A Comparative Study of EMG Analysis in Quadriceps Setting Exercises and Straight Leg Raises in Osteoarthritis Knee Patients

Pomila Chopra[1] Prabhleen Puri[2]

[1] Department of Orthopedics, Apeejay College, Jalandhar, Punjab, India
[2] Department of Orthopedics, DAV Institute of Physiotherapy, Jalandhar, Punjab, India

Address for correspondence Pomila Chopra, MPT Orthopedics, Apeejay College, Jalandhar, Punjab, India (e-mail: pomila01@gmail.com).

Int J Health Environ Res 2023;1:19–36.

Abstract

Introduction Knee osteoarthritis is a prevalent, painful, and disabling arthritic condition. Quadriceps weakness specifically of the vastus medialis is a common impairment. Rehabilitation professionals typically prescribe nonweight-bearing exercises, like isometric quadriceps contractions and straight leg raises (SLR). Electromyography (EMG) is a commonly used tool capable of providing information regarding muscle activation during rehabilitation exercises.

Objectives The aim of the study is to compare the effects of quadriceps setting exercises and SLR on pain, disability, and change in EMG activity of vastus medialis and rectus femoris muscles in grade 2, 3 osteoarthritis knee patients.

Methodology Thirty subjects were divided into two groups: A and B by convenience sampling method. Group A received hot-pack, quadriceps setting exercises, and transcutaneous electrical nerve stimulation (TENS). Group B received hot-pack, SLR, and TENS. Each group received 10-day treatment sessions and EMG data were collected from vastus medialis and rectus femoris during quadriceps setting exercises and during SLR. Visual analog scale and Western Ontario and McMaster Universities index of osteoarthritis were also taken. The data were taken on day 1, day 6, and day 11.

Results Both groups showed significant improvements in pain, disability, and EMG activity following 10 sessions of treatment, but the differences in the two groups were not statistically significant.

Conclusion Our findings suggest that ten treatment sessions of either quadriceps setting exercises or SLR along with hot-pack and TENS produced similar treatment effects for people suffering from grade 2, 3 osteoarthritic knee.

Keywords

- EMG
- osteoarthritis knee
- physiotherapy
- quadriceps setting exercises
- SLR

DOI https://doi.org/10.1055/s-0042-1755239.
ISSN xxxx-xxxx.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

Introduction

Osteoarthritis (OA) of the knee is a common problem throughout the world.[1] It is a chronic degenerative disorder of multifactorial etiology, including acute and/or chronic insults from normal wear and tear, age, obesity, and joint injury and is characterized by degradation of the articular cartilage. The true pathogenesis remains poorly understood.[2] Definitions can be based around clinical features, pathological findings, or radiological features.[3] Most studies show that the proportion of radiological disease that is symptomatic is between 40 and 80% and approximately 50% of subjects with symptomatic OA of the knee also have an associated disability.[3] Many exercises are used to strengthen the knee muscles, yet limited studies are done that evaluate the exercises exist.[4] Weight-bearing exercises are important because they incorporate demands required to perform many activities of daily living (ADLS); however, patients initially lack adequate quadriceps activation to safely perform weight-bearing exercise. Therefore, rehabilitation professionals typically prescribe nonweight-bearing exercises, like isometric quadriceps contractions and straight leg raises (SLR).[5] Also, a requirement exists for simple and inexpensive treatment protocols to fill the void between medication, exercise, and surgery.[2] Hence, this study aimed to find the best exercise for OA knee patients during the initial phases of their treatment.

Purpose of Study

The aim of this study was to compare the effect of quadriceps setting exercises and SLR exercise on pain, disability, and change in electromyography (EMG) activity of vastus medialis and rectus femoris muscles in OA knee patients.

Operational Definitions

- Symptomatic knee OA—Symptomatic knee OA is defined as knee pain, aching, or stiffness on most days plus the presence of a definite osteophyte in the symptomatic knee on knee X-ray (anteroposterior, skyline, or lateral view).[6]
- Kellgren and Lawrence criteria—In epidemiological studies, OA is often graded on radiographs according to the criteria of Kellgren and Lawrence, using an ordinal scale of five levels:

  Grade 0: Normal radiograph.
  Grade 1: Doubtful narrowing of the joint space and possible osteophytes.
  Grade 2: Definite osteophytes and absent or questionable narrowing of the joint space.
  Grade 3: Moderate osteophytes and joint space narrowing, some sclerosis, and possible deformity.
  Grade 4: Large osteophytes, marked narrowing of joint space, severe sclerosis, and definite deformity.[7]

- Quadriceps setting exercise—The quadriceps muscles extend the knee joint and are of prime importance in maintaining its stability. Static quadriceps contraction or setting is a free, nonweight-bearing exercise for knee extensors. In isometric or static muscle work, the length of the muscle remains the same throughout the muscle work and no movement results.[8]
- SLR exercise—SLR is a free, nonweight-bearing exercise for knee extensors strengthening, performed in lying, with quadriceps contractions followed by one straight leg lifting and lowering, slowly.[8]
- Hot-pack—Hot-packs or hydrocollator packs consist of a silicate gel, enclosed in a cotton fabric container. They are heated by being placed in a special tank of water warmed to 75 to 80°C by an electric heater controlled by a thermostat.[9]
- TENS (transcutaneous electrical nerve stimulation)—a technique used to relieve pain in an injured or diseased part of the body in which electrodes applied to the skin deliver intermittent stimulation to surface nerves and block the transmission of pain signals.[10]
- EMG—EMG refers to the methods of studying the electrical activity of muscles. Recordings are made of muscle unit action potentials as they pass from neuromuscular junctions along muscle to activate individual muscle fibers within motor units. The output is recorded as an EMG.[4]
- Visual analogue scale (VAS)—VAS is a pain rating scale that allows the patient to visually gauze the amount of pain along a 10 cm (100mm) line and is used for the assessment of pain in OA knee.[11]
- WOMAC (Western Ontario and McMaster Universities) index of OA—The WOMAC index is used to assess patients with OA of the hip or knee. It is a disease-specific measure of pain, stiffness, and physical function for individuals with knee OA and comprises five items related to pain, two items related to stiffness, and seventeen items related to physical function.[12]

Aims and Objectives

- To find the efficiency of quadriceps setting exercise on pain, disability, and the change in EMG activity of vastus medialis and rectus femoris muscles in OA knee patients.
- To find the efficiency of SLR exercise on pain, disability, and the change in EMG activity of vastus medialis and rectus femoris muscles in OA knee patients.
- To compare the effects of quadriceps setting exercise and SLR exercise on pain, disability, and the change in EMG activity of vastus medialis and rectus femoris muscles in OA knee patients.

Historical Perspective

Soderberg et al conducted a study on EMG analysis of quadriceps femoris muscle setting (QS) and SLR. The more muscle activity was found in vastus medialis, biceps femoris, and gluteus medius during QS than SLR. The rectus femoris was more active during SLR.[13] Spector et al conducted a study to find out the definition of OA of the knee for epidemiological studies. They compared anteroposterior weight-bearing radiographs and concluded that the best predictors were the Kellgren and Lawrence grade.[3] Miyaguchi et al conducted a study to analyze biochemical change in joint fluid after isometric quadriceps exercise for patients with OA of the knee. A SLR exercise was the exercise performed and they concluded that isometric quadriceps exercise resulted in significant changes in joint fluid biochemical parameters and the results shows decrease in pain score.[14] Hurley and Scott conducted a study to find out improvements in quadriceps sensorimotor function and disability of patients with knee OA following a clinically practicable exercise regime of 10 sessions. The results showed improved quadriceps strength, voluntary activation, knee joint opposition sense, and reduced the Lequesne Index. They concluded that the regime is relatively brief and clinically practicable.[15] Cheing et al conducted a study to determine whether 4 weeks of TENS and/or isometric exercises produce cumulative reduction of OA knee pain. They included 62 patients, who received either (1) TENS, (2) placebo stimulation, (3) isometric exercise training, or (4) TENS and exercises and concluded that isometric exercise training of the quadriceps alone also reduced knee pain toward the end of the treatment period on VAS scale.[16] Durmu conducted a study to find out the effects of TENS on pain, disability, quality of life and depression in patients with knee OA. Patients in the group 1 received TENS, exercise program, and hot-pack. Group 2 received placebo TENS, exercise program, hot-pack and served as a control group. The results of this study suggest that addition of TENS to hot-pack and exercise program is more effective in decreasing knee pain and related disability and quality of life.[17] Evcik et al conducted a study to find out the efficacy of balneotherapy and mud-pack therapy in patients with knee OA. The patients were separated into three groups. Group 1 received balneotherapy, group 2 received mud-pack therapy, and group 3 was hot-pack therapy group. The therapies were applied for a total of 10 sessions. The results show that there were statistically significant improvement in VAS and WOMAC pain scores in all the three groups. The WOMAC functional and global index also decreased in all the groups.[18]

Methodology

- Study design—Experimental study design.
- Study setting—The study was performed in outpatient department of DAV Institute of Physiotherapy and Rehabilitation, Jalandhar.
- Duration of study—One and half years.
- Sample size—Total 36 subjects were taken out of which six subjects dropped out because they discontinued the treatment and 30 subjects completed the protocol. A minimum number of 15 subjects were assigned in both the groups.
- Sampling technique—Convenience sampling was used.
- Sample selection—All subjects were selected according to the selection criteria as follows:

Inclusion Criteria

- Subjects with 40 to 60 years of age.
- Gender—both male and female.
- Symptomatic unilateral OA knee with grade 2 to 3 according to Kellgren and Lawrence criteria.

Exclusion Criteria

- Subjects with a history of lower limb surgery or any fracture of lower limb.
- Subjects who received intraarticular steroid injections, hyaluronans, or physiotherapy during preceding 6 months for their knee.
- Subjects who were unable to ambulate without assistance.
- Subjects with any prior arthroplasty or arthroscopy in either knee.
- Subjects with cardiac pacemakers.
- Subjects with a history of any unstable medical condition such as angina.
- Subjects with a history of any neurological disease such as parkinsonism.
- Bilateral symptomatic knee OA.

Method of Collection of Data

Protocol

- Thirty subjects were selected based on the inclusion and exclusion criteria. Once a signed written informed consent was obtained from the subject, the required assessment of the subject was done. Patients with grade 2 or 3 knee OA according to the Kellgren and Lawrence criteria based on weight-bearing radiographs (anteroposterior views) and diagnosed by one radiologist and orthopaedican were taken using convenience sampling.14,19
- After the initial examination, the subjects were assessed for pain using VAS. All subjects were assessed for disability using WOMAC. EMG activity was taken for all the subjects for vastus medialis and rectus femoris muscles.
- No patients routinely used any drugs such as nonsteroidal anti-inflammatory drugs or analgesics during the study period. Also, the patients were instructed not to perform any other exercise for the lower limb during the study period.

Fig. 1 Electromyography machine.

- Convenience sampling technique was used and the subjects were assigned into two groups—group A and group B. Both groups consisted of 15 subjects each. In group A, the choice of treatment was hot-pack, quadriceps setting exercise, and TENS. In group B, the choice of treatment was hot-pack, SLR exercise, and TENS. Total 10 treatment sessions (5 times a week for 2 weeks) were given to each group.[15,18,20]

Procedure

EMG Activity (►**Fig. 1**)

- The skin of the tested knee was wiped with alcohol-soaked gauze. Surface electrodes with an interelectrode distance of approximately 25 mm were placed over the muscle belly.[13,21]

Vastus Medialis (►**Fig. 2**)

- The electrode for the vastus medialis muscle was applied over the muscle belly found by visually inspecting the thigh, while the subject exerted a strong isometric contraction of the quadriceps muscles.[13,21]

Rectus Femoris (►**Fig. 3**)

- The electrode for the rectus femoris muscle was placed one-half the distance from the anterior superior iliac spine to the superior-most pole of the patella.[21,22]
- The ground electrode was placed over the fibular head. All electrode leads were plugged into main amplifiers.[13,21]
- EMG data was collected from vastus medialis and rectus femoris during quadriceps setting exercises and during SLR.

Quadriceps Setting Exercises (►**Fig. 3**)

Subjects assume long sitting position and were instructed to press the back of their knee as hard as possible into a small towel placed under the extended knee.[22]

Straight Leg Raises (►**Fig. 2**, **4** and **5**)

Subjects assumed supine position and were instructed to elevate the heel above on the command "set" and the investigator applied constant resistance just above the ankle and patella on the instruction "go."[13,21]

- Because the EMG data were to be normalized, each participant's maximally evoked EMG recording for each of the specified muscles was selected from three trials of maximal effort isometric contraction. Verbal commands of "ready," "set," and "push" or "pull" were given to the subjects.
- Rest period of 30 second between trials were given to allow data storage and during this period subjects were instructed to relax.[13,21] Five minutes rest was given to the subjects between the exercises testing to reduce the possible effect of fatigue.[22]
- The mean of the three trials was used in the exercise comparison analysis (►**Figs. 2–5**).[13,21]

Interventions of Group A

Hot-Pack

- Patient was in supine lying position. Hot-pack was applied over the affected knee for 15 minutes.[18]

Quadriceps Setting Exercise

- Subject sits with back supported and legs extended.
- A rolled-up towel was placed under the affected knee.
- Subject was asked to contract his/her quadriceps by pushing against the towel roll.
- Isometric quadriceps contraction in full extension was held for five seconds.
- 20 repetitions were performed.
- 10 second rests between repetitions were given.
- Vigorous verbal encouragements were given by the therapist.[23]
- Stop watch used.

TENS

- TENS was given for 15 minutes. Two electrodes were attached to painful areas in the affected knee with a frequency of 100 Hz. Stimulation was applied with a dose tolerated well by the patient.[18,24]

Interventions of Group B

Hot-Pack

- Patient was in supine lying position. Hot-pack was applied over the affected knee for 15 minutes.[18]

Straight-Leg-Raising Exercise

- The patients were instructed to lie on their back with the affected leg to be kept straight and the opposite knee bent.
- Then the leg was raised straight.
- During the exercise, the hip was flexed into 30 degrees while keeping knee at full extension and ankle

Fig. 2 Electromyography for vastus medialis during quadriceps setting exercise.

dorsiflexed. The hip angle was measured with a goniometer. The goniometer was placed with the stationary arm parallel to the edge of the table, the moving arm along the lateral midline of the thigh, and the axis over the superior half of the greater trochanter.

- A point was marked on the wall and the patient was instructed to lift the affected leg till that point and maintained for 10 seconds with attention paid to feeling quadriceps muscle contraction.
- Twenty repetitions were performed with 10 seconds rest between repetitions.
- Vigorous verbal encouragements were given by the therapist.[14,24,25]
- Stop watch was used.

Fig. 3 Electromyography for rectus femoris during quadriceps setting exercise.

Fig. 4 Electromyography for vastus medialis during straight-leg-raising.

TENS

- TENS was given for 15 minutes. Two electrodes were attached to painful areas in the affected knee with a frequency of 100 Hz. Stimulation was applied with a dose tolerated well by the patient.[18,24]

Data Collection Tools:

- EMG.
- VAS.
- WOMAC index of OA.

Outcomes were collected on day 1, 6 and 11

The interventions were given for 10 sessions and the patients were asked to come on 11th day for data collection.

Fig. 5 Electromyography for rectus femoris during Straight-leg-raising.

Data was collected before treatment to avoid any possible effects of fatigue due to the exercises being performed on EMG activity.

Results

Data Analysis

Data analysis was performed using SPSS software version 16.0. Intergroup and intragroup comparisons were done. Following tests were used: Repeated measure analysis of variance was used for within group analysis and post hoc test as paired "t" test was done for within group A and B analysis Unpaired "t" test was used to determine the significance of differences between experimental group A and group B. Level of significance selected for the study was $p < 0.05$ (►**Table 1–30**, ►**Figs 6–22**).

Variables:

- VAS—Visual analogue scale (V)
- WOMAC—Western Ontario and McMaster University Osteoarthritis (W)
- Vm QS—Vastus medialis quadriceps femoris. Vm SLR—vastus medialis straight leg raising.
- Rf QS—Rectus femoris quadriceps femoris
- Rf SLR—Rectus femoris straight leg raising
- **Days of data collection**—Day 1(D1), Day 6(D6), Day 11 (D11)

Table 1 Comparison within group A—VAS

Days	Mean ± SD	F-Value	Level of sig.
Day 1	86.40 ± 15.408	55.649	0.000(S)
Day 6	50.13 ± 13.065		
Day 11	21.73 ± 20.995		

Abbreviations: SD, standard deviation; VAS, visual analog scale.

Table 2 Post-hoc comparison within group A for VAS

Days	Mean ± SD	*t*-Value	*p*-Value
Day 1 VAS Day 6	86.40 ± 15.408	9.057	0.0000 (S)
	50.13 ± 13.065		
Day 6 VAS Day 11	50.13 ± 13.065	9.942	0.0002 (S)
	21.73 ± 20.995		
Day 1 VAS Day 11	86.40 ± 15.408	13.800	0.0000 (S)
	21.73 ± 20.995		

Abbreviations: SD, standard deviation; VAS, visual analog scale.

Table 3 Comparison within group B—VAS

Days	Mean ± SD	F-Value	Level of sig.
Day 1	88.07 ± 14.300	61.965	0.000(S)
Day 6	48.73 ± 17.310		
Day 11	22.40 ± 16.999		

Abbreviations: SD, standard deviation; VAS, visual analog scale.

Table 4 Post-hoc comparison within group B—VAS

Days	Mean ± SD	*t*-Value	*p*-Value
Day 1 VAS Day 6	88.07 ± 14.300	11.443	0.0000 (S)
	48.73 ± 17.310		
Day 6 VAS Day 11	48.73 ± 17.310	9.590	0.0000 (S)
	22.40 ± 16.999		
Day 1 VAS Day 11	88.07 ± 14.300	15.705	0.0000 (S)
	22.40 ± 16.999		

Abbreviations: SD, standard deviation; VAS, visual analog scale.

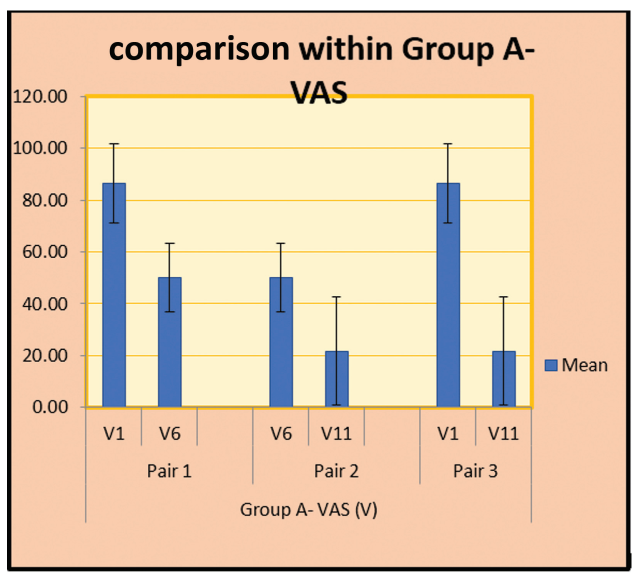

Fig. 6 Group A—Visual analog scale (VAS).

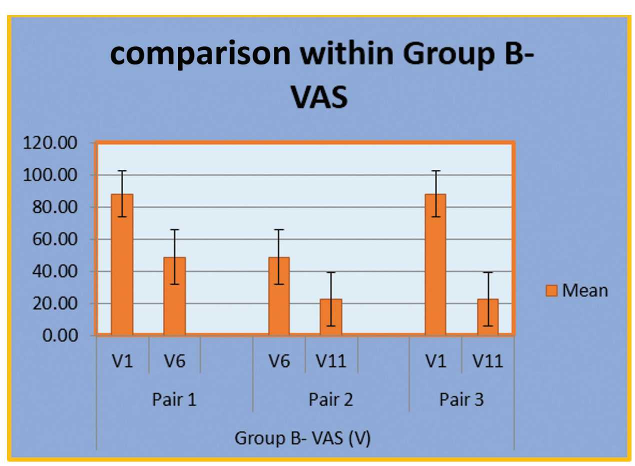

Fig. 7 Group B—Visual analog scale (VAS).

Table 5 Comparison within group A—WOMAC

Days	Mean ± SD	F-Value	Level of sig.
Day 1	82.00 ± 10.697	84.913	0.000(S)
Day 6	44.00 ± 12.065		
Day 11	24.00 ± 14.142		

Abbreviations: SD, standard deviation; WOMAC, Western Ontario and McMaster Universities.

Table 6 Post-hoc comparison within group A—WOMAC

Days	Mean ± SD	*t*-Value	*p*-Value
Day 1 VAS Day 6	82.00 ± 10.697	13.483	0.0000 (S)
	44.00 ± 12.065		
Day 6 VAS Day 11	44.00 ± 12.065	8.803	0.0000 (S)
	24.00 ± 14.142		
Day 1 VAS Day 11	82.00 ± 10.697	17.279	0.0000 (S)
	24.00 ± 14.142		

Abbreviations: SD, standard deviation; WOMAC, Western Ontario and McMaster Universities.

Table 7 Comparison within group B—WOMAC

Days	Mean ± SD	F-Value	Level of sig.
Day 1	78.27 ± 12.798	79.663	0.000(S)
Day 6	42.00 ± 13.784		
Day 11	24.00 ± 14.142		

Abbreviations: SD, standard deviation; WOMAC, Western Ontario and McMaster Universities.

Table 8 Post-hoc comparison within group B—WOMAC

Days	Mean ± SD	*t*-Value	*p*-Value
Day 1 VAS Day 6	78.27 ± 12.798	27.436	0.0000 (S)
	42.00 ± 13.784		
Day 6 VAS Day 11	42.00 ± 13.784	7.301	0.0000 (S)
	21.60 ± 10.561		
Day 1 VAS Day 11	78.27 ± 12.798	18.166	0.0000 (S)
	21.60 ± 10.561		

Abbreviations: SD, standard deviation; WOMAC, Western Ontario and McMaster Universities.

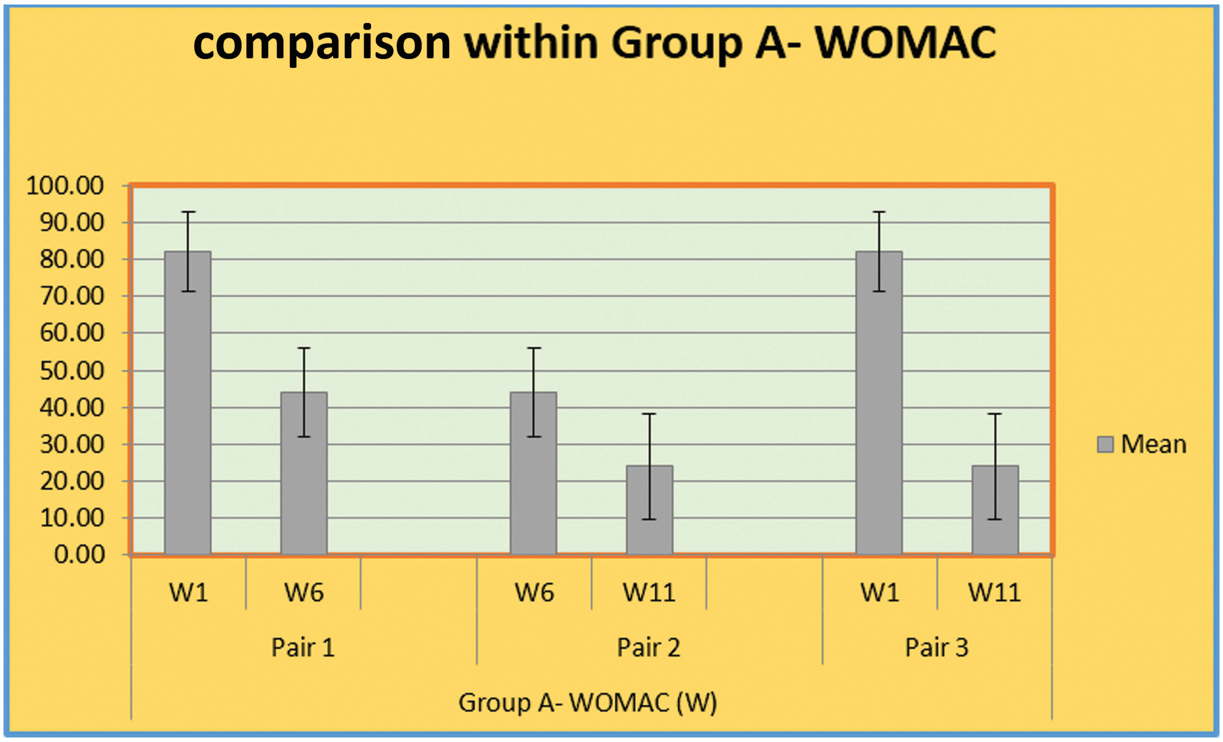

Fig. 8 Comparison with Group A—Western Ontario and McMaster Universities (WOMAC).

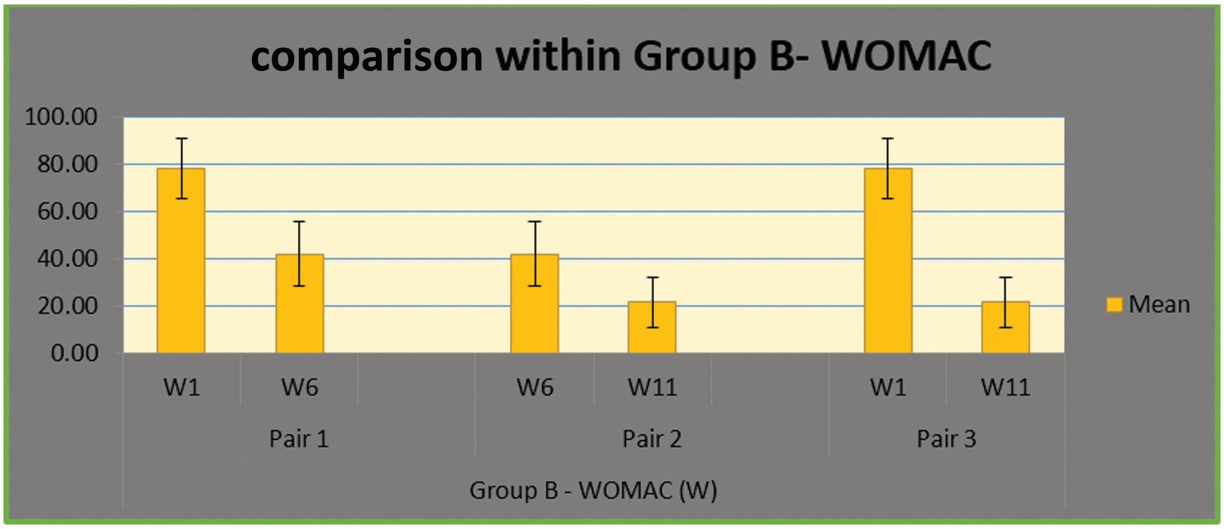

Fig. 9 Comparison with Group B—Western Ontario and McMaster Universities (WOMAC).

Table 9 Comparison within group A—Vm QS

Days	Mean ± SD	F-Value	Level of sig.
DAY 1	712.25 ± 207.760	9.344	0.000(S)
DAY 6	903.58 ± 241.583		
DAY 11	1125.59 ± 323.335		

Abbreviations: SD, standard deviation; Vm QS, vastus medialis quadriceps femoris.

Table 10 Post-hoc comparison within group A—Vm QS

Days	Mean ± SD	*t*-Value	*p*-Value
Day 1 VAS Day 6	712.25 ± 207.760	8.575	0.0000 (S)
	903.58 ± 241.583		
Day 6 VAS Day 11	903.58 ± 241.583	4.895	0.0002 (S)
	1125.59 ± 323.335		
Day 1 VAS Day 11	712.25 ± 207.760	7.307	0.0000 (S)
	1125.59 ± 323.335		

Abbreviations: SD, standard deviation; Vm QS, vastus medialis quadriceps femoris.

Table 11 Comparison within group B—Vm QS

Days	Mean ± SD	F-Value	Level of sig.
Day 1	729.73 ± 208.474	2.116	0.133(NS)
Day 6	796.82 ± 233.729		
Day 11	913.88 ± 294.372		

Abbreviations: SD, standard deviation; Vm QS, vastus medialis quadriceps femoris.

Table 12 Post-hoc comparison within group B—Vm QS

Days	Mean ± SD	*t*-Value	*p*-Value
Day 1 VAS Day 6	729.73 ± 208.474	3.562	0.0031 (S)
	796.82 ± 233.729		
Day 6 VAS Day 11	796.82 ± 233.729	5.596	0.0001 (S)
	913.88 ± 294.372		
Day 1 VAS Day 11	729.73 ± 208.474	5.576	0.0001 (S)
	913.88 ± 294.372		

Abbreviations: SD, standard deviation; Vm QS, vastus medialis quadriceps femoris.

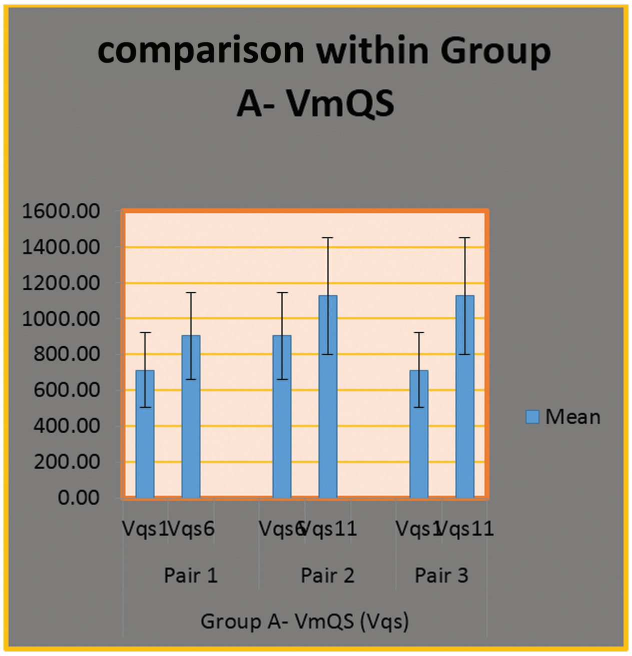

Fig. 10 Comparison with Group A—Vastus medialis quadriceps femoris (Vm QS).

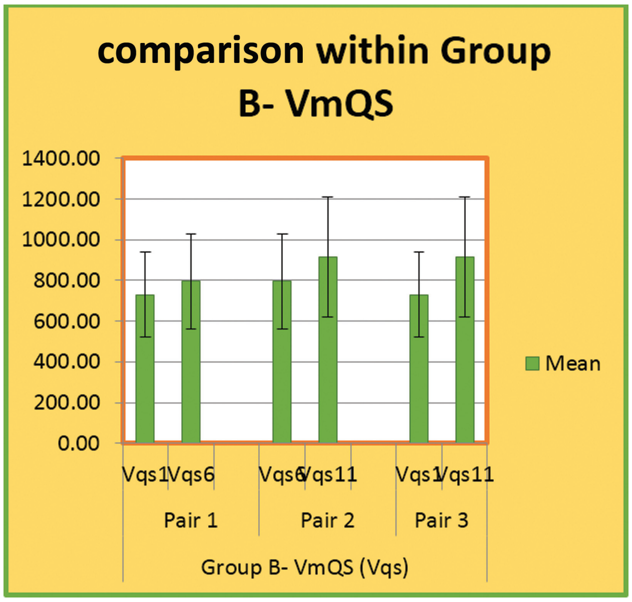

Fig. 11 Group B—Vastus medialis quadriceps femoris (Vm QS).

Table 13 Comparison within group A—Vm SLR

Days	Mean ± SD	F-Value	Level of sig.
Day 1	646.33 ± 205.753	5.283	0.009(S)
Day 6	763.77 ± 191.263		
Day 11	891.49 ± 221.69		

Abbreviations: SD, standard deviation; Vm SLR, vastus medialis straight leg raising.

Table 14 Post-hoc comparison within group A—Vm SLR

Days	Mean ± SD	*t*-Value	*p*-Value
Day 1 VAS Day 6	646.33 ± 205.753	5.194	0.0001 (S)
	763.77 ± 191.263		
Day 6 VAS Day 11	763.77 ± 191.263	7.490	0.0000 (S)
	891.49 ± 221.690		
Day 1 VAS Day 11	646.33 ± 205.753	8.066	0.0000 (S)
	891.49 ± 221.690		

Abbreviations: SD, standard deviation; Vm SLR, vastus medialis straight leg raising.

Table 15 Comparison within group B—Vm SLR

Days	Mean ± SD	F-Value	Level of sig.
Day 1	634.95 ± 192.32	7.302	0.002(S)
Day 6	749.86 ± 185.86		
Day 11	920.77 ± 236.49		

Abbreviations: SD, standard deviation; Vm SLR, vastus medialis straight leg raising.

Table 16 Post-hoc comparison within group B—Vm SLR

Days	Mean ± SD	*t*-Value	*p*-Value
Day 1 VAS Day 6	634.95 ± 192.327	9.201	0.0000 (S)
	749.86 ± 185.860		
Day 6 VAS Day 11	749.86 ± 185.860	8.069	0.0000 (S)
	920.77 ± 236.492		
Day 1 VAS Day 11	634.95 ± 192.327	13.158	0.0000 (S)
	920.77 ± 236.492		

Abbreviations: SD, standard deviation; Vm SLR, vastus medialis straight leg raising.

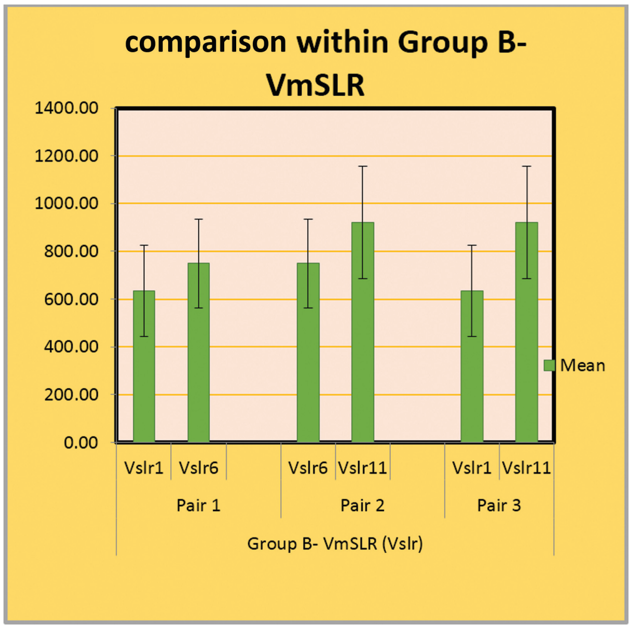

Fig. 13 Comparison with Group B—Vastus medialis straight leg raising (Vm SLR).

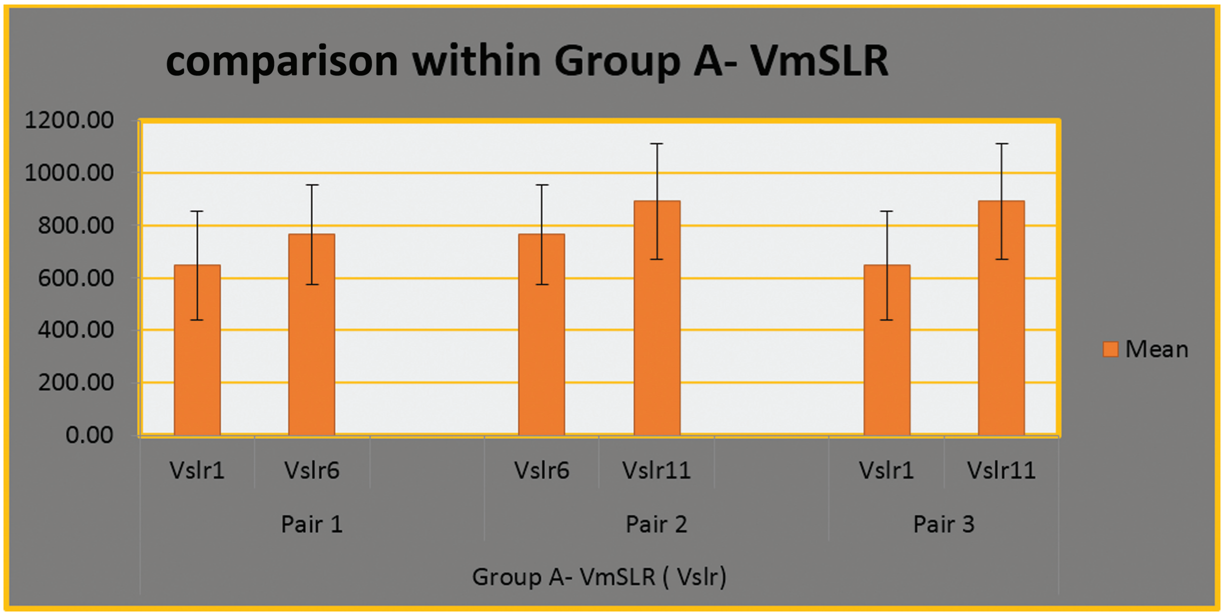

Fig. 12 Comparison with Group A—Vastus medialis straight leg raising (Vm SLR).

Table 17 Comparison within group A—Rf QS

Days	Mean ± SD	F-Value	Level of sig.
Day 1	644.42 ± 187.319	6.283	0.004(S)
Day 6	795.32 ± 158.606		
Day 11	884.67 ± 213.016		

Abbreviations: Rf QS, rectus femoris quadriceps femoris; SD, standard deviation.

Table 18 Post-hoc comparison within group A—Rf QS

Days	Mean ± SD	*t*-Value	*p*-Value
Day 1 VAS Day 6	644.42 ± 187.319	11.224	0.0000 (S)
	795.32 ± 158.606		
Day 6 VAS Day 11	795.32 ± 158.606	4.553	0.0005 (S)
	884.67 ± 213.016		
Day 1 VAS Day 11	644.42 ± 187.319	14.564	0.0000 (S)
	884.67 ± 213.016		

Abbreviations: Rf QS, rectus femoris quadriceps femoris; SD, standard deviation.

Table 19 Comparison within group B—Rf QS

Days	Mean ± SD	F-Value
Day 1	711.73 ± 159.631	6.467
Day 6	838.82 ± 177.848	
Day 11	942.16 ± 188.622	

Abbreviations: Rf QS, rectus femoris quadriceps femoris; SD, standard deviation.

Table 20 Post-hoc comparison within group B—Rf QS

Days	Mean ± SD	*t*-Value	*p*-Value
Day 1 VAS Day 6	711.73 ± 159.631	8.735	0.0000 (S)
	838.82 ± 177.848		
Day 6 VAS Day 11	838.82 ± 177.848	6.434	0.0000 (S)
	942.16 ± 188.622		
Day 1 VAS Day 11	711.73 ± 159.631	16.180	0.0000 (S)
	942.16 ± 188.622		

Abbreviations: Rf QS, rectus femoris quadriceps femoris; SD, standard deviation.

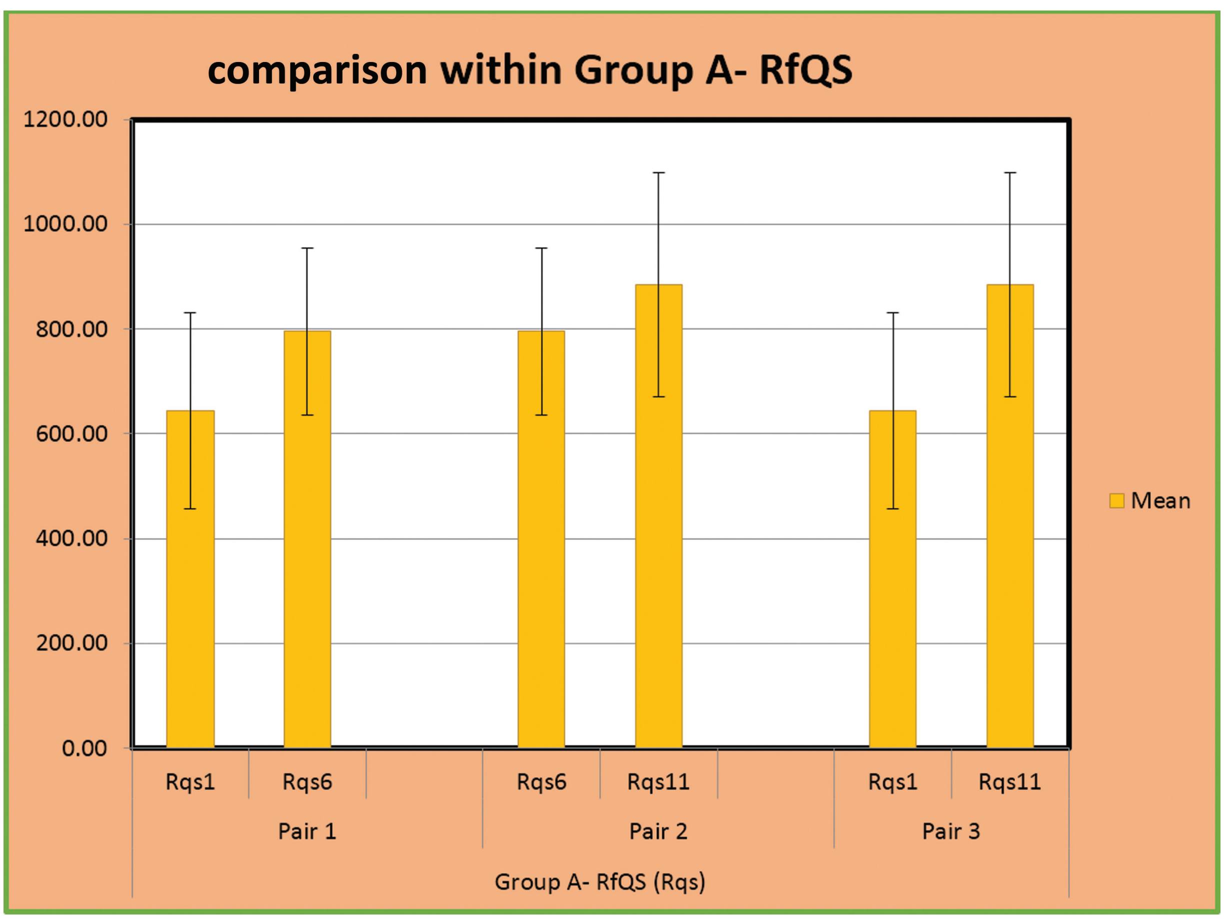

Fig. 14 Comparison with Group A—Rectus femoris quadriceps femoris (Rf QS).

Table 21 Comparison within group A—Rf SLR

Days	Mean ± SD	F-Value	Level of sig.
Day 1	728.87 ± 209.126	2.962	0.063(NS)
Day 6	823.71 ± 233.943		
Day 11	936.30 ± 255.621		

Abbreviations: Rf SLR, rectus femoris straight leg raising; SD, standard deviation.

Table 22 Post-hoc comparison within group A—Rf SLR

Days	Mean ± SD	*t*-Value	*p*-Value
Day 1 VAS Day 6	728.87 ± 209.126	7.422	0.0000 (S)
	823.71 ± 233.943		
Day 6 VAS Day 11	823.71 ± 233.943	6.158	0.0000 (S)
	936.30 ± 255.621		
Day 1 VAS Day 11	728.87 ± 209.126	8.645	0.0000 (S)
	936.30 ± 255.621		

Abbreviations: Rf SLR, rectus femoris straight leg raising; SD, standard deviation.

Table 23 Comparison within group B—Rf SLR

Days	Mean ± SD	F-Value	Level of sig.
Day 1	763.74 ± 174.716	8.826	0.001(S)
Day 6	951.23 ± 240.483		
Day 11	1130.34 ± 288.06		

Abbreviations: Rf SLR, rectus femoris straight leg raising; SD, standard deviation.

Table 24 Post-hoc comparison within group B—Rf SLR

Days	Mean ± SD	*t*-Value	*p*-Value
Day 1 VAS Day 6	763.74 ± 174.716	8.155	0.0000 (S)
	951.23 ± 240.483		
Day 6 VAS Day 11	951.23 ± 240.483	7.484	0.0000 (S)
	1130.34 ± 288.061		
Day 1 VAS Day 11	763.74 ± 174.716	10.127	0.0000 (S)
	1130.34 ± 288.061		

Abbreviations: Rf SLR, rectus femoris straight leg raising; SD, standard deviation.

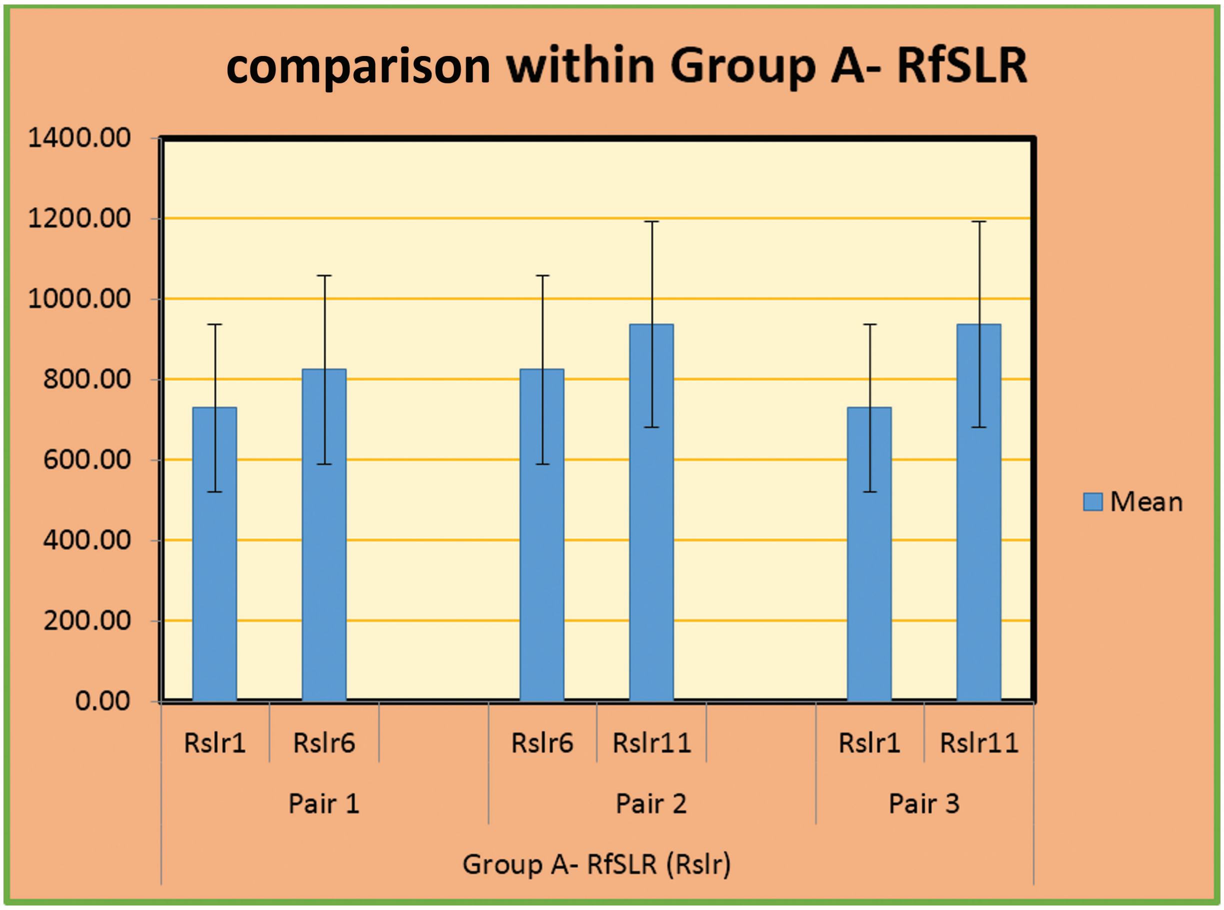

Fig. 15 Comparison with Group A—Rectus femoris straight leg raising (Rf SLR).

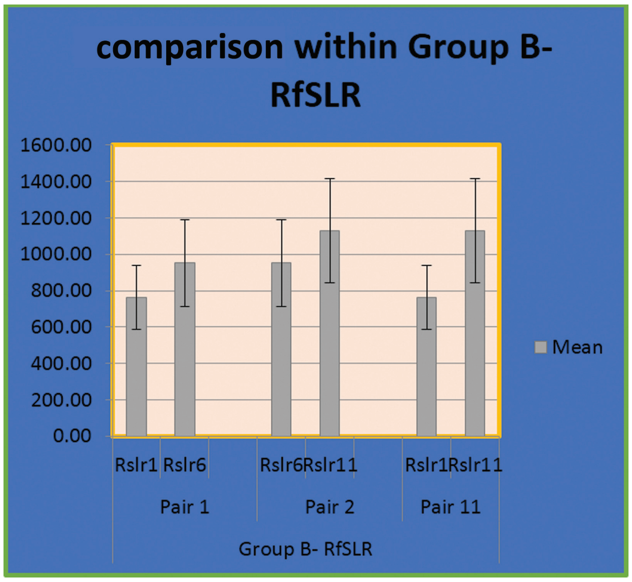

Fig. 16 Comparison within Group B—Rectus femoris straight leg raising (Rf SLR).

Table 25 Comparison of VAS between the groups

Days	Group A Mean ± SD	Group B Mean ± SD	*t*-Value	*p*-Value
Day 1	86.40 ± 15.408	88.07 ± 14.30	0.307	0.7611(NS)
Day 6	50.13 ± 13.065	48.73 ± 17.310	0.250	0.8044(NS)
Day 11	21.73 ± 20.995	22.40 ± 16.999	0.096	0.9245(NS)

Abbreviations: NS, not specified; SD, standard deviation.

Table 26 Comparison of WOMAC between the groups

Days	Group A Mean ± SD	Group B Mean ± SD	*t*-Value	*p*-Value
Day 1	82.0 ± 10.697	78.27 ± 12.798	0.866	0.3934(NS)
Day 6	44.0 ± 12.065	42.00 ± 13.784	0.423	0.6756(NS)
Day 11	24.0 ± 14.142	21.60 ± 10.561	0.526	0.6026(NS)

Abbreviations: NS, not specified; SD, standard deviation.

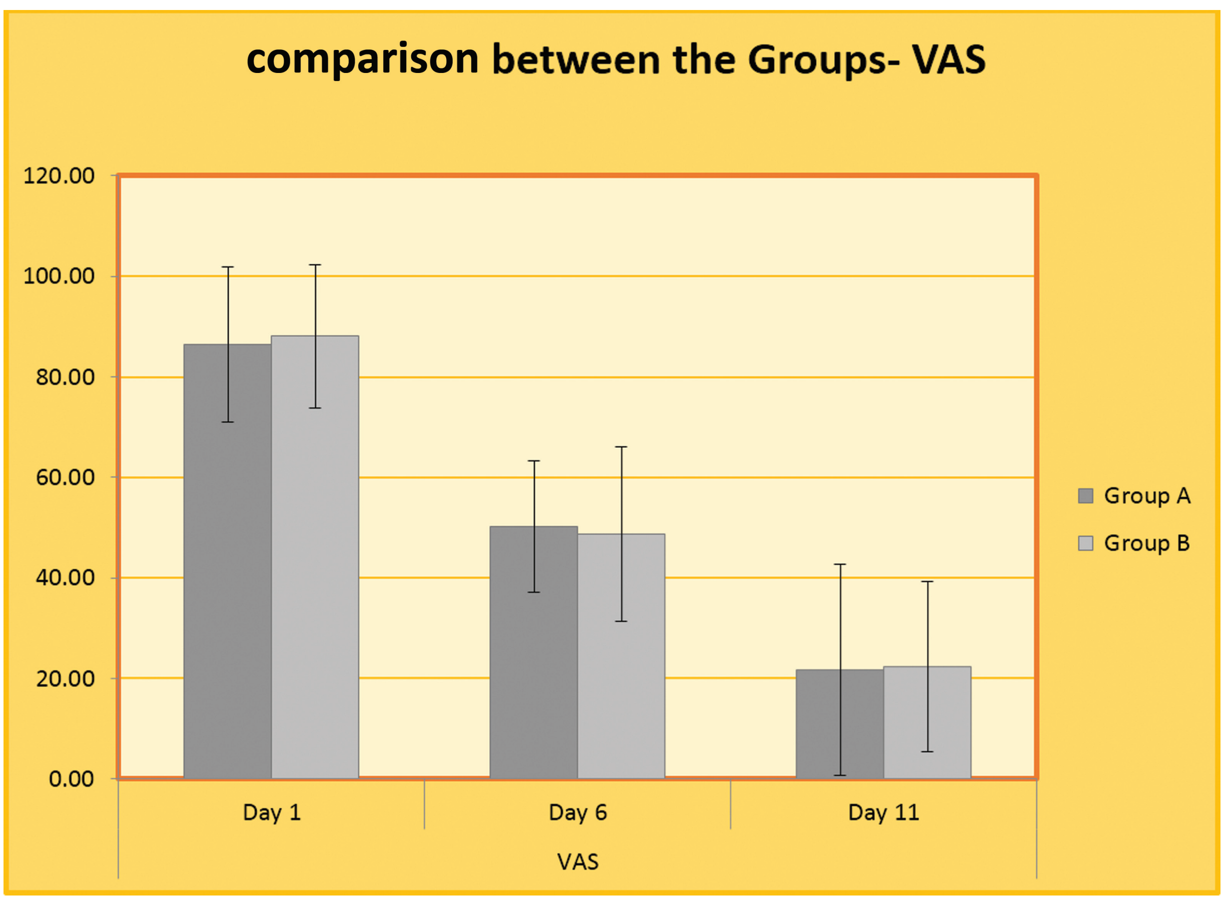

Fig. 17 Visual analog scale (VAS)—Between the groups.

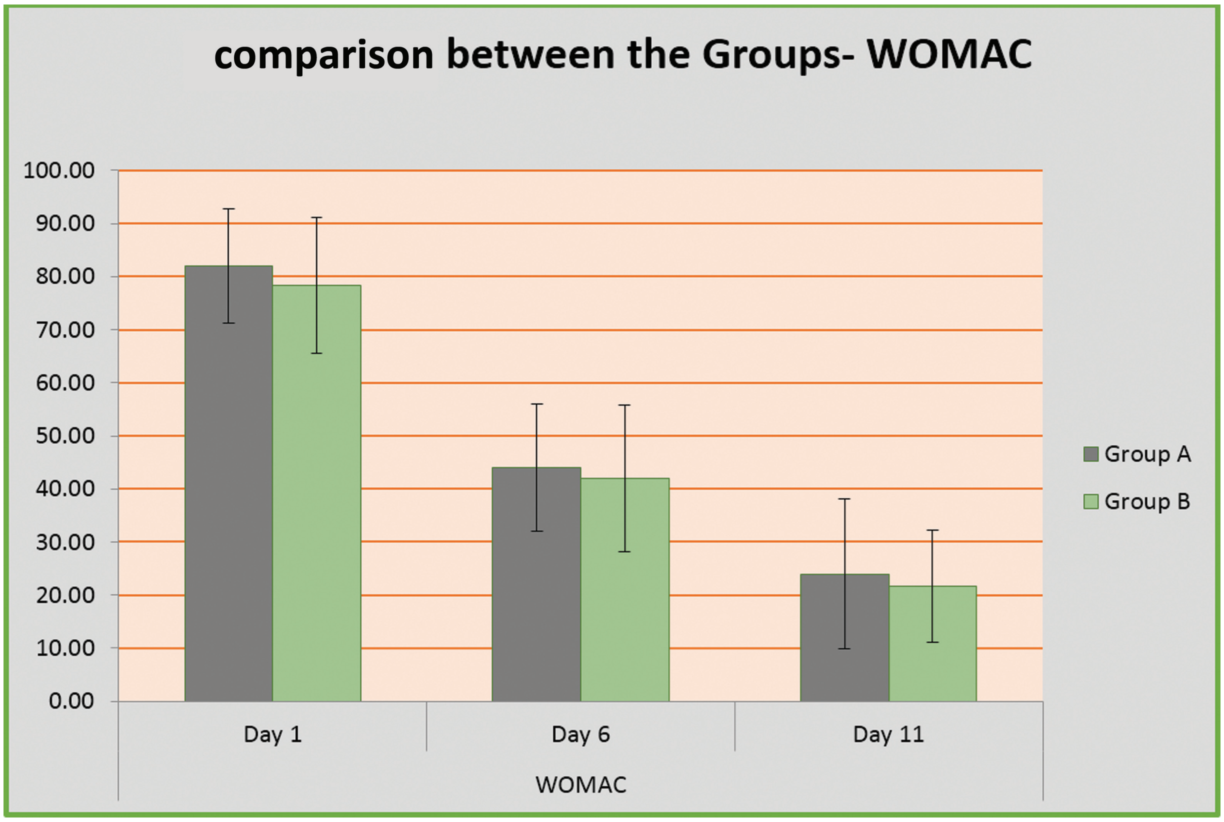

Fig. 18 Western Ontario and McMaster Universities (WOMAC)—Between the groups.

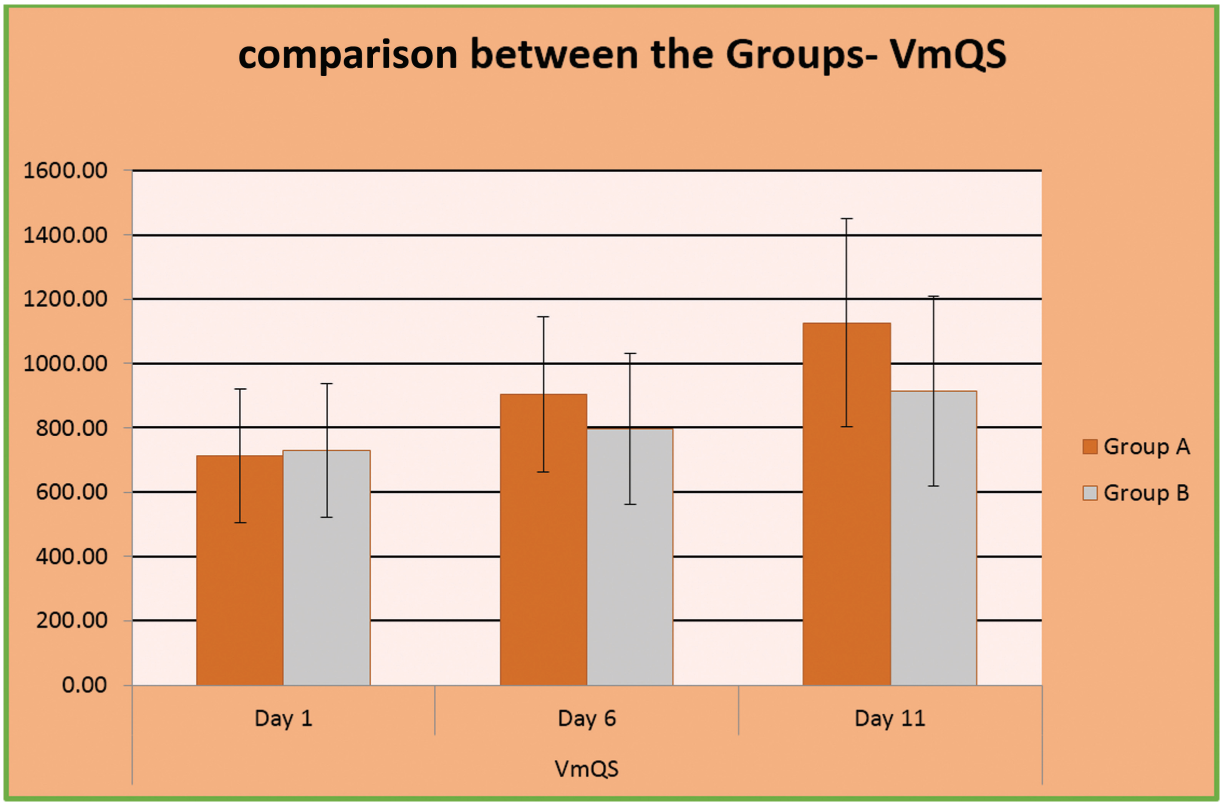

Fig. 19 Vastus medialis quadriceps femoris (Vm QS)—Between the groups.

Table 27 Comparison of Vm QS between the groups

Days	Group A Mean ± SD	Group B Mean ± SD	*t*-Value	*p*-Value
Day 1	712.25 ± 207.7	729.73 ± 208.4	0.230	0.8198(NS)
Day 6	903.58 ± 241.5	796.82 ± 233.7	1.229	0.2289(NS)
Day 11	1125.5 ± 323.3	913.88 ± 294.3	1.873	0.0712(NS)

Abbreviations: NS, not specified; SD, standard deviation.

Table 28 Comparison of Vm SLR between the groups

Days	Group A Mean ± SD	Group B Mean ± SD	*t*-Value	*p*-Value
Day 1	646.33 ± 205.5	634.95 ± 192.3	0.156	0.8768(NS)
Day 6	763.77 ± 191.2	749.86 ± 185.8	0.202	0.8414(NS)
Day 11	891.49 ± 221.6	920.77 ± 236.4	0.350	0.7291(NS)

Abbreviations: NS, not specified; SD, standard deviation.

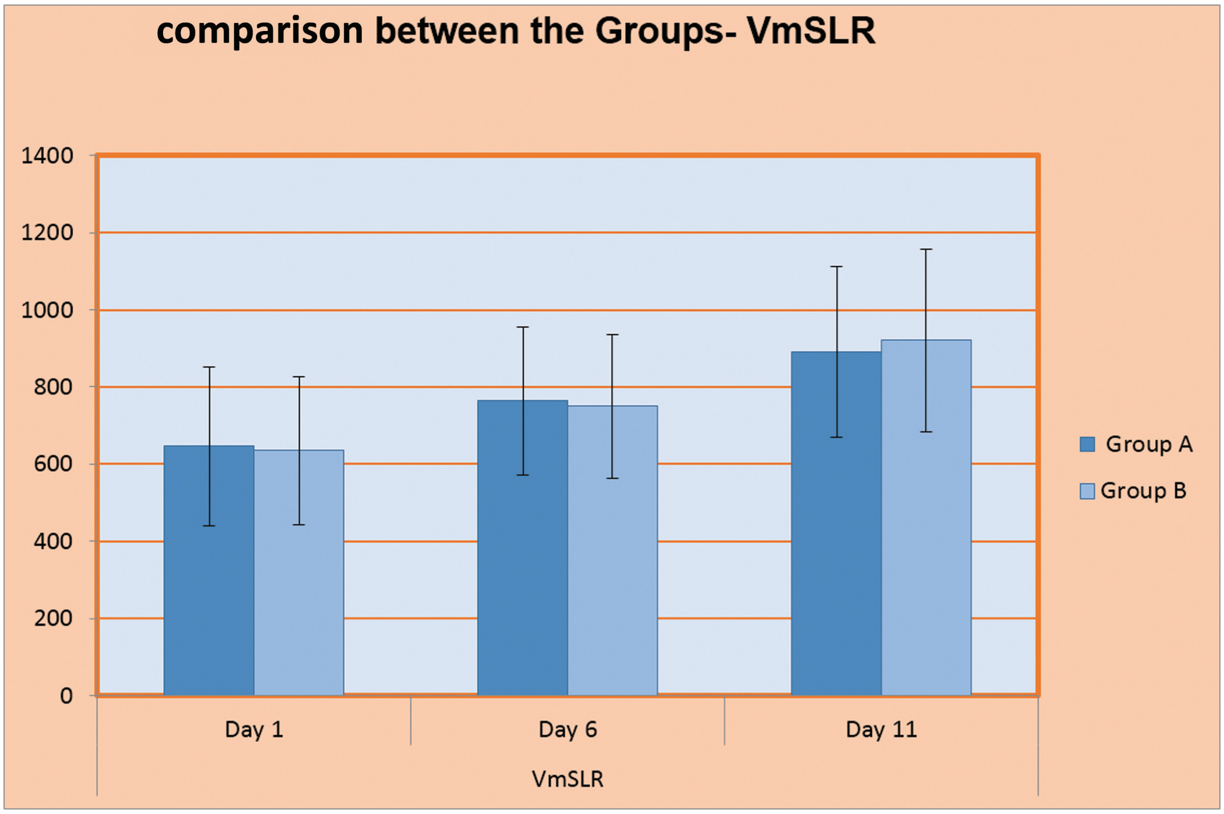

Fig. 20 Vastus medialis straight leg raising (Vm SLR)—Between the groups.

Table 29 Comparison of Rf QS between the groups

Days	Group A Mean ± SD	Group B Mean ± SD	*t*-Value	*p*-Value
Day 1	644.42 ± 187.3	711.73 ± 159.6	1.059	0.2985(NS)
Day 6	795.32 ± 158.6	838.82 ± 177.8	0.707	0.4854(NS)
Day 11	884.87 ± 213.0	942.16 ± 188.6	0.782	0.4405(NS)

Abbreviations: NS, not specified; SD, standard deviation.

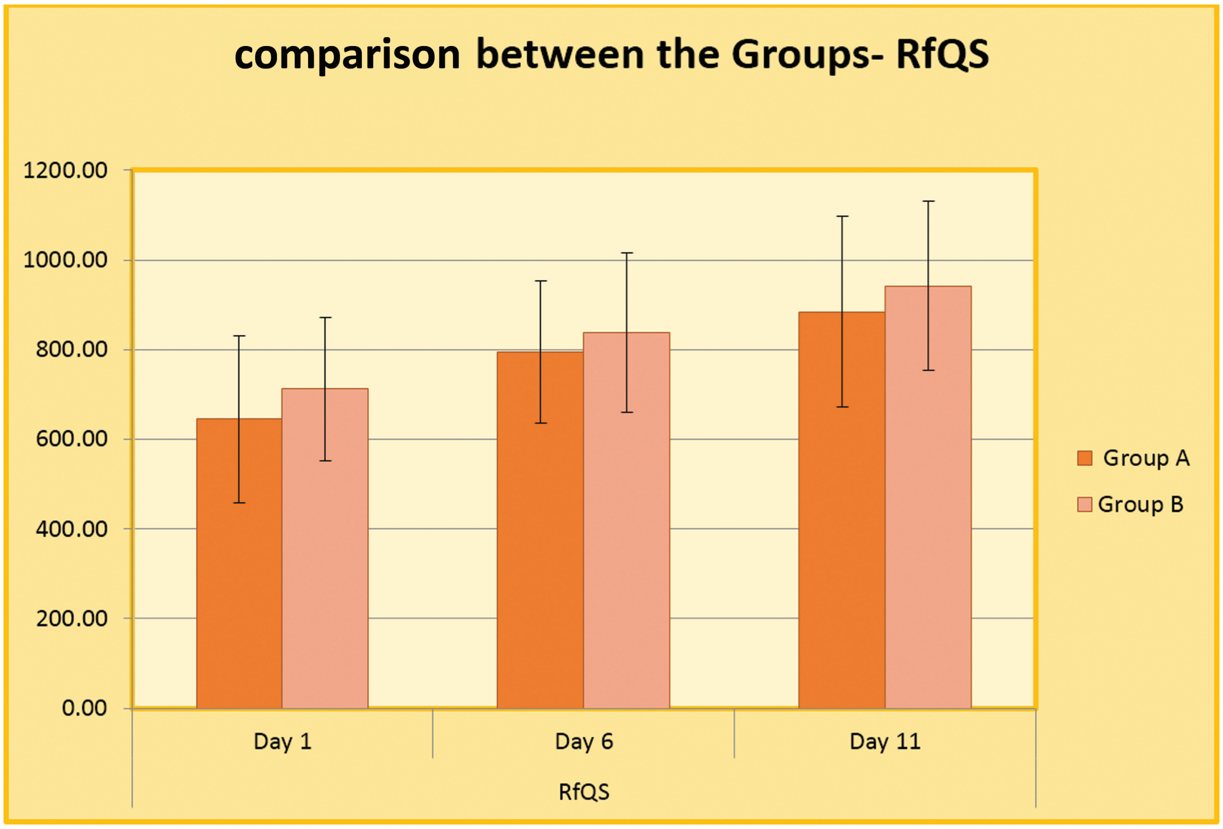

Fig. 21 Rectus femoris quadriceps femoris (Rf QS)—Between the groups.

Table 30 Comparison of Rf SLR between the groups

Days	Group A Mean ± SD	Group B Mean ± SD	*t*-Value	*p*-Value
Day 1	728.87 ± 209.1	763.74 ± 174.7	0.495	0.624(NS)
Day 6	823.71 ± 233.9	951.23 ± 240.4	1.471	0.1521(NS)
Day 11	936.3 ± 255.62	1130.3 ± 288.0	1.949	0.0611(NS)

Abbreviations: NS, not specified; SD, standard deviation.

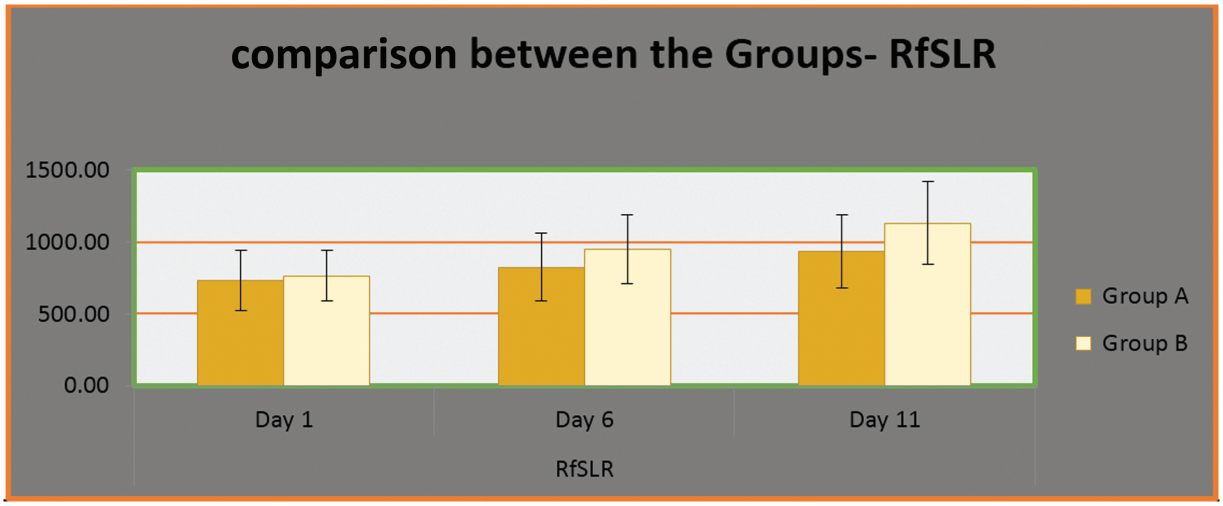

Fig. 22 Rectus femoris straight leg raising (Rf SLR)—Between the groups.

Discussion

Within group analysis of both the groups showed statistically significant improvement in pain, disability, and EMG activity for vastus medialis and rectus femoris in OA knee patients (i.e., reduction in pain and disability and increase in EMG activity). One possible mechanism by which these exercises may have reduced the pain and disability in subjects with OA knee is by increase in strength. Currier et al observed a significant increase in strength after only 10 daily sessions of isometric exercise.[26] Our results support the findings of previous studies indicating that strength training reduces pain and improves physical function in people with knee OA. A reduction of pain may result from improvement of muscle strength and this comes with the results of O'Reilly[27] et al and Bálint and Szebenyi[28] et al who concluded that improved quadriceps strength is associated with less knee pain and less disability. Another possible mechanism by which these isometric exercises may have reduced the pain and disability is by relief of reflex inhibition. A "reflex inhibition" mechanism is an important cause of quadriceps weakness in knee OA patients in addition to disuse atrophy. Reflex inhibition leads to neurogenic inhibition of the quadriceps muscle. The findings of Miyaguchi et al showed that isometric quadriceps exercise resulted in a significant increase in quadriceps strength without an increase in thigh circumference. This finding indicated that relief of reflex inhibition played an important role for increase in muscle strength.[14] Moritani and deVries concluded that after 2 weeks of training, 80% of the strength increments noted is attributable to "neural factors" as evidenced by greater integrated EMG activity. By 4 weeks of training, the majority of the strength gains is due to muscle hypertrophy. Beyond 4 weeks of resistance exercise, strength improvements became increasingly dependent on muscle hypertrophy.[29] The mechanism responsible for the increase in EMG activity with these isometric exercises in both the groups can be explained by the following: According to Balso and Cafarelli, adaptive alterations in the neuromuscular system can be induced in response to specific types of training. Adaptive changes in neural function following training are commonly investigated using the surface EMG as an indicator of change in efferent neural drive. Isometric training protocol induced a significant increase in maximum voluntary contraction (MVC) torque after just two training sessions. Data suggest that the increase in MVC torque may be attributed to an increased rate of activation, secondary to an increased descending volitional drive following isometric training.[30] The increased EMG activity following isometric training produced in our investigation adds support to the theory of DeLuca et al who suggested that a functional reserve of motor units exists that is not readily available for use during maximal contractions and that isometric training may allow the subject to learn to fully activate all motor units available.[31] Another mechanism should be considered for increase in EMG activity, that is, relief of pain in both the groups. In an experimental study conducted by Henriksen et al to find whether quadriceps muscle pain impairs knee joint control during walking. The results demonstrate that muscle pain modulated the function of quadriceps muscle, resulting in impaired knee joint control and joint instability during walking.[32] Thus, we can say that as pain improves EMG activity increases. One possible mechanism for the reduction in pain in both the groups can be due to the application of TENS. Our findings our similar with the findings of Durmu who concluded that addition of TENS to hot-pack and exercise program is more effective in decreasing knee pain and related disability and quality of life. Various theories have been suggested for its mechanism of action. These theories include inhibition of nociceptors, blockage of pain transmission in afferent nerves, sympathetic blockage, gate control theory, and increase in release of endogen opiates.[17] Another possible reason for pain reduction in both the groups is with the application of hot-packs. Denegar et al recommended that superficial heat is considered in the management of knee OA.[33] Heat therapy is applied to obtain analgesia, decrease muscle spasm, increase collagen extensibility, and accelerate metabolic processes.[34] There is no statistical significant difference between quadriceps setting exercises and SLR on pain, disability, and the change in EMG activity for vastus medialis and rectus femoris in OA knee patients was found. Both the exercises are shown to be equally effective. We could not compare our data to other studies for comparison between these two exercises because no similar calculations or comparisons of exercises have been reported and no study was found comparing these two exercises to our knowledge.

Conclusion

In conclusion, the results of the study elicit that, though both groups A and B showed statistically significant outcomes in within group analysis in terms of pain, disability, and EMG activity, there was no statistical significant difference between the two groups for any of the variables studied, that is, VAS, WOMAC, and EMG activity. Thus, we can conclude that both the exercises, that is, quadriceps setting exercise and SLR exercise when combined with hot-pack and TENS application shows similar treatment effects for people suffering from OA knee. There is no statistical significant difference between quadriceps setting exercises and SLR on pain, disability, and the change in EMG activity for vastus medialis and rectus femoris in OA knee patients hence proving the null hypothesis.

Clinical Relevance of the Study

This study shows that both the exercises, that is, quadriceps setting exercise and SLR exercise when combined with hot-pack and TENS, are equally effective for patients with OA knee and the treatment protocol is clinically practicable and relatively brief. Such improvements may delay or even avoid the need for surgical interventions. Hence, the protocols are cost-effective.

Conflict of Interest
None

Reference List

1 Chan KW, Chan LW. 'A qualitative study on patients with knee osteoarthritis to evaluate the influence of different pain patterns on patients' quality of life and to find out patients' interpretation and coping strategies for the disease'. Rheumatology Reports 2011;3(01):9–15

2 Pollard H, Ward G, Hoskins W, Hardy K. The effect of a manual therapy knee protocol on osteoarthritic knee pain: a randomised controlled trial. J Can Chiropr Assoc 2008;52(04):229–242

3 Spector TD, Hart DJ, Byrne J, Harris PA, Dacre JE, Doyle DV. Definition of osteoarthritis of the knee for epidemiological studies. Ann Rheum Dis 1993;52(11):790–794

4 Gryzlo SM, Patek RM, Pink M, Perry J. Electromyographic analysis of knee rehabilitation exercises. J Orthop Sports Phys Ther 1994; 20(01):36–43

5 Bolgla LA, Shaffer SW, Malone TR. Vastus medialis activation during knee extension exercises: evidence for exercise prescription. J Sport Rehabil 2008;17(01):1–10

6 Segal NA, Torner JC, Felson D, et al. Effect of thigh strength on incident radiographic and symptomatic knee osteoarthritis in a longitudinal cohort. Arthritis Rheum 2009;61(09): 1210–1217

7 Sullivan S, Schmitz T. Physical Rehabilitation. Philadelphia: Jaypee; 2006

8 Gardiner D. The Principles of Exercise Therapy. 4th edition. New Delhi: CBS Publishers & Distributors; 2005

9 Reed A, Low J. Electrotherapy explained-principles and practice. London, United Kingdom: Elsevier Health Services; 2000

10 Melzack R. Transcutaneous Electric Nerve Stimulation for Low Back Pain. 1983;63(04): 489–493

11 Magee DJ. Orthopedic Physical Assessment. Riverport Lane, St. Louis, Missouri: Elsevier Sanders; 2002

12 Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. J Rheumatol 1988;15(12):1833–1840

13 Soderberg GL, Cook TM. An electromyographic analysis of quadriceps femoris muscle setting and straight leg raising. Physic Therapy J 1983;63:1438

14 Miyaguchi M, Kobayashi A, Kadoya Y, Ohashi H, Yamano Y, Takaoka K. Biochemical change in joint fluid after isometric quadriceps exercise for patients with osteoarthritis of the knee. Osteoarthritis Cartilage 2003;11(04):252–259

15 Hurley MV, Scott DL. Improvements in quadriceps sensorimotor function and disability of patients with knee osteoarthritis following a clinically practicable exercise regime. Br J Rheumatol 1998;37(11):1181–1187

16 Cheing G, Chan C, Chan KM. Does four weeks of TENS and/ or isometric exercise produce cumulative reduction of osteoarthritic knee pain? Clin Rehabil J 2002;16(07):749–760

17 Durmu AD. Effects of TENS on pain, disability, quality of life and depression in patients with knee osteoarthritis. Turk J Rheumatol 2010;25:116–121

18 Evcik D, Kavuncu V, Yeter A, Yigit I. The efficacy of balneotherapy and mud-pack therapy in patients with knee osteoarthritis. Joint Bone Spine 2007;74(01):60–65

19 Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. Ann Rheum Dis 1957;16(04):494–502

20 Bjordal JM, Johnson MI, Lopes-Martins RA, Bogen B, Chow R, Ljunggren AE. Short-term efficacy of physical interventions in osteoarthritic knee pain. A systematic review and meta-analysis of randomised placebo-controlled trials. BMC Musculoskelet Disord 2007;8(51):51

21 Soderberg GL, Minor SD, Arnold K, et al. Electromyographic analysis of knee exercises in healthy subjects and in patients with knee pathologies. Phys Ther 1987;67(11):1691–1696

22 Maffiuletti NA, Lepers R. Quadriceps femoris torque and EMG activity in seated versus supine position. Med Sci Sports Exerc 2003;35(09):1511–1516

23 O'Reilly SC, Muir KR, Doherty M. Effectiveness of home exercise on pain and disability from osteoarthritis of the knee: a randomised controlled trial. Ann Rheum Dis 1999;58(01):15–19

24 Avraham F, Aviv S, Ya'akobi P, et al. The efficacy of treatment of different intervention programs for patellofemoral pain syndrome–a single blinded randomized clinical trial. Pilot study. ScientificWorldJournal 2007;7:1256–1262

25 Hsieh CY, Walker JM, Gillis K. Straight-leg-raising test. Comparison of three instruments. Phys Ther 1983;63(09): 1429–1433

26 Currier DP, Lehman J, Lightfoot P. Electrical stimulation in exercise of the quadriceps femoris muscle. Physic Therap J 1979;59: 1508–1512

27 O'Reilly SC, Jones A, Muir KR, Doherty M. Quadriceps weakness in knee osteoarthritis: the effect on pain and disability. Ann Rheum Dis 1998;57(10):588–594

28 Bálint G, Szebenyi B. Non-pharmacological therapies in osteoarthritis. Baillieres Clin Rheumatol 1997;11(04):795–815

29 Moritani T, deVries HA. Neural factors versus hypertrophy in the time course of muscle strength gain. Am J Phys Med 1979;58(03): 115–130

30 Del Balso C, Cafarelli E. Adaptations in the activation of human skeletal muscle induced by short-term isometric resistance training. J Appl Physiol 2007;103(01):402–411

31 De Luca CJ, LeFever RS, McCue MP, Xenakis AP. Behaviour of human motor units in different muscles during linearly varying contractions. J Physiol 1982;329:113–128

32 Henriksen M, Alkjaer T, Lund H, et al. Experimental quadriceps muscle pain impairs knee joint control during walking. J Appl Physiol 2007;103(01):132–139

33 Denegar CR, Dougherty DR, Friedman JE, et al. Preferences for heat, cold, or contrast in patients with knee osteoarthritis affect treatment response. Clin Interv Aging 2010;5:199–206

34 Kozanoglu E, Basaran S, Guzel R, Guler-Uysal F. Short term efficacy of ibuprofen phonophoresis versus continuous ultrasound therapy in knee osteoarthritis. Swiss Med Wkly 2003;133(23-24): 333–338

