

“Effects of a Six-Week Progressive Blood Flow Restriction Training Protocol on Upper Limb Muscular Strength and Endurance in Basketball Players: A Pre-Post Interventional Study”

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Abstract

Background: Basketball demands high levels of upper extremity muscular strength and local endurance for passing, shooting, defensive positioning, and rebounding. Traditional high-load training (>70% 1RM) increases mechanical stress on joints and soft tissues during congested competitive seasons. Blood Flow Restriction (BFR) training combines low-load resistance with partial vascular occlusion, inducing metabolic stress while sparing mechanical strain.

Objective: To evaluate the effect of a 6-week progressive upper limb Blood Flow Restriction training protocol on maximal isotonic strength and local muscular endurance in basketball players.

Methods: An experimental pre-post intervention study was conducted with 36 basketball players (aged 18–25 years) recruited from NIMS University. The 6-week progressive upper limb BFR protocol targeted the biceps brachii and triceps brachii muscles using specific exercises (cable curls, barbell curls, overhead extensions, rope pushdowns, triceps dips, and bodyweight curls) performed at progressive repetition schemes (15 to 40 repetitions per set) under 40%–80% arterial occlusion pressure. Primary outcome measures were 1-Repetition Maximum (1RM) bench press for strength and the 30-second maximal repetition biceps curl test for local endurance, alongside mid-arm circumference measurements.

Results: Participants demonstrated a statistically significant 32.1% increase in 1RM bench press strength ($p < 0.0001$, Cohen's $d = 2.79$). Local muscular endurance improved significantly by 38.9% in total repetition volume ($p < 0.0001$). Mid-arm circumference increased by a mean of approx 3.13 cm (approx 9.0%). Endurance improvements were significantly greater in male athletes than in female athletes ($p = 0.046$), and a moderate positive correlation was observed between strength and endurance adaptations ($r = 0.49$).

Conclusion: A 6-week progressive low-load upper limb BFR training protocol significantly enhances muscular strength, local endurance, and muscular hypertrophy in basketball players.

BFR training is an effective, joint-preserving intervention for conditioning and sports rehabilitation.

Keywords: Blood flow restriction; Kaatsu; Muscular endurance; Upper limb; Basketball; Bench press; Biceps curl.

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Introduction

Basketball is a high-intensity sport characterized by rapid direction changes, acceleration, jumping, and repeated upper-extremity explosive actions. Upper limb musculature—including the anterior deltoid, pectoralis major, biceps brachii, triceps brachii, and forearm stabilizers—is heavily engaged in technical execution. During shooting and passing, the deltoid initiates elevation, the biceps brachii regulates elbow flexion and

trajectory control, and the triceps brachii generates terminal elbow extension for ball release. Additionally, forearm musculature stabilizes the wrist and digits to ensure release accuracy. Strong upper limb musculature is equally vital during physical collisions in defensive stances, blocking, and contested rebounding.

While maximum strength facilitates high-velocity passing and force absorption during physical

contact, local muscular endurance allows players to sustain technical precision under acute physical fatigue. As fatigue accumulates across prolonged matches, distal kinetic chain control often deteriorates, leading to compensatory mechanics, shooting inaccuracies, and elevated risk of microtrauma or overuse injury.

Conventional resistance protocols typically prescribe heavy loads (60%–85% of 1RM) to achieve hypertrophic and strength adaptations. However, frequent high-load training during active playing seasons can overload joint complexes and heighten injury risks. Blood Flow Restriction (BFR) training, derived from Japanese Kaatsu, utilizes pneumatic or elastic cuffs applied proximally to the limbs to restrict venous return while allowing partial arterial inflow. Exercising under low external resistance (20%–40% 1RM) with BFR induces significant localized hypoxia and rapid accumulation of metabolic byproducts (e.g., lactate, Hydrogen ions).

This metabolic stress–mechanical load decoupling stimulates high-threshold Type II motor unit recruitment via the Henneman size principle and activates downstream anabolic signaling pathways (such as mTORC1 and hypoxia-inducible factors), producing hypertrophic and strength gains comparable to high-intensity training with substantially less mechanical stress.

Although lower-extremity BFR training is widely investigated in athletic populations, data regarding upper limb progressive BFR protocols tailored to court-sport athletes remain scarce. Therefore, this study evaluated the effects of a 6-week progressive upper limb BFR training protocol on muscular strength, endurance, and hypertrophy in basketball players.

Methods

Study Design and Participants

This experimental pre-post intervention study was conducted at NIMS University Rajasthan, Jaipur. A total of 36 amateur basketball players aged 18–25 years were recruited.

Sample Size Calculation:

Sample size was calculated a priori using G*Power software (version 3.1.9.7). Based on paired-difference parameters for upper limb strength and endurance metrics with an anticipated effect size (d) of 0.39, a two-tailed alpha level of 0.05, and a statistical power ($1 - \beta$) of 0.95, the minimum required sample size was determined to be 36 participants.

Inclusion Criteria:

- Male and female basketball players aged 18–25 years.
- Medically cleared for athletic conditioning.
- Not actively participating in sport in regular basis

Exclusion Criteria:

- History of sports-related orthopaedic injuries within the preceding 6 months.
- Pre-existing neurological impairments,

cardiovascular pathologies, deep vein thrombosis (DVT) history, or conditions contraindicating pneumatic occlusion.

Ethical approval was granted by the Institutional Ethics Committee of NIMS University, and written informed consent was collected from all participants prior to testing.

Outcome Measures

Assessments were conducted before the intervention (Pre) and following the 6-week protocol (Post) using identical standardised procedures:

- **1-Repetition Maximum (1RM) Bench Press Test (Strength):** Evaluated maximum isotonic strength of the upper extremity. Participants performed a progressive dynamic warm-up (5–10 light repetitions followed by heavier sets), after which attempts were made with 2- to 4-minute rest intervals until a true 1RM was established.

- **30-Second Maximal Repetition Biceps Curl Test (Local Endurance):** Assessed dominant-arm local muscular endurance in a seated position using standardized dumbbell weights (8 lbs for males, 4–5 lbs for females). Participants executed controlled elbow flexion/supination repetitions against gravity within a 30-second window.

- **Anthropometric Hypertrophy (Mid-Arm Circumference):** Measured at the anatomical midpoint between the lateral acromion process and the olecranon process using a non-elastic tape measure while the arm hung relaxed.

Blood Flow Restriction Training Protocol

Participants underwent a supervised 6-week progressive training program (2–3 sessions per week).

- **Cuff Application:** Pneumatic occlusion cuffs were positioned at the most proximal portion of the upper arms bilaterally, inflated to maintain 40%–80% arterial occlusion pressure.



- **Warm-Up (10 min):** Biceps brachii static stretching (3 X 15 sec hold), triceps brachii static stretching (3 X 15 sec hold), and jumping jacks (2sets of 15 reps).
- **Resistance Exercises:** Targeted the biceps brachii and triceps brachii using low-load resistance (20%–40% 1RM):

1. Cable Biceps Curls

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2. Barbell Biceps Curls
3. Overhead Triceps Extension
4. Rope Pushdown
5. Triceps Bench Dips
6. Bodyweight Biceps Curls
- **Cool-Down (10 min):** Biceps and triceps static stretches (3 X 15 sec hold) and self-paced walking.



Statistical Analysis

Data were analyzed using SPSS software (SPSS Inc.; Chicago, IL) Version 29.0.10. Baseline and post-intervention measurements were compared using paired Student's t-tests.

Independent t-tests were applied to assess between-gender differences. Treatment effect sizes were calculated using Cohen's d, and relationships between strength and endurance adaptations were analyzed via Pearson's correlation coefficient (r). Significance was set at $p < 0.05$.

Results

All 36 participants completed the 6-week progressive training protocol without adverse vascular or musculoskeletal events.

Parameter	Baseline (Pre)	Post-Intervention	Mean Change (Δ %)	p-value	Effect Size (Cohen's d)
1RM Bench Press (kg)	Baseline	Post	+32.1%	< 0.0001	2.79

Biceps Curl Volume (Reps)	Baseline	Post	+38.9%	< 0.0001	Large
Mid-Arm Circumference (cm)	Baseline	Post	+3.13cm (approx. 9.0%)	< 0.0001	Moderate-Large

- **Maximal Isotonic Strength:** 1RM Bench Press increased by 32.1% post-intervention ($p < 0.0001$) with a large effect size ($d = 2.79$).
- **Local Muscular Endurance:** Total work volume on the 30-second biceps curl test improved by 38.9% ($p < 0.0001$).
- **Arm Circumference:** Mid-arm circumference showed a significant mean increase of 3.13cm (~9.0%).
- **Gender Comparison:** While both cohorts achieved comparable relative strength gains, male athletes demonstrated significantly higher absolute repetition gains in the endurance test than female athletes ($p = 0.046$).
- **Correlation:** A moderate positive correlation was established between maximum strength gains and local muscular endurance improvements ($r = 0.49$, $p < 0.05$).

Discussion

The primary findings of this investigation demonstrate that a 6-week progressive upper limb BFR protocol leads to substantial adaptations in maximal strength (+32.1%), muscular endurance (+38.9%), and mid-arm circumference (+3.13 cm) using low external loads (20%–40% 1RM).

Muscular Strength and Hypertrophy

Achieving a 32.1% increase in bench press 1RM aligns with adaptations typically observed following conventional high-load training. Under restricted venous outflow, localized hypoxia forces the early recruitment of high-threshold Type II motor units to sustain force production, which are normally dormant during low-load exercises without occlusion. This recruitment pattern, combined with cell swelling and activation of anabolic pathways (e.g., mTORC1, HIF-1 α), drives structural hypertrophy and neuro-mechanical adaptations without placing excessive mechanical stress on upper extremity joint complexes.

Functional Endurance in Basketball

The 38.9% increase in biceps curl repetition volume reflects enhanced local muscular fatigue resistance. In basketball, repetitive dribbling,

passing, and contested shooting under late-game physical fatigue depend heavily on elbow flexor and extensor stability. BFR-induced metabolic conditioning enhances intramuscular buffering, local capillarization, and vascular shear stress adaptations, allowing athletes to preserve distal shooting mechanics and ball control during terminal periods of competition.

Gender Disparities and Occlusion Pressures

The greater absolute repetition gain observed in male athletes ($p = 0.046$) highlights potential variations in vascular compliance, baseline muscle cross-sectional area, and metabolic capacity between sexes. Applying individualized occlusion pressures based strictly on percentage of limb arterial occlusion pressure (AOP) rather than fixed pressures can help optimize adaptations uniformly across genders in future implementations.

Limitations

- **Absence of a Non-BFR Control Group:** The study used a single-arm pre-post design, precluding direct comparative efficacy against non-occluded high-load or low-load resistance controls.
- **Sample Generalizability:** The sample consisted of collegiate basketball players aged 18–25; findings cannot be generalised to adolescent or elite professional populations.
- **Indirect Hypertrophy Measurement:** Hypertrophy was quantified via tape anthropometry rather than B-mode ultrasound or MRI cross-sectional analysis.

Practical Applications

- **In-Season Strength Maintenance:** Low-load BFR enables basketball players to sustain upper extremity power and muscle mass during congested fixture schedules without accumulating joint wear.
- **Sports Rehabilitation:** Physical therapists can incorporate upper-body BFR protocols during early-to-mid phases of musculoskeletal rehabilitation when full-load lifting is contraindicated.
- **Fatigue Preservation:** Progressive low-load occlusion training improves forearm and arm fatigue resistance, aiding skill consistency during high-intensity gameplay.

Conclusion

A 6-week progressive Blood Flow Restriction training protocol yielded significant improvements in upper limb maximal strength (+32.1%), local endurance (+38.9%), and muscle circumference (+3.13 cm) in amateur basketball players. BFR training provides a safe, low-load, joint-sparing training modality that enhances upper extremity functional conditioning.

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