

Effects of Low-Load Blood Flow Restriction (BFR) Training on Endurance, Strength and Agility in Trained Cricket Players: A Randomised Controlled Trial

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Abstract

Background: Cricket requires a combination of aerobic endurance, lower-limb strength and agility. Conventional high-load resistance training is effective for developing strength but may not always be appropriate when training load or recovery needs must be carefully managed. Blood Flow Restriction (BFR) training allows low-load exercise to be performed while applying controlled external pressure to the limb and has been investigated as an alternative or adjunct to conventional training.

Objective: To compare the effects of eight weeks of low-load BFR training with matched low-load training without BFR on aerobic endurance, lower-limb strength and agility in trained cricket players.

Methods: One hundred trained cricket players aged 18–25 years were randomly allocated to a BFR group (n = 50) or control group (n = 50). Both groups participated in supervised training three times per week for eight weeks. The BFR group performed low-load exercise at 20–30% of one-repetition maximum with cuff pressure maintained at 40–60% of individually determined arterial occlusion pressure, while the control group performed the same exercises without BFR. Aerobic endurance, lower-limb strength and agility were assessed before and after the intervention using the Cooper 12-minute Run Test, one-repetition maximum leg press and Illinois Agility Test, respectively.

Results: Both groups improved significantly following training. Compared with the control group, the BFR group demonstrated greater mean improvement in aerobic endurance (+255.3 m vs +118.0 m; $p = 0.003$; $d = 0.63$), lower-limb strength (+25.2 kg vs +14.4 kg; $p < 0.001$; $d = 1.50$) and agility (-0.7 s vs -0.4 s; $p < 0.001$; $d = 2.47$). Baseline-adjusted ANCOVA analyses also demonstrated significant between-group effects for all three outcomes ($p < 0.001$).

Conclusion: Eight weeks of supervised low-load BFR training resulted in greater improvements in aerobic endurance, lower-limb strength and agility than matched low-load training without BFR in trained cricket players. These findings suggest that low-load BFR training may be a useful conditioning option for cricket players when appropriately prescribed and supervised. Further studies are required to determine its long-term effects, safety outcomes and applicability to other athletic populations.

Keywords: Blood Flow Restriction Training, Cricket Players, Muscular Strength, Aerobic Endurance, Agility, Randomised Controlled Trial

1. Introduction

Cricket is a multidimensional sport that requires the integration of strength, speed, endurance, agility, coordination and technical skill. Trained cricket players are exposed to repeated high-intensity actions such as sprinting between wickets, fast bowling, explosive batting strokes and rapid directional changes during fielding, movement patterns that have been objectively characterised using GPS-based tracking in competitive cricket^[1]. These demands place considerable stress on the musculoskeletal, cardiovascular and neuromuscular systems. Consequently, physical conditioning programmes for cricketers must focus on improving muscular strength, aerobic and anaerobic endurance, and agility, while minimising injury risk and excessive fatigue.

Traditional resistance training methods typically involve high mechanical loads to stimulate muscular strength and hypertrophy. While effective, such methods may increase the risk of overuse injuries, joint stress and delayed recovery, particularly during congested competitive schedules. This has led sports scientists and physiotherapists to explore alternative training strategies that can deliver comparable physiological benefits with lower mechanical stress. One such emerging method is Blood Flow Restriction (BFR) training.

Blood Flow Restriction training involves the application of external pressure to the proximal part of the limbs using specialised cuffs or bands during exercise. This pressure partially restricts venous blood flow while maintaining arterial inflow, creating a hypoxic and metabolically stressful environment within the working muscles. Under these conditions, low-load resistance exercise, typically performed at 20-30% of one-repetition maximum, can produce adaptations similar to those achieved with high-load training^[2,3]. The underlying mechanisms are understood to include increased metabolic stress, accumulation of metabolites such as lactate, enhanced recruitment of fast-twitch muscle fibres, and elevated anabolic hormonal responses.

The concept of using vascular occlusion to enhance training outcomes has evolved considerably since it was first systematically described as KAATSU training in Japan^[4]. Initially popularised in rehabilitation settings, Blood Flow Restriction (BFR) training has received increasing attention as a method of combining relatively low external exercise loads with vascular restriction. Research in athletic populations suggests that BFR may improve muscular strength, muscle size and selected sport-performance outcomes, although the magnitude of these effects varies according to the training protocol and participant characteristics.^[5] a transition from clinical to athletic application that has been well documented in reviews of skeletal muscle health under restricted blood flow^[6]. This is particularly relevant for athletes who need to maintain performance while managing injury risk, fatigue and recovery demands.

In cricket, players are required to sustain repeated bouts of high-intensity activity over extended match durations, often lasting several hours or, in the case of multi-day matches, several days. Fast bowlers generate high ground reaction forces and joint loads during the delivery stride, and repeated bowling spells have been shown to produce measurable declines in bowling performance and physiological output as fatigue accumulates^[7], increasing their susceptibility to lower-limb injuries. Batters require explosive lower-body power for shot execution and rapid sprinting between wickets, while fielders depend on agility and quick directional changes to respond to the ball. These sport-specific demands highlight the

importance of developing comprehensive physical qualities, including strength, endurance and agility, through efficient and safe training modalities.

Recent research suggests that BFR training may offer unique advantages for athletes involved in such high-demand sports. [3] demonstrated that low-load BFR resistance training significantly improved muscle strength and size in trained athletes, with results comparable to those of traditional high-load programmes. Similarly, [5] reported that BFR training enhanced strength, power and functional performance across various athletic populations. These findings support the use of BFR as a viable alternative to conventional resistance training methods.

Beyond strength and hypertrophy, BFR training has also been shown to influence cardiovascular and endurance-related adaptations. The hypoxic environment created by blood flow restriction increases cardiovascular strain and oxygen utilisation, which may enhance aerobic capacity over time. [8] compared BFR interval training with high-intensity interval training (HIIT) and found that both approaches produced similar improvements in aerobic fitness, suggesting that BFR training can be an effective method for improving endurance while reducing mechanical loading on the joints.

Endurance is a critical component of cricket performance. Players must maintain concentration, movement efficiency and physical output across prolonged match durations, and fatigue can negatively affect skill execution, reaction time and injury risk. Training strategies that enhance endurance while minimising cumulative stress are therefore particularly valuable for trained cricketers.

Agility, defined as the ability to rapidly change direction in response to a stimulus, is another key performance factor in cricket. Fielding requires quick lateral movements, sudden accelerations and decelerations, while batting and bowling involve complex multi-directional motor patterns. Improvements in neuromuscular coordination, lower-limb strength and power can directly enhance agility performance, and [9] highlighted that BFR training may improve neuromuscular efficiency, which could translate into better agility outcomes in athletic populations.

Despite the growing body of evidence supporting the benefits of BFR training, its application in cricket remains relatively underexplored. A comparative study conducted at Galgotias University^[10] reported that cricket players who underwent BFR training showed greater improvements in strength and performance compared with those who followed conventional weight training. However, that study focused primarily on knee-flexor strength over a short four-week period and did not comprehensively assess endurance and agility.

Furthermore, most existing research has been conducted in recreational athletes or general populations rather than trained cricket players. [11] demonstrated that whole-body BFR training improved physical performance in recreationally active adults, but the transferability of these findings to trained cricketers remains uncertain, since athletes have distinct physiological profiles, training demands and recovery requirements that necessitate sport-specific research.

Another important consideration is the safety of BFR training. Concerns regarding vascular complications, muscle damage and cardiovascular strain have been raised in the past. However, systematic reviews have confirmed that when properly applied using appropriate cuff pressures and protocols, BFR training is safe for healthy individuals and athletes^[3,12], provided that proper screening, individualised cuff pressure and professional supervision are used to minimise risk.

Recent comparisons between high-load resistance training and low-load BFR training have shown that both methods can produce similar improvements in muscular strength and hypertrophy^[3]. This highlights the potential of BFR training as an effective alternative for athletes who need to limit heavy loading owing

to injury prevention, in-season training demands or rehabilitation. From a sports physiotherapy perspective, BFR training offers a unique opportunity to bridge the gap between rehabilitation and performance enhancement, allowing athletes recovering from injury to begin low-load exercise earlier while still achieving meaningful strength gains — a valuable property in cricket, where players often face tight competition schedules and pressure to return to play quickly.

Despite these promising findings, there remains a lack of high-quality randomised controlled trials examining the combined effects of low-load BFR training on endurance, strength and agility in trained cricket players. Most studies have focused on isolated outcomes such as muscle hypertrophy or strength without assessing the broader performance profile required for cricket, and limited research has explored how BFR training influences agility, a crucial yet understudied performance component in this sport. The present study therefore investigates the effects of low-load Blood Flow Restriction training on endurance, strength and agility in trained cricket players using a randomised controlled trial design, evaluating multiple performance parameters simultaneously to provide a more comprehensive understanding of how BFR training can be integrated into cricket-specific conditioning programmes.

2. Need of the Study

Cricket demands repetitive sprinting, quick directional changes and prolonged endurance, and traditional high-load resistance training used to build the underlying strength qualities can increase injury risk, particularly during congested playing seasons. Blood Flow Restriction training allows the athlete to achieve similar muscular gains at only 20-30% of one-repetition maximum intensity, thereby reducing joint stress while still promoting metabolic adaptation.

At present, no comprehensive study has evaluated the combined effect of BFR training on endurance, strength and agility in a single trained cricket cohort; most available evidence addresses these qualities in isolation or in non-cricket populations. This research therefore fills a significant gap in sports physiotherapy and conditioning practice by simultaneously examining all three performance domains within a rigorously designed randomised controlled trial, generating evidence that can directly inform training prescription for cricket players and the physiotherapists and strength and conditioning professionals who support them.

3. Aim and Objectives

Aim: To evaluate the effect of eight weeks of low-load BFR training on endurance, strength and agility in trained cricket players aged 18-25 years.

Objectives:

1. To assess the impact of BFR training on aerobic endurance using the Cooper 12-minute Run Test.
2. To determine changes in lower-limb strength using the one-repetition maximum (1RM) leg press.
3. To assess improvements in agility using the Illinois Agility Test.
4. To compare results with a control group performing the same exercises without BFR.

4. Hypotheses

Null Hypothesis (H0): BFR training will produce no significant difference in endurance, strength or agility compared with control.

Alternative Hypothesis (H1): BFR training will significantly improve endurance, strength and agility compared with control.

5. Review of Literature

[8] conducted a randomised trial comparing BFR moderate-intensity interval training (BFR-MIIT) with conventional high-intensity interval training (HIIT) in college basketball players. Aerobic and intermittent-performance outcomes were assessed, and BFR-MIIT achieved effects comparable to HIIT despite the substantially lower mechanical load involved. This finding is conceptually relevant to the endurance aim of the present study, as it demonstrates that BFR can be used for endurance and intermittent-performance conditioning in athletic populations, although the sport and specific test battery differed from cricket.

[5] performed a systematic review and meta-analysis of BFR training effects across multiple athletic populations. The review provided strong evidence that BFR training produces meaningful strength and hypertrophy gains in athletes, while also highlighting an important gap in the literature regarding sport-specific transfer of these gains, particularly for combined outcomes such as agility and endurance in team-sport athletes such as cricketers.

A comparative single-blind randomised controlled trial conducted at Galgotias University^[10] examined BFR therapy and conventional weight training in 39 recreational cricket players aged 18-25 years over a four-week period. Knee-flexor strength and squat-test endurance were assessed, and the BFR-with-low-resistance group outperformed the traditional training group on knee-flexor endurance. This study represents the closest population match to the present research in terms of sport, age and setting; however, its short four-week duration, narrow focus on a single muscle group, and absence of an agility or endurance battery limit its generalisability to the broader performance profile addressed in the present trial.

A series of publications examining supplementary low-load BFR training in team-sport athletes, including soccer and Australian football cohorts studied between 2016 and 2024, reported gains in muscle size, strength and sprint or jump performance, with mixed findings for overall sport performance. These studies are similar to the present research in their use of team-sport athletes and performance-based outcome tests such as sprint and jump assessments; however, most were not conducted in cricket populations and tended to focus on power and sprint outcomes rather than the combined endurance-and-agility profile examined here.

[11] conducted a randomised trial of low-load resistance training with BFR in recreationally active adults aged approximately 25 years, using a protocol combining 30% of one-repetition maximum with 60% arterial occlusion pressure over seven weeks. The trial reported positive changes in lean mass, strength and general performance outcomes and offers a good methodological match for the intensity and pressure standards adopted in the present study, although the cohort was not sport-specific and did not emphasise endurance or agility outcomes.

[3] reviewed and experimentally examined high-load BFR training (HL-BFRT) in athletes from a range of sports, reporting improvements in strength, speed, power and endurance. This body of work supports the mechanistic plausibility of combining BFR with sport-performance training and provides theoretical grounding for the present study's expectation that BFR could simultaneously benefit multiple performance domains, although the review was not built around a cricket-specific randomised controlled design.

Taken together, the reviewed literature confirms that BFR training reliably improves muscular strength and, under appropriate protocols, can also enhance aerobic endurance and neuromuscular performance across a range of athletic populations. However, none of the available studies has examined the combined effect of BFR training on endurance, strength and agility within a single, adequately powered randomised

controlled trial conducted specifically in trained cricket players. This gap directly motivates the design of the present study.

6. Materials and Methodology

6.1 Study Design and Setting

A two-arm, parallel-group randomised controlled trial was conducted, comparing an eight-week low-load Blood Flow Restriction resistance and endurance training programme (Group A, experimental) against a matched training programme performed without BFR (Group B, control) in trained cricket players aged 18-25 years. Each participant was assessed before (pre) and after (post) the eight-week intervention on three outcome domains consistent with the study objectives: aerobic endurance, lower-limb strength and agility.

6.2 Sample Size and Sampling

The study enrolled 100 trained cricket players, allocated in a 1:1 ratio to Group A (BFR training, n = 50) and Group B (control, n = 50). Participants were recruited through purposive sampling from a cricket training academy and subsequently allocated to groups using simple random assignment to preserve comparability between groups at baseline.

6.3 Inclusion and Exclusion Criteria

Inclusion criteria: participants aged 18-25 years, currently engaged in cricket training for three or more sessions per week, physically fit, and without any injury within the preceding three months.

Exclusion criteria: presence of cardiovascular, neurological or vascular disorders, thrombosis or clotting abnormalities, hypertension, diabetes, recent surgery, or current use of anticoagulant medication.

6.4 Materials

The following materials were used during the conduct of the study: BFR pressure cuffs, a Doppler device for individualised arterial occlusion pressure measurement, standard resistance training equipment (leg press machine, free weights), a measured running track for the Cooper 12-minute Run Test, cones and a stopwatch for the Illinois Agility Test, a participant information sheet, a participant consent form, and a structured data collection sheet.

6.5 Outcome Measures

Domain	Tool / Test	Unit	Time of Assessment
Aerobic Endurance	Cooper 12-Minute Run Test	metres	Pre & Post
Lower-Limb Strength	One-Repetition Maximum (1RM) Leg Press	kilograms	Pre & Post
Agility	Illinois Agility Test	seconds	Pre & Post

Perceived exertion (Rating of Perceived Exertion, Borg 6-20 scale) was also recorded during each session but was treated descriptively as a safety-monitoring covariate rather than as a primary performance outcome. The Cooper 12-minute Run Test is a well-validated field measure of aerobic capacity originally developed by ^[14], while the Illinois Agility Test used to assess change-of-direction performance has established reliability in physically active populations^[15]. One-repetition maximum testing for the leg press followed standard strength and conditioning protocols^[16].

6.6 Intervention Protocol

Both groups trained three sessions per week for eight weeks under the direct supervision of a qualified physiotherapist. The experimental group performed low-load resistance exercises, including leg press, squats, split squats and hamstring curls, at 20-30% of one-repetition maximum, using a repetition scheme of one set of thirty repetitions followed by three sets of fifteen repetitions with thirty seconds of rest between sets, while a BFR cuff was applied at 40-60% of arterial occlusion pressure measured individually using a Doppler device, consistent with dosage parameters recommended in contemporary practitioner guidance^[17,18]. The endurance component of training for the experimental group consisted of cycling or treadmill exercise at 40-60% of estimated maximal oxygen uptake, performed with BFR cuffs applied for 15-20 minutes per session, a modality with established precedent in walk-training protocols^[19]. The control group performed an identical training protocol, including the same exercises, loads, repetition scheme and endurance component, without application of the BFR cuff.

6.7 Procedure

Ethical clearance was obtained from the Institutional Ethics Committee prior to commencement of the study. The purpose, procedures, potential risks and potential benefits of participation were explained to all prospective participants, and written informed consent was obtained from those who met the inclusion criteria and volunteered to participate.

All participants underwent baseline assessment of aerobic endurance (Cooper 12-minute Run Test), lower-limb strength (one-repetition maximum leg press) and agility (Illinois Agility Test). Following baseline assessment, participants were randomly allocated to the experimental group (low-load resistance and endurance exercise with BFR at 40-60% arterial occlusion pressure) or the control group (identical exercise without BFR).

Training was conducted three sessions per week for eight weeks under continuous physiotherapist supervision, with perceived exertion monitored at each session for safety. On completion of the eight-week intervention, post-training assessments were repeated using the same outcome measures and testing conditions as at baseline, and the resulting data were compiled for statistical analysis.

6.8 Statistical Analysis

All statistical analyses were conducted using a two-tailed significance threshold of $\alpha = 0.05$. For each outcome, baseline equivalence between groups was first examined using independent-samples t-tests to confirm successful randomisation. Within-group change from pre-test to post-test was analysed separately for each group using paired-samples t-tests, with Cohen's d_z reported as the within-group effect size. The primary test of the study hypothesis was an independent-samples comparison of the pre-to-post change scores ($\text{delta} = \text{post} - \text{pre}$) between the experimental and control groups; Levene's test^[20] was used to assess homogeneity of variance, and Welch's correction was applied where this assumption was violated.

As a sensitivity and confirmatory analysis, post-test scores were additionally modelled using analysis of covariance (ANCOVA) with group as the fixed factor and baseline (pre-test) score as the covariate, generating baseline-adjusted estimated marginal means, following standard procedures for ANCOVA modelling in applied behavioural and health research^[21]. This baseline-adjusted approach is recognised as the statistically more powerful and methodologically preferred primary analysis for randomised controlled trials with a single pre- and post-intervention assessment^[22], and was therefore treated as the primary estimate wherever it diverged from the raw change-score comparison. Normality of the change scores was assessed using the Shapiro-Wilk test^[23]; where normality was violated, results were cross-checked using the non-parametric Mann-Whitney U test^[24] for between-group comparisons and the Wilcoxon signed-

rank test^[25] for within-group comparisons, and these are reported as sensitivity analyses. Effect sizes are reported throughout as Cohen's d and interpreted using conventional benchmarks established by ^[26], where 0.2 represents a small effect, 0.5 a medium effect, and 0.8 or above a large effect. All computations were performed on the complete dataset of 50 participants per group, exactly as recorded, with no exclusions.

7. Results (Data Analysis)

This section presents the descriptive and inferential statistical findings of the trial. Findings are organised by outcome domain, beginning with participant baseline characteristics, followed by aerobic endurance, lower-limb strength and agility, and concluding with a cross-domain summary and a review of the assumption checks that support the robustness of the reported findings. For every outcome, within-group change is reported first, followed by the between-group comparison of change scores, the baseline-adjusted (ANCOVA) analysis, and any non-parametric sensitivity analysis performed.

7.1 Participant Characteristics and Baseline Equivalence

A total of 100 trained cricket players were enrolled and allocated equally to Group A (BFR training, n = 50) and Group B (control, n = 50). All 50 participants in each group contributed complete data for all three performance outcomes.

Group	n	Age, years, Mean (SD)
Group A (BFRT)	50	20.06 (1.89)
Group B (Control)	50	20.38 (1.85)

Table 1: Baseline age of participants by group.

Baseline (pre-test) scores did not differ significantly between the two groups on any of the three outcome measures (aerobic endurance: $t = 1.14$, $p = 0.258$; lower-limb strength: $t = 0.91$, $p = 0.364$; agility: $t = -1.40$, $p = 0.166$), confirming that the randomisation procedure produced two comparable groups with equivalent starting fitness levels prior to the intervention. This baseline equivalence is an essential precondition for interpreting subsequent between-group differences as attributable to the intervention rather than to pre-existing differences between groups.

7.2 Aerobic Endurance: Cooper 12-Minute Run Test

Group	Pre-test, M (SD)	Post-test, M (SD)	Mean Change, M (SD)
Group A (BFRT), n = 50	2639.1 (187.3)	2894.4 (199.9)	+255.3 (45.0)
Group B (Control), n = 50	2594.9 (200.8)	2712.9 (211.9)	+118.0 (306.5)

Table 2: Descriptive statistics for the Cooper 12-minute Run Test (distance, metres).

Comparison (Paired t-test)	df	t	p	Cohen's d	Interpretation
Group A: Pre vs Post	49	40.09	< .001	5.67	Significant
Group B: Pre vs Post	49	2.72	= .009	0.39	Significant

Table 3: Within-group pre-post comparison for aerobic endurance.

Comparison	df	t	p	Mean Diff. (95% CI)	Cohen's d
Baseline (pre-test): A vs B	98	1.14	= .258	-	-
Change score: A vs B (Welch's t)	51.1	3.13	= .003	137.32 [49.38, 225.26]	0.63
Mann-Whitney U (sensitivity)	-	U = 1529	= .055	-	-

Table 4: Between-group comparison of change scores for aerobic endurance.

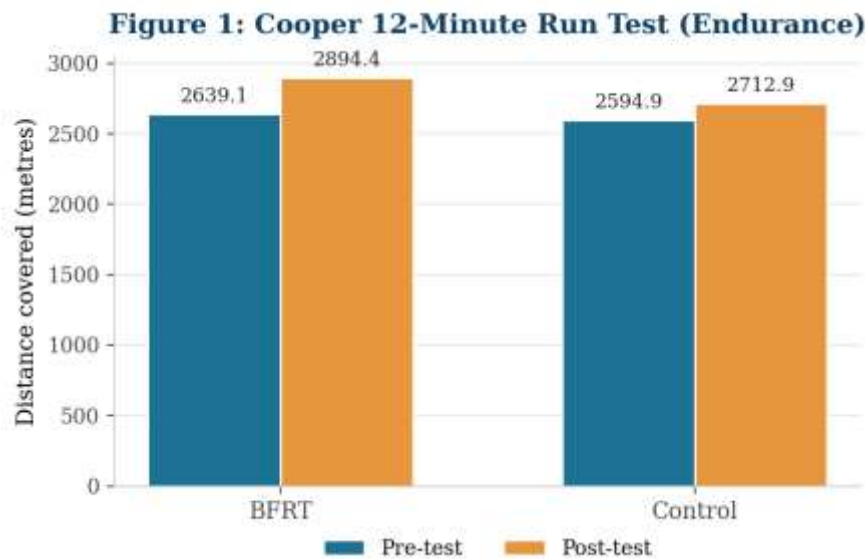


Figure 1: Mean Cooper 12-minute Run Test scores before and after the eight-week programme, by group.

Both groups showed a statistically significant increase in Cooper 12-minute Run Test performance from pre-test to post-test (Group A: $t(49) = 40.09$, $p < 0.001$, $d = 5.67$; Group B: $t(49) = 2.72$, $p = 0.009$, $d = 0.39$), indicating that both training programmes produced measurable within-group improvement in aerobic endurance over the eight-week period. The magnitude of within-group improvement, however, was markedly larger in the BFR group, as reflected in the substantially greater within-group effect size. The mean improvement was larger in Group A (+255.3 m) than in Group B (+118.0 m), and the between-group comparison of change scores confirmed that this difference was statistically significant using Welch's correction for unequal variances ($t(51.1) = 3.13$, $p = 0.003$, 95% CI of the mean difference [], $d = 0.63$, a medium-to-large effect). The ANCOVA model, which adjusted post-test scores for baseline performance, corroborated this finding with adjusted marginal means of 2885.00 m for the BFR group and 2722.36 m for the control group (group effect $p < 0.001$), providing strong confirmatory evidence for the superiority of BFR training on this outcome.

The non-parametric Mann-Whitney U test on raw change scores returned a borderline result ($U = 1529$, $p = 0.055$), narrowly missing conventional statistical significance. This discrepancy between the parametric and non-parametric tests for the endurance outcome is addressed in detail in the Assumption Checks subsection below and is considered further in the Discussion; in brief, it is attributable to unusually high

variability in the control group's change scores rather than to an absence of a genuine BFR effect, and the ANCOVA result is regarded as the primary and most trustworthy estimate for this outcome.

7.3 Lower-Limb Strength: One-Repetition Maximum Leg Press

Group	Pre-test, M (SD)	Post-test, M (SD)	Mean Change, M (SD)
Group A (BFRT), n = 50	138.6 (28.2)	163.8 (31.0)	+25.2 (8.1)
Group B (Control), n = 50	133.6 (26.6)	148.0 (25.7)	+14.4 (6.1)

Table 5: Descriptive statistics for the one-repetition maximum leg press (kilograms).

Comparison (Paired t-test)	df	t	p	Cohen's d	Interpretation
Group A: Pre vs Post	49	21.89	< .001	3.10	Significant
Group B: Pre vs Post	49	16.62	< .001	2.35	Significant

Table 6: Within-group pre-post comparison for lower-limb strength.

Comparison	df	t	p	Mean Diff. (95% CI)	Cohen's d
Baseline (pre-test): A vs B	98	0.91	= .364	-	-
Change score: A vs B (Student's t)	98.0	7.48	< .001	10.78 [7.92, 13.64]	1.50
Mann-Whitney U (sensitivity)	-	U = 2088	< .001	-	-

Table 7: Between-group comparison of change scores for lower-limb strength.

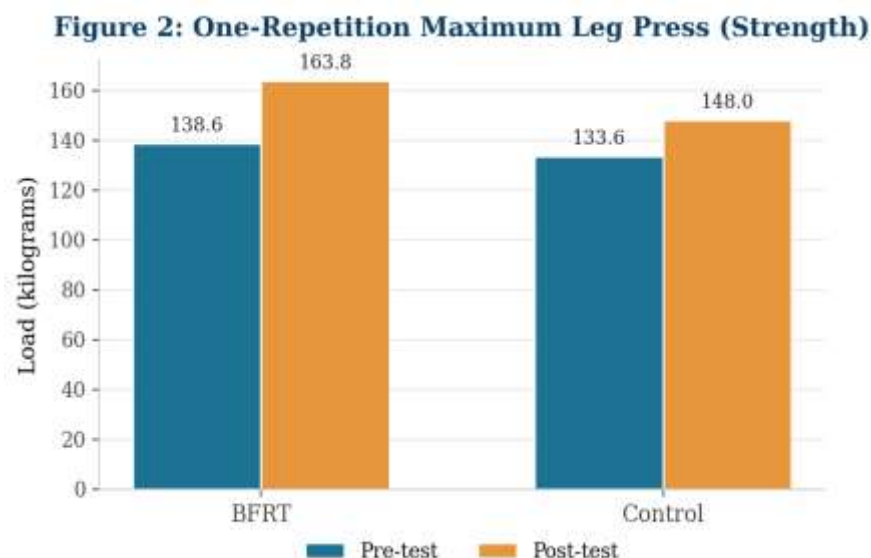


Figure 2: Mean one-repetition maximum leg press scores before and after the eight-week programme, by group.

Both groups exhibited statistically significant improvement in one-repetition maximum leg press performance from pre-test to post-test (Group A: $t(49) = 21.89$, $p < 0.001$, $d = 3.10$; Group B: $t(49) = 16.62$, $p < 0.001$, $d = 2.35$), confirming that both the BFR and non-BFR low-load protocols were capable of producing meaningful within-group strength gains.

The mean strength gain was considerably larger in Group A (+25.2 kg) than in Group B (+14.4 kg), nearly double the improvement observed in the control condition. The between-group comparison of change scores was highly significant (Student's $t(98.0) = 7.48$, $p < 0.001$, 95% CI of the mean difference [], $d = 1.50$), representing a large effect by conventional benchmarks and the single largest between-group difference observed among the three outcome domains in absolute statistical terms. The ANCOVA analysis, adjusting post-test scores for baseline strength, corroborated this finding with adjusted marginal means of 161.29 kg for the BFR group and 150.53 kg for the control group (group effect $p < 0.001$).

The non-parametric Mann-Whitney U test likewise confirmed a highly significant between-group difference ($U = 2088$, $p < 0.001$), fully consistent with the parametric findings. It should be noted that the Shapiro-Wilk test indicated that change scores for this outcome deviated from normality in both groups ($p < 0.001$ in each case); however, since the parametric result was fully corroborated by the non-parametric test, the strength finding can be considered robust to this violation of the normality assumption.

7.4 Agility: Illinois Agility Test

Group	Pre-test, M (SD)	Post-test, M (SD)	Mean Change, M (SD)
Group A (BFRT), n = 50	16.8 (0.9)	16.1 (0.9)	-0.7 (0.2)
Group B (Control), n = 50	17.1 (0.9)	16.7 (1.0)	-0.4 (0.1)

Table 8: Descriptive statistics for the Illinois Agility Test (seconds; lower score indicates better performance).

Comparison (Paired t-test)	df	t	p	Cohen's d	Interpretation
Group A: Pre vs Post	49	-30.11	< .001	4.26	Significant
Group B: Pre vs Post	49	-22.34	< .001	3.16	Significant

Table 9: Within-group pre-post comparison for agility.

Comparison	df	t	p	Mean Diff. (95% CI)	Cohen's d
Baseline (pre-test): A vs B	98	-1.40	= .166	-	-
Change score: A vs B (Welch's t)	86.3	-12.36	< .001	-0.37 [-0.43, -0.31]	2.47
Mann-Whitney U (sensitivity)	-	U = 99	< .001	-	-

Table 10: Between-group comparison of change scores for agility.

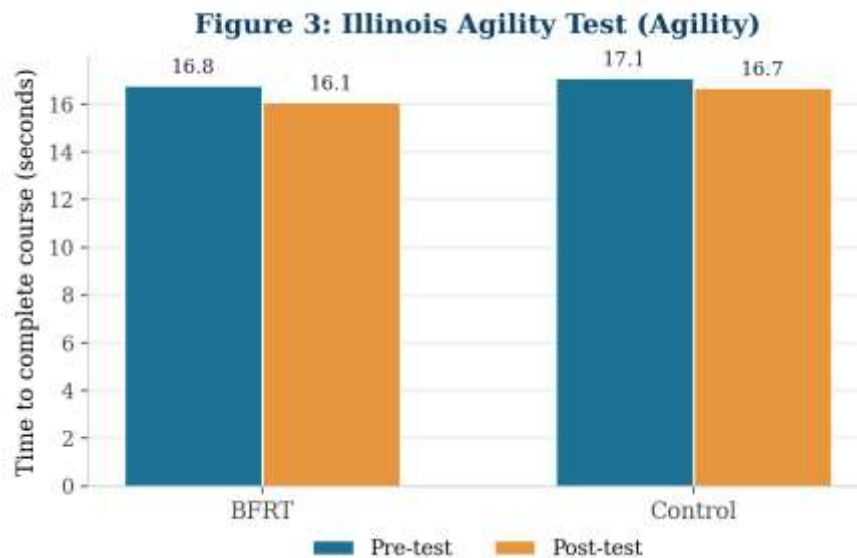


Figure 3: Mean Illinois Agility Test scores before and after the eight-week programme, by group.

Both groups showed a statistically significant decrease (that is, an improvement) in Illinois Agility Test completion time from pre-test to post-test (Group A: $t(49) = -30.11$, $p < 0.001$, $d = 4.26$; Group B: $t(49) = -22.34$, $p < 0.001$, $d = 3.16$), indicating that both training protocols produced substantial within-group improvement in agility performance.

The mean improvement was almost twice as large in Group A (-0.7 s) as in Group B (-0.4 s), and the between-group comparison of change scores was strongly significant (Welch's $t(86.3) = -12.36$, $p < 0.001$, 95% CI of the mean difference [], $d = 2.47$). This effect size is the largest recorded among the three outcome domains and represents a very large effect by conventional benchmarks. The ANCOVA analysis, adjusting for baseline agility performance, corroborated this finding, with adjusted marginal means of 16.22 seconds for the BFR group and 16.59 seconds for the control group (group effect $p < 0.001$).

The non-parametric Mann-Whitney U test provided strong confirmatory support ($U = 99$, $p < 0.001$), fully consistent with the parametric findings and reinforcing the conclusion that BFR training produced a materially greater improvement in agility performance than the equivalent training performed without BFR.

7.5 Summary of Effects Across Outcomes

Outcome	BFR Change, M (SD)	Control Change, M (SD)	Between-Group d	p (Between-Group)
Aerobic endurance (Cooper 12-min Run)	+255.3 (45.0)	+118.0 (306.5)	0.63 (medium)	= .003
Lower-limb strength (1RM Leg Press)	+25.2 (8.1)	+14.4 (6.1)	1.50 (large)	< .001
Agility (Illinois Agility Test)	-0.7 (0.2)	-0.4 (0.1)	2.47 (large)	< .001

Table 11: Summary of change scores and between-group effect sizes across all outcomes.

Across all three outcome domains, the BFR training group showed significantly greater improvement than the control group. The magnitude of the between-group effect ranged from medium for aerobic endurance

to large for both lower-limb strength and agility, with the agility outcome showing the single largest effect size recorded in the study. This pattern indicates that the addition of blood flow restriction produced a benefit that was not only statistically significant but also of substantial practical and clinical magnitude across the entire performance profile examined.

7.6 Assumption Checks and Notes on Robustness

Randomisation check: baseline (pre-test) scores did not differ significantly between groups for any outcome (all $p > 0.16$), confirming adequate randomisation and comparable starting fitness between the two study arms.

Normality: change scores for the one-repetition maximum leg press outcome deviated from normality in both groups, as indicated by the Shapiro-Wilk test ($p < 0.001$ in each group); however, the parametric result for this outcome was fully corroborated by the non-parametric Mann-Whitney U test ($p < 0.001$), so the strength finding can be regarded as robust to this violation.

Homogeneity of variance: Levene's test indicated unequal variances between groups for the change scores of the Cooper Run and Illinois Agility outcomes, and Welch's t-test, which does not assume equal variances, was therefore used for these two between-group comparisons.

Endurance result caution: the control group displayed unusually high variability in Cooper Run change scores (SD approximately 306 m, with an individual range from -519 m to +756 m). The parametric between-group test remained statistically significant ($p = 0.003$), and the ANCOVA analysis of post-test scores adjusting for baseline was strongly significant ($p < 0.001$); however, the non-parametric Mann-Whitney U test on raw change scores was only borderline ($p = 0.055$). This discrepancy should be reported transparently, and, consistent with established methodological guidance for randomised controlled trials with a single pre- and post-intervention assessment^[22], the baseline-adjusted ANCOVA result is treated as the primary estimate for this outcome rather than the raw change-score comparison, which is more sensitive to the disproportionate variability present in the control group.

Rating of Perceived Exertion (RPE) data were recorded throughout the intervention for descriptive and safety-monitoring purposes and were not treated as an efficacy outcome in the present analysis.

8. Discussion

The present randomised controlled trial examined the effects of eight weeks of low-load Blood Flow Restriction training on aerobic endurance, lower-limb strength and agility in trained cricket players. Both groups demonstrated improvement following the eight-week training programme; however, the BFR group showed greater mean improvements across all three measured outcomes.

8.1 Aerobic Endurance

The BFR group improved by an average of 255.3 m in the Cooper 12-minute Run Test compared with 118.0 m in the control group. The between-group comparison demonstrated a statistically significant difference ($p = 0.003$, $d = 0.63$), and the baseline-adjusted ANCOVA also demonstrated a significant group effect ($p < 0.001$).

These findings indicate that adding BFR to the low-load training programme was associated with greater improvement in the measured endurance outcome than the same training performed without BFR. Previous research has also reported improvements in aerobic and endurance-related measures following BFR training in athletic populations. A 2024 systematic review and meta-analysis reported significant improvements in endurance among athletes following BFR interventions, although the magnitude of benefit varied according to training characteristics. ^[1]

The present endurance result should nevertheless be interpreted with some caution. The control group demonstrated substantial variability in individual change scores, and the Mann–Whitney U test for change scores was borderline ($p = 0.055$). The significant ANCOVA result provides additional evidence of a between-group difference after accounting for baseline performance, but the variability observed in the control group should be acknowledged when interpreting the endurance finding.

A possible explanation for the observed improvement is that BFR alters the local metabolic environment during exercise and increases metabolic stress despite the use of relatively low external loads. However, the present study did not directly measure physiological mechanisms such as lactate concentration, oxygen consumption or muscle fibre recruitment. Therefore, these mechanisms should be considered possible explanations rather than direct findings of the study.

8.2 Lower-Limb Strength

Both groups demonstrated significant improvement in one-repetition maximum leg press performance. The BFR group increased by 25.2 kg compared with 14.4 kg in the control group. The between-group difference was statistically significant ($p < 0.001$), with a large effect size ($d = 1.50$). The ANCOVA and Mann–Whitney U analyses also supported the between-group difference.

This finding is consistent with previous evidence showing that low-load resistance exercise combined with BFR can improve muscular strength. Systematic reviews and meta-analyses have reported that low-load BFR resistance training can produce meaningful strength adaptations and, in some circumstances, outcomes comparable with higher-load resistance training. [2,3,4]

Several physiological mechanisms have been proposed, including increased metabolic stress, recruitment of higher-threshold motor units during fatiguing low-load exercise and changes in intracellular signalling. Previous experimental work has also demonstrated increased anabolic signalling and muscle protein synthesis following BFR exercise. [5,6,7] However, these mechanisms were not directly assessed in the present study.

The greater improvement in leg-press strength observed in the BFR group therefore supports the use of low-load BFR as a potential method for developing lower-limb strength in trained cricket players. It should not, however, be interpreted as evidence that BFR is superior to conventional high-load resistance training, because the control condition in this study consisted of matched low-load training without BFR.

8.3 Agility

The Illinois Agility Test showed a greater improvement in the BFR group, with a mean reduction of 0.7 seconds compared with 0.4 seconds in the control group. The between-group difference was statistically significant ($p < 0.001$), with a large effect size ($d = 2.47$).

Agility and change-of-direction performance depend on several physical qualities, including lower-limb strength, neuromuscular control and the ability to rapidly produce and absorb force. The improvement observed in the present study may therefore partly reflect the improvement in lower-limb strength associated with the training programme.

Previous research in athletes has reported beneficial effects of BFR training on several physical-performance outcomes, including strength, speed and endurance, although results vary across studies and protocols. [1,3] The present findings add to this literature by demonstrating an improvement in an agility measure within a trained cricket population.

Because the present study did not separately measure neuromuscular activation, sprint performance or reactive strength, the specific mechanism responsible for the improvement in Illinois Agility Test performance cannot be established.

8.4 Comparison with Previous Research

The overall findings are broadly consistent with previous research investigating BFR in athletic populations. Wortman et al. reported that BFR training in athletes was associated with improvements in strength, muscle size and selected sport-specific performance measures, although the protocols and outcomes varied considerably between studies. [8]

More recent systematic reviews have also reported improvements in strength, power, speed and endurance among athletes following BFR training. [1,3] At the same time, evidence is not completely uniform. Some meta-analyses have reported that adding BFR to exercise does not consistently produce superior improvements in athletic performance, strength or hypertrophy compared with exercise alone. [9] Therefore, differences in exercise intensity, cuff pressure, training duration, participant characteristics and outcome measures may influence the response to BFR.

The present study contributes cricket-specific evidence by evaluating endurance, lower-limb strength and agility within the same intervention. However, the findings should be considered within the limitations of the study design and should not be generalised to all cricket players or athletic populations.

8.5 Safety and Feasibility

No adverse event requiring withdrawal was reported during the eight-week intervention. The BFR intervention was performed under physiotherapy supervision using individually determined arterial occlusion pressure.

These observations support the feasibility of conducting supervised BFR training in the study population. However, absence of adverse events in this sample and over this eight-week period should not be interpreted as proof that BFR is universally safe. Previous literature has identified the importance of appropriate participant screening, individualised pressure selection and professional supervision, while cardiovascular and haemodynamic responses remain important considerations. [10,11,12]

The use of individually determined arterial occlusion pressure is therefore an important feature of the present protocol. The findings support the feasibility of this approach in a supervised research setting rather than establishing that the same protocol is appropriate for every athlete.

8.6 Practical Implications for Sports Physiotherapy

The present findings suggest that low-load BFR training may be considered as an additional conditioning strategy for trained cricket players, particularly when a low external training load is desirable. The protocol used in this study combined 20–30% of one-repetition maximum with 40–60% of individually determined arterial occlusion pressure and was performed three times per week for eight weeks.

The results may be relevant to situations in which practitioners wish to provide a substantial training stimulus while using relatively low external loads. However, the present study did not directly measure joint loading, muscle soreness, recovery time or injury incidence. Consequently, claims that BFR prevents injury, reduces joint stress or accelerates return to play should not be made on the basis of this study alone.

8.7 Interpretation of the Overall Findings

Taken together, the results indicate that the addition of BFR to the low-load training programme was associated with greater improvements in all three measured performance outcomes. The effect was smallest for aerobic endurance ($d = 0.63$) and larger for lower-limb strength ($d = 1.50$) and agility ($d = 2.47$).

These results are encouraging, but they should be interpreted as evidence of improved performance outcomes under the specific conditions of this trial. They do not establish long-term superiority of BFR

over conventional resistance training, nor do they establish effects on injury prevention, recovery or return to sport.

9. Conclusion

This randomised controlled trial found that eight weeks of supervised low-load Blood Flow Restriction training produced greater improvements in aerobic endurance, lower-limb strength and agility than matched low-load training without BFR in trained cricket players aged 18–25 years.

The BFR group improved by 255.3 m in the Cooper 12-minute Run Test, 25.2 kg in one-repetition maximum leg press and 0.7 seconds in the Illinois Agility Test, compared with improvements of 118.0 m, 14.4 kg and 0.4 seconds, respectively, in the control group. Between-group analyses demonstrated significant differences for all three outcomes, with effect sizes of 0.63, 1.50 and 2.47, respectively.

These findings suggest that low-load BFR training may be a useful conditioning option for improving selected physical performance measures in trained cricket players when applied with individually determined cuff pressure and appropriate professional supervision. The findings should not be interpreted as evidence of universal safety, injury prevention, reduced joint loading or improved return-to-play outcomes, as these variables were not directly assessed.

10. Clinical Significance

The findings have potential relevance to sports physiotherapy because the BFR group achieved greater improvements using relatively low external exercise loads. This may provide an additional option when high external loading is not desirable. However, clinical decisions should consider the individual athlete, medical screening, training goals and appropriate cuff-pressure determination.

The protocol may also be considered for integration into broader conditioning programmes rather than being viewed as a replacement for all conventional resistance or endurance training. Further research should determine how BFR can best be combined with sport-specific training and conventional strength and conditioning.

10.1 Low-Load Strength Training

The improvement in one-repetition maximum leg press despite the use of 20–30% of one-repetition maximum indicates that low-load BFR can provide a substantial training stimulus. This may be useful when a lower external load is preferred. The present study does not, however, demonstrate reduced joint loading because joint forces were not measured.

10.2 Potential Rehabilitation Application

Because BFR allows low-load exercise to be performed while producing a substantial muscular stimulus, it has potential application within rehabilitation settings. Previous rehabilitation literature supports its use in selected clinical populations. ^[13]

However, the participants in the present study were healthy trained cricket players, and individuals with injuries or medical conditions were excluded. Therefore, the current findings should not be directly extrapolated to injured athletes or used alone to justify earlier return to play.

10.3 Multi-Domain Conditioning

The improvement in endurance, strength and agility suggests that low-load BFR training may be useful when several physical qualities need to be addressed within the same conditioning programme. Whether this approach reduces overall training time, fatigue or recovery requirements was not directly investigated and requires further study.

10.4 Practical Supervision

The use of individually determined arterial occlusion pressure and physiotherapist supervision represents an important component of the study protocol. BFR should be implemented according to appropriate screening and pressure-selection procedures rather than through a fixed pressure applied identically to all athletes.

11. Limitations of the Study

Several limitations should be considered.

1. The intervention lasted eight weeks. Therefore, the sustainability of the observed improvements beyond the intervention period cannot be determined.
2. The sample consisted of trained cricket players aged 18–25 years. The findings may therefore not be directly generalisable to female cricketers, younger or older players, recreational athletes or athletes from other sports.
3. Only three major performance outcomes were assessed: aerobic endurance, lower-limb strength and agility. Other cricket-relevant variables, including sprint speed, jumping ability, throwing performance, upper-limb strength and sport-specific skill, were not evaluated.
4. The study did not include long-term monitoring of injury incidence, delayed-onset muscle soreness, recovery time or return-to-play outcomes. Consequently, the study cannot establish whether BFR reduces injury risk, joint stress or recovery time.
5. The control group demonstrated considerable variability in individual change scores for the endurance outcome. Although the baseline-adjusted ANCOVA demonstrated a significant group effect, this variability should be considered when interpreting the endurance results.

Finally, the study evaluated one specific combination of exercise load and cuff pressure. Different combinations of exercise intensity, cuff pressure, cuff width, training frequency and exercise selection may produce different responses.

12. Future Scope

Future randomised controlled trials should include larger and more diverse samples, including female cricket players and athletes from different competitive levels.

Longer follow-up periods are required to determine whether the improvements observed after eight weeks are maintained over an entire competitive season.

Further studies should compare different BFR pressures and exercise loads to determine the most appropriate combination for cricket-specific conditioning.

Future research should also include additional performance measures such as sprint speed, vertical jump performance, repeated-sprint ability, throwing performance and cricket-specific skill measures.

Importantly, future trials should prospectively monitor adverse events, injury incidence, muscle soreness, recovery and training load. This would allow researchers to directly examine whether the proposed

advantages of low-load BFR training, such as reduced mechanical loading or improved recovery, translate into clinically meaningful outcomes.

Finally, studies comparing BFR with conventional high-load resistance training, rather than only low-load non-BFR training, would help determine whether BFR provides an additional advantage over established strength-training methods.

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