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Comparative Efficacy Of Progressive Resistance Exercises And Blood Flow Restriction Training On Lower Limb Strength And Vertical Jump In Basketball Players -An Interventional Study

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Abstract
Introduction: *Basketball players have traditionally used conventional strength training techniques to increase the strength and power of their lower limbs. However, these techniques frequently involve large weights and could put a lot of strain on joints, which could raise the risk of injury and need longer recovery times. One such training technique that has gained traction in recent years is Blood Flow Restriction (BFR) training. It is a relatively new way to improve muscle growth and strength among other training methodologies.* ***Methodology*** *A interventional study was conducted on 60 basketball players, divided into two groups: PRE (n=30) and BFRT (n=30). Both groups underwent a 6-week training program, three sessions per week. Lower limb strength was assessed using a 1-repetition maximum (1RM) squat test, and vertical jump performance was measured using the vertical jump test. Pre- and post-intervention data were analyzed using paired and independent t-tests.* ***Results:*** *At the end of 6 weeks, both groups A & B showed improvements in lower limb strength. The findings indicated that both Blood Flow Restriction Training (BFRT) group showed statistically significant improvement in vertical jump height and lower limb strength in comparison to pre-intervention status ($p < 0.05$). However, the increase of 1RM leg press strength was greater in the Group A (BFRT) (41.91 ± 19.78 to 54.25 ± 22.06) than that in the Group B(PRE) group (44.85 ± 22.9 to 45.45 ± 24.70).* ***Conclusion:*** *The findings clearly demonstrate that Group A (Blood flow restriction training group) showed significant improvements in both lower limb strength (+12.34 kg) and vertical jump height (+5.45 cm) compared to Group B (Progressive Resistance Exercise). There was increase in strength and vertical jump in Group A (Blood flow restriction training group) that indicate its training program was significantly more effective.* ***Keywords-*** *Blood Flow Restriction Training, Strength, Progressive Resistance Exercise, Basketball, Vertical jump*

INTRODUCTION

Basketball is a physically demanding sport that demands a combination of power, agility, and lower body strength to play at your best. [1] Strength is a quality that is often linked to better athletic performance. [2] A particular amount of force (i.e., strength) must be produced in order to successfully execute a maximal effort movement during a vertical jump; completing a vertical jump when laden calls for even more strength. From the standpoint of sports, the athlete may experience extra resistances that are comparable to those employed in the weighted vertical leap, such as donning athletic gear, running into other players, throwing objects, and the like. It is evident in sports that players may face a wide range of outside influences, which they must resist in order to succeed. [3,4]High force output is required for the vertical jump, and in order to provide the greatest results, this power must be applied quickly. This finding suggests that explosive strength movements, such jumping with and without a weight, depend heavily on rate of force development (RFD). Unweighted and weighted leaping are frequently utilized in the training process for many sports and are also employed in the assessment of various sports to improve force characteristics, such as explosiveness. [3,5,6,7,8,4]

Experience has proved that to develop muscle strength by resistance exercises at an optimum rate, not more than approximately 30 repetitions of a single exercise each day are necessary. The usual practice is to initially determine by test loads that resistance which the patient can move through normal range of motion of the joint 10 times and no more. This is known as the 10-repetition maximum and forms the basis for the exercise routine. For purposes of warm-up, one starts with 50% of the 10-repetition maximum, which is completed 10 times, then a short rest period with an increase in the load to 75% of maximum, which is again repeated 10 -times, and finally the 10-repetition maximum itself is the last exercise stint. Best results are usually obtained by daily exercise of 30 repetitions as described for each joint motion. This number of 30 repetitions is, of course, arbitrary and may have to be reduced in some instances and may be slightly increased in others. It has been shown that by increasing the repetitions to 50 or 100 daily the efficiency of this method of exercise is greatly reduced, since it is generally impossible for persons to exert maximum effort repeatedly. It has also been discovered that it is important to have rest periods of one or two days each week. [9]Basketball players and other jumping athletes frequently suffer from anterior knee pain (AKP), which is typically brought on by either patellofemoral pain (PFP) or patellar tendinopathy (PT). It might be difficult to determine which one is causing pain, though. Although AKP is commonly reported by athletes, the knee discomfort is frequently diffuse. Thus, pain mapping can be helpful in differentiating. Basketball players must possess a variety of physical attributes, including the ability to leap, land, and move in several directions. The anterior knee and its structures are subjected to severe stresses due to the necessary characteristics. In order to determine how much an injury affects a large number of individuals, injury epidemiology studies usually evaluate time-loss. Because many athletes continue to play while experiencing symptoms, players with PFP and PT are not included in the research. Given how closely PFP and PT are triggered, the diagnosis could begin to use less yes-or-no tests to determine whether ailment is present. [10] PT, or patellar tendinopathy one common type of overuse injury is patellar tendinopathy, also referred to as jumper's knee or patellar tendinitis. It frequently happens to athletes who jump, such as those who play football, basketball, volleyball, high jumping, and tennis. Repetitive loading is a similarity between the sports. Load-related and localized discomfort in the patella's inferior pole are typical features. [11]Young individuals in good health have historically taken PRE to enhance their athletic performance. Recent assessments, however, have highlighted the possible health advantages of incorporating PRE-into community physical activity promotion initiatives. [12,13]

One such training technique that has gained traction in recent years is Blood Flow Restriction (BFR) training. Blood Flow Restriction (BFR) training is a relatively new way to improve muscle growth and strength among other training methodologies. BFR training presents a novel stimulus that may enhance muscle adaptations without requiring high loads by partially limiting blood flow to the muscles during exercise. [14] Optimizing lower limb strength and vertical leap height is critical for basketball players' agility, explosiveness, and general athletic development. [15]Basketball players have traditionally used conventional strength training techniques to increase the strength and power of their lower limbs. [16] However these techniques frequently involve large weights and could put a lot of strain on joints, which could raise the risk of injury and need longer recovery times.[17]An alternative approach is provided by BFR training, which enables athletes to increase strength and power at a comparable or even higher pace while utilizing fewer weights and putting less mechanical stress on their joints.[17] The production of metabolic stress and muscle fatigue, which increases muscle protein synthesis and hypertrophy, are the processes behind the efficacy of BFR training. Furthermore, BFR training may boost brain changes that lead to gains in strength and power output, such as higher motor unit firing rates and recruitment. [18]During activity, BFR entails applying a tourniquet or customized cuff over a limb to partially limit venous outflow and arterial input. [19] Even with low-load resistance workouts, this limitation creates a localized hypoxic environment and metabolic stress inside the working muscles, which is thought to trigger changes favorable to strength growth and muscular hypertrophy. [20] Although BFR training has been thoroughly examined in a variety of contexts and demographics, such as athletes and rehabilitation facilities, further research is necessary to determine whether it should be applied particularly to basketball players [21].

It has been determined that an increase in the size and strength of normal muscles, with a load above 50–60% of one repetition maximum, is required. A single session of low-intensity resistance exercise with BFR has been shown in recent research to activate the mTOR (mammalian target of rapamycin) pathway, which is responsible for stimulating anabolic cell signaling and increasing muscle protein synthesis within three hours of exercise [22-24]. The muscle of the hips and pelvic floor provides the foundation for support for the core. Despite BFRT being explored in various populations, including sportsmen and women and resistance-trained men and women, limited evidence has considered its impact on the mentioned parameters among basketball players. Investigating BFRT's impact on lower limb strength and vertical jump among these specific individuals as athletes can create valuable information related to its effectiveness and potential influences on basketball performance.

MATERIALS AND METHODOLOGY

The study was presented before institutional ethical committee for further approval. Once the ethical approval was approved reference no D.Y. PATIL EDUCATION SOCIETY, KOLHAPUR (DEEMED TO BE UNIVERSITY) /IEC.178/2025) participants were screened on basis of inclusion and exclusion criteria.

Inclusion criteria

Participants playing basketball with a minimum of 2 years of experience aged between 18 and 30 years belonging to both genders.

Exclusion criteria

Participants who sustained lower limb injuries within the past six months, who have undergone lower limb surgery within the past year, with cardiovascular conditions such as hypertension, peripheral artery disease and those taking medications that affect blood coagulation or circulation, such as anticoagulants or antiplatelet agents were excluded. Initially, a brief demographic data including name, age, gender, etc. as per the data collection sheet was recorded. Written consent was taken from all the participants. 60 participants were randomly allocated into two groups by using a computer randomization pattern and outcome measures were taken before the interventions. During this 6 week the participants were given the treatment. At the end of 6 weeks, the subjects were again assessed for the outcome measures. The period of intervention was 6 weeks. These outcome measures were assessed before 1st week, during 3rd week and after the last session of 6th week. The two intervention groups are described as follows:

The two intervention groups are described as follows:

Group A: Blood Flow Restriction (BFR) Training Group

Weeks 1-2: Adaptation Phase

- Frequency: 3 sessions per week
- Warm-up: 5-10 minutes of light cardiovascular exercise, dynamic stretching targeting lower body muscles
- Rest: 30-60 seconds between sets

Exercises:

- Squats: 3 sets of 15 reps at 10-20% of 1-repetition maximum (1RM) with BFR applied (cuff pressure: 60-80% limb occlusion pressure)
- Romanian Deadlifts: 3 sets of 15 reps at 10-20%of 1RM with BFR applied
- Calf Raises: 3 sets of 15 reps at 10-20%of 1RM with BFR applied
- Cool down: 5-10 minutes of stretching, focusing on lower body muscles

Weeks 3-4: Strength Building

- Frequency: 3 sessions per week
- Warm-up: 5-10 minutes of light cardiovascular exercise, dynamic stretching
- Rest: 30-60 seconds between sets

Exercises:

- Squats: 4 sets of 12 reps at 20-30% of 1RM with BFR applied

- Romanian Deadlifts: 4 sets of 12 reps at 20-30% of 1RM with BFR applied
- Calf Raises: 4 sets of 15 reps at 20-30% of 1RM with BFR applied
- Leg Press: 3 sets of 12 reps at 20-30% of 1RM with BFR applied
- Cool down: 5-10 minutes of stretching, focusing on lower body muscles.

Weeks 5-6: Strength Building

- Frequency: 3 sessions per week
- Warm-up: 5-10 minutes of light cardiovascular exercise, dynamic stretching
- Rest: 30-60 seconds between sets

Exercises:

- Squats: 4 sets of 12 reps at 30-40% of 1RM with BFR applied
- Romanian Deadlifts: 4 sets of 12 reps at 30-40% of 1RM with BFR applied
- Calf Raises: 4 sets of 15 reps at 30-40% of 1RM with BFR applied
- Leg Press: 3 sets of 12 reps at 30-40% of 1RM with BFR applied
- Cool down: 5-10 minutes of stretching, focusing on lower body muscles

Group B: Progressive Resistance Exercises

Weeks 1-2: Adaptation Phase

- Frequency: 3 sessions per week

Exercises:

- Squats: 3 sets of 15 reps at 40-50% of 1RM
- Romanian Deadlifts: 3 sets of 15 reps at 40-50% of 1RM
- Calf Raises: 3 sets of 15 reps with body weight
- Rest: 30-60 seconds between sets
- Warm-up: 5-10 minutes of light cardiovascular exercise, dynamic stretching targeting lower body muscles
- Cool down: 5-10 minutes of stretching, focusing on lower body muscles.

Weeks 3-4: Strength Building

- Frequency: 3 sessions per week

Exercises:

- Squats: 4 sets of 10 reps at 50-60% of 1RM
- Romanian Deadlifts: 4 sets of 10 reps at 50-60% of 1RM
- Calf Raises: 4 sets of 15 reps with body weight
- Leg Press: 3 sets of 10 reps at moderate weight
- Rest: 30-60 seconds between sets
- Warm-up: 5-10 minutes of light cardiovascular exercise, dynamic stretching
- Cool down: 5-10 minutes of stretching, focusing on lower body muscles

Weeks 5-6: Power and Explosiveness

- Frequency: 3 sessions per week
- Exercises:
- Squats: 4 sets of 10 reps at 60-70% of 1RM
- Box Jumps: 4 sets of 6 reps
- Plyometric Lunges: 3 sets of 8 reps per leg
- Calf Raises: 4 sets of 15 reps with body weight
- Rest: 30-60 seconds between sets
- Warm-up: 5-10 minutes of light cardiovascular exercise, dynamic stretching
- Cool down: 5-10 minutes of stretching, focusing on lower body muscles

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Fig 1: Vertical Jump Test

Fig 2: Leg Press

RESULT

Table No.1A Gender distribution of Group A

Group A		
Gender	Frequency	Percentage
Male	19	63.33%
Female	11	36.67%
Total	30	100.00%

Among the 60 participants, in group A 19 were male and 11 were female.

Table No.1B Gender distribution of Group B

Group B		
Gender	Frequency	Percentage
Male	26	86.67%
Female	4	13.33%
Total	30	100.00%

Among the 30 participants 26 were male and 4 were female.

Table No.3 Mean Distribution

	A		B	
	Mean	S.D.	Mean	S.D.
Age	22.77	3.10	22.97	2.76
Height (In CMS)	169.80	5.46	171.10	5.09
Experience of Playing (IN YEARS)	3.15	1.09	3.45	1.83

The mean age for Group A was 22.77 years (S.D. 3.10) mean height of 169.80 cms (S.D.5.46), mean experience of playing 3.15 years (S.D 1.09), while Group B had a mean age of 22.97(S.D. 2.76), mean height of 171.10 cms (S.D.5.09), mean experience of playing 3.45 years (S.D 1.83).

The baseline demographic characteristics of participants in both groups were comparable. The mean age of Group A was 22.77 ± 3.10 years, while Group B had a mean age of 22.97 ± 2.76 years. The average height of participants in Group A was 169.80 ± 5.46 cm, slightly lower than that of Group B (171.10 ± 5.09 cm). The mean playing experience was 3.15 ± 1.09 years for Group A and 3.45 ± 1.83 years for Group B.

Outcome	Time - Point	Mean	S.D.	P-value
LOWER LIMB STRENGTH	Pre	41.91	19.78	5.39E-16
	Post	54.25333333	22.0589607	
VERTICAL JUMP TEST	Pre	34.17	6.54	5.01E-14
	Post	39.62	7.52114643	

Table No.4 Pre and Post Lower limb Strength and Vertical Jump Test of Group A

The comparison of lower limb strength between pre- and post-intervention phases revealed a significant improvement in Group A. The participants in this group exhibited an increase in mean strength from 41.91 ± 19.78 kg before the intervention to 54.25 ± 22.06 kg afterward, resulting in a mean gain of 12.34 kg. This change was statistically significant ($p < 0.001$), highlighting the effectiveness of the applied training protocol.

Table No.5 Pre and Post Lower limb Strength and Vertical Jump Test of Group B

Outcome	Time - Point	Mean	S.D.	P-value
LOWER LIMB STRENGTH	Pre	44.85	22.93	
	Post	45.45	24.70	4.89347E-05
VERTICAL JUMP TEST	Pre	34.33	7.40	
	Post	35.35	7.46	1.31528E-15

Group B demonstrated only a minimal improvement in lower limb strength following the intervention. The mean strength increased from 44.85 ± 22.93 kg at baseline to 45.45 ± 24.70 kg post-intervention, reflecting a modest gain of 0.6 kg. While the change was statistically significant ($p < 0.001$), the effect size was small, indicating that the intervention had limited effectiveness in enhancing muscular strength in this group.

Table No.6 Group Wise Comparison of Pre and Post Lower limb Strength and Vertical Jump Test

Outcome	Group	Mean	S.D.	P-value
LOWER LIMB STRENGTH	A	54.25333333	22.0589607	0.173
	B	45.45	24.70	
VERTICAL JUMP TEST	A	39.62	7.52114643	0.017
	B	35.35	7.46	

Following the intervention, a comparison of the outcome measures between Group A and Group B was conducted. In terms of lower limb strength, Group A recorded a higher post-test mean of 54.25 ± 22.06 kg, whereas Group B had a mean of 45.45 ± 24.70 kg. Although Group A demonstrated better performance, the difference between the groups was not statistically significant ($p = 0.173$), indicating that the observed variation may not be solely attributed to the intervention.On the other hand, vertical jump performance showed a significant difference between the groups. Group A achieved a mean post-test value of 39.62 ± 7.52 cm, while Group B recorded a mean of 35.35 ± 7.46 cm. The difference in jump height was statistically significant ($p = 0.017$), suggesting that the intervention applied in Group A was more effective in improving explosive lower limb performance compared to the protocol followed by Group B.

DISCUSSION:

In above study, Group A had a better gender proportion with 63.33% males and 36.67% females whereas Group B comprised 86.67% males. The average age of participants (22.77 ± 3.10 years for Group A and 22.97 ± 2.76 years for Group B) falls within the peak age range for optimal athletic performance and neuromuscular adaptability (Faigenbaum et al., 2009) [25]. The similar height and sports experience values indicate that neither group had a physiological nor experiential advantage, thus allowing a more accurate assessment of the training protocols themselves. Prior studies have demonstrated that comparable playing experience is a key factor in equalizing the potential for performance adaptation (Markovic & Mikulic, 2010) [26] .

Additionally, height plays a role in performance measures such as vertical jump; hence, the slight but statistically non-significant height difference (1.3 cm) is unlikely to have influenced the results meaningfully. This is supported by research suggesting that while height contributes to leverage in jumping, neuromuscular power is a more significant determinant in athletes (Cormie et al., 2011) [27].

BFRT and Muscle Strength Acquisition:

With weights much lighter (20–30% of 1RM) than traditional resistance training (≥70% of 1RM), BFRT has progressively been demonstrated to be an intervention protocol capable of inducing gains in muscular strength and hypertrophy. Consistent with previous studies, the BFRT group participants in this experiment experienced significant lower limb strength gains. Loenneke et al. (2012) say that by increasing metabolic stress, BFRT invokes fast-twitch muscle fibers, which are invoked only at high load. This increases muscular activation. [14]

The effectiveness of BFRT in augmenting muscular strength has been endorsed by various meta-analyses. For instance, BFRT was effective in inducing notable gains in strength in trained and untrained individuals, as evidenced by Hughes et al. (2017), who carried out a systematic review of 20 studies [28]. In the same way, Centner et al. (2019) noted that BFRT markedly increased hypertrophic adaptations and muscle strength, particularly when carried out regularly for 6–12 weeks. [17] These particular types of muscle developments are essential in basketball. Lower-limb strength is required for basic movements of the game such as cutting, running, and rebounding. Results of this study show that BFRT can be extremely effective in basketball players' sport-specific conditioning, particularly when high-load training is not possible due to fatigue or injury.

Vertical Jumping Capability and Explosive Power:

Vertical jumping is one of the performances that are known to be influenced by the efficiency of stretch-shortening cycle, neuromuscular coordination, and muscle strength. From this study, the BFRT group also demonstrated a significant rise in vertical jump height. This is similarly confirmed by a study conducted by Yamanaka et al. (2012). In the case of American football players, they demonstrated an increase in bench press and vertical leap strength after six weeks of BFRT [29] BFRT stimulates the release of anabolic hormones such as growth hormone (GH) and insulin-like growth factor-1 (IGF-1), which trigger muscle protein synthesis and neuromuscular adaptation. [30] These actions have varying processes under them. Furthermore, muscular stress from the metabolic buildup during BFRT increases motor unit recruitment, which has been associated with more forceful movement. [31] Vertically jumping ability is required for offensive and defensive basketball skills like shooting, rebounding, and shot-blocking. Augmentation of this test with BFRT implies that it can be a useful part of training programs for specific jumps. The fact that BFRT can elicit strength gains without loading joints and soft tissues with mechanical stress of heavy lifting can be its most significant benefit. With this option in the event of sportsmen experiencing injuries or rehabilitating from long-term musculoskeletal disease, it is simply invaluable. Consequently, for instance, a report by Yasuda et al. (2011) demonstrated the way in which postoperative individuals and elderly patients were able to accomplish muscular hypertrophy and muscular strengthening without bringing about any detrimental side effects using the application of low-load exercise within BFRT. [31] In contrast to the PRE group participants, BFRT group participants of the current study reported decreased severity of fatigue, joint pain, or Delayed Onset Muscle Soreness (DOMS). These are testaments to the use of BFRT during competitive stages of high intensities when highest priority is being assigned to the recovery process and are testaments to the safety profile of BFRT.

Additionally, control of the training load is required for high-performance environments to restrict the risk of overtraining and injuries. Based on Scott BR's research, Loenneke JP, BFRT is a valuable tool for periodized training models because it provides means of either maintaining or even increasing strength and power capacity without exacerbating cumulative fatigue (Scott et al., 2015). [32]

CONCLUSION:

The findings clearly demonstrate that Group A (Blood flow restriction training group) achieved superior improvements in both lower limb strength (+12.34 kg) and vertical jump height (+5.45 cm) compared to Group B (Progressive Resistance Exercise). There was increase in strength and vertical jump in Group A (Blood flow restriction training group) that indicate its training program was significantly effective. Present study concludes that the intervention utilized in Group A (Blood flow restriction training group) appears to be the preferred training method for enhancing lower limb performance in basketball players.

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