THE NEW ZEALAND MEDICAL JOURNAL
Vol 118 No 1224 ISSN 1175 8716

The efficacy of EMG-biofeedback training on quadriceps muscle strength in patients after arthroscopic meniscectomy

Mehmet Kirnap, Mustafa Calis, Ali Osman Turgut, Mehmet Halici, Mehmet Tuncel

Abstract

Aims In 40 patients, we attempted to investigate the efficacy of electromyography-biofeedback (EMG-B) on quadriceps muscle strength after arthroscopic meniscectomy.

Methods The patients were randomly divided into two groups each consisting of 20 subjects. For the control group, a classical exercise program was given (five sessions of EMG-B application for 2 weeks postoperatively). Range of motions, Lysholm knee score, EMG electrical activity values of vastus medialis obliques (VMO), and vastus lateralis (VL) were measured pre- and postoperatively on the 3rd and 14th day, and at the 6th week.

Results When the ranges of motion values were compared, a significant difference (for average values of knee flexion angle) was found on the14th day and 6th week in favour of biofeedback group ($p<0.05$). When Lysholm knee scores on the 14th day and 6th week were compared in the control and biofeedback groups, and maximum contraction and average contraction values of VMO, VL muscles were compared with operated/non-operated %age ratios, there was a statistically significant difference in favour of the biofeedback group ($p<0.05$).

Conclusions Our results showed that EMG-B was an effective treatment modality in improving quadriceps muscle strength after arthroscopic meniscectomy surgery.

After knee surgery, extensor capacity of the knee decreases considerably. This muscle weakness occurs as a result of reflex inhibition of motor neurones. It is defined as 'pathogenic muscle weakness' and is not related to direct muscle injuries.[1–3]

During the postoperative inactivation process, quadriceps femoris muscle (responsible for the extensor mechanism) weakness is an important problem during the postoperative rehabilitation programme. Despite the advances in knee surgery, postoperative degenerative changes in joint cartilage, and observation of problems such as functional capacity deficit in extensor muscles, all force the investigators to develop rehabilitation protocols to minimise postoperative problems.[4]

The EMG-B instrument, which is mainly used for muscle re-education and relaxation, is a sensitive volt meter that can record muscle activities (superficially as µV or by rarely used needle electrodes).[5,6]

EMG-B is generally used to provide muscle re-education, and to regain muscle strength in cases of muscle weakness.[7,8] It is also applied in the treatment of muscle weaknesses due to postoperative immobilisation in orthopaedic rehabilitation. A patient's compliance to the exercise program can be improved by addition of EMG-B to the classical rehabilitation programs that are applied in those patients.[9–11]

In this study, we investigated whether the addition of EMG-B application to postoperative classical home exercise program after athroscopic meniscectomy patients is effective in improving quadriceps muscle strength in the postoperative rehabilitation program.

Materials and Methods

Design—Forty patients who had undergone arthroscopic menisectomy were included in the study. The patients were randomly divided into two equal groups: a biofeedback group and a control group.

The same exercise programme (conventional home-exercise programme) consisting of three phases was given to the patients in both groups from the postoperative first day. In the first phase of the exercise programme, cold application, quadriceps setting, patellar mobilisation, and straight-leg raising exercises were done; in the second phase, hip adductor strengthening and terminal knee extension exercises were done additionally (and in addition to) the above; while in the third phase, closed kinetic chain exercises and lateral step up exercises were applied. Furthermore, EMG-B training was applied to the patients in EMG-B group from the postoperative third day for 2 weeks.

The patients were followed up for 6 weeks. The measurements were performed preoperatively, on the postoperative 3rd and 14th days, and on the 6th week according to the assessment criteria.

Assessment criteria:

- Measurements of thigh and knee circumference (cm), and passive joint range of motion (degree);
- Lysholm knee score;[12] and
- Maximum contraction and mean contraction values of electrical activities (mV) of operated and non-operated aspects of VMO and VL muscles that are measured by EMG-B instrument. Operated/non-operated %age ratios were calculated. Those values were used as parameters in statistical studies.

Knee circumferences were measured from the middle part of the patella, and thigh circumferences were measured by marking the anterior aspect of the thigh at 15 cm proximal to the patella. Passive joint ranges of motions (ROM) were measured by goniometry.

Biofeedback training was performed with a Myomed 932 myofeedback unit (Enraf-Nonius®, serial no: 11490, Netherlands). During therapy and testing sessions, two active electrodes of the first channel of the instrument were placed 4 cm above the upper edge of patella on the VMO muscle and at 3 cm medial at an angle of 55° by the vertical plane; active electrodes of the second channel were placed 10 cm above the upper edge of patella on the VL muscle and at 6–8 cm lateral at an angle of 15° by vertical plane. The ground electrode was placed 2–3 cm below the patella on the same side of the limb.[13]

For measurements, the instrument were adjusted to give audible stimulation when a contraction above the threshold value with work time of 5 sec, rest time of 10 sec and 20 cycles was performed. The patients were asked to perform isometric quadriceps contraction during the work period.

Thus, the patient provided visual feedback by watching the contractions on the screen and provided audible feedback by signal sound when it exceeded the threshold value. The EMG-biofeedback test was performed with the patient sitting. During the test sessions on control days, maximum and average contraction values of VMO and VL muscles (that are defined in both groups of the patients at the end of 20 sets by the biofeedback instrument) were recorded.

For the patients in the EMG-B group, a biofeedback training session starting from the postoperative third day was applied once daily for 5 days per week. The patients had to contract their quadriceps muscle more strongly by increasing the threshold value every day.

Statistical analyses—Repeat measures ANOVA and student t-test were used to determine the differences between the controls and study group, respectively. Chi-squared tests were carried out, for qualitative data. All data were evaluated using the SPSS 9.0 statistical software program. Mean values were considered significantly different if $p<0.05$.

Results

All of the patients were male and their average age was 34.5±10.3. There was no significant difference in age between the control and biofeedback groups, nor right/left and dominant/non-dominant sides of operated limbs ($p>0.05$, $p>0.05$ respectively). There was no difference according to operation scheme between the control and EMG-B groups ($p<0.05$) (Table 1).

Table 1. Distribution of patients with operated extremity according to right/ left and dominant/nondominant side

Variable	EMG-biofeedback n (%)	Control n (%)	All patients n (%)
MM, partial meniscectomy	12 (60)	13 (65)	25 (62,5)
LM, partial meniscectomy	3 (15)	4 (20)	7 (17,5)
MM, bucket-handle tear, partial meniscectomy	4 (20)	2 (10)	6 (15)
LM, discoid meniscus, partial meniscectomy	1 (5)	1 (5)	2 (5)
Total n (%)	20 (100)	20 (100)	40 (100)

MM: medial meniscus; LM: lateral meniscus.

No statistically significant difference was detected between the control and biofeedback groups for average values of operated extremity thigh and knee circumferences that were measured pre- and postoperatively, and at the 3rd and14th day and 6th week ($p>0.05$, $p>0.05$ respectively).

When we compared the joint ranges of motions, no statistically significant difference was detected between the control and biofeedback groups for average values of flexion angle in the operated limb preoperatively, and on the postoperative 3rd day, while a significant difference was detected on the 14th day and 6th week in favour of the biofeedback group ($p<0.05$) (Table 2).

Table 2. Operated extremity knee flexion angle values at baseline, 3rd day, 14th day, and 6th week

Variable	N	Preop. X±SD	3rd day X±SD	14th day X±SD	6th week X±SD	P values
EMG-B group	20	134.3 ± 9.3	99.7 ± 17.8	129 ± 10.2	137.1 ± 6.5	<0.001
Control group	20	130.2 ± 8.8	98.2 ± 13.6	118.2 ± 11.7	129.2 ± 7.4	<0.001
P values		>0.05	>0.05	<0.05	<0.001	

No statistically significant difference was found between the groups in Lysholm knee score preoperatively and on the postoperative 3rd day; however when Lysholm knee scores on the 14th day and 6th week were compared, it was found that there was statistically significant difference in favour of the biofeedback group ($p<0.05$) (Table 3).

Table 3. Lysholm knee scores values at baseline, 3rd day, 14th day, and 6th week

Variable	n	Preop. X±SD	3rd day X±SD	14th day X±SD	6th week X±SD	P values
EMG-B group	20	70.3 ± 14.3	57.8 ± 11.6	85 ± 8,4	95.4 ± 3.7	<0.001
Control group	20	69.1 ± 12.9	54.5 ± 9.9	68.1 ± 7.8	79.6 ± 10.1	<0.001
P values		>0.05	>0.05	<0.001	<0.001	

During the preoperative evaluations, the only parameter that was significantly different between the groups was in operated/non-operated %age ratio of average contraction value of VMO muscle ($p<0.05$). On the other hand, as in the other parameters, there was no difference in average contraction value of VL muscle, preoperatively.

No statistically differences were found between the groups for maximum contraction and average contraction values of VMO and VL muscles preoperatively and at postoperative 3rd day in operated/non-operated %age ratios (except for preoperative VMO average contraction) while there was a statistically significant difference on the 14th day and 6th week (Figures 1, 2, 3, and 4).

Figure 1. Operated/non-operated % ratio of maximum contraction value of vastus medialis obliques (VMO) muscle

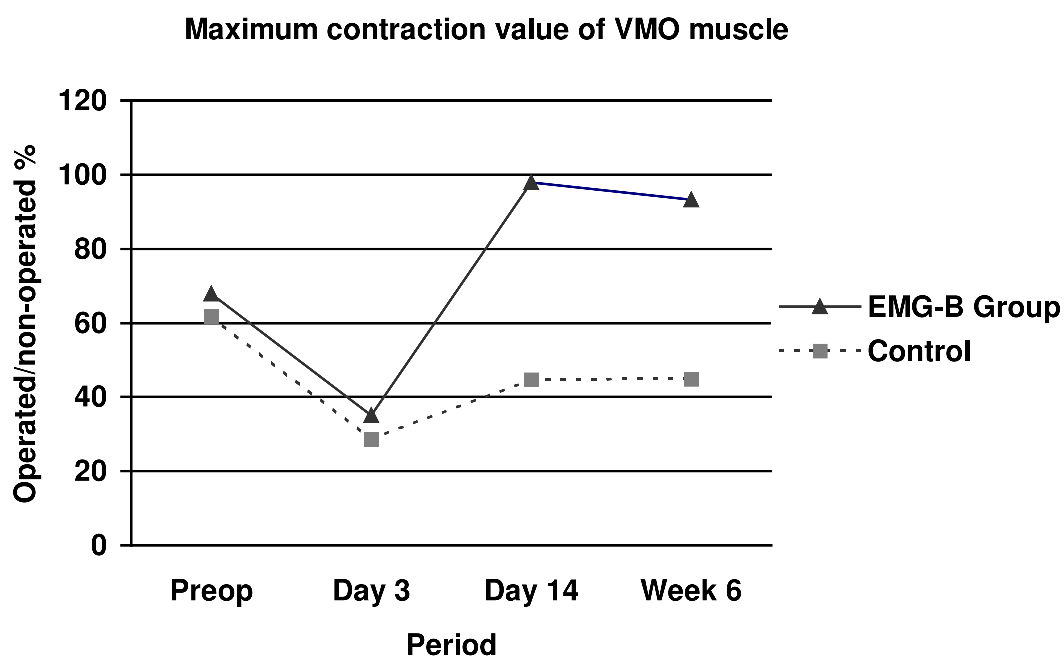


Figure 2. Operated/non-operated % ratio of maximum contraction value of vastus lateralis (VL) muscle

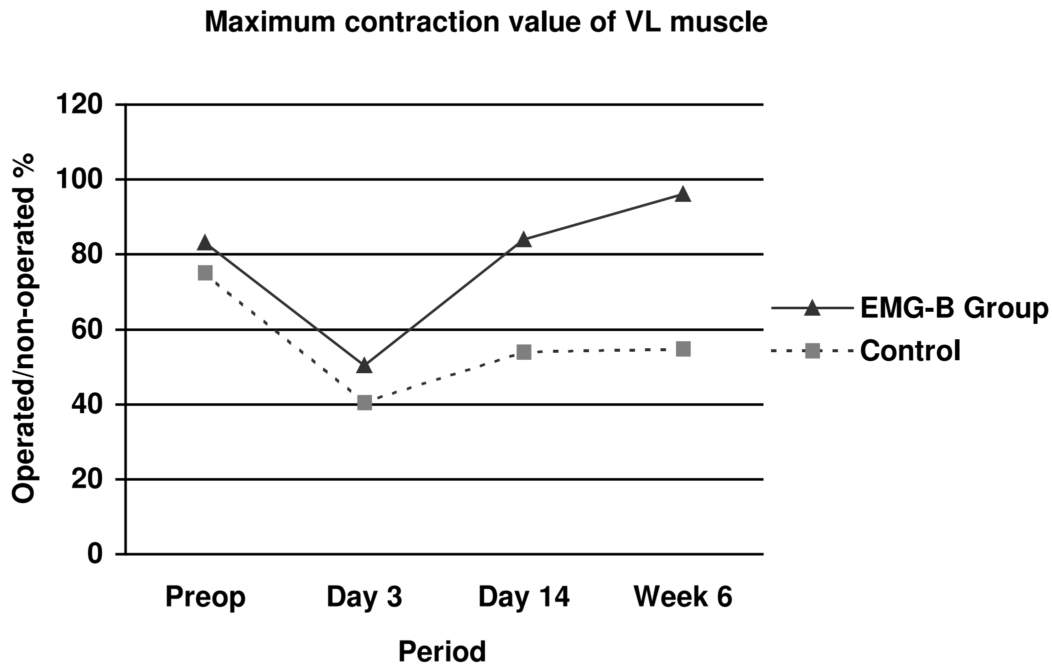


Figure 3. Operated/non-operated % ratio of average contraction value of VMO muscle

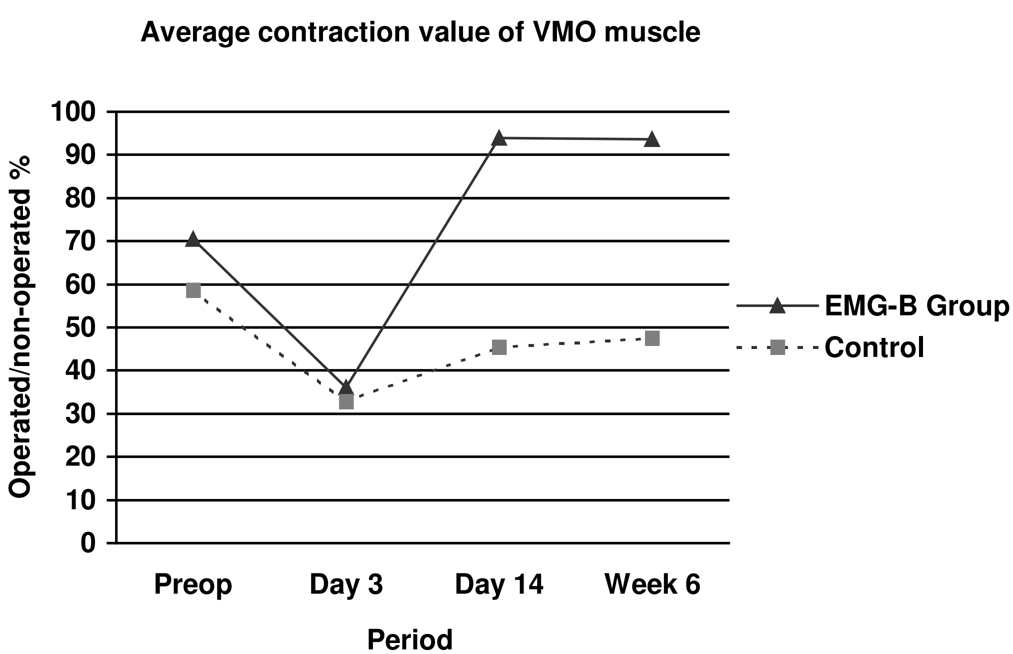
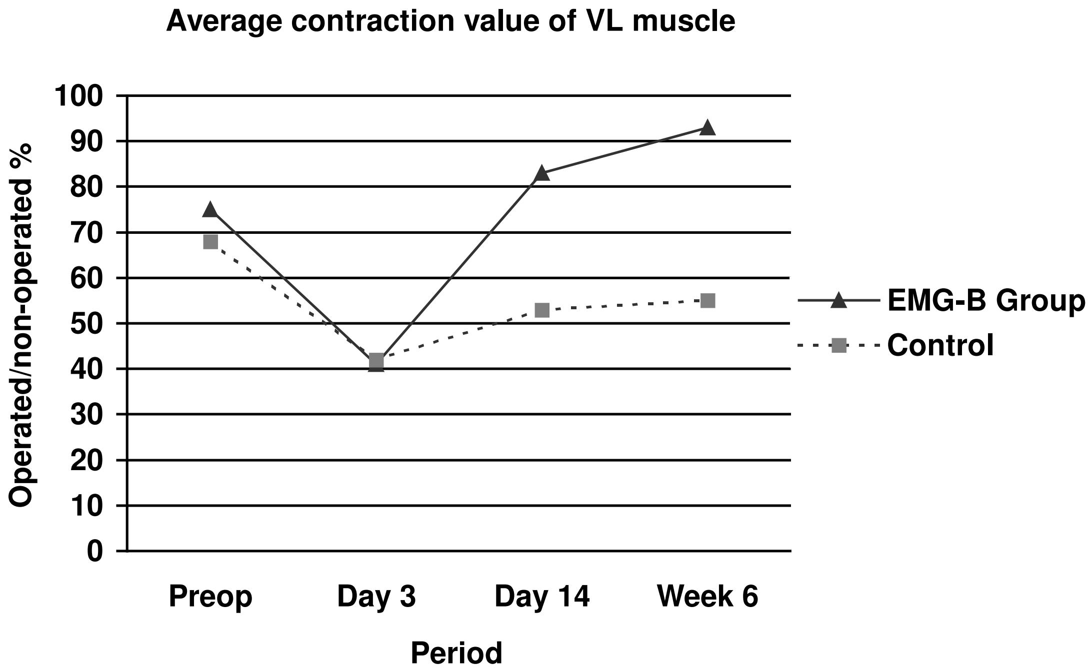


Figure 4. Operated/non-operated % ratio of average contraction value of VL muscle



Discussion

A strong correlation exists between quadriceps muscle strength and functional stability of the knee.[14] After knee surgery, a strong quadriceps muscle is required for normal joint kinematics and to return the patient back to normal activities. Additionally, for the normal walking pattern not to be effected negatively, quadriceps muscle strengthening exercises are important in both conservative treatment and postoperative rehabilitation protocols of the knee.[15–19]

A 20–30% deficit was detected during flexion and extension (especially in patients who had preoperative meniscus lesions), and this deficit in knee function with effusions have been mostly observed in the quadriceps muscles.[20] In our study, we have also seen that preoperative meniscus lesion causes quadriceps muscle inhibition and that affects the VMO muscle more than the VL muscle. Our results suggest that there is a difference in affected ratios between VMO and VL muscles during preoperative period.

Postoperative data has suggested that VMO muscle was also more affected than VL muscle postoperatively. This result supports those studies showing that VMO muscle is more affected during knee injuries.[21]

It has been reported that quadriceps inhibition continues for 6 month following arthroscopic knee surgery, and the inhibition effects are observed not only in the operated extremity but also in the intact extremity.[22] Stam et al[23] detected a 13%

deficit in maximum isometric torque and a 28% deficit in maximum isokinetic torque 8 weeks after meniscectomy.

In the early postoperative period, there is a transient decrease in proprioceptive feedback due to several factors such as pain and oedema. Because of this, conventional exercises could not be done effectively during the early postoperative period. This negativity can be dealt with by visual and audible feedbacks from the EMG-B instrument substituting for muscle strength, tendon tension, and joint position feedbacks in a certain ratio.

Croce[24] has investigated that the effect of EMG-B application on quadriceps muscle strengthening in healthy volunteers, and EMG values of muscle activity and quadriceps muscle strengthening in the EMG-B group were found to be significantly greater than those in the placebo and non-biofeedback groups.

Maitland et al[25] reported that knee stability could be increased and quadriceps inhibition decreased by EMG-B-assisted quadriceps-hamstring contraction education in the unstable knee. In a study comparing operated/non-operated age ratios of the groups (measuring isokinetic test and peak torque values of patients in that EMG-B application added to a classical rehabilitation programme during postoperative period and in patients with anterior transverse ligament reconstruction), higher peak torque age ratios were recorded in the biofeedback group.[11]

In a study comparing operated/non-operated ratios of the groups (in which isokinetic test and peak torque values were measured in patients having EMG-B application in addition to a classical rehabilitation programme during postoperative period following anterior transverse ligament reconstruction), higher peak torque ratios were recorded in the biofeedback group.[11]

In a study of meniscectomy patients, Krebs et al[9] administrated a classical exercise program to a group, and an additional EMG-B to another group; and after treatment, they detected that the average electrical activity output difference in the biofeedback group was 10 times greater than the group in which only the exercise programme was administrated. Similarly, when electrical stimulation and EMG-B were compared in patients in whom arthroscopic anterior transverse ligament reconstructions were administrated, EMG-B administration was shown to be more effective.[10]

In the records obtained on postoperative 14th day and 6th week, there was a significant difference between electrical activity levels of VMO and VL muscles and quadriceps muscle strength in favour of biofeedback group. Additionally, knee flexion angle and Lysholm scores in the patients of this group were significantly better on the 14th day and 6th week.

Thus these results show the effectiveness of EMG-B in the functional improvement of the knee, possibly provided by its positive effect on quadriceps muscle strength. Our results are consistent with other results in the literature, in that EMG-B was a very effective modality in increasing muscle strength.[10,11,24,26]

Furthermore, these results show that during the postoperative period there is more rapid improvement, and quadriceps muscle strength could be increased greater in patients to whom EMG-B is administrated. Indeed, EMG biofeedback application may be beneficial for postoperative rehabilitation protocols of knee pathologies and conservative programmes.

Ethics approval: This study was carried out with the prior approval of the Ethics Committee of Erciyes University.

Author information: Mehmet Kirnap, Professor, Physical Medicine and Rehabilitation Department; Mustafa Calis, Assistant Professor, Physical Medicine and Rehabilitation Department; Ali Osman Turgut, MD, Physical Medicine and Rehabilitation Department; Mehmet Halici, Associate Professor, Orthopaedics and Traumatology Department; Mehmet Tuncel, Professor, Orthopaedics and Traumatology Department; Medical Faculty, Erciyes University, Kayseri, Turkey

Acknowledgements: This study was supported by a grant (02-54) from the Directorate of Scientific Research Projects, Erciyes University.

Correspondence: Dr Mustafa Calis, Department of Physical Medicine and Rehabilitation, Medical Faculty, Erciyes University, 38039 Kayseri, Turkey. Fax: +90 352 4378553; email: mcalis@erciyes.edu.tr

References:

1. Bolgla LA, Keskula DR. Reliability of lower extremity functional performance tests. J Orthop Sports Phys Ther. 1997;26:138–42.
2. Hopkins JT, Ingersoll CD, Krause BA, et al. Effect of knee joint effusion on quadriceps and soleus motoneuron pool excitability. Med Sci Sports Exerc. 2001;33:123–6.
3. Hurley MV. The effects of joint damage on muscle function, proprioception and rehabilitation. Man Ther. 1997;2:11–17.
4. Lucca JA, Recchiuti SJ. Effect of electromyographic biofeedback on an isometric strengthening program. Phys Ther. 1983;63:200–3
5. Basmajian JV. Biofeedback in physical medicine and rehabilitation. In: DeLisa JA (ed). Rehabilitation Medicine: Principles and Practice. Philadelphia: Lippincott-Raven; 1993, p425–39.
6. Basmajian JV. Research foundations of EMG biofeedback in rehabilitation. Biofeedback Self Regul. 1988;13:275–98.
7. Ingersoll CD, Knight KL. Patellar location changes following EMG biofeedback or progressive resistive exercises. Med Sci Sports Exerc. 1991;23:1122–7.
8. Dursun N, Dursun E, Kilic Z. Electromyographic biofeedback-controlled exercise versus conservative care for patellofemoral pain syndrome. Arch Phys Med Rehabil. 2001;82:1692–5.
9. Krebs DE. Clinical electromyographic feedback following meniscectomy. A multiple regression experimental analysis. Phys Ther. 1981;61:1017–21.
10. Draper V, Ballard L. Electrical stimulation versus electromyographic biofeedback in the recovery of quadriceps femoris muscle function following anterior cruciate ligament surgery. Phys Ther. 1991;71:455–61.
11. Draper V. Electromyographic biofeedback and recovery of quadriceps femoris muscle function following anterior cruciate ligament reconstruction. Phys Ther. 1990;70:11–7.
12. Lysholm J, Gillquist J. Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. Am J Sports Med. 1982;10:150–4.
13. Bennell SM, Hodges KL. The test–retest reliability of the onset of concentric and eccentric vastus medialis obliquus and vastus lateralis electromyographic activity in a stair stepping task. Cowan Phys Ther in Sport. 2000;1:129–36.

14. Keays SL, Bullock-Saxton JE, Newcombe P, Keays AC. The relationship between knee strength and functional stability before and after anterior cruciate ligament reconstruction. J Orthop Res. 2003;21:231–7.
15. Moxley Scarborough D, Krebs DE, Harris BA. Quadriceps muscle strength and dynamic stability in elderly persons. Gait Posture. 1999;10:10–20.
16. Keays SL, Bullock-Saxton J, Keays AC, Newcombe P. Muscle strength and function before and after anterior cruciate ligament reconstruction using semitendonosus and gracilis. Knee. 2001;8:229–34.
17. Lewek M, Rudolph K, Axe M, Snyder-Mackler L. The effect of insufficient quadriceps strength on gait after anterior cruciate ligament reconstruction. Clin Biomech. 2002;17:56–63.
18. Bodor M. Quadriceps protects the anterior cruciate ligament. J Orthop Res. 2001;19:629–33.
19. Corrigan D, Bohannon RW. Relationship between knee extension force and stand-up performance in community-dwelling elderly women. Arch Phys Med Rehabil. 2001;82:1666–72.
20. Moffet H, Richards CL, Malouin F, et al. Effects of the type of meniscal lesion on knee function. J Electromyogr Kinesiol. 1998;8:411–22.
21. Torry MR, Decker MJ, Viola RW, et al. Intra-articular knee joint effusion induces quadriceps avoidance gait patterns. Clin Biomech. 2000;15:147–59.
22. Suter E, Herzog W, Bray RC. Quadriceps inhibition following arthroscopy in patients with anterior knee pain. Clin Biomech. 1998;13:314–9.
23. Stam HJ, Binkhorst RA, van Nieuwenhuyzen HF, Hagmeier R. The long-term consequence of strength deficits after menisectomy. Arch Phys Med Rehabil. 1993;74:271–5.
24. Croce RV. The effects of EMG biofeedback on strength acquisition. Biofeedback Self Regul. 1986;11:299–310.
25. Maitland ME, Ajemian SV, Suter E. Quadriceps femoris and hamstring muscle function in a person with an unstable knee. Phys Ther. 1999;79:66–75.
26. Beckham JC, Keefe FJ, Caldwell DS, Brown CJ. Biofeedback as a means to alter electromyographic activity in a total knee replacement patient. Biofeedback Self Regul. 1991;16:23–35.