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The Effects of Closed Kinetic Chain Exercise Using EMG Biofeedback on PFPS Patients` Pain and Muscle Functions

Jae-Young Kang[1], Tae-Gon Kim[2] and Kyung-Yoon Kim[3]

[1] Department of Physical Therapy Jungang Hospital, Mokpo, Korea, [2] Department of Physical Therapy DongIn Hospital, Yeosu, Korea, [3] Department of Physical Therapy Dongshin University, Naju, Korea
[1]xpeed1541@daum.net, [2]tgkimlove@naver.com, [3]redbead7@daum.net

Abstract

This study aimed to examine the effects of closed kinetic chain exercise using electromyography (EMG) biofeedback for selective strengthening of the vastus medialis oblique (VMO) on patllofemoral joint pain and functional characteristics of patllofemoral joint muscles. The subjects of this study were 30 patellofemoral pain syndrome (PFPS) patients and they were equally and randomly assigned to a control group (I), a closed kinetic chain exercise group (II), and an EMG biofeedback closed kinetic chain exercise (III). They received intervention three times per week (for 30 minutes per each time) for six weeks. Measurement methods included visual analogue scale (VAS) and EMG. According to the study result, there were significant differences in groups II and III compared to group I in VAS ($p<.01$). During a squat position, there were significant differences in groups II and III compared to group I in median frequency (MDF) and VMO/vastus lateralis (VL) muscle activity ratios ($p<.05$). According to the this study result, PFPS patients' muscle functions improved by enhancing muscle control and response ability using EMG biofeedback with which real-time bioinformation on the muscles is provided during closed kinetic chain exercise in order to raise treatment efficiency.

Keywords: *EMG biofeedback, PFPS, VMO, VL*

1. Introduction

Patellofemoral pain syndrome (PFPS) is defined as pain appearing in the anterior or posterior knees during kneeling or squatting [1]. The etiology of PFPS is not clear yet but considered to include pressure on or tilting of the patella and imbalance between the vastus medialis oblique (VMO) and vastus lateralis (VL); In particular, imbalance between the muscles near the knees resulting from the weakening f the VMO is regarded the most important cause [2].

In a study which examined VMO/VL ratios in PFPs patients and normal people during voluntary isometric knee extension, Makhsous et al.[3] reported that the muscle activity ratios of PFPS patients were lower than those of normal people. Such imbalance between VMO and VL triggers lateral tracking and malalignment of the patella and further increases pressure on the interface of the patellofemoral joint, triggering pain [4]. Therefore, for balance between and stability of the VMO and the VL, training for selective strengthening of the VMO is very crucial [5].

The most universal physical therapy intervention for PFPS patients is quadriceps femoris muscle (QFM) strengthening exercise [6]. Muscle strengthening exercise is divided into open kinetic chain exercise and closed kinetic chain exercise and traditionally open kinetic chain exercise has been used much [7]. However, it was reported that increase in the force of the QFM by open kinetic chain exercise increased pressure on the patellofemoral joint and pain in a lot of PFPS patients [8]. On the other hand, closed kinetic exercise like squat exercise

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provides high stability resulting from co-contraction of the QFM and biceps femoris muscle (BFM) and provides minimal stress on the patellofemoral joint within functional range; therefore, it is an effective and safe exercise method [9].

Clinically, biofeedback is mostly used when patients need help for voluntary muscle control in muscle retraining. It provides information on muscle activity while patients perform their task. It is usefully employed in motor learning exercise and rehabilitation process [10]. Yilmaz *et al.*, [11] applied muscle strengthening exercise in combination with electromyography (EMG) biofeedback to knee osteoarthritis patients for three weeks and reported decrease in their pain and increased in their muscle strength. However, although closed kinetic chain exercise has been much used for rehabilitation and training of PFPS patients until recently, research which examined improvement of muscle control and response ability by self-controlling muscle activity using EMG biofeedback during closed kinetic chain exercise aimed at heightening treatment efficiency is very insufficient.

This study intends to examine the effects of improvement in muscle control and response ability of PFPS patients by having them self-control muscle activity using EMG biofeedback during close kinetic chain exercise on functional characteristics of their patellofemoral joint muscles.

2. Subjects and Methods

2.1. Subjects

The characteristics of the subjects are shown in Table 1. Thirty students were selected as subjects among 200 female undergraduates in M University located in Jeollanam-do. The subjects did not have a history of orthopedic or neurosurgical disease and understood the purpose of this study and provided written informed consent prior to their participation in the study in accordance with the Teacher`s research ethic guidelines. They were randomly and equally divided into a control group (I), a closed kinetic chain exercise group (II), and a closed kinetic chain exercise group using EMG biofeedback (III).

Table 1. General Characteristics of Each Group

	Group Ⅰ	Group Ⅱ	Group Ⅲ
Age(Years)	21.80±1.22	21.40±0.96	20.80±0.91
Height(㎝)	161.81±5.05	159.90±4.17	156.75±6.09
Weight(㎏)	55.18±3.35	53.91±2.74	51.72±4.16
BMI(㎏/㎡)	22.28±4.99	21.58±2.84	20.77±2.19

Value are given as mean±standard deviation
Group I : control, Group II : closed kinetic chain exercise, Group III : closed kinetic chain exercise using EMG biofeedback

2.2. Measurement Methods

In order to look at the effects of closed kinetic chain exercise for six weeks using EMG biofeedback on PFPS patients' functional characteristics of patellofemoral joint muscles, this study conducted visual analogue scale (VAS) and electromyography prior to and after the intervention.

2.3. Closed Kinetic Chain Exercise

For closed kinetic chain exercise, the subjects folded their arms lightly, had their legs shoulder-width apart, straightened the trunk up, and kept the back on the wall [12]. After the subjects received sufficient training on the posture prior to the exercise, they bent their knees to 60 degrees, maintained a squat position for 10 seconds, and stood again. They took a rest for 20 seconds and conducted the exercise three times per week for 30 minutes per each time. During the squat exercise, the angle of the knees was maintained constant using an electronic goniometer attached to the lateral leg (Simple Sensor Twin Axis Goniometer, Biopac, USA).

2.4. Closed Kinetic Chain Exercise Using EMG Biofeedback

In order to selectively maintain muscle activity of the VMO at maximal level, EMG biofeedback (Mymed 132, Enraf Nonius, Netherlands) was used [13]. The monitor was placed in front of the subjects so that they may identify EMG biofeedback signals easily. Their contraction time was 10 seconds and their resting time was 20 seconds. They conducted the exercise three times per week, for 30 minutes per each time.

2.5. Analysis on Pain

VAS was used to evaluate subjective pain of the subjects [14]. VAS is for a subject to himself or herself mark and record changes in pain perceived by him or her. A 10 cm line is drawn on a paper, with zero indicating no pain and 10 meaning unbearable pain. As the value comes near to zero, pain decreases.

2.6. Assessments of Functional Ability

Functional ability was used to evaluate Kujala patellofemoral score (KPS) of the subjects [15]. KPS developed by Kujala *et al.*, is comprised of 13 questions. These questions inquire whether there is pain during walking up and down stairs, squatting, running, jumping, or prolonged sitting with the knee in flexion; whether there is limping, swelling, or subluxation of the patella; the amount of atrophy in the quadriceps muscle, flexion deficiency, and pain, and whether there is a need for a walking aid. The total score ranges from 0 to 100, the highest indicating the best score.

2.7. EMG Analysis

Surface EMG (MP150, Biopac system, USA) was used for collection and processing of EMG signals from the VMO and the VL. The sampling rate for EMG signal collection was 1,000 and the frequency band filter was set at 20 to 50 ㎐. Measurement was taken when the subjects in a squat position sat on an experimental chair with the upper body fixed and extended the knees against manual resistance. Recording electrodes were attached on the VMO and the VL and the ground electrode was attached on the tibial tuberosity [16]. Analysis of EMG signals was made using Acqknowledge 4.1 software program (Biopac, USA), and root-mean-square (RMS) amplitude and median frequency (MDF) of the signals were analyzed.

Table 2. Electrode Location

Muscle	Location
VMO	Apprximately 4 cm superior to and 3 cm medial to the superomedialal patella border, and orientated 55° to the vertical.
VL	Apprximately 10 cm superior and 6 to 8 cm lateral to the superior border of the patella, and orientated 15° to the vertical.

2.8. Data Analysis

All data from this study were analyzed using the SPSS 12.0 statistics program. In order to examine normality of each measured item, the single-sample Shapiro–Wilk test was conducted. Differences among the groups in changes in VAS and EMG values were analyzed using analysis of variance and covariance (ANCOVA). Bonferroni test was conducted as post-hoc analysis. In order to verify significance of all statistical analyses, the significance level was set at $\alpha=0.05$.

3. Results

3.1. Changes of VAS

The result of ANCOVA on differences in changes in VAS values among the groups is displayed in Table 3. Changes in VAS were significantly different among the groups ($p<.01$). According to Bonferroni post hoc test results, there were significant changes in Groups II ($p<.01$) and III ($p<.01$) compared to Group I.

Table 3. Changes of VAS

(cm)

	Pre	Post	F	P
Group Ⅰ	5.91±1.67	5.73±1.42	7.74	.002$^{\#\#}$
Group Ⅱ	5.57±1.73	3.52±1.13 $^{1)**}$		
Group Ⅲ	5.62±1.67	3.33±1.85 $^{2)**}$		

Value are given as mean±standard deviation
Test by ANCOVA($^{\#}$; P<.05). Post-hoc was Bonferroni test. $^{1)}$; I-II (**;p<.01), $^{2)}$; I-III (**; p<.01)

3.2. Changes of Functional Ability

The result of ANCOVA on differences in changes in VAS values among the groups is displayed in Table 4. Changes in KPS were significantly different among the groups ($p<.01$). According to Bonferroni post hoc test results, there were significant changes in Groups II ($p<.05$) and III ($p<.05$) compared to Group I.

Table 4. Changes of KPS

(score)

	Pre	Post	F	P
Group Ⅰ	79.10±5.40	79.90±5.25	5.45	.01$^{\#\#}$
Group Ⅱ	78.90±6.31	84.90±4.72 $^{1)**}$		
Group Ⅲ	78.20±4.36	85.60±4.67 $^{2)**}$		

Value are given as mean±standard deviation
Test by ANCOVA($^{\#}$; P<.05). Post-hoc was Bonferroni test. $^{1)}$; I-II (**;p<.05), $^{2)}$; I-III (**; p<.05)

3.3. Changes in MDF during a Squat Position

The result of ANCOVA on differences among the groups in changes in MDF values during a squat position is shown in Table 5. Changes in median frequency values were significantly different among the groups ($p<.05$) and according to Bonferroni post-hoc test results, there were significant changes in Groups II ($p<.05$) and III ($p<.05$) compared to Group I.

Table 5. Changes of MDF During a Squat Position

(Hz)

	Pre	Post	F	P
Group Ⅰ	14.09±0.90	14.22±0.68		
Group Ⅱ	13.75±0.85	14.86±0.93 1)*	4.368	.023#
Group Ⅲ	13.38±0.87	14.68±0.95 2)*		

Value are given as mean±standard deviation
Test by ANCOVA(#; P<.05). Post-hoc was Bonferroni test. 1); I-II(*; p<.05), 2); I-III (*; p<.05)

3.4. Changes in VMO/VL Muscle Activity Ratios During a Squat Position

During a squat position, differences among the groups in changes in MDF values were significant (p<.05) and according to Bonferroni post-hoc test results, there were significant changes in Groups II (p<.05) and III (p<.05) compared to Group I.

Table 6. Changes of VMO/VL Muscle Ratios During a Squat Position

(㎶)

	Pre	Post	F	P
Group Ⅰ	0.75±0.10	0.76±0.12		
Group Ⅱ	0.76±0.09	0.89±0.11 1)*	4.976	.015#
Group Ⅲ	0.75±0.11	0.88±0.12 2)*		

Value are given as mean±standard deviation
Test by ANCOVA(#; P<.05). Post-hoc was Bonferroni test. 1); Ⅰ-Ⅱ(*; p<.05), 2); Ⅰ-Ⅲ(*; p<.05)

4. Discussion

In order to evaluate the treatment effects of PFPS patients, diverse kinds of measurement tools are used. Among them, VAS is the most reliable measurement tool [17]. In a study on test-retest reliability of 60 PFPS patients, Bennell *et al.*, [18] reported that VAS was high at *r*=.70 and another previous study employed VAS in order to evaluate pain of PFPS patients [19]. Witvrow et al. [20] applied closed and open kinetic chain exercises to PFPS patients for five weeks and reported reduction in their pain, and Yilmaz *et al.*, [11] observed that application of muscle strengthening exercise using EMG biofeedback to gonarthritis patients for three weeks resulted in decrease in their VAS values. In the present study as well, the degree of pain of the subjects with PFPS was measured prior to and after the intervention using VAS, and there were significant decreases in pain in the two other groups relative to the control group. This is considered because improvement in muscle strength and co-contraction of QFM and BFM resulting from each intervention enhanced stability of the patella, effectively influencing pain reduction.

Surface EMG analysis is an important equipment to evaluate treatment result in a treatment process and provides useful information [21]. Median frequency resulting from frequency spectrum analysis on EMG signals is widely used to measure muscle fatigue [22]. Callaghan *et al.*, [23] reported that two different electrical stimulations to the QFM of PFPS patients resulted in significant decrease in their muscle fatigue. In the present study, MDF values significantly increased in all the groups after the intervention compared to prior to the intervention. The degree of fatigue significantly decreased in the closed kinetic chain exercise group using EMG biofeedback relative to the closed kinetic exercise group.

Souza and Gross [24] reported that VMO/VL muscle activity ratios were close to 1:1 during normal subjects' isometric exercise. Powers [25] noted that VMO/VL muscle activity ratios were lower in PFPS patients than in normal people. Dursun et al. [13] applied universal treatment and treatment in combination with EMG biofeedback to 60 PFPS patients for improvement in balance between the VMO and VL, and reported that VMO/VL muscle activity ratios significantly increased in the group which received treatment in combination with EMG biofeedback compared to the control group. In the present study, all the groups' VMO/VL muscle activity ratios became close to 1:1 after the intervention, but the muscle activity ratios significantly increased in the closed kinetic exercise group which used EMG biofeedback relative to the closed kinetic exercise group. This is regarded because EMG biofeedback enabled self-control of muscle activity and improved muscle control and response ability, more effectively influencing decrease in muscle fatigue and improvement in muscle activity ratios than the other interventions.

To sum up the above results, closed kinetic chain exercise is effective in reducing PFPS patients' pain through improvement in their muscle functions, but closed kinetic chain exercise in combination with EMG biofeedback providing biometric information on a real-time basis more significantly decreases their pain because the patients make efforts to create changes.

5. Conclusion

The above results signify that when the subjects self-control muscle activity using EMG biofeedback which provides biometric information on the relevant muscles on a real-time basis for efficient treatment, their muscle control and response ability and muscle functions improve.

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Authors

Jae-Young, Kang, received the B.S. degree in physical therapy from Mokpo Science College, Korea in 2000. He received the M.S. degree in physical therapy from Dongshin University, Korea in 2012. Currently, he is an physical therapist in the Department of physical therapy at Jungang Hospital, Korea. His present research is therapeutic exercise and biomechanics.

Tae-Gon Kim, received the B.S. degree in physical therapy from Seonam University, Korea in 2004. He received the M.S. degree in physical therapy from Dongshin University, Korea in 2012. Currently, he works as Ph.D. student at Dongshin University, Korea and physical therapist in the Dongin Hospital, Korea. His present research is therapeutic exercise and biomechanics.

Kyung-Yoon Kim, received the B.S. degree (2000) and the M.S. degree (2002) in physical therapy from Dongshin University, Korea. He is received the Ph.D in the same area from Dongshin University, Korea in 2007. Currently, he is an Associate Professor in the Department of Physical Therapy at Dongshin University, Korea. His present research is therapeutic exercise and biomechanics.