ORIGINAL RESEARCH ARTICLE

Effect of Electromyographic Biofeedback Training on Pain, Quadriceps Muscle Strength, and Functional Ability in Juvenile Rheumatoid Arthritis

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ABSTRACT

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Objective: To investigate the effects of electromyographic (EMG) biofeedback training on pain, quadriceps strength, and functional ability in juvenile rheumatoid arthritis (JRA).

Design: This is a randomized controlled study; 36 children (11 boys and 25 girls) with polyarticular JRA, with ages ranging from 8 to 13 years, were selected and assigned randomly, using computer-generated random numbers, into 2 groups. The control group ($n = 18$) received the conventional physical therapy program, whereas the study group ($n = 18$) received the same program as the control group in addition to EMG biofeedback-guided isometric exercises for 3 days a week for 12 weeks. Pain, peak torque of quadriceps strength, and functional ability were evaluated before, after 6 weeks, and at the end of 12 weeks of the treatment program.

Results: By 6 weeks, significant differences were observed in the study group ($P < 0.05$) in all measured variables except pain levels, whereas nonsignificant differences were observed in all measured variables in the control group. By 12 weeks, each group demonstrated significant improvements in pain, quadriceps strength, and functional ability ($P < 0.05$), with significantly greater improvements seen in the study group compared to the control group ($P < 0.05$). Both groups showed significant improvement at 12 weeks compared to that at 6 weeks.

Conclusions: Electromyographic biofeedback may be a useful intervention modality to reduce pain, improve quadriceps strength, and functional performance in JRA.

Key Words: EMG Biofeedback, Pain, Muscle Strength, Functional Ability, Juvenile Rheumatoid Arthritis

Juvenile rheumatoid arthritis (JRA) is one of the most common pediatric rheumatic diseases, with peak age at 4 and 10 years.[1] Children with JRA often experience joint pain, swelling, and limited functional mobility, which contribute to decreased physical activity, fitness, and function.[2] It is one of the major causes of short- and long-term morbidity, and growth impairment is one of the complications, especially in polyarticular and systemic JRA.[3]

Children and adolescents with JRA have decreased muscle strength, bone health, and well-being compared to healthy peers.[4] The disease can affect school performance, physical activity, family life, and leisure time activities.[5] Pain is one of the major symptoms and restricts the child's activities, disrupts school attendance, and contributes to psychosocial distress.[6] Muscle weakness and atrophy are most severe near inflamed joints but may also occur in distant areas and persist long after remission of the arthritis.[7]

Biofeedback is a method through which various biological processes of the body can be monitored, recorded, and controlled by the patient undergoing treatment with the assistance of specialized equipment. These processes can be recorded with electronic equipment that translates the input to visual, auditory, or other cues. The patient may become aware of these autonomous functions and may attempt to influence or control them.[8,9] Electromyographic (EMG) biofeedback is a specific form of biofeedback. The biofeedback device records muscle activity through the application of electrodes superficially or subcutaneously when targeting specific muscles.[10] Muscle activity is turned into visual, auditory, or other cues, which vary as muscle tension increases or decreases. The patient receives the feedback from the electronic equipment and is able to modify muscle tension.[10]

Several studies suggested that, EMG biofeedback is more effective in facilitating the recovery of quadriceps peak torque when combined with the strengthening exercise program in osteoarthritis,[11] in post–anterior cruciate ligament reconstruction,[12] after menisectomy,[13–15] and in patellofemoral pain syndrome.[16,17]

To date, there are no published studies that investigate the effects of EMG biofeedback in JRA. Therefore, the purpose of the present study was to investigate the effects of EMG biofeedback training on pain, quadriceps strength, and functional ability in children with JRA.

MATERIALS AND METHODS

Study Design

A randomized controlled trial design was selected for testing the hypothesis of this study, where baseline measurements were taken before the intervention at week zero, and posttreatment readings were taken at the end of the sixth week and the 12th week. These results were then compared to find out the effects of EMG biofeedback training on the dependent variables. The outcome measures selected for this study were pain, quadriceps strength, and functional ability in JRA.

Subjects

Thirty-six children (11 boys and 25 girls) with polyarticular JRA, with ages ranging from 8 to 13 years, participated in this study. Juvenile rheumatoid arthritis was diagnosed by a pediatric rheumatologist according to the American College of Rheumatology criteria for polyarticular JRA.[18] They were recruited from the outpatient clinic of physical therapy department, College of Applied Medical sciences, Najran University, Najran, KSA. Children in both groups were selected with inclusion criteria, including presence of arthritis in 5 or more joints during the first 6 months of disease. Symmetry of arthritis and degree of involvement was varied. Cardinal hallmark signs and symptoms of joint involvement that generally were pain, swelling, and morning stiffness. Exclusion criteria included children with systemic or oligoarthritis onset who had severe tightness, congenital or acquired skeletal deformities, cardiopulmonary dysfunctions, and advanced radiographic changes (including bone destruction, bony ankylosis, knee joint subluxation, epiphyseal fractures, and growth abnormalities related to marked skeletal changes of JRA). They were assigned randomly, using computer-generated random numbers, into 2 groups. The control group consisted of 18 children (6 boys and 12 girls) and received the conventional physical therapy program, whereas the study group consisted of 18 children (5 boys and 13 girls) and received the same program given to the control group in addition to EMG biofeedback–guided isometric exercise program.

All children and their parents were given an explanation of the purpose, procedures, and potential risks and benefits of the study. This work was carried out in accordance with the code of ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. All parents of the children signed a consent form before participation. In addition, acceptance of the ethical committee of the University was taken.

Randomization

In the present study, 44 children with polyarticular JRA were assessed for eligibility. Six children were excluded as they did not meet the inclusion criteria, and 2 children were excluded as their parents refused to participate in the study. Following the baseline measurements, randomization process was performed for 36 children using computer-generated random numbers combined with stratification. Groups were stratified with regard to age, sex, and stages of disease during examination (acute/subacute/chronic) to be equally represented in both intervention groups. The investigator used a computer software program that generates the random sequence with each child allocated either to the control group or the study group. The experimental design is shown as a flow diagram in Figure 1.

Procedures

Weight and height were recorded using a calibrated floor scale (ZT-120 model, Hangzhou Tianheng Technology Co, Ltd, Hangzhou, China) and health scale. Each child was evaluated for pain, quadriceps strength, and functional ability before, at the end of the sixth week, and at the end of the 12th week of treatment by the same examiner who was blinded regarding the group to which each child was assigned. All procedures for evaluation and treatment were explained to all children and their parents.

Pain

Pain was measured by using the visual analog scale (VAS). It is a measurement instrument that was used to determine the degree of perceived pain. The child was asked to choose a number between zero and 10 on a 10-cm chart, with zero indicating no pain and 10 indicating unbearable pain. The child marked the number corresponding to the pain intensity of both knee joints. Using VAS for pain assessment has some advantages in clinical trials, as it is the most common and reliable type of pain scale.[19]

Quadriceps Muscle Strength

Peak torque of quadriceps strength of both sides was measured by isokinetic dynamometer. The Biodex System 3 multijoint system testing and rehabilitation (Biodex Medical System, Shirley, NY) was used. The system consists of head assembly housing the servomotor responsible for moving the lever arm and has a fully adjustable orientation, seat for positioning the child that adjusted independently vertical or horizontal, and control unit consisting of personal computer and operator equipment. Velocity, range of motion (ROM) setting, and contraction mode are addressed through the system controller. Dynamometry attachments are selected according to the tested part. Previous studies have demonstrated the reliability and validity of isokinetic devices for measuring muscle strength in adults as well as in children.[20]

Peak torque of the quadriceps strength was measured during concentric contraction at 120 degrees per second. The dynamometer orientation was adjusted according to the standard instructions for knee testing so that the dynamometer head and chair were rotated to 90 degrees. Children sat with their thighs at an angle of 110 degrees to the trunk. With the tested knee positioned at 90-degree flexion, the mechanical axis of the dynamometer was aligned with the lateral epicondyle of the knee. The trunk and both thighs were stabilized with belts, and the knee ROM was 90 degrees (90-0 degree of flexion). The distal aspect of the dynamometer arm was placed 2 cm proximal to the medial malleolus, torque was gravity corrected, and dynamometer calibration was performed before every session in accordance with the manufacturer's instructions. Each child performed 10 concentric contractions at 120 degrees per second (flexion and extension), and peak torque of the quadriceps of both sides was recorded.

Functional Ability

The Juvenile Arthritis Functional Assessment Report for children (JAFAR-C) was used for evaluating physical functional ability in children with JRA. It is a reliable and valid 23-item scale and has both child and parent reports.[21] The responses are in the form of 3-point scales about the activities of daily living, and total scores range from zero to 46, where lower scores indicate better function. Both these versions have good construct validity, reliability, and responsiveness.[21,22] The JAFAR-C has been used in multiple clinical studies to assess physical function in children with JRA,[23] and was considered one of the standard measures of physical function.[24] The content for the JAFAR was derived from the Health Assessment Questionnaire, Arthritis Impact Measurement Scale, and the McMaster Health Index Questionnaire.[25] The greatest limiting feature for JAFAR is that these questionnaires and scale cannot be used in children younger

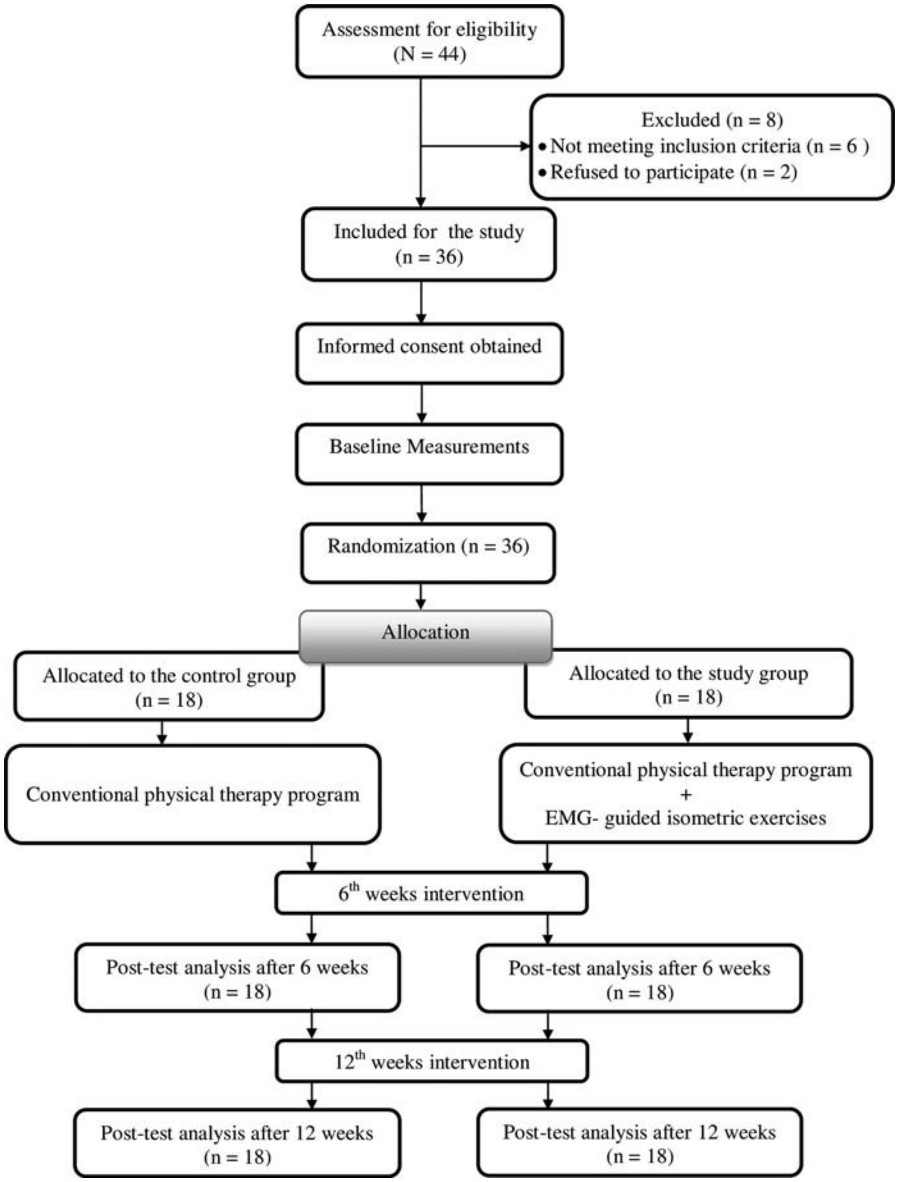

FIGURE 1 *Flow chart showing the experimental design of the study.*

than 7 years of age. Given the age range of the study participants, assessments were completed by the children themselves.

Treatment

Control Group

The children in the control group received the usual medical treatment in addition to the physical therapy program for 1 hour per session, 3 times per week for 12 weeks. In acute stage, cold packs, passive ROM, and isometric exercises were applied. In subacute stage, isometric and isotonic exercises were given. In chronic stage, hot packs, proprioception training, flexibility exercises (stretching of the lower limb muscles, including hip flexors, hip adductors, quadriceps, hamstrings, calf muscles, and iliotibial band) and strengthening exercises (for the hip flexors and extensors, knee flexors and extensors, ankle dorsiflexors, and plantar flexors) using weight resistance (sand bags from 2 to 6 kg). The children performed each strengthening exercise for 3 sets with 10 repetitions.

Study Group

The children in the study group received the usual medical treatment, the same physical therapy program as the control group for 45 minutes, in addition to EMG biofeedback–guided isometric exercises for 15 minutes 3 days a week for 12 weeks. In the present study, isometric exercises were chosen, as it is suitable for acutely inflamed joints, and provide adequate muscle tension without exacerbation of clinical disease activity.[26]

Biofeedback Training

Myomed 932 (Enraf Nonius, Rotterdam, The Netherlands) was used for the biofeedback training. It is a 2-channel EMG machine with full screen displaying the EMG signal with a curve obtained for both vastus medialis oblique, and rectus femoris.

Electrode Placement

Before the electrode placement, the skin under the electrodes must be appropriately prepared by scrubbing with an alcohol solutions to clean the area and to reduce skin resistance. Surface electrodes were used to record muscle activity. Two electrodes were placed 4 cm superior and 3 cm medial to superomedial border of the patella to record the recruitment of vastus medialis oblique. The other two electrodes were placed midway on a line drawn between the base of the patella and the anterior superior iliac spine for rectus femoris. The electrodes were placed parallel to the muscle fibers, with a center-to-center interelectrode constant distance of 2 cm and remained on the skin throughout the duration of the trial. The reference electrode was placed below the tibial tubercle.[11]

Exercise Procedure

The configuration of the EMG biofeedback system was adjusted to be as follows:

- Detecting EMG signals of 5 μV to 10 mV.
- Main amplification stage with amplification 1000.
- Frequency response of 20 to 500 Hz.
- Maximum sampling rate of 1000 Hz for each of 2 channels.
- Nominal preamplification stage of 4.5 volt/volt.
- Noise less than 2 μV root mean square (20–500 Hz).

Before starting the session, the children were asked to lie in a comfortable supine position with semi-flexed knee by using a towel under the knee joint. They were instructed to contract the quadriceps maximally to their EMG threshold level. During training, the children were instructed to maximally contract the quadriceps above its threshold level with maintaining the audible signal for 10 seconds followed by rest for 20 seconds.

DATA ANALYSIS

To avoid a type II error, a preliminary power analysis (power, 0.87; effect size, >0.5) determined a sample size of 36 for this study. The sample size was determined by using the Slovin Formula ($n = N/1 + Ne2$), where N represents the population size and e represents the margin of error. Subject characteristics were compared between both groups using t test. Mixed multivariate analysis of variance (MANOVA) was conducted to compare the mean values of VAS and knee extensors peak torque between the study and the control groups across 3 time periods (pretreatment, post I, and post II). The Mann-Whitney U test was conducted for comparison of JAFAR-C between both groups. The Friedman test was conducted for comparison between pre, post I, and post II measurements of JAFAR-C in each group. Wilcoxon signed ranks test was conducted for pairwise comparison of JAFAR-C in each group. The level of significance of statistical tests was set at $P < 0.05$, and the level of significance for multiple comparisons was set at $P < 0.017$ according to Bonferroni correction. All statistical analyses were conducted through SPSS (Statistical Package for Social Sciences, version 19).

RESULTS

Subjects' Characteristics

The demographic and clinical characteristics of the children are described in Table 1. The mean ± SD age, weight, and height of the study group were 11.38 ± 1.33 years, 29.88 ± 1.6 kg, and 128.55 ± 2.12 cm, respectively; and those of the control group were 10.83 ± 1.72 years, 30.66 ± 1.45 kg, and 128.94 ± 1.3 cm, respectively. There was no significant difference between both groups for age, weight, and height ($P > 0.05$). There was no significant difference in the age of onset and disease duration between both groups, ($P = 0.79$) and ($P = 0.26$), respectively.

Effect of Treatment on VAS and Quadriceps Peak Torque

Mixed MANOVA was conducted to investigate the effect of treatment and time on VAS and quadriceps peak torque. Table 2 shows comparison between the study and the control groups at pretreatment, post I, and post II. Table 3 shows comparison between the 3 time intervals in each group.

Mixed MANOVA revealed that there was a significant interaction between treatment and time, Wilks lambda ($F = 20.04$, $P = 0.0001$). There was a significant main effect of time, Wilks lambda ($F = 110.2$, $P = 0.0001$), and a significant main effect for group, Wilks lambda ($F = 7.86$, $P = 0.001$).

At post I, there was a significant increase in right and left quadriceps peak torque of the study

TABLE 1 *t* Test for comparison of demographic and clinical characteristics of children between the study and control groups

	Mean ± SD			
	Study Group	Control Group	*T* Value	*P*
Age, yrs	11.38 ± 1.33	10.83 ± 1.72	1.08	0.28[a]
Weight, kg	29.88 ± 1.6	30.66 ± 1.45	−1.52	0.13[a]
Height, cm	128.55 ± 2.12	128.94 ± 1.3	−0.66	0.51[a]
Male/Female	5/13	6/12		
Age of disease onset, yrs	8.44 ± 0.48	8.38 ± 0.75	0.26	0.79[a]
Disease duration, yrs	2.94 ± 1.12	2.44 ± 1.47	1.14	0.26[a]

[a]Nonsignificant.
P, level of significance; SD, standard deviation; yrs, years.

group compared to the control group ($P > 0.001$), whereas there was no significant difference in VAS between groups ($P = 0.83$). At post II, there was a significant decrease in VAS ($P = 0.001$) and significant increase in right and left quadriceps peak torque of the study group compared to the control group ($P = 0.0001$).

Comparison between the 3 time intervals in the study group revealed that there was no significant difference in VAS between pretreatment and post I ($P = 0.38$), whereas there was a significant decrease in VAS at post II compared to pretreatment and post I ($P = 0.0001$). There was a significant increase in right and left quadriceps peak torque at post I compared to pretreatment ($P = 0.0001$); also, there was a significant increase in right and left quadriceps peak torque at post II compared to pretreatment and post I ($P = 0.0001$).

Comparison between the 3 time intervals in the control group revealed that there was no significant difference in VAS and peak torque of right and left quadriceps between pretreatment and post I ($P < 0.05$), whereas there was a significant decrease in VAS at post II compared to pretreatment and post I ($P = 0.0001$). There was a significant increase in right and left quadriceps muscle peak torque at post I compared to pretreatment ($P = 0.0001$); also, there was a significant increase in right and left quadriceps peak torque at post II compared to pretreatment and post I ($P = 0.0001$).

Effect of Treatment on JAFAR-C

At post I, the study group showed significant decrease in JAFAR-C compared to the control group ($P = 0.002$); also, there was a significant decrease in JAFAR-C of the study group compared to the control group at post II ($P = 0.0001$) (Table 4).

Comparison between the 3 time intervals in the study group revealed a significant decrease in JAFAR-C at post I compared to pretreatment ($P = 0.0001$) and a

TABLE 2 Comparison of VAS and quadriceps peak torque between the study and control groups at pretreatment, post I, and post II

	Study Group	Control Group		
	Mean ± SD	Mean ± SD	MD	*P*
Pretreatment				
VAS	7.05 ± 0.87	7.11 ± 0.75	−0.06	0.84[a]
Right quadriceps peak torque, Nm	39.05 ± 3.47	38.22 ± 3.87	0.83	0.5[a]
Left quadriceps peak torque, Nm	35.55 ± 3.41	34.33 ± 5.04	1.22	0.4[a]
Post I				
VAS	6.88 ± 0.83	6.94 ± 0.72	−0.06	0.83[a]
Right quadriceps peak torque, Nm	44 ± 3.72	39.11 ± 4.56	4.89	0.001[b]
Left quadriceps peak torque, Nm	40.83 ± 2.99	35 ± 4.92	5.83	0.0001[b]
Post II				
VAS	3.33 ± 0.97	4.94 ± 0.72	−1.61	0.001[b]
Right quadriceps peak torque, Nm	50.16 ± 3.76	42.33 ± 4.49	7.83	0.0001[b]
Left quadriceps peak torque, Nm	47.33 ± 3.14	40.38 ± 5.57	6.95	0.0001[b]

MD, mean difference.
[a]Nonsignificant.
[b]Significant.

TABLE 3 Comparison of VAS and quadriceps peak torque between pretreatment, post I, and post II treatments of the study and control groups

	Pretreatment	Post I	Post II	*P*		
	Mean ± SD	Mean ± SD	Mean ± SD	Pre vs Post I	Pre vs Post II	Post I vs Post II
Study group						
VAS	7.05 ± 0.87	6.88 ± 0.83	3.33 ± 0.97	0.38[a]	0.0001[b]	0.0001[b]
Right quadriceps peak torque, Nm	39.05 ± 3.47	44 ± 3.72	50.16 ± 3.76	0.0001[b]	0.0001[b]	0.0001[b]
Left quadriceps peak torque, Nm	35.55 ± 3.41	40.83 ± 2.99	47.33 ± 3.14	0.0001[b]	0.0001[b]	0.0001[b]
Control group						
VAS	7.11 ± 0.75	6.94 ± 0.72	4.94 ± 0.72	0.38[a]	0.0001[b]	0.0001[b]
Right quadriceps peak torque, Nm	38.22 ± 3.87	39.11 ± 4.56	42.33 ± 4.49	0.44[a]	0.0001[b]	0.0001[b]
Left quadriceps peak torque, Nm	34.33 ± 5.04	35 ± 4.92	40.38 ± 5.57	0.25[a]	0.0001[b]	0.0001[b]

[a]Nonsignificant.
[b]Significant.

significant decrease in JAFAR-C at post II compared to pretreatment and post I ($P = 0.0001$).

Comparison in the control group revealed no significant difference in JAFAR-C between pretreatment and post I ($P = 0.1$), whereas there was a significant decrease in JAFAR-C at post II compared to pretreatment and post I ($P = 0.0001$) (Table 5).

DISCUSSION

Up to our knowledge, this is the first study that investigated the effects of EMG biofeedback training on pain, quadriceps strength, and functional ability in children with JRA. The main finding of this study was that EMG biofeedback induced significant improvements in all measured variables when comparing posttreatment measurements between both groups after 12 weeks of treatment. The results of this study offer preliminary support for the premise that EMG biofeedback training combined with proper physical therapy program could reduce pain and improve muscle strength and physical functional performance in children with JRA.

The time course of improvement of the study group was different from improvement of the control group. The study group that received EMG biofeedback combined with the exercise program achieved most of its gains relatively rapidly, in the first 6 weeks, whereas the control group that received the exercise alone achieved most of its gains between 6 weeks and 12 weeks. This indicates that EMG biofeedback combined with exercise provides more rapid improvement than exercise alone.

Significant differences were observed when comparing the posttreatment results in favor of the EMG biofeedback group, indicating that EMG biofeedback clearly provides benefit in regaining strength and reducing pain faster.

These findings are consistent with previous studies,[17,27] which reported that EMG biofeedback could be a useful alternative modality for reducing musculoskeletal pain when added to the exercise program in patients with patellofemoral pain syndrome. Moreover, Shahnaz et al.[16] examined the efficacy of EMG biofeedback on quadriceps in patients (20–55 yrs) with patellofemoral pain syndrome and

TABLE 4 Comparison of JAFAR-C between the study and control groups at pretreatment, post I, and post II

	Study Group	Control Group		
	Median (Range)	Median (Range)	*U* Value	*P*
Pretreatment	38 (14)	39 (14)	157	0.87[a]
Post I	32 (15)	37 (12)	64.5	0.002[b]
Post II	20 (16)	33 (14)	9.5	0.0001[b]

[a]Nonsignificant.
[b]Significant.
P value, level of significance; *U* value, Mann-Whitney test value.

TABLE 5 Comparison of JAFAR-C between pretreatment, post I, and post II treatments of the study and control groups

	Pretreatment	Post I	Post II	*P*		
	Median (Range)	Median (Range)	Median (Range)	Pre vs Post I	Pre vs Post II	Post I vs Post II
Study group	38 (14)	32 (15)	20 (16)	0.0001[b]	0.0001[b]	0.0001[b]
Control group	39 (14)	37 (12)	33 (14)	0.1[a]	0.0001[b]	0.0001[b]

[a]Nonsignificant.
[b]Significant.

found greater improvements of isometric quadriceps strength and subsequent reduced pain in those who exercised with EMG biofeedback than those who participated in the exercise program alone.

Structural changes or inflammation may provoke arthrogenic inhibition and resultant wasting.[28] Therefore, reduced pain after EMG biofeedback training may be due to increased quadriceps peak torque and subsequent decreased loading over the knee joints, as a reduced muscle function causing greater knee joint load.[29] Several studies suggested that neuromuscular exercises may reduce loading across the knee joints in subjects with and without knee osteoarthritis during more functionally challenging tasks than walking.[29,30]

The results of this study seem to demonstrate that decreased knee pain was associated with improved ability to exercise with subsequent improved quadriceps peak torque. The association of quadriceps pain with weakness is not specifically confirmed by this current study as a causal relationship, However, it is clear that quadriceps strength is important to functional ability.

Hassan et al.[31] confirmed the findings of this study and reported that pain reduction was clearly associated with increased maximum muscle strength and muscle activation in subjects with knee osteoarthritis. Moritani and DeVries[32] described that increased number of motor units by using biofeedback may cause a reorganization of facilitation patterns. This reorganization may be responsible for increased firing rate or increased number of motor units recruited, as demonstrated by increased peak torque of the quadriceps strength in the EMG biofeedback group.

Concerning functional ability, the posttreatment results demonstrate functional improvement in favor of EMG biofeedback group. Physiologically, neuromuscular training aims to enhance the unconscious motor response by calling upon both afferent signal and central mechanisms responsible for dynamic control.[33]

These results are consistent with Woodford and Price[34] who assessed the effects of EMG biofeedback for motor function recovery after a stroke. They suggested that EMG biofeedback combined with a standard physiotherapy induced improvements in motor power, functional recovery, and gait quality compared to a standard physiotherapy alone.

Electromyographic biofeedback advocated positive results in functional ability in children. Early studies suggested that EMG biofeedback of triceps surae muscle activity during gait may be effective in improving gait symmetry in children with cerebral palsy.[35] Significant improvement was also observed in muscle tone, ankle range of movement, and gait in children with cerebral palsy, who received EMG biofeedback combined with exercise than exercise alone.[36]

Clinical implications of the present study suggested that to achieve better physical performance, improving muscle strength and pain management, EMG biofeedback should be one of the therapeutic modalities in the rehabilitation process of musculoskeletal disorders, especially for children with JRA. Moreover, strength training with EMG biofeedback becomes easier, has fast response, and maximizes the recovery potential in the rehabilitation process of children with JRA.

The major limitations of this study were the small sample size consisting of only 36 children, and the short duration of the study, which was not adequate to study the long-term effect of the EMG biofeedback. It would be desirable to extend the duration of the study with a larger sample size. Therefore, future large-scale studies with a larger sample and longer duration are recommended to overcome these limitations and to increase the generalizability of the findings from this study.

CONCLUSIONS

Electromyographic biofeedback training combined with proper physical therapy program could reduce pain and improve muscle strength and functional performance in children with JRA. This study concluded that EMG biofeedback seems to be a valuable adjunct to the exercise program in the rehabilitation of musculoskeletal disorders, especially for children with JRA.

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Supplementary Checklist

CONSORT Checklist: http://links.lww.com/PHM/A248

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