The Effectiveness of Electromyographic Biofeedback Supplementation During Knee Rehabilitation After Injury

Carrie Silkman and Jennifer McKeon

Clinical Scenario

Regaining neuromuscular control of the quadriceps muscle group is a major focus of therapeutic exercise programs for knee injuries. A key component in restoring neuromuscular control involves increasing muscle strength. It is important to restore quadriceps strength to improve function and increase stability of the knee. Electromyographic (EMG) biofeedback is a tool used to estimate the electrical activity taking place in the muscle and is used to give visual and/or audio feedback to the patient about activity levels in the muscle of interest. There is conflicting evidence regarding the effectiveness of EMG biofeedback for improving muscle function when used in as part of rehabilitation protocols. However, many clinicians continue to use this therapy as a supplement to conventional therapeutic exercise.

Focused Clinical Question

For patients with knee injuries, is the use of EMG biofeedback, in conjunction with a conventional therapeutic exercise program, more effective in improving quadriceps muscle activation and knee function than a conventional therapeutic exercise program alone?

Summary of Search, “Best Evidence” Appraised, and Key Findings

- We searched the literature for studies of level 2 evidence or higher, in accordance with the Oxford Centre for Evidence Based Medicine, that investigated the effects of EMG treatment in patients with knee injuries. Studies at level 2 would generally be moderately designed, with instances of investigator bias. Level 1 studies would be well designed with minimal instances of investigator bias.
- Four studies1–4 that were randomized control trials were included.
Two studies\textsuperscript{2,3} demonstrated that EMG biofeedback was effective at improving muscle activation and function of the quadriceps when used with a conventional therapeutic exercise program versus a conventional therapeutic exercise program alone.

Two studies\textsuperscript{1,4} demonstrated that EMG feedback did not improve outcomes when used with a conventional therapeutic exercise program versus a conventional therapeutic exercise program alone.

**Clinical Bottom Line**

There is modest evidence to suggest that EMG biofeedback, when used in conjunction with a conventional exercise program, may have a positive influence on quadriceps muscle activation and knee function in patients with a knee injury.

**Strength of Recommendation**: There is level C (inconsistent) evidence to support the use of EMG biofeedback in knee rehabilitation. When used with a conventional therapeutic exercise program, it is not conclusive that EMG biofeedback increases muscle activation and function of the quadriceps in patients with knee injuries compared with conventional exercises alone.

**Search Strategy**

**Terms Used to Guide Search Strategy**

- **Patient/Client group**: knee injuries
- **Intervention (or assessment)**: Biofeedback with exercise or therapy or rehabilitation
- **Comparison**: control group (performed therapeutic exercise program alone)
- **Outcomes**: maximum contraction or mean contraction or knee strength

**Sources of Evidence Searched**

- CINAHL
- ERIC
- MEDLINE
- PsycINFO
- SPORTDiscus
- PEDro
- Cochrane Library
- Hand search

**Inclusion and Exclusion Criteria**

**Inclusion**

- Studies investigating EMG biofeedback of knee rehabilitation
- Level 2 evidence or higher
• Limited to English
• Limited to humans
• Published within the last 10 years (1999–2009)

Exclusion

• Studies investigating a form of biofeedback other than EMG biofeedback
• Studies that did not incorporate a conventional therapeutic rehabilitation program as a control

Results of Search

Four relevant studies were located and categorized as shown in Table 1 (based on levels of evidence, Centre for Evidence Based Medicine, 1998).

Best Evidence

The studies in Table 1 were identified as the best evidence and selected for critical appraisal. Reasons for selecting these studies were that they were graded with a level of evidence of 2 or higher and studied an EMG biofeedback supplement to a rehabilitation program in patients with knee injuries.

Implications for Practice, Education, and Future Research

Two of the 4 studies\(^2,3\) selected for this critically appraised topic (CAT) supported the use of EMG biofeedback in therapeutic rehabilitation of knee injuries (see Table 2). Two additional studies indicated that EMG biofeedback did not enhance the conventional therapeutic exercise program. All therapeutic exercise programs of the included studies were focused on rehabilitation of the quadriceps muscle group, specifically the vastus medialis oblique (VMO) and vastus lateralis (VL). However, the types of knee injuries and outcomes that were investigated were considerably different among the 4 studies. EMG biofeedback may be effective in enhancing therapeutic rehabilitation of knee injuries in some patient populations, but the findings of this CAT are inconclusive.

Table 1  Summary of Study Designs of Articles Retrieved

<table>
<thead>
<tr>
<th>Level of evidence</th>
<th>Experimental design</th>
<th>Number located</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1b</td>
<td>randomized controlled trial</td>
<td>2</td>
<td>Dursun et al(^1)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Ng et al(^3)</td>
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<tr>
<td>2b</td>
<td>randomized controlled trial</td>
<td>2</td>
<td>Kirnap et al(^2)</td>
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<td></td>
<td></td>
<td></td>
<td>Yip and Ng(^4)</td>
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Table 2 Characteristics of Included Studies

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<tr>
<td>Participants</td>
<td>60 patients with PFPS (48 women, 12 men, 17–50 y). Randomly assigned to an EMG-biofeedback group (with conventional therapeutic exercise program) or a control group (conventional therapeutic exercise program). Subjects were eligible if they had diagnosed unilateral PFPS, with full knee range of motion. Subjects were excluded if they had evidence of other intra- or extra-articular knee pathologies, history of knee trauma or intra-articular injection therapy or surgery, or had used nonsteroidal anti-inflammatory drugs within 15 days before treatment began. There were no group differences based on demographics.</td>
<td>40 male patients who had undergone arthroscopic meniscectomy (mean age 34.5 ± 10.3 y). Randomly assigned to an EMG-biofeedback group (with conventional therapeutic exercise program) or a control group (conventional therapeutic exercise program). No significant difference in age or leg dominance between control and biofeedback groups.</td>
<td>26 subjects (16 women, 10 men) diagnosed with PFPS by attending physicians (20–55 y). Randomly assigned to an EMG-biofeedback group (with conventional therapeutic exercise program) or a control group (conventional therapeutic exercise program). Subjects were eligible if they had insidious onset of anterior knee pain for at least 6 mo and received no physiotherapy and had pain in at least 2 of the following activities: ascending stairs, descending stairs, squatting, kneeling, prolonged sitting, hopping, or jumping. There were no initial significant differences between groups.</td>
<td>26 subjects (16 women, 10 men) diagnosed with PFPS by attending physicians (22–55 y). Randomly assigned to an EMG-biofeedback group (with conventional therapeutic exercise program) or a control group (conventional therapeutic exercise program). Subjects were eligible if they had insidious onset of PFPS for at least 6 mo, a positive apprehension test, and pain in at least 2 of the following activities: ascending stairs, descending stairs, squatting, kneeling, prolonged sitting, hopping, or jumping. Subjects were excluded if they had degenerative changes on radiography, chondral damage, meniscal lesion, ligamentous instability, previous knee surgery or traumatic injury, or signs of acute inflammation. There were no initial significant differences between groups.</td>
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</table>
Intervention investigated

30 min surface EMG-biofeedback training with 2-channel EMG machine positioned on the VM and VL. Auditory feedback was provided for the VM 3 d/wk for 4 wk.

Conventional therapeutic exercise program was supervised by a physical therapist and performed 5 d/wk for first 4 wk and 3 d/wk for remaining 2 mo by both groups. The program consisted of isometric strengthening exercises for quads and VMO, flexibility training, proprioception training, and endurance training on a bicycle.

No blinding of subjects, assessors, or therapists.

Outcome measures

Primary Outcome: Maximum and mean contraction values of VM and VL.

Secondary Outcomes: Pain measures (visual analog scale) and functional status (Functional Index Questionnaire).

Primary Outcome: Maximum and mean contraction values of VMO and VL.

Secondary Outcomes: Knee range of motion and Lysholm knee scores.

Primary Outcome: VMO:VL EMG ratio during 6-h assessment of daily activities after 8 wk of training.

Secondary Outcomes: Patellar alignments (according to McConnel using Vernier calipers) and perceived pain severity (PPSS).

Surface EMG-biofeedback training was performed with a 2-channel EMG machine located on the VMO and VL 5 ×/wk for 2 wk. Isometric quadriceps contractions were performed (20 cycles of 5 s work, 10 s rest).

A conventional therapeutic home-exercise program of 3 phases was performed by both groups for 2 wk.

No blinding of subjects, assessors, or therapists.

Surface EMG-biofeedback unit was given to those in the biofeedback group to measure activity of the VMO and VL. Exercise protocol was followed with use of the EMG machine.

A conventional therapeutic exercise protocol included warm-up, knee-extensor strengthening, proprioception training, and agility drills aimed at VMO strengthening (30 min, 8 wk).

Subjects and assessors were blinded.

Surface EMG-biofeedback machine measured activity of the VMO and VL during the exercise protocol.

The conventional therapeutic exercise protocol consisted of flexibility exercises, strengthening exercises for the quadriceps with emphasis on VMO, balance and proprioception training, and plyometric and agility training for 15 min/d for 8 wk.

Subjects kept logs of exercise time and frequency.

Assessor and therapists were blinded.
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<tr>
<td>Main findings</td>
<td>Primary Findings: Mean contraction values of VM at all 3 mo and VL at end of first month were significantly higher ($P = .046$, $P = .042$, $P = .036$, $P = .007$) for the biofeedback group than control. Secondary Findings: Maximum contraction values improved significantly in both groups at end of first month compared with baseline (biofeedback: VM $P = .000$, VL $P = .015$; control: VM $P = .003$, VL $P = .005$). VAS and FIQ scores improved in both groups ($P = .000$).</td>
<td>Primary Findings: No difference between groups for max and mean contraction values of VMO and VL 3 d post-op. Statistically significant difference between groups on day 14 and week 6 post-op for max and mean contraction values of the VMO and VL ($P &lt; .05$) in favor of the biofeedback and exercise group. Secondary Findings: No difference was found between groups for average value of knee-flexion angle 3 d post-op, but significant difference at day 14 and 6 wk post-op in biofeedback group ($P &lt; .05$). Significant improvement in Lysholm knee scores at day 14 and 6 wk post-op for biofeedback group ($P &lt; .05$).</td>
<td>VMO:VL EMG ratio did not improve after 8 wk of training in the exercise-only group ($P = .355$) but significantly improved for the biofeedback-plus-exercise group ($P = .016$).</td>
<td>Primary Findings: Overall isokinetic peak torque and total work increased throughout 8 wk ($P = .005$, $P = .037$). No significant difference between groups. Secondary Findings: Significant changes of patellar alignment in both groups ($P = .045$) at end of 8 wk. PPSS decreased in both groups but not significantly ($P = .08$).</td>
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<tr>
<td>Level of evidence</td>
<td>Validity score</td>
<td>Conclusion</td>
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<tr>
<td>1b</td>
<td>PEDro 5/10</td>
<td>EMG biofeedback did not result in further improvements compared with a conventional therapeutic exercise program in patients with PFPS.</td>
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</tr>
<tr>
<td>2b</td>
<td>PEDro 6/10</td>
<td>EMG biofeedback was an effective treatment in improving quadriceps muscle activation in patients recovering from arthroscopic meniscectomy when used in conjunction with a conventional therapeutic exercise program compared with a conventional therapeutic exercise program alone.</td>
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<tr>
<td>1b</td>
<td>PEDro 6/10</td>
<td>Incorporating EMG biofeedback into a conventional therapeutic rehabilitation program assists VMO activation during daily activities compared with a conventional therapeutic rehabilitation program alone.</td>
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<tr>
<td>2b</td>
<td>PEDro 6/10</td>
<td>EMG biofeedback supplementation to an 8-wk exercise program had no measurable effects on VMO activation in patients with PFPS.</td>
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</table>

Abbreviations: PFPS, patellofemoral pain syndrome; VM, vastus medialis; VL, vastus lateralis; VMO, vastus medialis oblique; PPPS, Patellofemoral Pain Severity Scale.
The notable differences among the studies were the types of knee injuries that were the focus of the rehabilitation. Three studies\textsuperscript{1,3,4} investigated participants with patellofemoral pain syndrome, and 1 study\textsuperscript{2} examined participants who had undergone arthroscopic meniscectomy. Although the injuries were different, we included both because knee rehabilitation regularly includes quadriceps strengthening regardless of the condition. Patellofemoral pain syndrome is an overuse injury, and it was necessary to be included that participants had exhibited signs and symptoms for more than 6 months, whereas meniscectomy is an acute trauma to the knee. The dissimilarity in onset of injury might help explain some of the variation in EMG biofeedback’s effectiveness.

All 4 studies examined the effect of EMG biofeedback by evaluating muscle activity, but there were some differences in the choice of outcome measures. Activity ratio of the VMO:VL EMG,\textsuperscript{3} the relationship of muscle activity of the VMO and VL, was one measure chosen to indicate effects of the EMG biofeedback therapy. Two studies\textsuperscript{1,2} used the maximum muscle contraction and the average muscle contraction as outcome measures. These values indicate the maximum and mean muscle activity measured in \(\mu\text{V}\), which is also a measure of activity. The final study\textsuperscript{4} evaluated peak torque and total work of the quadriceps measured by an isokinetic machine. All the measures are adequate for assessing the effects of EMG biofeedback but are not consistent across the 4 studies.

These differences among reported outcomes present a challenge in synthesis of information. A measure of quadriceps strength might be more clinically relevant than contraction value, a measure of voltage within a muscle during a contract, or a VMO:VL ratio that requires an EMG machine to record activity, not just a biofeedback unit. All the outcome measures, however, help elucidate what is happening in the quadriceps muscle group after EMG biofeedback protocols.

Although there were discrepancies across the included studies in the outcome measures and nature of knee injury, it was shown that EMG biofeedback may have positive effects on VMO activation\textsuperscript{3} and knee function\textsuperscript{2} when used with a conventional therapeutic exercise program. Feedback is essential to patients in order to progress through an exercise program. Knowledge of activity that is taking place in the muscle can provide a key insight to neuromuscular control, which can lead to strength gains.

In the course of clinical practice, it is uncertain whether EMG biofeedback should be used as a supplement to conventional therapeutic rehabilitation for knee injuries. Although there is conflicting evidence of the effectiveness of the therapy, EMG biofeedback demonstrates little to risk to the patient. Clinicians with EMG biofeedback units available to them might use them as a tool to involve the patient in the rehabilitation process and to demonstrate the activity within the quadriceps muscle group. If an EMG biofeedback unit is not available, the results of this CAT do not support the purchase of one if funds are limited.

References

