knee joint axis of rotation was aligned with the rotation axis of the unit. Then each child was asked to perform three trials of knee extension without resistance, to help accommodate the unit. The child was then asked to do three trials with his/her maximum strength of quadriceps muscle and the mean was calculated [23].

Knee excursion range

An electro-goniometer, consisting of a potentiometer, pivot, and two arms (stationary and movable) was utilized to assess

knee joint excursion, with the potentiometer recording the degree of joint excursion. It is a reliable tool to measure knee joint range as it indicates good reliability with ICC > 0.7 and a standard error of measurement (SEM) of 2.16, regarding intra-rater reliability [24].

To measure knee excursion, the child was sitting at the edge of the bed, with both hips and knees maintained at a right angle. The stationary arm of the goniometer was laterally placed parallel to the thigh, the pivot was placed at the lateral articulation of the knee joint, and the movable arm was placed parallel to the longitudinal axis of the leg. Straps were used for the fixation of the goniometer in place. With the ankle neutrally positioned, children were asked to actively extend the knee for its maximum range. Once the motion was completed, the position was held for a second and the angle between both goniometer arms was recorded [24].

Statistical Analysis

For comparison of age between groups, a t-test was conducted. Sex distribution was compared between groups using the Chi-squared test. Normality of data and group homogeneity were checked using the Shapiro-Wilk test and Levene’s test for homogeneity of variances, respectively. To compare the mean values of knee extensors’ peak torque and knee excursion between groups, a t-test was conducted. The level of significance was set at $p < 0.05$. Statistical analysis was performed by the statistical package for social studies (SPSS) version 22 for windows (IBM SPSS, Chicago, IL, USA).

Results

Participants characteristics

Table 1. shows the subject characteristics of the groups (A &B). There was no significant difference between groups in the mean age and sex distribution ($P > 0.05$).

Table 1. Basic characteristics of participants

Characteristic	Group A [n = 15]	Group B [n = 15]	P-value
Age [years]	8.2 ± 0.9	8.4 ± 0.7	0.471
Sex	Female [N (%)]	7 (0.47)	0.562
	Male [N (%)]	8 (0.53)	

SD – Standard deviation; N – number

Effect of treatment on knee extensors’ peak torque and knee excursion

Within-group comparison

There was a significant increase in knee extensors’ peak torque and knee excursion after 2 weeks of cast removal in the groups (A) and (B) compared with that immediately after removal of the cast ($P < 0.001$). The percent of the increase in knee extensors’ peak torque and knee excursion in group (A)

was 139.12 and 114.81% respectively, (table 2) and that for group (B) was 94.84 and 105.45% respectively, (table 3).

Between groups comparison

There was a significant increase in knee extensors’ peak torque (table 2) and improvement in knee excursion (table 3), immediately after removal of cast and after 2 weeks of cast removal in the group (B) compared with the group (A) ($P < 0.001$).

Table 2. Knee extension peak torque immediately and after two weeks of cast removal in both groups (A & B)

Characteristic	Group A (n = 15) Mean ± SD	Group B (n = 15) Mean ± SD	MD	p-value
Knee extensors' peak torque (N.M.)				
Immediately After cast removal	4.78 ± 2.16	9.32 ± 3.17	-4.54	0.001*
After 2 weeks of cast removal	11.43 ± 4.83	18.16 ± 2.13	-6.73	0.001*
MD	-6.65	-8.84		
% of change	139.12 ↑↑	94.84 ↑↑		
P value**	0.001*	0.001*		

SD – standard deviation; MD – mean difference; p-value – probability value; * Significant difference ($p < 0.05$).

Table 3. Knee excursion immediately and after two weeks of cast removal of both groups (A & B)

Knee excursion (degrees)	Group A (n = 15) Mean ± SD	Group B (n = 15) Mean ± SD	MD	p-value
Knee excursion [degrees]				
Immediately After cast removal	17.76 ± 3.52	29.17 ± 4.39	-11.41	0.001*
After 2 weeks of cast removal	38.15 ± 4.89	59.93 ± 4.87	-21.87	0.001*
MD	-20.39	-30.76		
% of change	114.81 ↑↑	105.45 ↑↑		
P value**	0.001*	0.001*		

SD – standard deviation; MD – mean difference; p-value – probability value; * Significant difference ($p < 0.05$).

Discussion

It is believed that knee extension and its control found to be challenging following semitendinosus release in children with spastic quadriplegic CP and it is essential for gait performance, if disabled it will affect gait [25]. It is a neuromuscular disorder that affects 1 in 400 children and causes limitation of daily living activities. Essential elements to improve function are feedback and repetition. Feedback about the performance sent back to the subject (e.g., biofeedback) can be a potent modality for improving autonomy and self-efficacy [26].

The results of this research revealed that there was a significant difference in the favor of the group (B). It was noticed that both groups had greater range and better gait following two weeks after cast removal than immediately after removal.

Gait disorders in children with CP firstly lead to functional deformities that later become structural. These deformities extremely increase energy consumption and thus diminish function [27]. Children with CP usually have limited selective motor control that causes limitations in motor function. Pathological gait in children with CP can improve in a rapid response to visual biofeedback [28]. EMG biofeedback can be used to either increase activity in weak or paretic muscle or to reduce tone in a spastic muscle. Electromyographic biofeedback has been used in both musculoskeletal and neurological rehabilitation [11]. A previous study showed that two children with CP treated using EMG

biofeedback showed improved toe clearance during the swing phase of gait and they learned the ability to recruit and relax the anterior tibialis muscle [29].

Reviewing the findings of this work, the improvement in the values of peak torque of knee extension and knee strength immediately following cast removal between both groups in the favor of group (B) clarified that EMG feedback training improves motor connections and assists efferent's pathways.

These results were consistent with the work of Dursun and colleagues, [30] who evaluated the effectiveness of biofeedback treatment on gait function in children with CP. They demonstrated that children who received biofeedback showed significant improvements in muscle tone and ankle range of movement when compared to children who received the exercise program only. Also, gait showed statistically significant progress in both groups, but the biofeedback group was superior to the exercise-only group.

In the same way, a profound increase was seen in mean values of all variables following 14 days of cast removal between both groups in the favor of group (B). This can be because biofeedback provides biological information to patients in real-time that would otherwise be unknown. This information can be expressed as augmented or extrinsic feedback; the unit provides the user with extra data, above and beyond the data that is naturally available to them as opposed to the sensory (or intrinsic) feedback that gives self-generated information to the user from various intrinsic

sensory receptors [31]. Thoughtful biofeedback model can strengthen the confidence in the effect of biofeedback interventions for facilitating motor rehabilitation in people with CP. If biofeedback is given too frequently, it may prevent the child from learning independently so the therapist should use consistent and concurrent feedback to improve simple/specific motor activities [32].

This work presents significant reliable findings with many strength aspects. This is the first study to examine the effect of biofeedback training timing following hamstring release operations in spastic quadriplegic children. Also, the study employs many objective tools for assessing the outcomes as the isokinetic system and electro-goniometer, both of which are valid and reliable tools that are extensively used in research. However, the study had weaknesses too, as the children were recruited following the surgery, so they could not be evaluated before the procedure.

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Conclusion

From the current results, it could be observed that the use of electromyographic feedback training to handicapped CP patients following semitendinosus lengthening surgery resulted in vital enhancements of the peak torque of knee extension and the range of knee excursion. These findings suggest that biofeedback training is a beneficial adjunct to the rehabilitation of post-operative semitendinosus tendon lengthening in quadriplegic cerebral palsied children. Also, applying biofeedback training at earlier stages following the operation could significantly improve postoperative outcomes.

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