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Effect of Plyometric Training on Shoulder Strength and Active Movements in Children with Erb's Palsy

Maya Galal Abd Al-Wahab[1]*, Elham El-Sayed Salem[1], Eman Ibrahim El-Hadidy[1] and Hassan Magdy El-Barbary[2]

[1]Department of Physical Therapy for Growth and Developmental Disorders in Children and its Surgery, Faculty of Physical Therapy, Cairo University, Egypt.[2]Faculty of Medicine, Cairo University, Egypt

Abstract: ***Background:*** Children with Erb's palsy often have residual weakness of the affected shoulder musculature and limitation in arm movements resulting in difficulties of their functional activities.
Aim: This study aimed to determine the effect of plyometric training on shoulder strength and active movements in children with Erb's palsy. ***Methods:*** A total of 40 children with Erb's palsy (3-6 years) were randomly assigned into two groups; a control group received a selected physical therapy program and a study group received the same program as the control group in addition to plyometric training. All children were assessed pre and post 6 successive weeks of training using hand-held dynamometer for shoulder flexors and external rotators strength and active movement scale for active shoulder flexion and external rotation movements.
Results: Significant improvement was found in all measured variables of the control and study groups when comparing their pre and post treatment mean values except for the active shoulder external rotation movement of the control group. Comparing the post treatment mean values of all measured variables showed no significant difference between both groups, while the percent of improvement was greater in the study than the control group in all the measured variables.
Conclusion: Plyometric training is an effective training for improving strength and active movements in children with Erb's palsy.
Keywords: Plyometric training, Erb's palsy, shoulder strength, active movement scale.

1.Introduction

Erb's palsy is the most common birth injury of the brachial plexus seen in 46% of children with obstetric brachial plexus palsy (OBPP) and affecting the upper trunk roots (C5, C6) of the plexus[1,2]. Although Erb's palsy has the best prognosis of recovery, about 25 percent of children with Erb's palsy have some degree of residual deficits including weakness, contracture, gleno-humeral joint deformity and limb length discrepancy in addition to the influence on child's global development and family life[1,3]. Treatment for Erb's palsy includes physical and occupational therapy and surgery in some cases, many treatment programs have been proposed to increase the strength and active range of movement of the affected limb and also to improve the functional recovery[4]. Plyometric training is a nontraditional type of resistance training based on the stretch shortening cycle; emphasizing muscle loading during eccentric muscle action, followed by quick rebound concentric action[5].

Plyometric training is safe and effective for children with average or above average motor competence in all phases of maturity when age-appropriate program design, gradual progression and qualified supervision are used[6,7]. Plyometric program should be consistent with the child's needs, interests, and abilities. It is always better to underestimate child physical abilities rather than overestimate and risk negative consequences such as dropout or injury[8]. Previous research has supported upper extremity plyometrics increases in power[9,10]. Plyometrics is implemented in later phases of rehabilitation and is more effective when applied in combination with other types of training; also it adds fun for children who tend to dislike prolonged periods of monotonous training[11,12].

Plyometrics commonly used for young children as a method of conditioning to improve fitness and sports performance[12]. Few present studies used plyometrics as a treatment method for children with disability as in children with cerebral palsy, Down syndrome and neurofibromatosis[13,14,15]. No studies were found on the use of plyometric training for children with Erb's palsy, the purpose of this study was to determine the effect of plyometric training on shoulder strength and active movements in children with Erb's palsy. We hypothesized that the shoulder strength and active movements would be different after treatment in the control and study groups.

2. Subjects and methods

2.1. Subjects

This study was approved by the Ethics Committee of Faculty of Physical Therapy, Cairo University and was conducted in the period from March 2015 to December 2015. A total of forty children with Erb's palsy from both sexes were selected from the Outpatient Clinic of Pediatrics, Faculty of physical therapy, Cairo University and the National Institute of Neuromuscular System. Children were eligible to participate in this study if they met the following inclusion criteria:

- Diagnosed as obstetric Erb's palsy (C5-6).
- Aged between 3 and 6 years.
- Had grade 3 or 4 of Mallet classification in initial evaluation[16].
- Able to perform one or two sets of six to ten repetitions of a preparatory low intensity exercise[17] (wall push-up or medicine ball chest pass).
- Able to understand and follow instructions included in the evaluation and training procedures.

Children were excluded from the study if they had any of the following:

- Contractures or fixed deformities in their arms.
- History of fractures or previous surgical intervention in the upper extremities.
- Visual or auditory impairment.

Forty children had met the inclusion criteria. Parents of all eligible children signed an informed consent form authorizing the child’s participation in this study. Randomization was used for children allocation using opaque sealed envelope containing a card for either the control or study group. The control group received only a selected physical therapy program and the study group received the same selected program as the control group in addition to an upper body plyometric training program.

From the initial 40 children participated in the study 6 children dropped out (4 in the control group and 2 in the study group) owing to family reasons or loss of interest. Details of children participation are shown in Figure 1. The general characteristics of children are presented in Table 1.

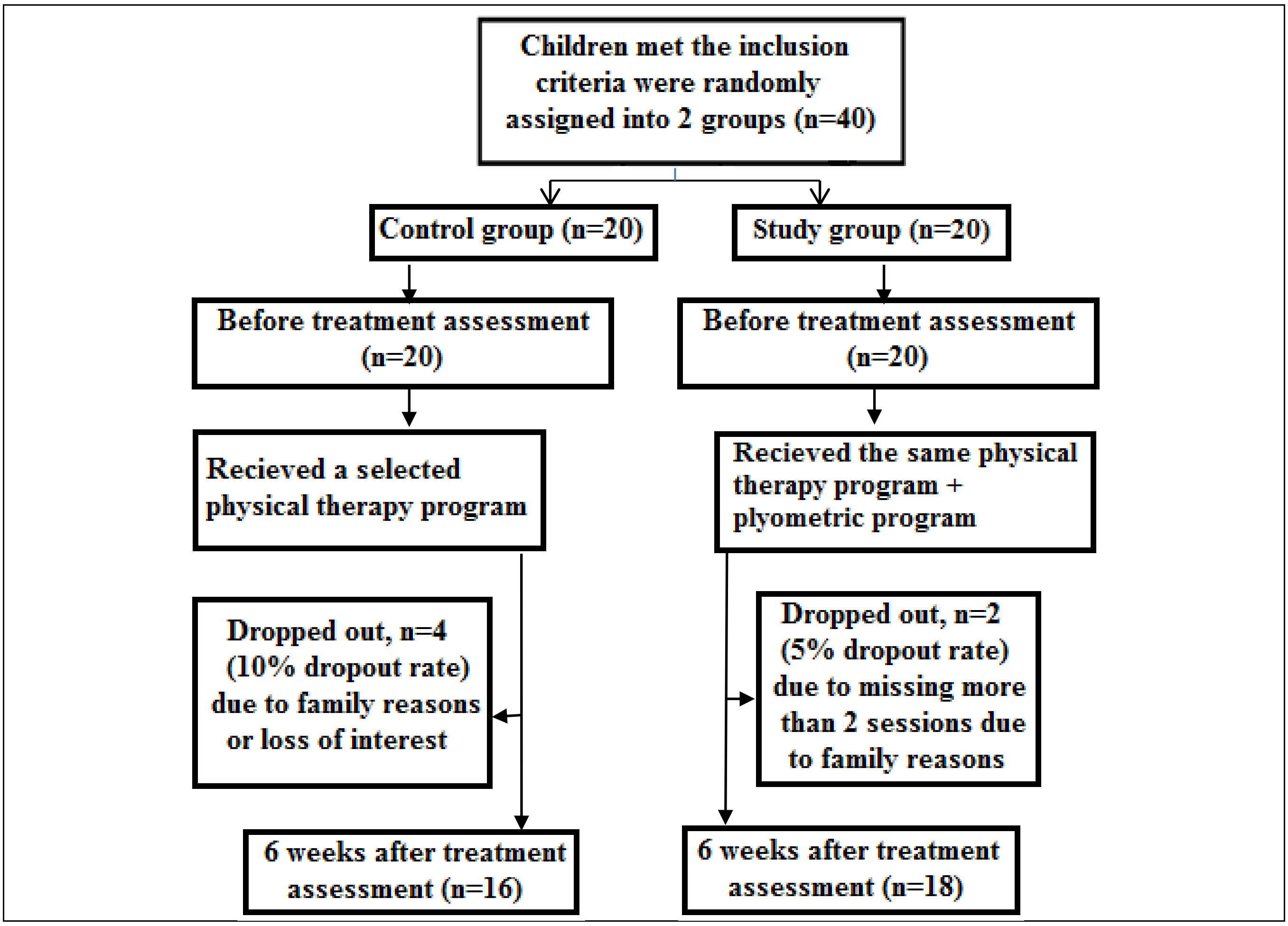

Fig. 1: Flow chart showing children participation in this study.

Table 1- General characteristics of the participating children in both groups.

Characteristics	Control Group (n=16)	Study Group (n=18)
Age (years) ($\bar{X}$ ±SD)	4.3±0.68	4.4 ± 0.63
Gender (girls/boys)	8 girls 8 boys	10 girls 8 boys
Involved side (right/left)	10 right side 6 left side	11 right side 7 left side

2.2. Methods

2.2.1. Methods for evaluation

2.2.1.1. *Mallet classification*. It was used only for the selection of children of both groups. Child was asked to actively perform 5 shoulder movements: abduction, external rotation, placing hand to nape of neck, hand to back, and hand to mouth. The total score of the 5 movements was graded on 5-grade scale from 1 (poor function) to 5 (excellent function). Children who had grade 3 or 4 were included in this study.

2.2.1.2. *Hand held dynamometer (HHD)*. All children were assessed pretreatment and post 6 successive weeks of treatment using Lafayette manual muscle tester (Model 01163) for objective quantification of isometric muscle strength of shoulder flexors and external rotators.

2.2.1.3. *Active Movement scale (AMS)*. The active shoulder flexion and external rotation movements were selected to be assessed in all children pre and post treatment using the AMS; it is a functional scale evaluates 15 joint movements from the shoulder to hand on an eight-grade scale (0 meaning no muscle contraction when gravity is eliminated and 7 meaning full range against gravity) to quantify active movement[18].

2.2.2. Methods for treatment

Medicine ball. A 1 kg weighted plyoball was used for plyometric training of the study group.

3. Procedures

3.1. Procedures for evaluation

All children were assessed pretreatment and 6 successive weeks post-treatment by the same therapist. Data of each child was documented in a follow-up sheet that includes child's personal data, Mallet score, handheld dynamometer strength measurements and AMS scores.

3.1.1. Lafayette Hand held dynamometer (HHD) was used to measure the maximum isometric muscle strength for the affected shoulder flexors and external rotators. Before starting, movement was demonstrated by the examiner and each child performed two warm-up trials at submaximal effort. The transducer was then positioned on the limb and the child performed 3 maximal efforts of 5 seconds each with 30 seconds rest between trials. Instructions and verbal encouragement were given to children to push as hard as they could during the test. Examiner resisted a maximal voluntary contraction done by the child which is the isometric force.

Shoulder flexors strength was measured from supine position with the shoulder flexed 90° in neutral horizontal adduction and the dynamometer was placed just proximal to the elbow. Shoulder external rotators strength was measured from supine position with the arm at side, shoulder abducted 45°, elbow flexed to 90°, forearm in the mid position. The dynamometer was placed just proximal to wrist joint on extensor surface of forearm.

3.1.2. The active movement scale (AMS) (Appendix I) was used to assess the active shoulder flexion and external rotation movement of the affected shoulder. Movement is quantified on an eight-point ordinal scale, with 0 equating to ‘‘no contraction visible’’ and 7 being ‘‘full motion’’ present (Appendix). General guidelines were followed during the use of AMS; score 4 (full range of motion with gravity eliminated) must be achieved before higher score can be assigned; movement grades are assigned within the available range of passive motion.

Appendix I

The Active Movement Scale

Observation	*Muscle Grade*
Gravity eliminated	
No contraction	0
Contraction, no motion	1
Motion ≤ 1/2 range	2
Motion > 1/2 range	3
Full motion	4
Against gravity	
Motion ≤ 1/2 range	5
Motion > 1/2 range	6
Full motion	7

3.2. Procedures for treatment

All children received 2 sessions on nonconsecutive days per week for 6 weeks. The control group participated in a selected physical therapy program only and the study group received the same selected physical therapy program and participated in a plyometric training program designed for the upper extremities and focusing on strengthening the shoulder muscles.

3.2.1. The Control Group

Children included in this group received a selected physical therapy program (~45min) in the form of:

-*Stretching exercises* for tight shoulder internal rotators; long head of biceps muscle; wrist flexors. For each stretch therapist stretched the tight muscle three times per session with a hold of 15-20 seconds at the end of every stretching exercise.

-*Isotonic resistive exercises* for weak scapular retractors, shoulder flexors and external rotators, elbow flexors and extensors, forearm supinators and wrist extensors, with manual leading resistance. For each exercise the child performed 8-10 repetitions per set and 3 sets per session.

-*Approximation by hand weight bearing positioning* to improve proximal control of the affected limb by weight bearing on extended arm from different positions as side sitting, quadruped and tripod positions.

3.2.2. The Study Group

Children of this group received the same selected physical therapy program as the control group followed by 5-minute warm-up of dynamic flexibility exercises (trunk rotation and side bending with plyoball), administration of the of plyo push-ups and plyoball throw exercises, then a 5-minute cool-down activity.

The plyometric program (Appendix II) was developed using the National Strength and Conditioning Association guidelines for strength training in children and youth and taking into consideration the recommendations of the American College of Sports Medicine and the American Academy of Pediatrics[8,19,20]. The plyometric training program volume (total session work) ranged from 60 to 80 per session; increased gradually throughout the 6 weeks of the program. The program consisted of 2 to 3 sets of 5 up to 15 repetitions of upper-extremity exercises (plyo push-ups and throw exercises). Children were provided with adequate time (2-3 minute) for recovery between sets. The plyometric program lasted about 30 min.

Appendix II

Plyometric program for the study group

Week	Plyometric Exercises	Sets X Reps	Volume
1st week	Plyo push-up against wall Two-hand chest pass + Plyoball (Standing)	3 x10 3 x10	**60**
2nd week	Plyo push-up against wall Two-hand chest pass +Plyoball (Standing) Two-hand side throw +Plyoball (Standing)	2 x15 2 x10 3 x5	**65**
3rd week	Plyo clap push-up against wall Two-hand chest pass +Plyoball (Seated) Two-hand side throw +Plyoball (Standing)	3 x10 2 x10 2 x10	**70**
4th week	Plyo clap push-up against wall Plyoball arch chop Two-hand underhand side throw +Plyoball (Standing)	3 x10 3 x10 3 x5	**75**
5th week	Bench Plyo push-up Two-hand side throw +Plyoball (Seated) Slams +Plyoball	2 x15 3 x10 2 x10	**80**
6th week	Bench Plyo push-up Two-hand side throw +Plyoball (Seated) Two-hands wall throw +Plyoball	2 x10 3 x10 3 x10	**80**

4. Statistical analysis

Descriptive data were calculated for all measured variables. The raw data of each variable measured during this study were statistically treated to determine the mean and standard deviation for the two groups and the multiple pair wise comparison tests (Post hoc tests) were calculated for each variable to assess group differences for the variables of interest including shoulder flexors and external rotators strength and active shoulder flexion and external rotation movements. Statistical analyses were carried out using SPSS version 18 (SPSS, Inc., Chicago, IL) and statistical significance was set at $p < 0.05$.

5. Results

The two groups did not differ significantly at baseline in the general characteristics (Table 1) or the mallet score ($p>0.05$).The obtained results in this study revealed no significant difference ($p>0.05$) between the pretreatment mean values of the control and study groups in all measured variables, while a significant improvement was observed in all measured variables of the two groups when comparing their pre and post treatment mean values except for the active external rotation shoulder movement of the control group. Results also showed no significant difference ($p>0.05$) between both groups the for post treatment mean values of the measured variables, while the percent of improvement was greater in the study group in all the measured variables as shown in Table 2 and 3.

Table 2- Comparison of the pre and post treatment mean values in each group

Groups and measured variables	Pre-test $\overline{X}$ ± SD	Post-test $\overline{X}$ ± SD	P-value	Significance	Percent of improvement
Control group					
Shoulder Strength					
Flexors	3.15±0.72	3.47±0.83	0.000	S	10.15
External Rotators	2.40±0.65	2.61±0.68	0.000	S	8.75
Active Movements					
Flexion	5.18±0.40	5.54±0.52	0.028	S	6.94
External Rotation	4.27±0.46	4.54±0.52	0.078	NS	6.32
Study group					
Shoulder Strength					
Flexors	3.37±0.60	3.83±0.65	0.000	S	13.64
External Rotators	2.6±0.62	2.89±0.65	0.000	S	11.15
Active Movements					
Flexion	5.23±0.43	5.76±0.59	0.001	S	10.13
External Rotation	4.46±0.51	4.84±0.55	0.01	S	8.52

$\overline{X}$ =Mean SD=Standard Deviation P-value=Probability Value S=Significant NS=non-significant

Table 3- Comparison between the post treatment mean values of both groups

Groups variables	Control group $\overline{X}$ ± SD	Study group $\overline{X}$ ± SD	P-value	Significance
Shoulder Strength				
Flexors				
External Rotators	3.47±0.83	3.83±0.65	0.24	NS
Active Movements	2.61±0.68	2.89±0.65	0.329	NS
Flexion				
External Rotation	5.54±0.52	5.76±0.59	0.345	NS
	4.54±0.52	4.84±0.55	0.188	NS

$\overline{X}$ =Mean SD= Standard Deviation P-value= Probability Value NS= non-significant

4. Discussion

Loss of functional movement is a common sequel of OBPP related to muscle contractures and motor weakness, compromising quality of life[22]. This study was conducted to determine the effect of plyometric training on shoulder strength and active movements in children with Erb's palsy. The participating children in this study were chosen with age range from 3 to 6 years old to be able to perform plyometric training and follow instructions. Mallet classification was used for the selection of children; it is a well-defined reliable scale to quantify global shoulder function[23]. The Lafayette handheld dynamometer was used in this study for quantification of muscle strength as it has acceptable to high reliability in clinical setting and it was stated that the isometric muscle force of two year old and older children can be reliably measured with a hand held dynamometer[24]. Shoulder flexion and external rotation were selected because it is the most commonly affected in children with Erb's palsy leading to many functional activities limitations[25,26]. The AMS was used in this study for quantification of active shoulder movements, it has moderate to excellent reliability when used on children with OBPP from 1 month to 15 year old and there was evidence on its strong psychometric properties[19,23,27].

Strength gains can be achieved through traditional training methods, as the use of manual resistance and weights, or through functional training methods as plyometric training. Upper extremity rehabilitation programs had incorporated plyometric activities in order to promote restoration of neuromuscular control and functional joint stability[28]. A 6-week plyometric training program was designed for children with Erb's palsy in this study to add enjoyment and motivation into their treatment by making strengthening exercises as play activities. Many plyometric movements actually similar to movements that are encountered in the normal play of children; no specific strength level is needed to begin such programs[29].

The results of this study come in consistent with other studies that strongly suggested that plyometric training has an effect on strength and power in children[12,17,30,31]. Plyometrics can increase child’s power production and speed of movement by conditioning the nervous system to react more quickly to the stretch-shortening cycle (SSC). The use of SSC gain more power output because of releasing the elastic energy stored in the muscles. Plyometric movement needs less motor units and less oxygen utilization to achieve force compared to concentric or eccentric contractions alone; that allows recruitment of the additional motor units to produce more force and makes muscles more resistant to fatigue[15,32].

Results of this study showed significant improvement in active shoulder flexion and external rotation for both groups in favor for the study group; that come in consistent with other studies found improvement in motor performance skills observed with plyometric training[8,12,13].

The significant improvement in the active shoulder external rotation movement found in the study group only may be explained by what was stated about the variation in muscle length and shoulder weakness found in children with Erb's palsy that alters the dynamic shoulder stability and may account for group differences in the scapulohumeral pattern[33]. Incorporation of plyometric exercises in rehabilitation is thought to improve neuromuscular control, proprioception and kinesthesia, which are beneficial to functional joint stability[27]. The current study findings agree with previous studies recommended the addition of plyometric training to resistance training in rehabilitation programs for enhancing power[28,30].

However results of this study revealed greater percent of improvement in shoulder strength and active movements for the study group, non-significant difference between both groups was found; this may be attributed to the possibilities that exercises were novel to children, they were not used to train with a weighted ball and this decreased the velocity of training motion as child might focus on doing correct technique. The prolonged amortization phase decreases the ability of muscles to use the stored elastic energy and the stretching of the muscle spindles to create the desired training response.

The selected upper extremities plyometric exercises in this study were limited to low and moderate intensities only and no high intensity one-hand throws were used to avoid the risk of overestimation of children abilities that risk negative consequences, in addition that the two-hand plyoball exercises can be beneficial to children with Erb's palsy to encourage bilateral hand use; as most activities which can be done with one hand, are not a problem, as children using their non-involved hand.

Limitations of this study were the lack of blinding and real randomization. It was practically impossible to carry out blinding as all of the evaluative and therapeutic procedures were executed by the same therapist. As for real randomization, patients were enlisted to this study over the course of 10 months.

This study added a new concept of using plyometric training in the treatment of children with Erb's palsy that was not present in previous studies. This study suggest incorporating plyometric training program with appropriate safety guidelines into the treatment of children with Erb's palsy as an effective enjoyable training to gain strength and improve active movements.

5. Conclusion

Plyometric training is an effective training for improving strength and active movements in children with Erb's palsy.

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Conflict of interest

No conflict of interest was declared by the authors.

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