

COMBINED EFFECTS OF BLOOD FLOW RESTRICTION TRAINING AND AUGMENTED SOFT TISSUE MOBILIZATION ON RANGE OF MOTION, MUSCLE STRENGTH AND FUNCTIONAL RECOVERY IN PATIENTS FOLLOWING TOTAL KNEE ARTHROPLASTY

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Abstract

Total knee arthroplasty (TKA) is commonly performed for advanced knee osteoarthritis, yet postoperative limitations in knee range of motion (ROM), quadriceps muscle strength, functional recovery, and functional mobility may persist. This study determined the combined effects of blood flow restriction (BFR) training, augmented soft tissue mobilization (ASTYM), and conventional postoperative rehabilitation in patients following TKA. A single-blinded randomized controlled trial included 28 participants following primary unilateral TKA, allocated to an experimental group (n = 14) and a control group (n = 14). The experimental group received BFR training and ASTYM in addition to conventional rehabilitation, whereas the control group received conventional rehabilitation alone for 6 weeks. ROM, muscle strength, Lysholm Knee Score, and Timed Up and Go (TUG) were assessed before and after treatment. Significant within-group improvements occurred in all outcomes in both groups ($p < 0.001$). In the experimental group, ROM improved from $80.71 \pm 9.57^\circ$ to $107.20 \pm 9.36^\circ$, muscle strength from 13.84 ± 1.57 to 21.71 ± 2.00 , Lysholm Knee Score from 43.00 ± 5.13 to 75.50 ± 5.05 , and TUG from 16.36 ± 1.33 s to 10.81 ± 0.96 s. In the control group, ROM improved from $83.19 \pm 7.00^\circ$ to $102.21 \pm 5.50^\circ$, muscle strength from 13.71 ± 1.85 to 18.45 ± 1.66 , Lysholm Knee Score from 43.79 ± 5.19 to 64.79 ± 4.00 , and TUG from 15.84 ± 1.42 s to 12.89 ± 1.17 s. Post-treatment muscle strength, functional recovery, and functional mobility were significantly better in the experimental group ($p < 0.001$), whereas ROM did not differ significantly between groups ($p = 0.10$). Combined BFR and ASTYM may therefore be useful adjuncts to conventional rehabilitation following TKA.

Introduction

Total knee arthroplasty is an accepted surgical procedure and a significant problem is knee osteoarthritis. While TKA can reduce pain and

restore function, there can still be significant impairments after surgery [1, 2]. The importance of quadriceps weakness is noted as knee arthroplasty can lead to a significant early

loss of strength and decreased physical function and activity, yet can be maintained despite patient satisfaction with the surgery [3, 4]. These restrictions may cause a delay in walking, negotiating stairs and the ability to participate in daily living activities [5, 6]. Therefore, the primary goal of early rehabilitation is to restore joint motion and function, muscle performance and gait, and ability to function independently while preventing damage to the operated knee [7]. BFT has become an interest for low-load strength training. During exercise, a partial occlusion of the arterial return and venous return is achieved with a pneumatic cuff placed proximally to the limb [8, 9]. BFR can offer a high-intensity resistance stimulus with minimal mechanical load to the recovering joint when paired with low-intensity resistance exercise [10]. This feature is applicable following TKA, when the normal high load-bearing might not be tolerated or suitable. BFR has been investigated in knee osteoarthritis, prehabilitation prior to TKA, and post-rehabilitation after other knee surgeries, and these have been shown to increase muscle strength and physical function. ASTYM is a soft tissue intervention with an instrument to treat dysfunctional or restricted soft tissue [11]. Specialized instruments are used on tissues to detect irregular areas and provide precise mechanical stimulation [12]. Soft tissue mobility can impact motion, exercise tolerance and functional performance in the postoperative rehabilitation phase. There is limited evidence on using BFR combined with instrument-assisted soft-tissue mobilization during postoperative TKA rehabilitation, despite the fact that the two techniques have been studied individually [13]. A combination of both muscular weakness and soft tissue restriction can be potentially treated with an integrated approach. The present study thus focused on the effect of BFR training + ASTYM, compared with traditional postoperative rehabilitation, on knee ROM, muscle strength, functional recovery and functional mobility after TKA. It was hypothesized that the combined intervention would be more effective than conventional rehabilitation for postoperative outcomes.

Materials and Methods

A single blinded randomized controlled trial was performed in three physiotherapy departments at Pak Red Crescent Hospital, Dina Nath Multan Road and Nawaz Sharif Social Security Hospital, Multan Chungi, Lahore. The study was conducted within 4 months of the approval of the synopsis. Recruitment was done using non-probability convenience sampling. The study population consisted of adults aged 50–75 years who had received their primary unilateral TKA [14], and were in the early postoperative period. The sample size required was calculated using G*power ver 3.1.9.4 with muscle strength as outcome, alpha = 0.05, statistical power = 0.80 and pooled standardized mean difference = 1.11. The number of participants needed was 28. In addition, the sample size planning was made in the thesis, and the results of the analyzed data were 28 samples, including 14 samples in each group [15]. The study included only patients who met the following criteria: age 50-75, female or male, primary unilateral THK, medically and hemodynamically stable, not enrolled in another clinical trial within the prior 3 months, and informed consent. Previous surgery of the involved knee and severe lower-limb or neuromuscular disease that would impact gait or muscle function, uncontrolled cardiovascular, respiratory, or metabolic disease, cognitive or communication deficits, or contraindications to BFR (a history of thromboembolism, peripheral vascular disease, or uncontrolled hypertension) were also excluded. The participants were randomly divided into two groups: experimental and control. The experimental group got BFR training and ASTYM and conventional postoperative rehabilitation. The control group was given conventional physical therapy and BFR. BFR was performed with a pneumatically inflated cuff around the upper thigh of the operated leg. Pressure was personalized at around 40-60% of the pressure needed to cause occlusion of the limb. Low-load quadriceps exercises such as straight leg raise, knee extend exercises were performed at around 20–30% of 1RM as clinically appropriate. The four sets were with a 30-15-15-15 repetition scheme and 30-60 second rest between sets [16]. The dose of

BFR was increased 3 times a week and advanced as per tolerance and postoperative rehabilitation stage [17]. Specialized instruments were used to administer ASTYM to the quadriceps, hamstrings and peri-patellar soft tissues as clinically indicated [18]. Controlled instrument strokes were applied in areas of soft-tissue dysfunction and mobilisation of tissue was achieved [19]. The three times per week, 6 week sessions of ASTYM lasted about 10-15 minutes at a time. The interventions were adjunctive to conventional rehabilitation. All patients were treated with standard post-operative treatment protocol consisting of continuous passive motion, active and passive range of motion, quadriceps strengthening, gait training and functional mobility exercises. The conventional program was given to the control group with the addition of BFR. The number and length of rehabilitation sessions were equalized between groups to minimize differences in the amount of rehabilitation received. Knee range of motion was determined using a goniometer [20]. The selected clinical muscle strength assessment, described in the thesis, was used to measure muscle strength [21]. Functional recovery was evaluated by the Lysholm Knee Score [22], and functional mobility with the Timed Up and Go test [23], which was assessed by the time it took to complete the test (shorter

completion time, better mobility). Before treatment, and again at 6 weeks following treatment, by a baseline assessment was performed by a blind assessor. The Institutional Review Board (IRB) approved the study and informed written consent was obtained prior to enrollment. Confidentiality was ensured by using coded data and securely stored data, and participants could withdraw without impacting their treatment. SPSS version 25 was used to analyze the data. Data were presented as mean $\pm$ SD. The normality test, Shapiro-Wilk test was used to find baseline normality. Within-group comparisons were performed using paired-samples t-tests, and between group comparisons using independent-samples t-tests. The p-values <0.05 were regarded as statistically significant.

Results

Twenty-eight subjects were studied – 14 each in both groups. The experimental group included 11 (78.60%) males and 3 (21.40%) females, whereas the control group included 7 (50.00%) males and 7 (50.00%) females. Table 1 shows the demographic characteristics. Baseline Shapiro-Wilk p-values for ROM, strength, functional recovery and functional mobility were all > 0.05 for both groups, and so were parametric tests used.

Table 1. Participant characteristics

Characteristic	Experimental (n=14)	Control (n=14)
Age	58.71 $\pm$ 7.60	57.79 $\pm$ 7.78
Height	165.36 $\pm$ 7.17	164.86 $\pm$ 7.60
Weight	75.29 $\pm$ 6.83	76.79 $\pm$ 7.50
BMI	27.47 $\pm$ 0.55	28.19 $\pm$ 0.63
Male	11 (78.60%)	7 (50.00%)
Female	3 (21.40%)	7 (50.00%)

Within group statistically significant improvements were seen in all 4 outcomes in both groups ($p < 0.001$). The experimental group improved in ROM from 80.71 $\pm$ 9.57 to 107.20 $\pm$ 9.36, strength from 13.84 $\pm$ 1.57 to 21.71 $\pm$ 2.00, Lysholm Knee Score from 43.00 $\pm$ 5.13 to 75.50 $\pm$ 5.05, and TUG from 16.36 $\pm$ 1.33 to

10.81 $\pm$ 0.96 seconds. The corresponding control-group values were 83.19 $\pm$ 7.00 to 102.21 $\pm$ 5.50 for ROM, 13.71 $\pm$ 1.85 to 18.45 $\pm$ 1.66 for strength, 43.79 $\pm$ 5.19 to 64.79 $\pm$ 4.00 for Lysholm Knee Score, and 15.84 $\pm$ 1.42 to 12.89 $\pm$ 1.17 seconds for TUG.

Table 2. Within-group comparison of study outcomes

Outcome	Group	Pre Mean $\pm$ SD	Post Mean $\pm$ SD	Mean Diff	p-value
Knee ROM	Experimental	80.71 $\pm$ 9.57	107.20 $\pm$ 9.36	-26.49	<0.001
Knee ROM	Control	83.19 $\pm$ 7.00	102.21 $\pm$ 5.50	-19.01	<0.001
Muscle strength	Experimental	13.84 $\pm$ 1.57	21.71 $\pm$ 2.00	-7.87	<0.001
Muscle strength	Control	13.71 $\pm$ 1.85	18.45 $\pm$ 1.66	-4.74	<0.001
Functional mobility (TUG)	Experimental	16.36 $\pm$ 1.33	10.81 $\pm$ 0.96	5.55	<0.001
Functional mobility (TUG)	Control	15.84 $\pm$ 1.42	12.89 $\pm$ 1.17	2.94	<0.001
Functional recovery (Lysholm)	Experimental	43.00 $\pm$ 5.13	75.50 $\pm$ 5.05	-32.50	<0.001
Functional recovery (Lysholm)	Control	43.79 $\pm$ 5.19	64.79 $\pm$ 4.00	-21.00	<0.001

No significant baseline differences were found between groups for ROM ($p = 0.44$), muscle strength ($p = 0.85$), functional recovery ($p = 0.69$) and functional mobility ($p = 0.33$). All parameters showed significant preference for

the experimental group at post-treatment (all $p < 0.001$). The experimental group had a higher post treatment ROM, although this was not statistically significant ($p = 0.10$).

Table 3. Between-group comparison of study outcomes

Outcome/time	Experimental Mean $\pm$ SD	Control Mean $\pm$ SD	Mean Diff	p-value
ROM Pre	80.71 $\pm$ 9.57	83.19 $\pm$ 7.00	-2.49	0.44
ROM Post	107.20 $\pm$ 9.36	102.21 $\pm$ 5.50	4.99	0.10
Strength Pre	13.84 $\pm$ 1.57	13.71 $\pm$ 1.85	0.12	0.85
Strength Post	21.71 $\pm$ 2.00	18.45 $\pm$ 1.66	3.26	<0.001
Functional Recovery Pre	43.00 $\pm$ 5.13	43.79 $\pm$ 5.19	-0.79	0.69
Functional Recovery Post	75.50 $\pm$ 5.05	64.79 $\pm$ 4.00	10.71	<0.001
Functional Mobility Pre	16.36 $\pm$ 1.33	15.84 $\pm$ 1.42	0.52	0.33
Functional Mobility Post	10.81 $\pm$ 0.96	12.89 $\pm$ 1.17	-2.09	<0.001

Discussion

This randomized controlled trial evaluated the 3-dimensional approach of BFR combined with ASTYM and conventional rehabilitation for TKA postoperative rehabilitation compared to conventional rehabilitation. There was a significant improvement for both groups in

knee ROM, muscle strength, functional recovery and functional mobility. The experimental group showed greater improvements, however, in post-treatment muscle strength, Lysholm Knee Score, and TUG performance, and did not show a between-group difference in post-treatment

ROM. These results indicate that the extra interventions could have a stronger effect on some aspects of recovery than on others. The improvement is clinically plausible in both groups as conventional post-TKA rehabilitation explicitly targets typical post-TKA impairments. Active and passive ROM exercises and CPM are used to restore joint motion, quadriceps strengthening exercises, gait training and functional mobility exercises address muscle weakness and activity limitations [24]. Therefore, the control group was an active rehabilitation program, not an untreated control. Any other effects that were seen in the experimental group should therefore be considered as added value rather than just rehabilitative therapy. There was a significant increase in knee ROM in both groups. The experimental group improved from $80.71 \pm 9.57^\circ$ to $107.20 \pm 9.36^\circ$, while the control group improved from $83.19 \pm 7.00^\circ$ to $102.21 \pm 5.50^\circ$. However, there was no significant difference between groups after the post-treatment ($p = 0.10$). It means this composite intervention was not significantly better at the end in terms of ROM, although it had a higher value at the end. The factors contributing to ROM following TKA include postoperative swelling, pain, capsular stiffness, surgery and the amount of normal exercises performed [25]. A significant part of the improvement observed may be attributed to the conventional ROM rehabilitation program, since both groups were treated in this manner. The muscle-strength results were in favor of the experimental intervention. Strength increased from 13.84 ± 1.57 to 21.71 ± 2.00 in the experimental group and from 13.71 ± 1.85 to 18.45 ± 1.66 in the control group. The post-treatment mean difference was 3.26, with $t = 4.69$ and $p < 0.001$. BFR could have a specific application in the early postoperative setting, as they are developed to create a training stimulus with relatively low external loads. This could enable the quadriceps to be trained in the presence of high mechanical loading when high mechanical loading is difficult or undesirable. In addition, previous literature referenced in the thesis has mentioned BFR as a possible strategy to enhance muscular outcomes in the knee rehabilitation. The current results agree with

evidence suggesting BFR has a positive effect on muscle recovery in knee-related conditions, but there is not universal agreement about the results in TKA studies. Factors contributing to differences between studies could be the differences in time of BFR, cuff pressure, type of exercise, exercise progression, surgical stage, or comparator treatments. In this protocol, cuff pressure was set to ~ 40 -60% of limb occlusion pressure and the low-load exercise was 30-15-15. With the introduction of ASTYM, the intervention should not be viewed as a stand-alone test of BFR. The Lysholm Knee Score also showed a benefit for the experimental group in terms of functional recovery. The experimental score increased from 43.00 ± 5.13 to 75.50 ± 5.05 , compared with an increase from 43.79 ± 5.19 to 64.79 ± 4.00 in the control group. The post-treatment mean difference was 10.71 ($t = 6.22$, $p < 0.001$). Knee surgery outcomes are influenced by multiple factors, such as, joint mobility, muscular control, symptoms, gait and confidence during daily activities. More improvement in muscle function may thus be associated with improved patient-reported knee function [19]. Additionally, ASTYM may help to facilitate exercise participation by reducing soft tissue restriction around the knee. Both groups showed a significant increase in functional mobility, measured with TUG, and functional mobility was significantly higher in the experimental group following treatment. TUG time decreased from 16.36 ± 1.33 to 10.81 ± 0.96 seconds in the experimental group and from 15.84 ± 1.42 to 12.89 ± 1.17 seconds in the control group. At post-treatment, the mean difference was -2.09 seconds, with $t = -5.16$ and $p < 0.001$. Since TUG involves standing, walking, turning and sitting, improvement is related to overall mobility not just individual muscles. Then, the findings imply that the whole program led to a quantifiable functional benefit. The study has implications for postoperative physiotherapy. Consider BFR when a key focus is to enhance strength and traditional high-load strengthening is not an appropriate option. ASTYM can be used as an adjunct if there is a clinically significant issue of soft-tissue restriction [17]. The findings of this study, however, should not be assumed to be

superior for all outcomes with the combined intervention, as it did not yield a significant difference in ROM between groups. Treatment choice should always be tailored to the individual, and consider medical stability, contraindications to BFR, post-operative tissue status and patient tolerance [26].

Several limitations should be considered. Some differences in follow-up to prescribed rehabilitation sessions could have affected results. Variability may also have been due to differences among patients, in recovery, level of exercise, pain tolerance, and recovery from rehab. Further, due to the cost and availability limitations, the muscle strength was not quantified via electromyography, and therefore, there was no objective data that could be obtained about neuromuscular activation and recruitment that could be used. Further studies should compare various BFR pressures, exercise intensities, treatment frequencies, and exercise durations, as well as include other objective and patient-reported outcome measures.

Conclusion

Both conventional postoperative rehabilitation and the combination of BFR training, ASTYM therapy, and conventional rehabilitation were effective in improving knee ROM, muscle strength, functional recovery, and functional mobility following TKA. Overall, the combined intervention resulted in more muscle strength, functional recovery, and functional mobility than conventional rehabilitation. The improvements in ROM were similar between the groups but no difference was found after treatment.

Declarations

Ethics and consent: Written informed consent was obtained from all participants. Participant information was kept confidential and study procedures followed the ethical requirements described in the approved research protocol.

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