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EFFECTIVENESS OF ELECTROMYOGRAPHY BIOFEEDBACK IN COMMON KNEE DISORDERS-A REVIEW

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ABSTRACT

Present study focuses on examining effectiveness of Electromyography (EMG) biofeedback in treatment of ailments and disorders related to knee-joint. In order to carry out the literature survey, terms knee and biofeedback were used as keywords in the databases such as, Physiotherapy evidence Database (PEDro), Cumulative Index of Nursing and allied Health literature (CINAHL), Sport DISCUS and PubMed. Outcomes from the researches conducted incorporating EMG biofeedback and quadriceps exercises used for knee rehabilitation were analysed. Data from the randomised controlled trials were collected on various categories such as, the number of patients; age-range, sex of the participants, type of injury/disorder, duration of symptom, placement of electrodes etc were considered under the purview of the review. Out of two-hundred twenty articles, after all scrutiny done based on the PRISMA guidelines, only eleven met the criteria for inclusion and were taken up for analysis. While eight of the selected articles were analysed for functional outcomes and seven others were analysed for quadriceps strength. A total of 413 participants was included in the trials mentioned. Age of the participants ranged from as low as 23 till 55 ± 7.09. The average PEDro score of the trials included in the review was 5.619. EMG biofeedback (BF) intervention technique has been observed as beneficial for the post-surgical knee disorders rather than chronic disorders like Osteoarthritis.

KEYWORDS: ***knee, biofeedback, rehabilitation***

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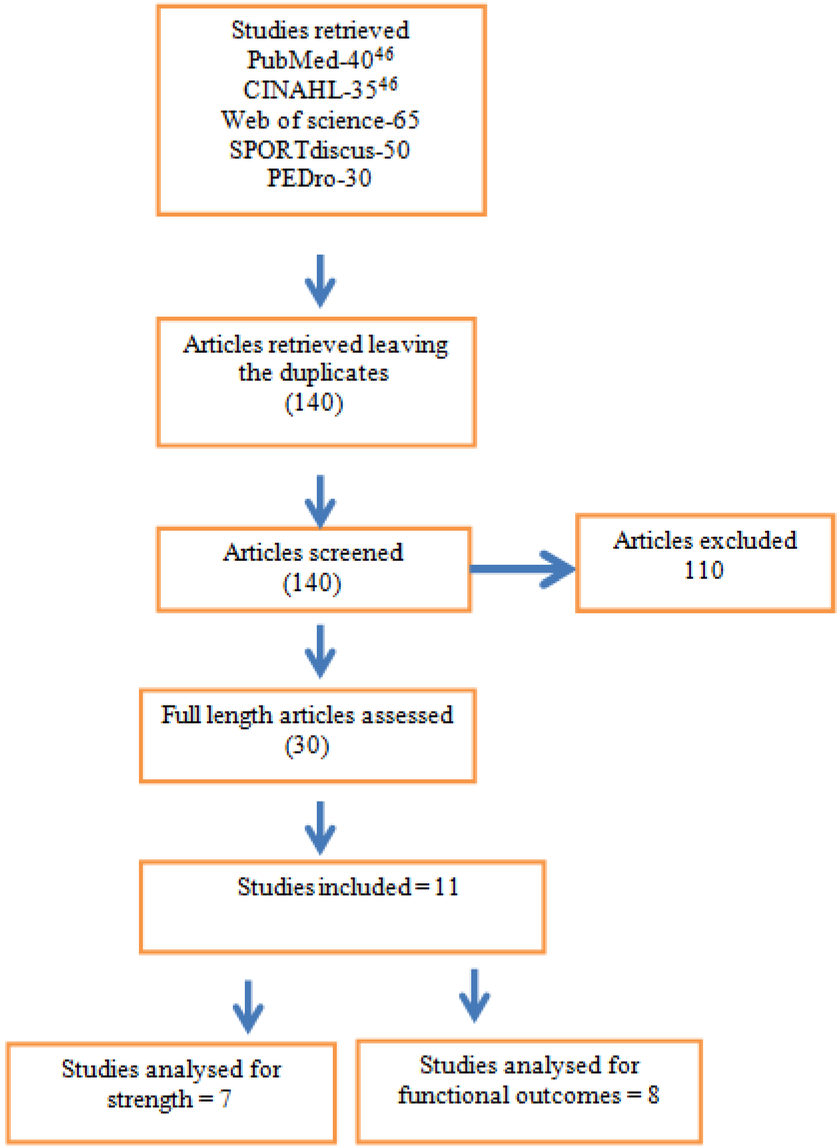
1. INTRODUCTION

Pathologic conditions in knee-joints are often accompanied by muscle weakness, chronic joint pain and loss of range of motion and also loss of voluntary control over the joint and adjacent muscles. Under such conditions, it becomes absolutely essential to restore or in some cases to initiate more complete muscle contractions and resulting increase in muscular activities[1]. Out of differential muscle strengthening exercises, electromyography (EMG) indices derived from surface EMG electrodes are known to convert electrical muscle potentials into auditory or visual signals. These signals via monitoring units enables the individual suffering from knee-joint problems in better regulation of voluntary activity in the quadriceps femoris muscle[2]. Electromyographic (EMG) biofeedback with autosensory observations allows a patient to monitor electrical muscle potentials in a voluntary contraction[3]. With adequately monitored training and practice, patients learn to regulate their maxima voluntary contraction, and improve the voluntary control by either relaxing the neuromuscular component or by re-educating the muscle after an injury[4], which further enhances motivation and exercise adherence of the patients[2]. EMG-biofeedback (EMGBF) intervention techniques have largely been effectively utilised in the treatment of stroke patients to improve motor function[5]; in problems associated with temparomandibular disorders[6], paralysis of facial muscles[7] and in tension headaches[8]. Most of the researches done in the field of sports medicine and orthopaedics have been observed to focus onto knee joint and especially on quadriceps muscle activities since those are more related to knee outcomes[9-13]. Thus, it is evident that EMGBF intervention has been popularly employed in treatment of many musculoskeletal disorders, while only a few studies have highlighted efficacy of EMGBF in knee disorders. There are only a few review articles done on EMGBF to rigorously analyse the methodology and the results of the researches. With such a back ground this review aims to analyse the detailed research protocols evident mainly in the randomised controlled trials (RCT) done employing EMGBF in the treatment of knee disorders.

Figure 1
PRISMA flow diagram showing the selection of trials[45]



2. Methods

For searching into the databases keyword terms ‘knee’ and ‘biofeedback’ were used, and the following research databases were searched: Physiotherapy evidence Database (PEDro); Cumulative Index of Nursing and allied Health literature (CINAHL); Sport DISCUS and PubMed. Evidence relating to EMG biofeedback and quadriceps exercises used for knee rehabilitation was analysed.

2.1 Selection protocol of Experimental studies

Studies were selected based on the following categories:

2.1.1 Inclusion Criteria

Randomised Control Trials (RCT) in which Electromyography Biofeedback intervention techniques were incorporated for treatment of ailments in the knee under various orthopaedic conditions

2.1.2 Exclusion Criteria

Experimental research paradigms followed – Other than RCT;
Researches conducted on healthy participants;
Outcome measures were other than gait, functional outcomes and pain, and
Articles published in languages other than English.

2.2 Assessment of Research Methods

Research methods followed in the experimental studies with RCT were analysed by employing PEDro criteria. These criteria include – eligibility criteria; randomised allocation of participants; concealed allocation by sequentially numbered, opaque, sealed envelopes (SNOSE)[14]; baseline similarity; blinding of participants, assessors, therapists[15]; follow up; intention to treat analysis; statistical comparison and point estimate[16]. Researchers in the field of physiotherapy and rehabilitation studies, while reviewing literatures have preferred to look for the PEDro score, since it has high inter-tester reliability[17].

2.3 Extraction of data

The data were extracted according to –

1. Number of Patients (participants) included;
2. Age of participants;
3. Sex of participants;
4. Types of Injury/Disorder;
5. Duration of Symptom;
6. Placement of Electrodes;
7. Types of Feedback provided;
8. Types of Exercise interventions introduced;
9. Whether Follow Up was introduced or not;
10. Strength Testing Method, and
11. Outcome Measures

2.4 Analysis

A total of 220 articles specific to the search terms were found of which 80 were duplicates. A hand search did not yield any articles. Based on the title and abstract 140 articles were searched. This led to elimination of 110 articles. The remaining 30 articles were assessed based on the inclusion criteria. Three articles were excluded due to the fact they were not in English[15-17]. Two articles were excluded since they didn't have a control group[18,19]. 4 articles were excluded due to inappropriate outcome measures[20-23].6 articles due to confounded treatment effects[24-29],3 articles due to inclusion of healthy participants[30-32].1 article due to duplication of data between the groups[33].11 articles met the criteria for inclusion and were taken up for analysis[34-44].8 articles were analysed for functional outcomes and7 articles were analysed for quadriceps strength.

Table 1
PEDro scores of the RCT

Study	Eligibility criteria	Random allocation	Concealed allocation	Baseline Similarity	Blind participants	Blinding therapists	Blinding assessors	Follow	Intention to treat analysis	group comparison	Point and variability measures	Score
Yip and Ng[34] 2006	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	6/11
Yilmaz et al [35]2010	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	6/11
Levitt et al [36]1995	Yes	No	No	Yes	No	No	No	No	No	Yes	Yes	4/11
Kirnap et al[37] 2005	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	6/11
Dursun etal[38] 2001	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	6/11
Durmus et al[39] 2007	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	6/11
Draper and Ballard [40]1991	Yes	Yes	No	No	No	No	No	Yes	No	Yes	Yes	5/11
Draper [41]1990	Yes	yes	No	No	No	No	No	Yes	No	Yes	Yes	5/11
Anwer et al [42]2011	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	8/11
Christanell et.al [43]2012	Yes	Yes	No	Yes	No	Yes	No	No	Yes	Yes	Yes	7/11
Akkaya et.al [44]2012	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	9/11
Score	11/11	10/11	1/11	9/11	1/11	1/11	1/11	9/11	3/11	11/11	11/11	5.619

2.4.1 PEDro SCORE

The average PEDro score of the trials included in the review was 5.619.Blinding of subjects, assesors and subjects was missing in most of the trials. Most of the trials did not score on intention to treat analysis.

Table 2
Demographic characteristics of the RCT

Researcher	Diagnosis	Subjects	Symptoms duration	Mean age	Male	Female
Yip and Ng[34] 2006	Patellofemoral pain syndrome	26	-	32.5±8.8	10	16
Yilmaz et al [35]2010	Osteoarthritis	40	9-23 months	55.6±7.2	5	35
Levitt et al [36]1995	Arthroscopy	51	After surgery	45±15	35	16
Kirnap et al[37] 2005	Arthroscopy	40	After surgery (3 days)	34.5 ±10.3	40	0
Dursun etal[38] 2001	Patellofemoral pain syndrome	60	3-17 months	36.9±9.2	12	48
Durmus et al[39] 2007	Osteoarthritis	50	No	54.7±1.8	0	50
Draper and Ballard [40]1991	ACL reconstruction	30	After surgery	25±8.1	16	14
Draper [41]1990	ACL reconstruction	22	After surgery (1 week)	23	15	7
Anwer et al [42]2011	osteoarthritis	33	-	55.27± 7.08	10	23
Christanell et.al [43]2012	Arthroscopy	16	After surgery	30	12	4
Akkaya et.al [44]2012	Arthroscopic partial meniscectomy	45	After surgery	49	19	26

2.4.2 Analysis of Subjects

In the experimental studies considered for review a total of 413 participants were used in the trials mentioned. Age of the participants however ranged from as low as 23 year up to 55 years. Out of the total sample, 174 individuals were male participants, 239 candidates were female subjects. Bulk of male patients reportedly underwent arthroscopic surgery for different kinds of ligament injuries, while majority of the female subjects evidentially had problems of osteoarthritis (n = 35, 50) and patellofemoral pain syndrome (n = 48). When the age of the subjects in all these trials were analysed most of the patients in the studies reviewed[38, 42,45] belonged to over 50 years of age, while younger individuals age ranged between 23-25 were observed to participate in other trials[43,44].

2.5 EMG equipment

Myomed and Myotrac were evidentially most commonly used Electromyography biofeedback equipments, while only surface EMG (SEMG) was used in all of the clinical trials. *Vastus medialis and vastus lateralis* muscles were observed as the most preferred muscle considered for electrode placement sites. Placement of electrodes in different trials is clearly represented in the Table 3.

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Table 3
Characteristics of EMGBF in the RCT

Researcher	Device used	Locations of electrodes	Type of feedback	Level of threshold
Yip and Ng[34] 2006	Custom-designed device	2: Midpoint of VMO, about 4 cm superior and 3 cm medial border of the patella; VL: 10 cm superior and 7 cm lateral to the superior border of the patella	V	NO
Yilmaz et al [35]2010	Myomed 932	2: VM and VL	V&A	NO
Levitt et al [36]1995	BioPrompt portable	2: VMO and VL	V&A	NO
Kirnap et al[37] 2005	Myomed 932	2: VMO: placed 4 cm above the upper edge of the patella on the VMO muscle and at 3 medial;VL: placed 10 cm above the upper edge of the patella and 6–8 cm lateral cm	A	Threshold increase daily
Dursun etal[38] 2001	Myomed 932	2: VM and VL,	V&A	80% of average
Durmus et al[39] 2007	Myomed 432	2: rectus femoris, vastus medialis, and vastus lateralis muscles"	V&A	No
Draper and Ballard [40]1991	Myotrac	1: Placed 3–5 cm above the superior border of the patella and 2–3 cm medial	V&A	Maximal effort
Draper [41]1990	Cyborg	Placed just proximal to the patella and 2 cm medial	V&A	Different at each session
Anwer et al [42]2011	Myomed 932	4 cm superior and 3 cm medial to patella	V	Average of 3 max contraction lowered by 20 %
Christanell et.al [43]2012	Myotrainer	Vastus medialis	V&A	Threshold increase daily
Akkaya et.al [44]2012	Myomed 932	Vastus medialis, Vastus lateralis	V&A	Threshold increase daily

2.6 Type of feedback

Two trials[34,42] used visual feedback, 1 trial[37] used auditory feedback and the other trials used both visual and auditory feedback. The level of threshold was not consistent among the trials .Some trials increased the threshold frequently; one trial used a threshold of 80% of maximum contraction.

2.7 Treatment for control group

The common intervention for control group was aimed at exercising the quadriceps. Few trials included electrotherapy, aquatic and lymphatic drainage along with exercise. The frequency of exercise ranged from 2 weeks to maximum of 12 weeks. The number of sessions per week ranged from daily session, 3 days/week or five days/week session.

Table 4
Characteristics of intervention in RCT

Researcher	Treatment for control group	Exercise done	Repetitions	Frequency
Yip and Ng[34] 2006	Only exercise	Quadriceps exercise	NA	Daily for 8 weeks
Yilmaz et al [35]2010	Only exercise	Quadriceps exercise	10	3d/w for3 weeks
Levitt et al [36]1995	Only exercise	Quadriceps exercise	5 secs cont 10 sec rest	3x/d for 10 days
Kirnap et al[37] 2005	Only exercise	Quadriceps exercise	5 secs cont 10 sec rest	5d/wk for 2 weeks
Dursun etal[38] 2001	Only exercise	Quadriceps exercise	NA	80% of average
Durmus et al[39] 2007	Exercise and electro	Quadriceps exercise	NA	No
Draper and Ballard [40]1991	Exercise and electro	Quadriceps exercise	10/20	6week
Draper [41]1990	Only exercise	Quadriceps exercise	Progression	12 week
Anwer et al [42]2011	Only exercise	Quadriceps exercise	5/10	5 days per week for 5 weeks
Christanell et.al [43]2012	Electro, lymphatic drainage, aquatics, physiotherapy	Quadriceps exercise	4 sec cont 10 sec rest	8-EL,8 MLD,8 AWT
Akkaya et.al [44]2012	Only exercise	Quadriceps exercise	10/20 for 30 mins	5 days per week for 2 weeks

2.8 Measurement of Outcomes

Research outcomes mostly focussed onto increment in strength and functional outcomes, as those were measured at baseline (evident in all of the clinical experiments). The interval between measurements was observed to range from a minimum of 2 weeks to a maximum of 3 months.

Table 5
Charcteristics of outcome measures and result

Researcher	Outcomes	Measurement intervals	Result between groups post intervention
Yip and Ng[34] 2006	Peak torque-isokinetic Patellofemoral pain syndrome severity scale	Baseline, 4 and 8week	No differences in groups for both peak torque and PFPS severity scale
Yilmaz et al [35]2010	Peak torque-isokinetic VAS, WOMAC, Nottingham Health Profile	Baseline,3 week	Nottingham health profile scale in EMGBF better than exercise only control
Levitt et al [36]1995	Pain rating scale, isokinetic peak torque	Baseline ,14 days	No differences in peak torque and pain scale
Kirnap et al[37] 2005	Lysholm knee score	Pre op,3 day and 2 and 6 week post operatively	Lysholm knee score better tin EMGBF than control
Dursun etal[38] 2001	VAS, Functional index questionnaire	Baseline ,1,2, and 3 month	No differences in groups
Durmus et al[39] 2007	1 RM,10,RM VAS,WOMAC,50 m walk, ascending and descending 10 stair flight	Baseline. 4 week	No difference in the outcomes EMGBF and control
Draper and Ballard [40]1991	Isometric peak torque	6 wk post op	Less peak torque in EMGBF group compared to control
Draper [41]1990	Isometric peak torque	12 week Post op	Less peak torque in EMGBF group compared to control
Anwer et al [42]2011	Quadriceps strength	Baseline and 2,3,5 weeks	EMGBF increased the strength
Christanell et.al [43]2012	IKDC guideline, HHD, ROM, integrated EMG	BASELINE, postop 1,2,4,6 week	EMGBF increased the muscle activity, passive knee extension and HHD
Akkaya et.al [44]2012	Pain ,gait velocity, Lysholm knee score, ROM, Swelling ,muscle power	Preop,2, 6 weeks	EMGBF increased the muscle power

3. RESULTS & DISCUSSION

Table 6
Mean differences in functional outcomes including pain

Researcher	EMGBF	CONTROL	Cohen's (d)	Effect size	95%CI		Variance (v)
	Mean/SD	Mean/SD			lower	higher	
Yip and Ng[34] 2006	35.4±22.7 (13)	29.9±21.2 (13)	0.25	0.12	-0.5213	1.022	0.1551
Yilmaz et al [35]2010	9.52±4.42 (19)	9.3±3.07 (20)	0.06	0.03	-0.5699	0.6861	0.1027
Levitt et al [36]1995	6.6±3(28)	6.3±6 (23)	0.06	0.03	-0.4864	0.617	0.0792
Kirnap et al[37] 2005	85±8.4(20)	68.1±7.8 (20)	2.08	0.72	1.3257	2.8689	0.155
Dursun etal[38] 2001	12±1.7(30)	12.8±2 (30)	-0.43	-0.21	-0.9429	0.0809	0.0682
Durmus et al[39] 2007	3.04±0.48 (25)	2.44±0.51 (25)	1.2116	0.51	0.6085	1.8146	0.0947
Christanell et.al [43]2012	1± 1(8)	1± 1(8)	0	0	-0.98	0.98	0.25
Akkaya et.al [44]2012	2.3± 2.1(15)	3.4± 2.9(15)	-0.4345	-0.21	-1.158	0.2896	0.1365

Figure 1
Mean differences in functional outcomes including pain

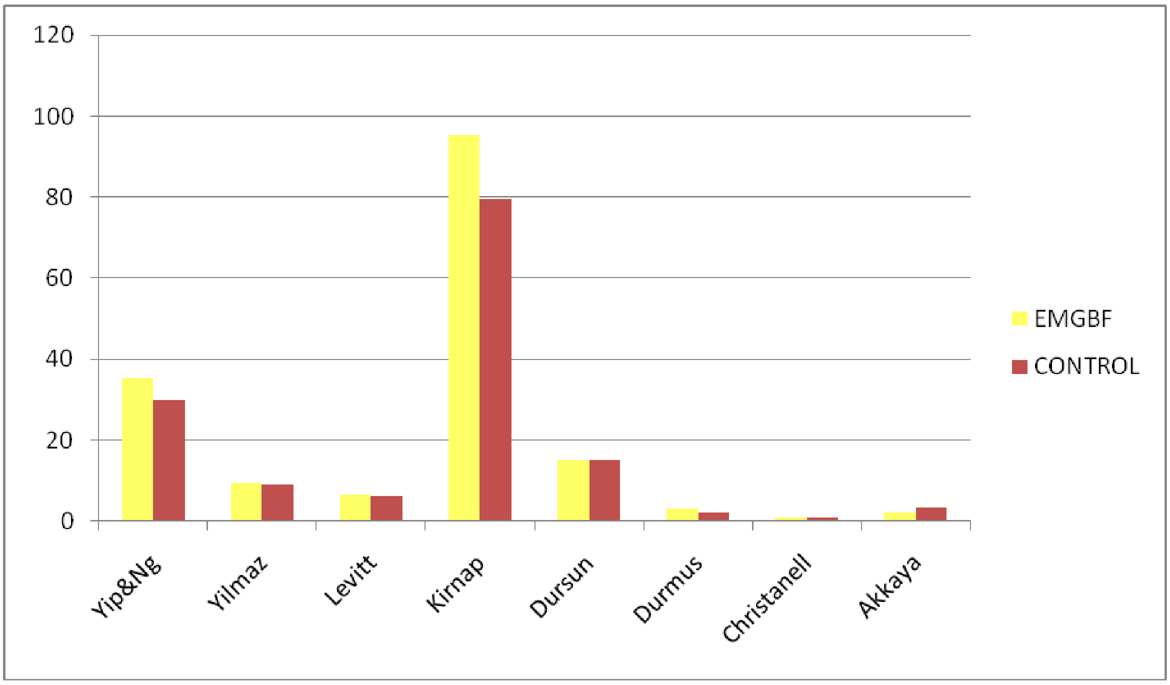


Table 7
Mean differences in quadriceps strength

Researcher	EMGBF	CONTROL	Cohen's(d)	Effect size	95%CI		Variance (v)
	Mean/SD	Mean/SD			Lower	Higher	
Yip and Ng[34] 2006	138.8 ±85.8(13)	116.1±69.7 (13)	0.2921	0.14	-0.4808	1.0649	0.1555
Yilmaz et al [35]2010	54.47± 17.97(19)	62.95± 22.8(20)	-0.4118	-0.20	-1.0463	0.2227	0.1048
Levitt et al [36]1995	43±27(28)	29±18(23)	0.6101	0.29	0.0349	1.1622	0.0827
Durmus et al[39] 2007	11.92±0.65 (25)	12.6±0.88 (25)	-0.879	-0.40	-1.4595	-0.2985	0.0877
Draper and Ballard [40]1991	46.4±10.5 (15)	37.9±12.4 (15)	0.7398	0.35	0.0001	1.4796	0.1425
Anwer et al [42]2011	13.68 ±1.99(15)	11.06± 1.56(15)	1.4653	0.59	0.6593	2.2714	0.1691
Christanell et.al [43]2012	124.9 ±52(16)	70.3± 45.8(16)	1.1143	0.49	0.3695	1.8591	0.1444

Figure 2
Mean differences in quadriceps strength

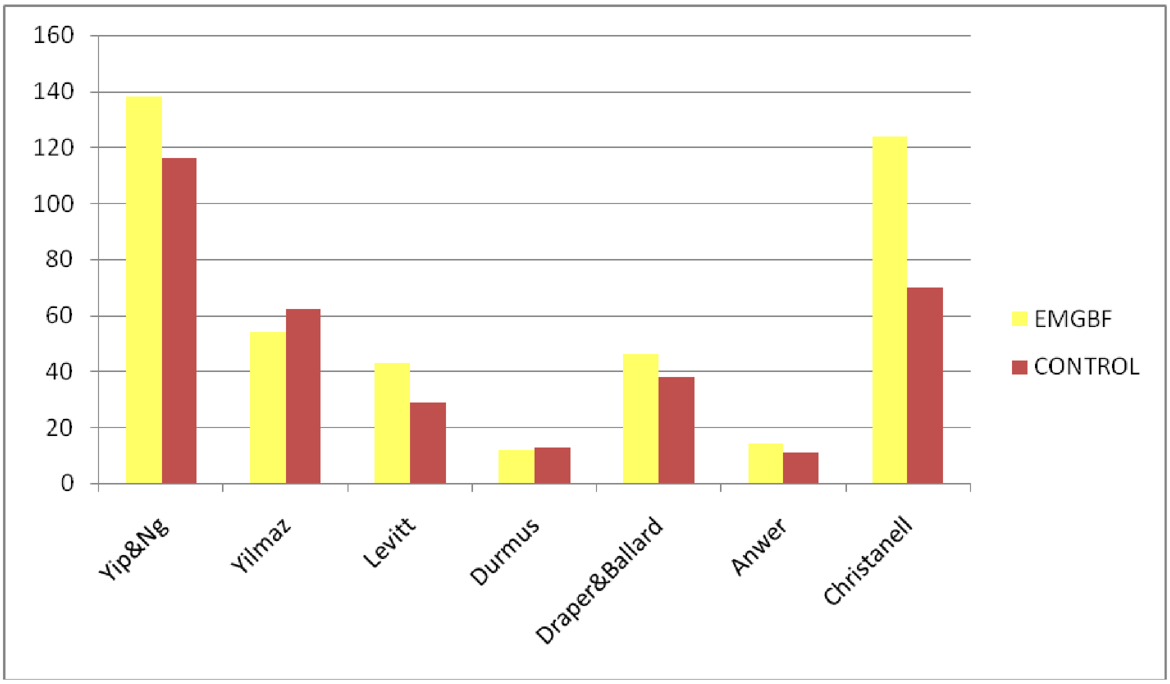
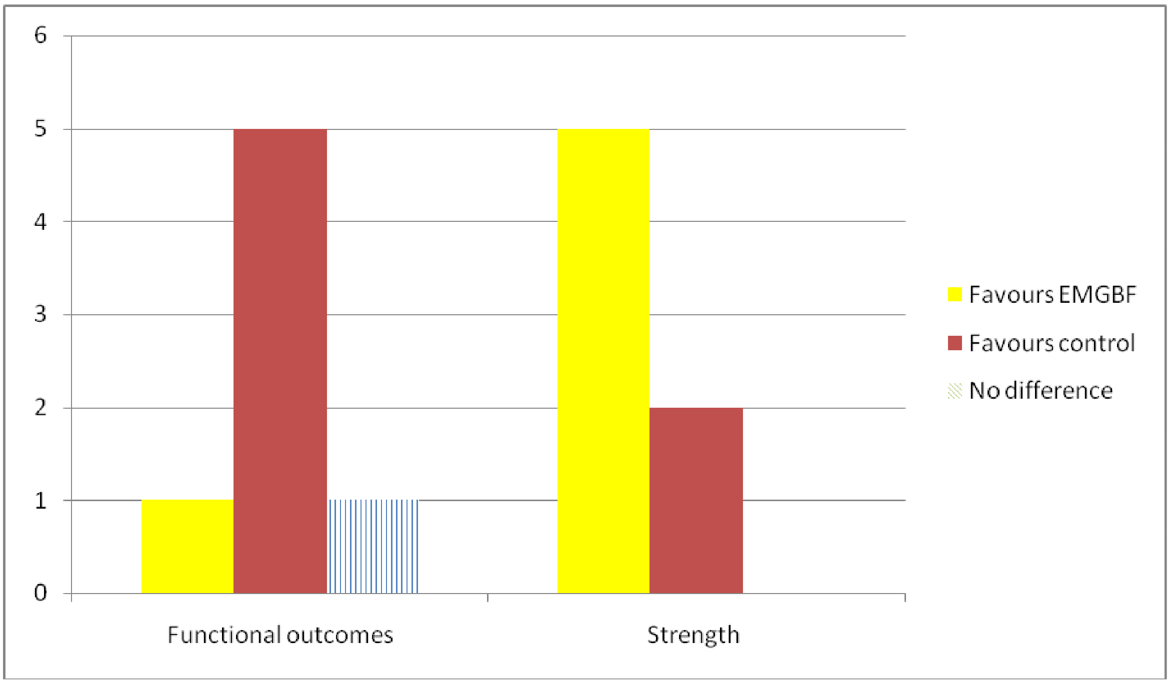


Figure 3
Graph showing trials favouring strength and functional outcomes



From the outcomes of the eleven experimental trials, conducted on a total of 413 participants suffering from knee problems, 123 participants were observed to have osteoarthritis of knee (3 trials, [38,42,45]n=123); 152 others had gone through arthroscopic surgery (4 trials,[39,40,46,47] n=152); 52 of the patients had gone through ACL reconstruction (2 trials,[43,44] n=52) and rest of the participants (n=86) have been observed to have patellofemoral pain syndrome(2 trials,[37,41]). As far as types of EMGBF intervention techniques are concerned, treatment modalities employed for improvement in maximal voluntary contraction of the quadriceps muscles were not uniform among the trials. Dual channels EMG biofeedback technique was used in most of the trials. *Vastus medialis (VM) or vastus medialis obliqus* (VMO) and *vastus lateralis muscles* (VLM) were evident as the most preferred electrode-placement sites. Studies were also observed to omit the issue of placement site of the electrodes in the methodology section, and hence the obtained EMG data could not be attributed to the impact of EMGBF intervention on any particular muscle group[42]. Similarly, discrepancy in the types of exercise interventions introduced in between the EMGBF and the no-intervention control group was also evident[42]. Apart from that, issues like frequency; intensity; duration; no of sets; repetitions of exercise intervention protocol and recovery time after the exercises were not clearly discussed by most of the authors. Duration of exercise training sessions introduced also varied from 10 days to 12 weeks, with the variable frequencies like 2 to 7 days per week and 1 to 3 times daily. The results of two trials[43,44] must be interpreted with caution due to the fact that these trials were more prone to be biased. These studies were evident as having post-test design only and had a low PEDro score. Out of the eleven experimental studies included for analysis, four trials were done on patients who underwent arthroscopic knee surgery, 3 trials were on patients with osteoarthritis, 2 trials on patellofemoral pain syndrome and 2 on anterior cruciate ligament (ACL) reconstruction. Based on the reports available from the aforementioned studies, discrepancy in the outcome measures employed was evident. Studies were mostly observed to employ WOMAC, Visual Analog scale (VAS), functional index questionnaire, patellofemoral pain severity scale, Lysholm knee score, 50m walk, ascent and descent of stair and Nottingham health profile etc. Knee strength was evaluated using isokinetic peak torque[34,35,36], isometric peak torque[40,41] and 1-10 repetition maximum[39]. The isokinetic peak torque was analysed at 120°/second in one trial and 60° and 180° /sec in 2 trials. The isometric peak torque was assessed at 90, 60 and 45 degree of knee flexion. Questions could be raised with the limitation pertaining inadequate sample size[35] and inadequate duration of intervention (3 days/wk for only 3 weeks)[35]. Compared to that studies were also carried out without having consideration of any no-intervention control group, wherein participants under intervention were compared as their own control (compared between pre and post-intervention outcomes)[39], while question of sustainability of the impact of intervention was not evaluated[39] . Contradictions were also observed in terms of the final outcomes reported, since a few of the researches could confirm beneficial impact of EMG biofeedback intervention over other forms of exercise regimes[35,37,41,42,43,44], whereas inhibitive impact of EMG biofeedback intervention was also reported[40], wherein reduction in peak torque followed EMGBF was observed. Contrary to these findings, other studies reportedly evidenced no impact of EMGBF at all[34,36,38 &39]. When functional outcomes and reduction in pain followed by EMGBF & other exercises were kept on consideration, 6 studies were observed (TABLE 6) favouring control group, 1 study favoured EMGBF and 1 study reported no difference at all. Whereas, if improvement in strength of quadriceps was kept in concern, 5 of the experimental trials (TABLE 7) confirmed beneficial impacts of EMGBF and 2 other studies were reportedly in favour of activities followed by the control group participants. However findings were suggestive of the facilitative impact of EMGBF as an adjunct to exercise, in post surgical knee conditions and their rehabilitation, since EMGBF helps the patient to overcome the fear of pain and pain during movement. This perhaps had happened, as EMGBF helps in the reduction of disuse atrophy of the thigh muscles. However, introduction of EMGBF in chronic disorders of knee joint, for instance, in case of osteoarthritis and patellofemoral pain syndrome has not yet been substantiated in any of the trials reviewed hereafter.

4. CONCLUSION

Outcome of this study has identified trends on the effectiveness of electromyography biofeedback intervention for common knee disorders. Improvements in knee functional outcomes and knee extensor strength have been found as improved by the introduction of electromyography biofeedback in post surgical situations. This facilitative impact was not observed in chronic cases such as osteoarthritis and patellofemoral pain syndrome. Results of the review should be treated with caution due to the limited data used in the review. More randomised controlled trials should be included in future review, which may be either in favour or against the trends observed in this report.

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