



Timing of rehabilitation in children with obstetric upper trunk brachial plexus palsy

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Abstract

Objectives The initiation timing of rehabilitation in children with obstetric brachial plexus palsy is controversial. The aim of the present study is to evaluate the effectiveness of rehabilitation timing to the functional outcomes of patients with obstetric upper trunk brachial plexus palsy.

Material and methods Twenty-nine patients, who did not previously received any rehabilitation programme but attended our outpatient clinic, were included for the study. The electrophysiological findings, obstetric characteristics, and demographic features of the patients were recorded. The range of motion (ROM) of shoulders, elbows, and wrists and the strength of the muscles associated with these joints were evaluated. Modified Mallet Scale (MMS) was used for functional evaluation. A 4-week rehabilitation programme was performed twice at 2-month intervals. Patients were divided into three groups according to their ages as follows: 1–3 years old (group 1), 3–5 years old (group 2), and 5–7 years old (group 3). The ROMs, muscle strengths, and MMS scores of the patients were all evaluated.

Results Two out of 29 patients were female (6.9%) and 27 were male (93.1%). All 29 patients had right upper extremity palsy (100%). The MMS scores, ROMs, and muscle strength of the upper extremities had improved in all the groups following the standardized rehabilitation programme.

Conclusions A rehabilitation programme is the best choice of treatment before surgical procedures in patients with mild to moderate obstetric upper trunk brachial plexus palsy regardless of age and the initiation time.

Keywords Brachial plexus · Upper extremity · Rehabilitation

Introduction

Obstetric brachial plexus palsy (OBPP) can be defined as the traction lesion of brachial plexus during delivery. The incidence of OBPP ranges from 0.5 to 3 per 1000 births [5]. Unfortunately, the incidence increases per year in accordance with the improvement of life support for newborns [2]. OBPPs are generally unilateral, involve the right arm, and can be anatomically classified as upper (C5–6), mid (C7), and lower (C8–T1) trunk lesions [20]. Electrophysiological studies are useful for diagnostic and prognostic assessment as well as

preoperative evaluation and are certainly recommended in the 1–3-month age group [9, 19].

Total functional recovery rates for all OBPPs range from 13 to 97% [8]; therefore, the cutoff lines between conservative and surgical treatment options are unclear. Although certain indications for surgical treatment are defined, the issue remains controversial [10]. Particularly, the high spontaneous recovery rates for upper brachial trunk lesions lessen the requirement for surgery.

The reasons for conservative treatment include the prevention of joint contractures and the prohibition of upper extremity neglect by improving motor function [15]. Although surgical treatment procedures have been discussed previously from different viewpoints in literature, there is insufficient data about the timing and duration for conservative treatment modalities [16, 21]. The aim of the present study is to evaluate the effect of rehabilitation timing to functional outcomes of patients with obstetric upper trunk brachial plexus palsy.

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Material and method

Twenty-nine patients, who had not previously received any rehabilitation programme but who attended our outpatient clinic, were included for the study. Patients under the age of 12 months or more than 7 years old, who had not previously received any rehabilitation programme and/or undergone any surgical procedure, who had a progressive or non-progressive neurological disorder or metabolic disease, who had additional upper extremity trauma, and who had brachial plexus palsy due to non-obstetric causes were all excluded. Patients who had mid and/or lower trunk palsy or who had mild partial or total axonal degeneration electrophysiologically were also excluded. The study was approved by the Ethics Committee of our Hospital, conducted in accordance with Helsinki Declaration criteria, and signed informed consent of the patients was obtained.

The demographic features and perinatal histories of the patients including their age, gender, birth weight, means of delivery and presentation, maternal age, and gestational comorbidities such as diabetes mellitus and infection were recorded.

Electroneuromyographic evaluation (ENMG) of the patients was performed in our clinic by Medelec Synergy 10-channel electroneuromyography device (Oxford, UK) according to Oh protocol [13].

Range of motions (ROM) including flexion and abduction of the shoulder, flexion and supination of the elbow, and flexion and extension of the wrist were measured by goniometer and then recorded. The muscle strength of the associated joints was evaluated according to the Medical Research Council Scale (MRCS) and scored from 0 to 5 (0 no constriction, 1 observed mild constriction, 2 constriction by ground force inhibition, 3 active motion against ground force, 4 active motion against ground force and resistance, 5 full muscle strength).

The functional status of the patients was evaluated by Modified Mallet Scale (MMS) [12]. According to MMS, shoulder, elbow, and wrist function is evaluated by five functional activities and scored from 1 to 25. Lower scores are associated with better functional activity.

Caregivers of the patients were given different information about positioning when asleep or awake for every age group. They wanted to support the involved muscles with pillows in a tightened position during sleep and let the patient use the involved extremity functionally with toys when awake. They were also informed about developmental postural exercises suitable for every age group including rotation, stretching, and sitting to avoid functional asymmetry.

The physical therapy programme was structured as follows: (1) local hot pack application to the affected extremity for 10 to 20 min; (2) passive ROM exercises

including flexion, extension, abduction, and adduction for the shoulder; flexion, extension, supination, and pronation for the elbow; and flexion and extension for the wrist twice a day with 2 sets and 20 repetitions; (3) galvanic current for 20 min with a 5-min interval five times a week; and (4) occupational therapy for sensory motor muscle training twice a day for 20 min. This 4-week programme was performed twice at 2-month intervals. The caregivers were also informed about a home exercise programme including the same passive ROM exercises during the interval.

Patients were divided into three groups according to their age at which they started the physical therapy programme as 1–3 years old (group 1), 3–5 years old (group 2), and 5–7 years old (group 3). ROMs and muscle strength of the associated joints and MMS scores of the patients were evaluated before and after the rehabilitation programme.

Statistical analysis

Descriptive analyses were performed as average $\pm$ standard deviation (ave $\pm$ SS) for continuous variables and as a percentage (%) for nominal variables. Statistical significance between the groups was evaluated using the ANOVA test for dependent variables and the Kruskal-Wallis test for independent variables. Nominal variables were evaluated by the chi-squared test. Significant difference between repeated measurements in the groups was evaluated by the Friedman and Wilcoxon rank test. $p < 0.05$ values were accepted as statistically significant.

Results

Of all our patients, 2 were female (6.9%) and 29 were male (93.1%). The average age of the patients was 3.87 ± 1.80 years. Ten of the patients were in group 1 (1–3 years old) (34.5%), 10 were in group 2 (3–5 years old) (34.5), and 9 were in group 3 (5–7 years old) (31%). The involved side was the right arm in all patients (100%). The average birth weight of the patients was 3.85 kg (4.06 ± 0.99). The demographic features and obstetric characteristics of the patients are given in Table 1.

There was no significant difference between the demographic features and obstetric characteristics of the patients ($p > 0.05$). Twenty-six patients were diagnosed as having moderate (89.7%) and three patients were diagnosed as having moderate-severe (10.3%) partial axonal degeneration by ENMG evaluation. The ROMs and muscle strength according to MRCS and MMS scores of the patients before treatment are given in Table 2.

There was no significant difference between ROMs and muscle strength according to MRCS and the MMS scores

Table 1 The demographic and obstetric features of the patients

	Group 1 (<i>n</i> = 10), <i>n</i> (%), ave ± SD	Group 2 (<i>n</i> = 10), <i>n</i> (%), ave ± SD	Group 3 (<i>n</i> = 9), <i>n</i> (%), ave ± SD	<i>p</i>
Sex				
Female	0	2 (20)	0	
Male	10 (100)	8 (80)	9 (100)	0.536
Age (years)	2.70 ± 0.75	4.30 ± 0.42	5.83 ± 0.25	0.001
Effected side				
Right	10 (100)	10 (100)	9 (100)	1.000
Left	0	0	0	
Delivery				
Spontan vaginal	0	0	0	
Cesarean	10 (100)	10 (100)	9 (100)	1.000
Forceps/vacuum	0	0	0	
Presentation				
Head	9 (90)	8 (80)	6 (66.7)	
Back	1 (10)	2 (20)	3 (33.3)	0.867
Head and shoulder				
Birth weight (kg)	4.11 ± 0.84	4.21 ± 1.48	3.96 ± 0.32	0.673
Advanced maternal age	4 (40)	5 (50)	7 (77.8)	0.129
Maternal comorbidity	1 (10)	1 (10)	2 (22.2)	0.918

Italic numbers represent statistically significant values

ave ± SD average ± standart deviation

of the patients before treatment ($p > 0.05$). ROMs and muscle strength according to MRCS and the MMS scores of the patients after treatment are given in Tables 3, 4, and 5.

In group 1, all ROMs of the shoulder, flexion, and supination of the elbow were significantly improved by the second month compared to the baseline evaluation ($p = 0.011$ for shoulder flexion, $p = 0.015$ for shoulder abduction, $p = 0.036$ for shoulder internal rotation, $p = 0.037$ for shoulder external rotation, $p = 0.038$ for elbow flexion, and $p = 0.025$ for elbow supination). Shoulder flexion ($p = 0.011$), shoulder abduction, and elbow supination were significantly improved by the end of the treatment period when compared to the second month evaluation ($p = 0.11$ for shoulder flexion, $p = 0.007$ for shoulder abduction, and $p = 0.019$ for elbow supination). All ROMs of the shoulder and elbow had significantly improved after the rehabilitation programme when compared to the baseline evaluation ($p = 0.001$ for shoulder flexion, abduction, and elbow supination; $p = 0.003$ for shoulder internal rotation; $p = 0.004$ for shoulder external rotation; $p = 0.006$ for elbow flexion). Muscle strength according to the MRCS of shoulder extension, abduction, external rotation, elbow flexion, and supination were significantly improved in the second month when compared to the baseline evaluation ($p = 0.001$ for shoulder extension, $p = 0.002$ for shoulder external rotation, $p = 0.029$ for elbow supination, and $p = 0.037$ for shoulder abduction and elbow flexion). The muscle strength of shoulder abduction and external

rotation, elbow extension, and supination had significantly improved at the end of the treatment when compared to the second month evaluation ($p = 0.01$ for shoulder external rotation and wrist supination, $p = 0.004$ for shoulder abduction, $p = 0.037$ for elbow extension). All MRCS scores of the shoulder ($p = 0.008$ for flexion, $p = 0.001$ for extension, abduction, and external rotation) and elbow ($p = 0.006$ for extension, $p = 0.001$ for flexion and supination) had significantly improved after the rehabilitation programme when compared to the baseline evaluation. The MMS scores of the patients were also better in the fourth month when compared to the baseline evaluation ($p = 0.0024$).

In group 2, all ROMs of the shoulder except external rotation ($p = 0.012$ for internal rotation, $p = 0.001$ for flexion and abduction) and elbow flexion and supination ($p = 0.015$ for flexion and $p = 0.017$ for supination) had significantly improved in the second month when compared to the baseline evaluation. There was no significant difference in ROMs between the second- and fourth-month evaluation ($p > 0.005$). All shoulder and elbow ROMs had improved in the fourth month when compared to the baseline evaluation ($p = 0.001$ for shoulder flexion, abduction, and elbow supination; $p = 0.010$ for shoulder internal rotation and elbow flexion; $p = 0.016$ for shoulder external rotation). Muscle strength according to the MRCS of shoulder extension, abduction, external rotation, elbow flexion, and supination had significantly improved in the second-month evaluation when compared to the baseline evaluation ($p =$

Table 2 ROM and muscle strength according to MRCS and MMS scores of the patients before treatment

	Group 1 (<i>n</i> = 10), ave ± SD	Group 2 (<i>n</i> = 10), ave ± SD	Group 3 (<i>n</i> = 9), ave ± SD
ROM			
Shoulder			
Flexion (0–180°)	116.50 ± 41.96	114.00 ± 12.64	116.67 ± 20.02
Abduction (0–180°)	113.50 ± 42.23	117.00 ± 29.73	113.34 ± 10.01
Internal rotation (0–90°)	58.00 ± 37.94	59.00 ± 18.97	60.00 ± 15.11
External rotation (0–90°)	54.00 ± 32.04	65.00 ± 16.99	56.33 ± 15.20
Elbow			
Flexion (0–150°)	110.50 ± 19.23	113.00 ± 4.20	118.33 ± 25.00
Supination (0–90°)	45.00 ± 37.50	48.00 ± 34.25	40.05 ± 30.02
Wrist			
Flexion (0–80°)	72.00 ± 24.51	65.00 ± 14.58	73.0 ± 0.21
Extantion (0–70°)	61.50 ± 22.11	65.00 ± 4.16	68.0 ± 4.11
Muscle strength			
Shoulder			
Flexion	3.50 ± 0.14	3.30 ± 1.22	3.00 ± 0.96
Extantion	2.20 ± 0.91	2.90 ± 1.07	2.60 ± 1.01
Abduction	2.70 ± 1.15	2.80 ± 1.31	2.80 ± 0.45
External rotation	2.50 ± 1.08	2.90 ± 0.42	2.50 ± 0.70
Elbow			
Flexion	2.80 ± 0.63	2.80 ± 1.04	2.66 ± 0.55
Extantion	3.30 ± 0.67	3.10 ± 0.35	3.00 ± 0.87
Supination	2.30 ± 0.94	2.60 ± 0.67	2.50 ± 1.26
Wrist			
Flexion	3.90 ± 0.73	3.90 ± 0.78	4.08 ± 0.81
Extantion	3.90 ± 0.56	3.90 ± 1.07	3.86 ± 0.43
Modified Mallet Scale Score	14.9 ± 5.53	14.8 ± 4.14	15.65 ± 4.64

ave ± SD average ± standart deviation, ROM range of motion, MRCS Medical Research Council Scale, MMS Modified Mallet Scale

0.001 for shoulder extension, $p = 0.009$ for shoulder abduction, $p = 0.012$ for shoulder external rotation, $p = 0.024$ for elbow supination, and $p = 0.031$ for elbow flexion). Muscle strength of elbow flexion, extension, and supination had significantly improved in the fourth month when compared to the second-month evaluation ($p = 0.001$ for extension, $p = 0.029$ for supination, and $p = 0.032$ for flexion). Muscle strength of the shoulder and elbow for every motion had significantly improved in the fourth month when compared to the baseline evaluation ($p = 0.001$ for shoulder abduction, elbow flexion, extension, and supination; $p = 0.003$ for shoulder extension; $p = 0.005$ for external rotation; and $p = 0.009$ for shoulder flexion). The MMS scores of the patients had both significantly improved in the second- and fourth-month evaluations when compared to the baseline ($p = 0.017$ and $p = 0.008$, respectively).

In group 3, only ROMs of shoulder abduction and elbow supination had significantly improved in the second-month evaluation compared to the baseline ($p = 0.003$ and $p = 0.002$, respectively). Shoulder abduction and flexion were found to have significantly improved ($p = 0.007$, $p = 0.003$,

respectively), but no significant improvement in elbow ROMs was found in the fourth month when compared to the second-month evaluation. Shoulder and elbow ROMs were found to have significantly improved in the fourth-month evaluation when compared to the baseline ($p = 0.001$ for shoulder flexion, abduction, and elbow supination; $p = 0.018$ for shoulder internal rotation; $p = 0.019$ for shoulder external rotation; $p = 0.021$ for elbow flexion). Muscle strength according to MRCS of only shoulder extension and abduction were found to have significantly improved in the fourth month when compared to the second-month evaluation ($p = 0.014$ and $p = 0.016$, respectively). Muscle strength of the shoulder and elbow for every motion had significantly improved in the fourth-month evaluation when compared to the baseline ($p = 0.001$ for shoulder extension, elbow flexion, and supination; $p = 0.002$ for shoulder abduction; $p = 0.003$ for shoulder external rotation; $p = 0.008$ for shoulder flexion; and $p = 0.016$ for elbow extension). The MMS scores of the patients were also better in the fourth month when compared to the baseline evaluation ($p = 0.021$).

Table 3 ROM and muscle strength according to MRCS and MMS scores of group 1 before treatment and 2 and 4 months after treatment

	Group 1 (<i>n</i> = 10)		
	Before treatment, ave $\pm$ SD	2-month control, ave $\pm$ SD	4-month control, ave $\pm$ SD
ROM			
Shoulder			
Flexion (0–180°)	116.50 $\pm$ 41.96	143.50 $\pm$ 37.49	172.50 $\pm$ 8.57
Abduction (0–180°)	113.50 $\pm$ 42.23	138.50 $\pm$ 32.91	169.00 $\pm$ 11.97
Internal rotation (0–90°)	58.00 $\pm$ 37.94	73.50 $\pm$ 23.45	85.00 $\pm$ 23.13
External rotation (0–90°)	54.00 $\pm$ 32.04	71.00 $\pm$ 25.69	84.00 $\pm$ 24.24
Elbow			
Flexion (0–150°)	110.50 $\pm$ 19.23	125.50 $\pm$ 13.00	129.00 $\pm$ 9.66
Supination (0–90°)	45.00 $\pm$ 37.50	59.00 $\pm$ 31.42	79.50 $\pm$ 10.12
Wrist			
Flexion (0–80°)	72.00 $\pm$ 24.51	75.00 $\pm$ 11.54	78.00 $\pm$ 0.52
Extantion (0–70°)	61.50 $\pm$ 22.11	67.50 $\pm$ 8.89	70.00 $\pm$ 0.0
Muscle strength			
Shoulder			
Flexion	3.50 $\pm$ 0.14	3.80 $\pm$ 0.22	4.10 $\pm$ 0.73
Extantion	2.20 $\pm$ 0.91	4.80 $\pm$ 1.47	4.90 $\pm$ 0.69
Abduction	2.70 $\pm$ 1.15	3.20 $\pm$ 0.99	4.20 $\pm$ 0.67
External rotation	2.50 $\pm$ 1.08	3.10 $\pm$ 0.48	4.30 $\pm$ 0.42
Elbow			
Flexion	2.80 $\pm$ 0.63	3.40 $\pm$ 0.51	3.70 $\pm$ 0.63
Extantion	3.30 $\pm$ 0.67	3.50 $\pm$ 0.52	3.90 $\pm$ 0.56
Supination	2.30 $\pm$ 0.94	2.80 $\pm$ 0.51	3.60 $\pm$ 0.59
Wrist			
Flexion	3.90 $\pm$ 0.73	4.00 $\pm$ 0.47	4.15 $\pm$ 0.24
Extantion	3.90 $\pm$ 0.56	4.10 $\pm$ 0.31	4.32 $\pm$ 0.42
Modified Mallet Scale Score	14.9 $\pm$ 5.53	18.2 $\pm$ 4.48	22.1 $\pm$ 3.02

ave $\pm$ SD average $\pm$ standart deviation, ROM range of motion, MRCS Medical Research Council Scale, MMS Modified Mallet Scale

At the end of the study, four patients from group 2 and five patients from group 3 were consulted for tendon transfer operation with appropriate indications.

Discussion

OBPPs involve C5–T1 roots, related trunks, divisions, and terminal branches resulting in the sensory motor dysfunction of the affected extremity unilaterally or bilaterally [15]. Obstetric injury of the upper trunk of the brachial plexus is known as “Erb Palsy” and constituted almost half of the cases and is characterized by sensory motor loss latter joint contracture resulting in extremity dysfunction [3]. Motor dysfunction is evident in shoulder abduction, flexion, elbow flexion, and supination which brings out “waiter hand” posture [3, 8–10, 12, 13, 15, 16, 19–21].

Treatment choices of OBPPs include conservative and surgical techniques. Surgical treatment is often necessary for severe cases with total axonal degeneration in 3 to 4 months but surgical indications for Erb Palsy are controversial because of the high spontaneous recovery rates [10, 15, 21]. Strombeck et al. [17] reported better functional recovery with surgical treatment in their study with 247 patients with Erb Palsy. Xu et al. [22] reported no difference between surgical and conservative treatment and suggested delay of surgery for up to 2 years because of the high spontaneous resolution rate. Badr et al. [4] indicated the importance of conservative treatment in their long-term follow-up study. Like Badr et al., many recent studies have indicated the importance of early rehabilitation for these cases [3, 6, 9]. We aimed to evaluate the effect of rehabilitation initiation timing in Erb Palsy cases. We determined all ROMs of the shoulder and elbow separately to bring about an exact recovery

Table 4 ROM and muscle strength according to MRCS and MMS scores of group 2 before treatment and 2 and 4 months after treatment

	Group 2 (<i>n</i> = 10)		
	Before treatment, ave $\pm$ SD	2-month control, ave $\pm$ SD	4-month control, ave $\pm$ SD
ROM			
Shoulder			
Flexion (0–180°)	114.00 $\pm$ 12.64	176.00 $\pm$ 8.43	176.00 $\pm$ 6.65
Abduction (0–180°)	117.00 $\pm$ 29.73	171.00 $\pm$ 12.64	174.00 $\pm$ 7.74
Internal rotation (0–90°)	59.00 $\pm$ 18.97	73.00 $\pm$ 18.73	74.00 $\pm$ 12.56
External rotation (0–90°)	65.00 $\pm$ 16.99	69.00 $\pm$ 15.49	79.00 $\pm$ 5.27
Elbow			
Flexion (0–150°)	113.00 $\pm$ 4.20	134.00 $\pm$ 5.16	135.00 $\pm$ 7.46
Supination (0–90°)	48.00 $\pm$ 34.25	65.00 $\pm$ 15.38	78.00 $\pm$ 11.29
Wrist			
Flexion (0–80°)	65.00 $\pm$ 14.58	70.00 $\pm$ 9.29	75.00 $\pm$ 4.21
Extantion (0–70°)	65.00 $\pm$ 4.16	66.00 $\pm$ 3.25	71.00 $\pm$ 4.11
Muscle strength			
Shoulder			
Flexion	3.30 $\pm$ 1.22	3.60 $\pm$ 0.35	4.00 $\pm$ 0.94
Extantion	2.90 $\pm$ 1.07	4.00 $\pm$ 0.94	4.00 $\pm$ 0.85
Abduction	2.80 $\pm$ 1.31	3.70 $\pm$ 1.24	4.00 $\pm$ 0.76
External rotation	2.90 $\pm$ 0.42	3.70 $\pm$ 1.22	3.90 $\pm$ 0.66
Elbow			
Flexion	2.80 $\pm$ 1.04	3.30 $\pm$ 1.15	3.90 $\pm$ 1.05
Extantion	3.10 $\pm$ 0.35	3.30 $\pm$ 0.26	4.20 $\pm$ 0.78
Supination	2.60 $\pm$ 0.67	3.30 $\pm$ 0.87	3.90 $\pm$ 1.03
<i>El bileği</i>			
Flexion	3.90 $\pm$ 0.78	4.00 $\pm$ 0.66	4.20 $\pm$ 0.41
Extantion	3.90 $\pm$ 1.07	4.00 $\pm$ 1.07	4.20 $\pm$ 0.18
Modified Mallet Scale Score	14.8 $\pm$ 4.14	21.6 $\pm$ 3.01	22.22 $\pm$ 3.43

ave $\pm$ SD average $\pm$ standart deviation, ROM range of motion, MRCS Medical Research Council Scale, MMS Modified Mallet Scale

of our patients. Our results indicate significant improvement in ROMs, muscle strength, and the upper extremity by means of a structured rehabilitation programme independent of age and in accordance with recent data.

Total recovery with an appropriate rehabilitation programme in patients with Erb Palsy is reported to be 66% up to the age of 7 years [11]. In another study, spontaneous recovery for these cases is reported to initiate at 2 to 3 months and continues up to the age of 2 years [8]. However, the timing, duration, and consistency of a rehabilitation programme for these cases are controversial. Early initial rehabilitation within the first month is shown to result in total recovery without any secondary complication in two thirds of cases [1]. Active and passive ROM and stretching exercises with myofascial relaxation techniques are reported to be effective for functional recovery in patients with Erb Palsy [6, 14].

Appropriate positioning and indoor activities for upper extremity functionality are also shown to be beneficial [15]. In contrast with these results, Eng et al. [7] reported only 22% partial recovery in their study with patients with Erb Palsy. In our study, we structured the rehabilitation programme with exercise and electrotherapy including galvanic current. Our results have shown significant improvement of upper extremity function in all age groups with such a scheduled rehabilitation programme.

In our study, all patients under 3 years of age achieved total functional recovery but 50% of patients over 3 years of age required tendon transfer surgery. These findings suggest the importance of early rehabilitation initiation, and in fact, those patients who required surgical treatment may have surgical treatment indications before any rehabilitation procedure. Furthermore, patients over 3 years of age achieved more significant

Table 5 ROM and muscle strength according to MRCS and MMS scores of group 3 before treatment and 2 and 4 months after treatment

	Group 3		
	Before treatment, ave $\pm$ SD	2-month control, ave $\pm$ SD	4-month control, ave $\pm$ SD
ROM			
Shoulder			
Flexion (0–180°)	116.67 $\pm$ 20.02	126.66 $\pm$ 5.00	166.00 $\pm$ 8.43
Abduction (0–180°)	113.34 $\pm$ 10.01	138.00 $\pm$ 7.50	164.00 $\pm$ 7.24
Internal rotation (0–90°)	60.00 $\pm$ 15.11	70.04 $\pm$ 10.10	77.00 $\pm$ 10.27
External rotation (0–90°)	56.33 $\pm$ 15.20	63.33 $\pm$ 2.55	73.00 $\pm$ 11.73
Elbow			
Flexion (0–150°)	118.33 $\pm$ 25.00	121.67 $\pm$ 19.98	134.00 $\pm$ 5.16
Supination (0–90°)	40.05 $\pm$ 30.02	65.00 $\pm$ 22.50	72.00 $\pm$ 9.29
Wrist			
Flexion (0–80°)	73.0 $\pm$ 0.21	80.00 $\pm$ 0.0	80.00 $\pm$ 0.0
Extantion (0–70°)	68.0 $\pm$ 4.11	70.00 $\pm$ 0.0	70.00 $\pm$ 0.0
Muscle strength (1–5)			
Shoulder			
Flexion	3.00 $\pm$ 0.96	3.70 $\pm$ 0.28	3.80 $\pm$ 0.14
Extantion	2.60 $\pm$ 1.01	3.00 $\pm$ 1.50	3.80 $\pm$ 3.22
Abduction	2.80 $\pm$ 0.45	3.10 $\pm$ 1.37	3.84 $\pm$ 1.15
External rotation	2.50 $\pm$ 0.70	3.10 $\pm$ 0.44	3.50 $\pm$ 0.40
Elbow			
Flexion	2.66 $\pm$ 0.55	3.33 $\pm$ 0.50	3.75 $\pm$ 0.54
Extantion	3.00 $\pm$ 0.87	3.66 $\pm$ 0.62	3.77 $\pm$ 0.34
Supination	2.50 $\pm$ 1.26	3.10 $\pm$ 1.50	3.60 $\pm$ 0.18
Wrist			
Flexion	4.08 $\pm$ 0.81	4.13 $\pm$ 0.83	4.20 $\pm$ 0.04
Extantion	3.86 $\pm$ 0.43	4.10 $\pm$ 0.62	4.14 $\pm$ 0.56
Modified Mallet Score Scale	15.65 $\pm$ 4.64	20.99 $\pm$ 4.04	22.98 $\pm$ 3.01

ave $\pm$ SD average $\pm$ standart deviation, ROM range of motion, MRCS Medical Research Council Scale, MMS Modified Mallet Scale

resolution after the second rehabilitation programme suggesting that structured rehabilitation programmes are beneficial for all Erb Palsy patients independent of age. However, the importance of surgical procedures should not be forgotten in certain indications. Socolovsky et al. emphasized the importance of rehabilitation after surgery [18]. As in their study, we strongly recommend a well-structured rehabilitation programme even after surgery and think that both treatment procedures are inseparable.

In conclusion, OBPPs have slow but high spontaneous recovery rates and structured rehabilitation programmes clearly contribute to the recovery. Although cases with upper trunk lesions have certain surgical indications, the decision to perform surgery in cases of Erb Palsy is controversial. However, secondary complications such as joint contracture may bring about the need for surgical treatment in these cases. Our findings have shown that early initiated structured

rehabilitation procedures are beneficial for Erb Palsy cases and should be considered before opting for surgery in every case independent of age.

Compliance with ethical standards

Conflict of interest There is no disclosure or conflict of interest for this study.

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