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Effect of Blood Flow Restriction and Proprioception Training in Recurrent Ankle Sprain Patients

Mahmoud Gaber Nagdi [1], Wadida H. Elsayed [2], Mahmoud Abouzied [3], Rania R. Ali[*4]

1. Basic Science Department, Faculty of Physical Therapy, May University in Cairo, Egypt
2. Basic Science Department, Faculty of Physical Therapy, Cairo University, Egypt
3. Faculty of Medicine, Benha University, Egypt
4. Basic Science Department, Faculty of Physical Therapy, Cairo University, Egypt

***Correspondence:** Rania R. Ali; Basic Science Department, Faculty of Physical Therapy, Cairo University, Giza, Egypt; email: rania.refaat@cu.edu.eg

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Abstract

Introduction: Ankle sprains are among the most common recurrent injuries of the lower extremity. Blood flow restriction (**BFR**) training can provide a more effect to low-load training. The present study aimed to study the effect of blood flow restriction and proprioception training on muscle strength and ankle abilities in recurrent ankle sprain patients. **Material and methods**: 34 patients participated in this study, randomly assigned to two groups. **Control Group** received conventional therapy only. **Experimental Group** received conventional therapy, blood flow restriction and proprioception training. Peak torque of dorsiflexors and planter flexors were measured by isokinetic dynamometer, physical function by Foot Ankle Ability Measure. **Results**: MANOVA was carried out to test the impact of treatment**.** Dorsi-flexor peak torque at 60º post study revealed that, there was significant difference between the two groups (P = 0.001) and at 180º there was significant difference between them (P = 0.001), in favor to **experimental group**. Planter flexor peak torque at 60º and 180º post study revealed that, there was significant difference between groups (P = 0.001), in favor to **experimental group**. Foot Ankle Ability Measure post study revealed that there was significant difference between groups (p=0.001) in favor to **experimental group**. **Conclusions**: Low load blood flow restriction training combined with proprioception training enhanced muscle strength and ankle abilities in unilateral recurrent ankle sprain patients. There was a positive clinical important improvement, post compared with the pre study.

Keywords: Recurrent ankle sprain, blood flow restriction, peak torque, Foot Ankle Ability Measure.

Introduction

One of the most frequent recurrent lower extremity injuries is an ankle sprain. Over 75% of reported cases of ankle sprains involve injuries to the lateral ankle, with medial ankle sprains accounting for the remaining 25% of cases **(1).**

Regardless matter whether it is a first-time or recurring lateral ankle sprain, instability, inflammation, and pain can develop into chronic symptoms. Chronic ankle instability (**CAI)** may develop as a result of recurring ankle sprains caused by these symptoms if left untreated **(2**)**.** These persistent symptoms might appear in up to 40% of cases of ankle sprains and last for at least a year after the injury **(3).**

Recurrent experiences or feelings that the ankle is giving way are typically the hallmarks of **CAI**. Persistent symptoms include discomfort, muscle weakness, reduced ankle range of motion (**ROM)**, decreased expressed function, and repeated ankle sprains are also common **(4).**

Many authors have embraced a theory that suggests the potential causes of **CAI** include mechanical ankle instability (**MAI**) and functional ankle instability (**FAI**) (**5-8).** Functional ankle instability occurs due to deficiencies in the neuromuscular system and the body's awareness of its position in space which can result in joint instability and be described most effectively as a sensation of "giving way" **(9).**

Due to the prevalence of recurring ankle sprains and the disadvantages they create, numerous attempts have been made to develop effective treatment techniques **(10).** The most widely used therapeutic modalities have been centered around physical exercises, with a particular emphasis on exercises for strengthening and balance **(11).**

However, most rehabilitation programs have been restricted, making it impossible to apply a strong load or resistance; as a result, they were unable to completely trigger the metabolic stress and muscle contraction that serve as a crucial signal for muscle growth and strength **(12).**

Low load blood flow restriction (**LL-BFR**) training is an additional technique for strengthening muscles that involves completely blocking venous outflow and just partially blocking artery inflow in the working muscles during exercise **(13).**

Performing exercise with reduced blood flow achieved by restriction of the vasculature proximal to the muscle dated to **Dr. Yoshiaki Sato in Japan 2008** where it was known as **"kaatsu training"** meaning "training with added pressure." Kaatsu training is currently carried out worldwide and is more often known as "**BFR** training." and pneumatic tourniquets are used to accomplish this **(14,15).**

Low load blood flow restriction training can provide a more effect to low-load training alone and a more tolerable technique to heavy-load training **(16).**

Ankle proprioception is a crucial component of balance because it gives essential information that enables the adjustment of ankle positions to successfully carry out the complex motor actions that are essential for maintaining equilibrium **(17).**

In considering this, the results of the relevant literature samples indicate that ankle proprioception and balance control are strongly associated, with reduced ankle proprioception following injuries having a negative impact on balance control **(18).**

To enhance ankle strength, balance, and coordination in this this context, clinical recommendations suggested proprioceptive training techniques following the sprain. These techniques include balance exercises and techniques that encourage functional motions **(19).**

So, the present study aimed to study the combined effect of low load blood flow restriction combined with proprioception training on dorsiflexors and planter flexors muscle strength and on foot and ankle abilities in ADLs activities in unilateral recurrent ankle sprain patients.

Materials and Methods

This study was done to measure the effect of combined treatment of low load blood flow restriction technique and proprioception training in unilateral recurrent ankle sprain patients.

Participants

Experimental randomized controlled study with repeated measurement was organized. The study was conducted between November 2022 and September 2023. All participants were informed of the procedures, benefits and risks of the study, and they signed informed consent before enrolling in the study. The Ethical Committee of Faculty of Physical Therapy, Cairo university, Egypt, has given their approval (No: P.T.REC/012/003451), The study was listed on Pan Africa clinical trials registry (www.pactr.org) with the number PACTR202207579387579.

The sample size was estimated by the software, G- power. We selected the two-way MANOVA test and gave an alpha error (0.05) and a statistical power (0.95). The effect size (0.56) was calculated based on a previous article**(Thomas, 2021),** with expected 10% of attrition, 30 subjects are needed. Finally, the sample size calculation was 34 subjects, which were distributed to two groups, with 17 participants in each group.

Thirty-four patients, both sexes, were recruited in this study. Their age ranged from 20 to 30 years old, and their BMI was 18 to 24.9 kg/m2. All had a history of unilateral recurrent ankle sprain **(20)** were diagnosed and referred by orthopedic surgeon as suffering from unilateral recurrent ankle sprain with a pain and a decrease ability in physical functional performance while performing their routine activities of daily living. The exclusion criteria consisted of a history of previous surgeries in either limb of the lower extremities, history of a fracture in either limb of the lower extremities requiring realignment, acute injury to musculoskeletal structures of other joints of the lower extremity in the previous 3 months, hip joint or, knee joint replacement, patients who were possibly at risk of adverse reactions of low load blood flow restriction, any neurological conditions which affect proprioception, vestibular deficits, vision problems and pregnancy. A flow chart of the procedure is given in **Figure 1.**

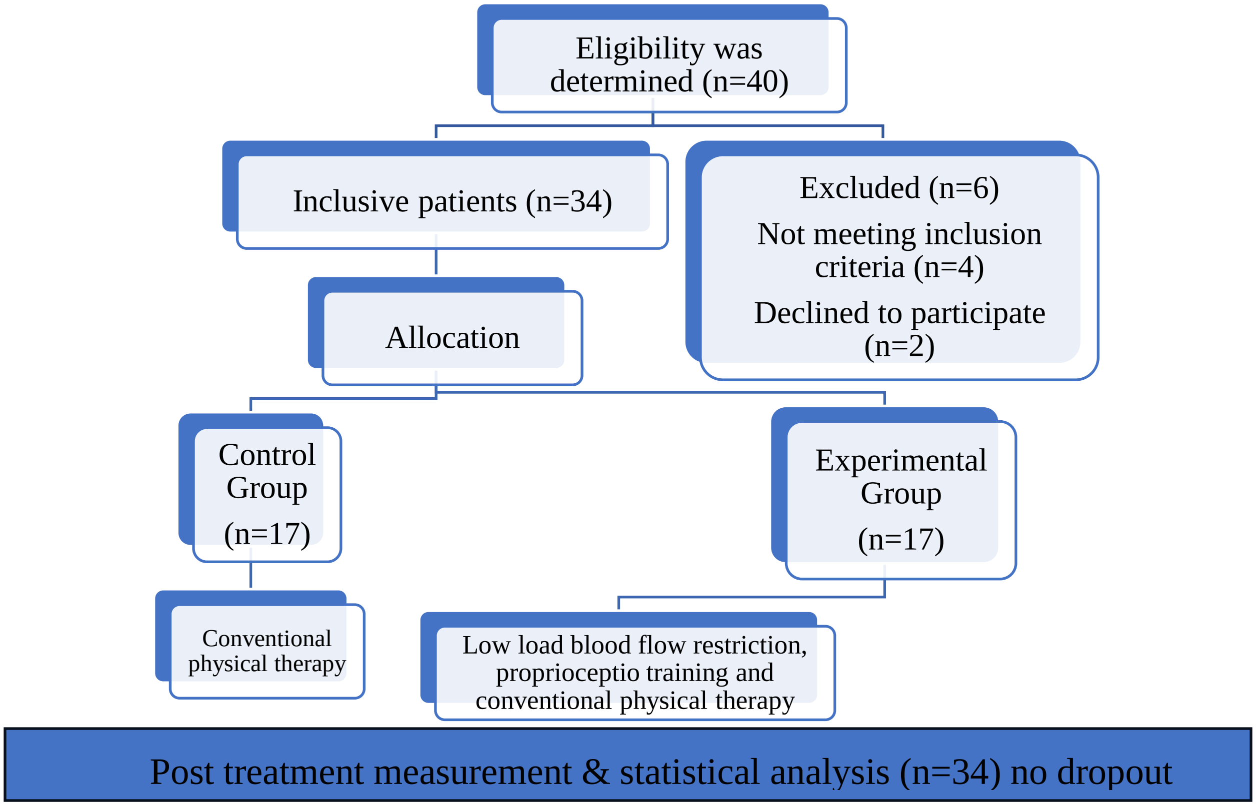

Figure 1: Flow Chart of the study

Procedures

The patients were randomly assigned into two groups using an allocation number in a sealed envelope and underwent a treatment according to the recruited order and the corresponding random number sealed in an envelope. Patients were assigned into **control group** and **experimental group**. All patients were blind to the treatments.

Thirty-four patients with grade I, and II unilateral recurrent lateral ankle sprain, were referred from orthopedic physician. Their ages ranged from 20 to 30 years old. All patients were assigned randomly into two groups, **control group** and **experimental group,** seventeen participants per group.

Outcome measures

Peak torque

In this study, peak torque (Nm) of ankle dorsiflexors and planter flexors were measured using BIODEX system 3 pro Isokinetic dynamometers (BIODEX Medical Systems, Shirley, New York, USA). Peak torque (Nm) was measured before and after 4 weeks of treatment at two speeds 60 deg/sec and 180 deg/sec.

Repeated trials conducted on the same day as well as on various days yielded mechanically reliable torque (Nm), position, and velocity measurements using the BIODEX System 3 isokinetic dynamometer. For both clinical and research applications, the peak torque and position data' validity was acceptable **(21).**

Foot and ankle abilities

Functional outcome was measured using foot ankle ability measure **FAAM**. The **FAAM** includes 21-item Activities of Daily Living Subscale. Every item is graded from "no difficulty at all" to "unable to do" on a 5-point Likert scale (4 to 0). Totals of the item scores, ranging from 0 to 32 for the Sports subscale and 0 to 84 for the ADL subscale. were converted to percentage scores after that. For each subscale, higher scores indicate higher levels of functioning, and 100% indicate no dysfunction.

Eman (2019) mentioned on their study about validity and reliability of the FAAM questionnaire's Arabic translation that the **FAAM** showed a wide range of score distribution with no floor or ceiling effect; Also, they revealed that the internal consistency of observer scale of the **FAAM ADL** was high level with Cronbach's alpha = 0.947.

Intervention

Conventional Therapy

Patients with **FAI** benefit from muscle strengthening exercises because they reduce the frequency of giving-way episodes, increase balance and stability, and enhance function **(23).**

Strengthening began with active resisted exercises performed in four directions of ankle movement (dorsiflexion, planter flexion, eversion, and inversion) and progressed with resistance using ankle weights **(24).**

The participants received strengthening exercises for four weeks of rehabilitation, three times per week with 3 sets of 10 repetitions for 4 directions of ankle movement each movement (dorsiflexion, planter flexion, inversion, and eversion) **(17).**

The participants received instructions from the therapist about using and applying the soft brace. The soft brace is based on the principles of the functional tape bandage.

Low load blood flow restrictions training

To ensure that a significant physiological stimulus is achieved, low exercise loads (20–40%) of one repetition maximum (**1RM**) should be used in conjunction with short inter-set rest intervals (30–60 s) and relatively large training volumes (50–80 repetitions per exercise) **(25).**

Participants allocated in the low load blood flow restriction training groups received low load resistance exercise (20-40 % **1RM**) using tourniquet around thigh proximally to knee joint to occlude arterial blood flow by 50-80 %. The cuff needs to be tightened to a specific pressure that occludes venous flow while still allowing arterial flow whilst exercises are being performed as venous flow needs less pressure than arterial flow to be occluded. A wide cuff is preferred in the correct application of **LL-BFR**. 10-12cm cuffs are generally used. A wide cuff of 15cm may be best to allow for even restriction. Modern cuffs are shaped to fit the natural contour of the arm or thigh with a proximal to distal narrowing. There are also specific upper and lower limb cuffs that allow for better fitment **(26).**

Proprioception training

Patients received proprioception exercises for 30 minutes per session. Treatment sessions frequency was 3 times weekly for 4 consecutive weeks **(27).**

Progression of proprioceptive training was from static to dynamic (such as lateral movements, backward movements, jumping, cutting, twisting, pivoting), slow speeds to faster speeds with balance and control, two legs to one leg, and with visual control to no visual control **(27).**

Statistical analysis

Descriptive statistics for demographic data were expressed as mean and standard deviation mean. The Shapiro–Wilk test was used to check whether the data was normally distributed. Test of Chi squared was performed for evaluation of allocation of sex among groups. The Variance's homogeneity test of Leaven was performed to evaluate among groups homogeneity which revealed normally distributed data with variance homogeneity. Boxplot showed no data outliers.

MANOVA was carried out to examine the impact of treatment (between groups), time (pre versus post) besides the interaction impact on values of mean of peak torque of ankle dorsiflexors, planter flexors and **FAAM.** The significance level for all statistical examinations appointed at $p < 0.05$. Version 20 of the statistical package for social studies (SPSS) for windows (IBM SPSS, Chicago, IL, USA) was employed for all statistical tests.

Results

Demographic data

This study was conducted on 34 participants with grade I, and II unilateral recurrent ankle sprain were randomized equally into two equal groups. As shown in table (1); the mean value of age of **control group and experimental group** was 22.76±2.59 and 23.47±2.85 years respectively. The mean value of height was 168.65±6.78 and 170.7±6.43 cm respectively. The mean value of weight was 68.65±6.37 and 71.53±5.95 kg. The mean value of BMI was 20.41±1.18 and 20.88±0.99 kg/m^2 respectively. There was no significant difference between groups of mean values of age, height, weight and BMI (p> 0.0.05).

The number (%) of males of groups **control** and **experimental** were 11 (65%) and 11 (65%) and the number (%) of females were 6 (35%) and 6 (35%) respectively. There was no significant difference in sex distribution, hand dominancy and side of hand affection between the two groups (p >0.05).

Table (1): Descriptive statistics and ANOVA, chi square for subject characteristics of the two groups.

	Control Group	Experimental Group	f-value	p-value
Age (years)	22.76±2.59	23.47±2.85	2.23	0.092
Height (cm)	168.65±6.78	170.7±6.43	1.5	0.221
Weight (kg)	68.65±6.37	71.53±5.95	1.25	0.299
BMI (kg/m^2)	20.41±1.18	20.88±0.99	1.37	0.257
Sex Males **Females**	11 (65%) 6 (35%)	11(65%) 6 (35%)	$\chi^2 = 0.197$	0.978

Data represented as mean ±SD or number (percentage), χ^2 : Chi squared value

Peak torque results

A- Dorsiflexors

Within group comparison

The mean value ± SD of Dorsi- flexor peak torque at 60^o pre and post study of **control group** was 41.1±8.2 and 44.6±8.5 N.m. respectively, with a mean difference -3.5. There was no statistically significant difference post study (p = 0.244). The mean value ± SD of Dorsi- flexor peak torque at 180^o pre and post study of **control group** was 36.1±8.2 and 37.6±8.5 N.m. respectively, with mean difference -1.5. There was no statistically significant difference post study (p = 0.612)

The mean value ± SD of Dorsi-flexor peak torque at 60^o pre and post study of **experimental group** was 35.5±8.7 and 60.4±9.3 N.m. respectively, with mean difference -24.9.

There was a statistically significant increase in post study by 70% (p = 0.001). The mean value ± SD of Dorsi- flexor peak torque at 180^{o} pre and post study of **experimental group** was 30.5±8.7 and 53.4±9.4 N.m. respectively, with mean difference -22.9. There was a statistically significant increase in post study by 75% (p = 0.001) (Table **2**).

Between groups comparison

There was no statistically significant difference in the mean values of Dorsi- flexor peak torque at 60^{o} and 180^{o} pre-study between the two groups (p= 0.233 and 0.232). While there was statistically significant difference post study between the two groups (p= 0.001). Post hoc tests through pairwise multiple comparisons for Dorsi- flexor peak torque at 60^{o} post study revealed that, there was significant difference between both groups (P = 0.001) in favor to **experimental group**.

Post hoc tests through pairwise multiple comparisons for Dorsi- flexor peak torque at 180^{o} post study revealed that, there was significant difference between both groups (P = 0.001) in favor to **experimental group** (Table **2**).

Table (2): Descriptive statistics and 4×2mixed MANOVA design for dorsi-flexion peak torque between groups at various periods of measuring.

Dorsi flexor peak torque	60^{o}		p-value	180^{o}		p-value
	Control Group	Experimental Group		Control Group	Experimental Group	
Pre-study	41.1±8.2	35.5±8.7	0.233	36.1±8.2	30.5±8.7	0.232
Post study	44.6±8.5	60.4±9.3	0.001*	37.6±8.5	53.4±9.4	0.001*
MD	-3.5	-24.9		-1.5	-22.9	
% of change	8.5%	70%		4.2%	75%	

Multiple comparisons pair wisely between pre and post study values for dorsi-flexion peak torque at the two groups

	60^{o}		180^{o}	
	Control Group	Experimental Group	Control Group	Experimental Group
F-value	1.37	68.18	0.258	57.7
p-value	0.244	0.001*	0.612	0.001*

Post hoc tests through pairwise multiple comparisons for dorsi-flexion peak torque among two groups post study

		60^{o}	180^{o}
		Control Group Vs. Experimental Group	Control Group Vs. Experimental Group
Post study	Mean difference	-15.8	-15.8
	p-value	0.001*	0.001*

***Significant at alpha level <0.05; p-value: Probability value; F-value: F- statistic**

B- Planter flexors

Within group comparison

The mean value ± SD of Planter flexor peak torque at 60^{o} pre and post study of **control group** was 70.6±8.3 and 79.6±8.5 N.m. respectively, with mean difference -9. There was a statistically significant increase in post study by 12.7% (p = 0.001). The mean value ± SD of Planter flexor peak torque at 180^{o} pre and post study of **control group** was 56.1±8.2 and 79.6±8.5 N.m. respectively, with mean difference -23.5. There was a statistically significant increase in post study by 41.9% (p = 0.001).

The mean value ± SD of Planter flexor peak torque at 60^{o} pre and post study of **experimental group** was 65.6±8.7 and 95.4±9.4 N.m. respectively, with mean difference -29.8. There was a statistically significant increase post study by 45.4% (p = 0.001). The mean value ± SD of Planter flexor peak torque at 180^{o} pre and post study of **experimental group** was 50.5±8.7 and 95.4±9.4 N.m. respectively, with mean difference -44.9. There was a statistically significant increase in post study by 88.9% (p = 0.001) (table **3**).

Between groups comparison

There was no statistically significant difference in the mean values of Planter flexor peak torque at 60^{o} and 180^{o} pre-study between the two groups (p= 0.254 and 0.242). While there was statistically significant difference post study between the two groups (p= 0.001). Post hoc tests through pairwise multiple comparisons for Planter flexor peak torque at 60^{o} post study revealed that, there was significant difference between control both groups (P = 0.001), in favor to **experimental group**.

Post hoc tests through pairwise multiple comparisons for Planter flexor peak torque at 180^{o} post study revealed that, there was significant difference between both groups (P = 0.001 in favor to **experimental group** (Table **3**).

Table (3): Descriptive statistics and 4×2mixed MANOVA design for planter flexor peak torque between groups at various periods of measuring.

Planter flexor peak torque	**60^{o}**		**p-value**	**180^{o}**		**p-value**
	Control Group	**Experimental Group**		**Control Group**	**Experimental Group**	
Pre-study	70.6±8.3	65.6±8.7	0.254	56.1±8.2	50.5±8.7	0.242
Post study	79.6±8.5	95.4±9.4	0.001*	79.6±8.5	95.4±9.4	0.001*
MD	-9	-29.8		-23.5	-44.9	
% of change	12.7%	45.4%		41.9%	88.9%	

Multiple comparisons pair wisely between pre and post study values for planter flexor peak torque at the two groups

	60^{o}		**180^{o}**	
	Control Group	**Experimental Group**	**Group A**	**Group D**
F-value	9.01	97.69	220.1	60.51

p-value		0.001*	0.001*	0.001*	0.001*
Post hoc tests through pairwise multiple comparisons for planter flexor peak torque among two groups post study					
		60°		**180°**	
		Control Group Vs. Experimental Group		**Control Group Vs. Experimental Group**	
Post study	**Mean difference**	-15.8		-15.8	
	p-value	0.001*		0.001*	

***Significant at alpha level <0.05; p-value: Probability value; F-value: F- statistics**

Foot and ankle ability measure results

Within group comparison

The mean value ± SD of FAAM pre and post study of **control group** was 78.5±6.6 and 88.8±7.4 respectively, with mean difference -10.3. There was a statistically significant increase post study by 13.1% (p = 0.001).

The mean value ± SD of FAAM pre and post study of **experimental group** was 76.6±6.1 and 95.9±4 respectively, with mean difference -19. There was a statistically significant increase in post study by 24.8% (p = 0.001) (table **4**).

Between groups comparison

There was no statistically significant difference in the mean values of FAAM pre-study between the two groups (p= 0.763). While there was statistically significant difference post study between the two groups (p= 0.001). Post hoc tests through pairwise multiple comparisons for FAAM post study revealed that there was significant difference between both groups (p=0.001) in favor to e**xperimental group**. (table **4**).

Table (4): Descriptive statistics and 4×2mixed MANOVA design for FAAM between groups at various periods of measuring.

FAAM	**Control Group**	**Experimental Group**	**p-value**
Pre-study	78.5±6.6	76.6±6.1	0.763
Post study	88.8±7.4	95.9±4	0.001*
MD	-10.3	-19	
% of change	13.1%	24.8%	
Multiple comparisons pair wisely between pre and post study values for FAAM at the two groups			
	Control Group	**Experimental Group**	
F-value	*26.9*	*94.4*	
p-value	0.001*	0.001*	
Post hoc tests through pairwise multiple comparisons for FAAM among two groups post study			

		Control Group Vs. Experimental Group
Post study	Mean difference	-7.1
	p-value	0.001*

***Significant at alpha level <0.05; p-value: Probability value; F-value: F- statistics**

Discussion

It is believed that up to 40% of ankle sprains might progress to recurrent ankle sprains **(28).** The majority of people who suffer from recurrent ankle sprains have a reduction in the strength and volume of the muscles that control multiplanar motion in the ankle joint **(29).** As a result, healing and treating recurring ankle sprains depend on strengthening weakening muscles **(30).**

Recent studies have shown that, in comparison to low load resistance training alone, adding **BFR** to the active musculature during low load resistance training can result in considerable strength and hypertrophy increases, using weights as low as 30% **1RM (31).**

The main aim of this study was to study the effect of low load blood flow restriction and proprioception training on muscle strength and foot and ankle abilities in unilateral recurrent ankle sprain patients.

Our findings suggested that low load blood flow restriction technique combined with proprioception training can help in treatment of unilateral recurrent ankle sprain and have beneficial effect on dorsiflexors and planter flexors muscle strength. Also, our study reported that there was a positive clinical important improvement, post compared with the pre study, in dorsiflexors and planter flexion peak torque. For dorsiflexors peak torque, there was a clinical improvement in post study by 70% (p = 0.001) for group which received LL-BFR training, proprioception training and conventional physical therapy. For planter flexors peak torque, there was a clinical enhance in post study by 12.7% (p = 0.001) for group which received conventional physical therapy only and there was a clinical increase post study by 45.4% (p = 0.001) for group which received LL-BFR training, proprioception training and conventional physical therapy.

Our findings suggested that low load blood flow restriction technique combined with proprioception training also have beneficial effect on foot and ankle abilities in ADLs activities in unilateral ankle sprain patients. There was a positive clinical important improvement, post compared with the pre study for **FAAM** results. For **FAAM** results there was a clinical increase post study by 13.1% (p = 0.001) for group which received conventional physical therapy only and there was a clinical reinforcement in post study by 24.8% (p = 0.001) for group which received LL-BFR training, proprioception training and conventional physical therapy.

The results obtained in this study come in line with **Jacob et al. (2019)** who measured the effect of **LL-BFR** on muscle activation in patients with recurrent ankle sprain. It was concluded that greater muscle activation was observed during **LL-BFR** exercises. But this study examines just the immediate effect of **LL-BFR**, without control group and with too small sample size. So, this immediate responses in recurrent ankle sprain patients requires further research examining **LL-BFR** as a potential ankle rehabilitation tool.

Agreeing with our results **Khalid et al. (2020)** measured the combined effects of strengthening and Proprioceptive training on self-reported functional status which concluded that progressive strengthening and proprioceptive training protocols have positive effect on self-reported functional status in patients with recurrent ankle sprain. That study conducted subjective examination with small sample size, and without control group. Also, it applied traditional strengthening exercises with no differentiation in protocol ofexercises between groups.

The results of this study are corroborated by **Phurichaya and Tossaporn's (2022)** findings, which indicate that adding **BFR** to a traditional physical therapy program over the course of four weeks improves strength and functional performance in patients with recurrent ankle sprains more than traditional rehabilitation alone.

Limitations

The point of this study is relatively new so there is a little previous studies which allow a little background about results and discussion of our study.

Conclusion

Low load blood flow restriction training combined with proprioception training enhanced muscle strength of ankle dorsiflexors and plantar flexors as measured by the BIODEX isokinetic dynamometer. Also, improved foot and ankle functional abilities at ADLs activities in unilateral recurrent ankle sprain patients. This information may help physical therapists develop and design a physical therapy program for unilateral recurrent ankle sprain patients which have positive effect on patients and improve their abilities. Also, our study reported that there was a positive clinical important improvement, post compared with the pre study, in dorsiflexors peak torque, planter flexion peak torque and FAAM results.

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