RESEARCH PAPER

Running title: Plyometric versus circuit training in recreational badminton players

Effects of Plyometric versus Circuit Training on Flexibility and Agility in Recreational Badminton Players: A Quasi-Experimental Study

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ABSTRACT

Background

Badminton is a high-intensity sport placing considerable demands on explosive leg power, agility, and neuromuscular control. Agility and flexibility are particularly consequential for court performance. Relatively few studies have directly compared training methods for developing these qualities in recreational populations. This study evaluated and contrasted the effects of six-week plyometric and circuit-based training programmes on hamstring and lumbar flexibility and multidirectional agility in recreational badminton players.

Methods

A quasi-experimental two-group pre-test and post-test design was used. Fifty-six recreational badminton players (aged 18-35 years) were equally assigned to two groups of 28. Group A completed six weeks of plyometric training and Group B six weeks of circuit training (three supervised sessions per week each). Flexibility was assessed using the Sit-and-Reach Test (SAR) and multidirectional agility using the T-Agility Test (AGT). Within-group differences were examined with paired-samples t-tests and between-group comparisons with independent-samples t-tests ($p < 0.05$).

Results

Both programmes produced highly significant within-group gains in flexibility and agility. Analysis of training-induced change scores showed that the plyometric group achieved considerably larger improvements in both outcomes compared to the circuit training group.

Conclusions

Six weeks of either plyometric or circuit training produced meaningful gains in flexibility and agility among recreational badminton players. Plyometric training yielded significantly larger improvements across both outcomes and appears to be the more effective conditioning choice for this group. Circuit training remains a useful complementary option.

Keywords: plyometric training; circuit training; agility; flexibility; badminton.

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INTRODUCTION

Badminton is acknowledged as one of the most intense racket sports. Contemporary match analysis reveals that the sport demands considerable physical exertion, characterised by relentless sprint-lunge, jumping, and defensive actions.[1] Players at any level must combine rapid sprint accelerations with technically demanding overhead and lateral stroke mechanics, all within a court environment where reaction windows are measured in fractions of a second.[2,3] Reactive agility and mobility serve as the most critical factors for enhancing performance and protecting against injury.[4] This high-intensity, stop-and-go activity causes significant mechanical loading on the lower body and lumbar spine, which cannot be adequately prepared for solely through technical training.

Despite research focusing on elite players, recreational badminton is equally physically demanding and represents the largest portion of global players. Because many recreational athletes prioritise technical repetition over physical training, they develop a conditioning imbalance that leaves them prone to injuries such as ankle sprains and patellofemoral issues.[5] Amateur players routinely execute high-intensity actions like jump smashes and deep split-step lunges, creating joint stress comparable to elite athletes.[6]

Agility is a complex, multi-component physical attribute combining explosive reactivity, limb coordination, and the neuromuscular capacity to rapidly adjust movement direction. Flexibility works alongside agility by allowing joints to handle extreme demands such as deep lunges, wide lateral reaches, and rotational power in smashes.[7] These two attributes are biologically connected; sufficient range of motion enhances force transfer efficiency during rapid changes of direction, boosts elastic energy storage within the muscle-tendon complex, and attenuates impact forces upon landing.[8]

Circuit training structures various resistance and functional exercises into back-to-back stations with limited recovery time, simultaneously building muscular endurance, aerobic capacity, and movement coordination.[9] Plyometric exercises, in contrast, utilise the stretch-shortening cycle (SSC), where rapid eccentric muscle action enhances the power of the immediate concentric contraction to improve explosive and reactive neuromuscular performance.[10,11] Agility, defined as a complex multi-component capacity to rapidly adjust movement direction in response to a stimulus, is a primary determinant of court success.[12]

While separate bodies of literature support each modality, direct comparative trials examining their relative effects on agility and flexibility in recreational badminton cohorts remain scarce.[13] The present study was therefore designed to directly compare the effects of six-week plyometric and circuit training programmes on SAR-assessed flexibility and T-test-assessed agility in recreational badminton players.

METHODS

Study Design and Ethics

This research adopted a quasi-experimental two-group repeated-measures framework with pre-intervention and post-intervention assessment points. Ethical approval was obtained from the Institutional Ethics Committee of Malla Reddy University (Certificate No. PG/MPT/2025/119). All procedures conformed to the principles of the Declaration of Helsinki. Every participant received thorough verbal and written explanation of study objectives, intervention nature, potential risks, and their right to withdraw before providing written informed consent.

Participants

Recreational badminton players between the ages of 18 and 35 were enrolled using convenience sampling and allocated to one of two training groups of 28 participants each. Sample size was calculated using G*Power software (effect size d = 0.9, alpha = 0.05, power = 0.95, one-tailed independent t-test), yielding a minimum requirement of 28 participants per group. No withdrawals or losses to follow-up occurred during the six-week programme.

Inclusion criteria: recreational badminton players with at least six months of consistent play (at least twice per week), not enrolled in any formal competitive training programme.

Exclusion criteria: diagnosed cardiovascular, neurological, respiratory, or orthopaedic condition contraindicating strenuous exercise; lower-limb injury or surgery within the preceding six months; simultaneous participation in another structured fitness programme; anticipated absenteeism exceeding 20% of training sessions; or use of medications known to affect physical performance or post-exercise recovery.

Outcome Measures

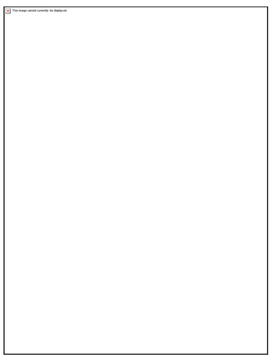
The Sit-and-Reach Test (SAR) was used to measure hamstring and lumbar flexibility. With footwear removed and knees held fully extended, each participant reached as far forward as possible along a standardised calibrated tape, holding the furthest position for two seconds. The best of three recorded attempts was retained for analysis.

Multidirectional agility was evaluated using the T-Agility Test (AGT). Four cones were arranged with Cone A at the start, Cone B 10 m ahead, Cone C 5 m to the left of B, and Cone D 5 m to the right of B. Each participant sprinted from A to B, side-shuffled to C, across to D, back to B, and finally backpedalled to A. The fastest of three trials formed the final score (unit: seconds).

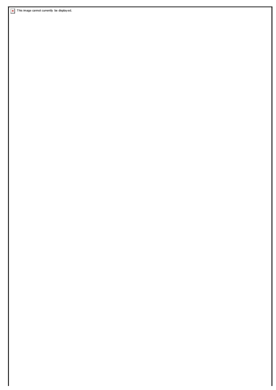
Training Interventions

A six-week, 18-session supervised training programme (three sessions per week) was implemented, with a qualified researcher monitoring technique and compliance. Assessments occurred pre- and post-intervention using standardised procedures and a consistent assessor.

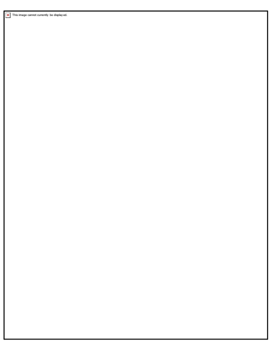
Group A - Plyometrics: A 3x15 routine was performed, consisting of single or double-leg hops, ankle jumps, lateral side jumps, zigzag jumps, vertical depth jumps, bench side jumps, and box jumps. Each set was followed by 5-7 seconds of passive recovery.



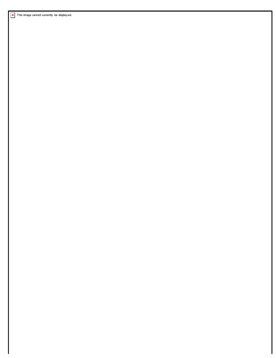
SINGLE HOPS



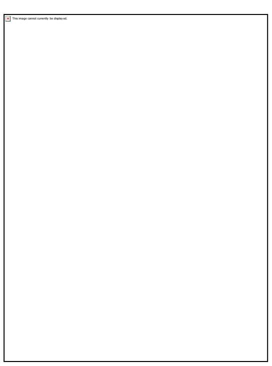
ZIG ZAG JUMPS

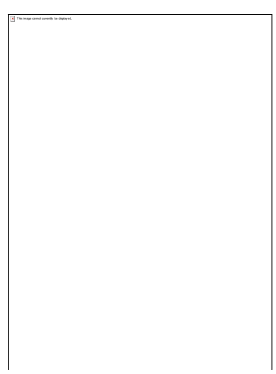


ANKLE JUMPS



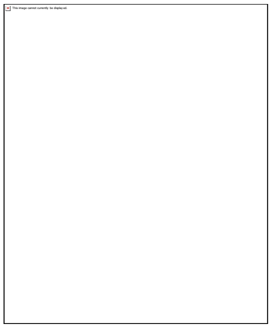
VERTICAL JUMPS



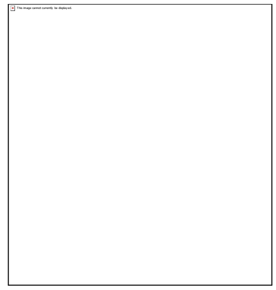


SIDE JUMPS

SIDE JUMPS OVER THE BENCH

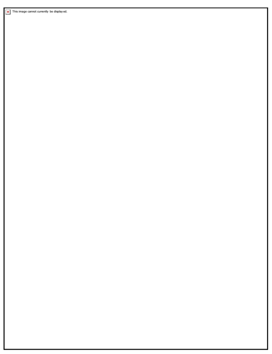


DOUBLE LEG JUMP

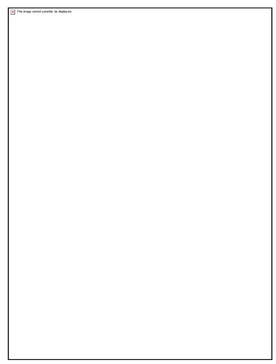


BOX JUMP

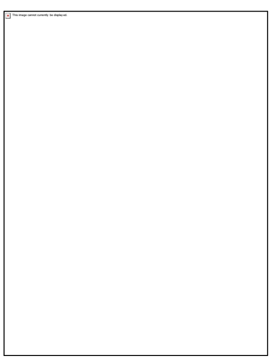
Group B - Circuit Training: Sessions featured eight exercises in a station-to-station format: jumping jacks, kicking backs, high-heel runs, lateral side hops, bodyweight squats, flutter kicks, Pilates leg pull-ups, and Pilates leg pull-downs. Participants completed three circuits, working at each station for 30-60 seconds following a five-minute warm-up. Each session involved 30-45 minutes of active exercise.



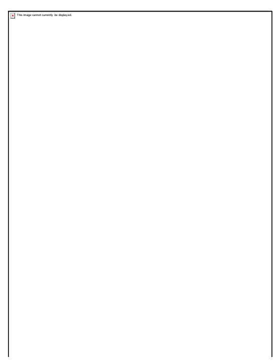
JUMPING JACKS



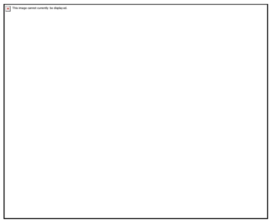
KICKING BACKS



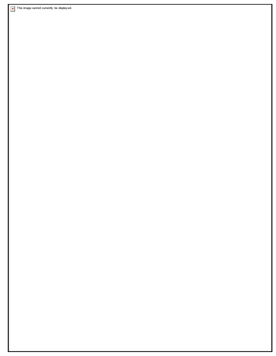
SIDE HOPS



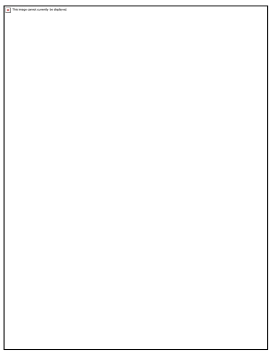
PILATES LEG



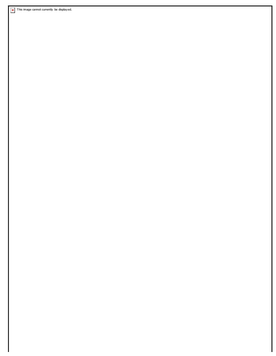
SQUATS



PILATES LEG PULL DOWN



HIGH KNEE STRIDE



FLUTTER KICK

Statistical Analysis

Descriptive statistics were expressed as mean +/- standard deviation. Normality of score distributions was verified by visual inspection of frequency histograms. Within-group pre-to-post differences were examined using paired-samples t-tests. Between-group comparisons of absolute post-test scores and net change scores were conducted using independent-samples t-tests. Statistical significance was defined at alpha = 0.05; findings reaching $p < 0.001$ were classified as highly significant.

RESULTS

Participant Characteristics

A total of 56 participants were recruited and equally divided into two groups of 28 each. Group A underwent plyometric training and Group B underwent circuit training. Demographic characteristics are presented in Table 1.

Variable	Group A (Plyometric Training)	Group B (Circuit Training)
Sample Size (n)	28	28
Mean Age (years)	22.71 +/- 2.76	24.43 +/- 4.70
Age Range (years)	19 - 30	19 - 35
Male	17 (60.7%)	17 (60.7%)
Female	11 (39.3%)	11 (39.3%)

Table 1. Baseline demographic profile of both training groups.

Both groups were well-matched in sample size (n = 28 each) and gender composition (17 males, 11 females per group). Group A had a mean age of 22.71 years while Group B averaged 24.43 years, with Group B showing slightly greater age variability (SD = 4.70 vs 2.76), supporting the validity of between-group comparisons.

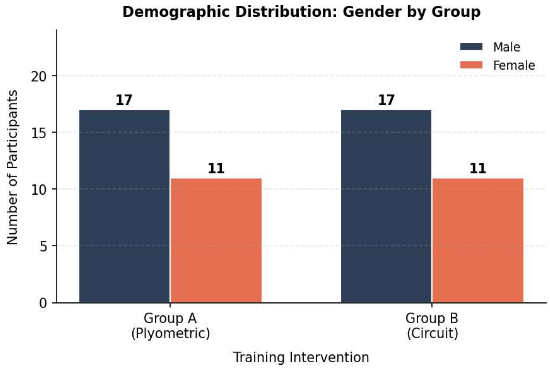


Figure 1. Gender distribution across training groups.

Group A - Plyometric Training: Pre and Post Analysis

Sit-and-Reach Test (Flexibility)

Measure	Mean (cm)	SD	Mean Diff.	SE	t-value	p-value	Significance
Pre-test	18.65	2.10	+3.193	0.101	31.558	< 0.001	**
Post-test	21.85	2.16	-	-	-	-	-

Table 2. Group A - Sit-and-Reach Test pre- and post-test results.

Table 2 summarises the pre- and post-test SAR scores for Group A. The mean score increased from 18.65 cm to 21.85 cm, a gain of +3.19 cm. The highly significant t-value ($t = 31.558$, $p < 0.001$) confirms that plyometric training produced a reliable and substantial enhancement in flexibility.

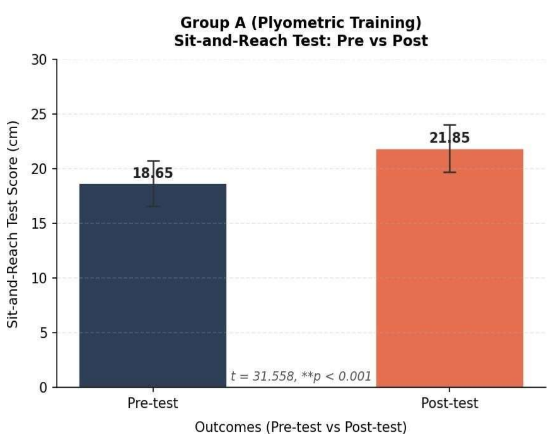


Figure 2. Group A - Sit-and-Reach Test: Pre vs Post scores (cm) +/- SD.

T-Agility Test (Agility)

Measure	Mean (sec)	SD	Mean Diff.	SE	t-value	p-value	Significance
Pre-test	13.75	1.62	-1.450	0.073	19.860	< 0.001	**
Post-test	12.30	1.66	-	-	-	-	-

Table 3. Group A - T-Agility Test pre- and post-test results.

Table 3 presents agility test data for Group A. The mean completion time decreased from 13.75 s to 12.30 s, an improvement of 1.45 seconds. The highly significant paired t-test ($t = 19.860$, $p < 0.001$) confirms that plyometric training consistently and substantially enhanced agility performance across all participants.

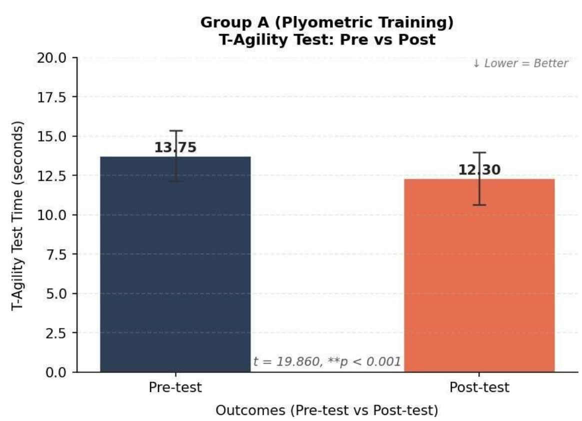


Figure 3. Group A - T-Agility Test: Pre vs Post times (seconds) +/- SD.

Group B - Circuit Training: Pre and Post Analysis

Sit-and-Reach Test (Flexibility)

Measure	Mean (cm)	SD	Mean Diff.	SE	t-value	p-value	Significance
Pre-test	18.55	2.72	+2.386	0.097	24.524	< 0.001	**
Post-test	20.94	2.68	-	-	-	-	-

Table 4. Group B - Sit-and-Reach Test pre- and post-test results.

Table 4 details SAR results for Group B. The mean score rose from 18.55 cm to 20.94 cm, a gain of +2.39 cm. The paired t-test (t = 24.524, p < 0.001) confirms highly significant improvement. While circuit training did improve flexibility, the mean gain (+2.39 cm) was lower than Group A (+3.19 cm), suggesting plyometric training provides a greater flexibility stimulus.

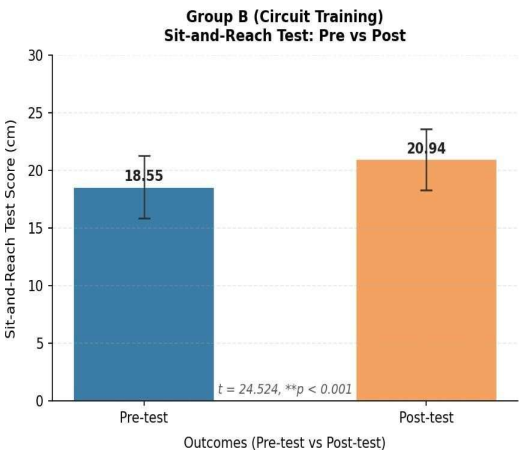


Figure 4. Group B - Sit-and-Reach Test: Pre vs Post scores (cm) +/- SD.

T-Agility Test (Agility)

Measure	Mean (sec)	SD	Mean Diff.	SE	t-value	p-value	Significance
Pre-test	14.27	1.65	-1.168	0.054	21.546	< 0.001	**
Post-test	13.10	1.49	-	-	-	-	-

Table 5. Group B - T-Agility Test pre- and post-test results.

Table 5 presents agility results for Group B. The mean T-test time decreased from 14.27 s to 13.10 s, an improvement of 1.17 s. The paired t-test (t = 21.546, p < 0.001) confirms significant agility improvement. However, the gain (1.17 s) was slightly smaller than Group A (1.45 s), tested formally in the between-group analysis.

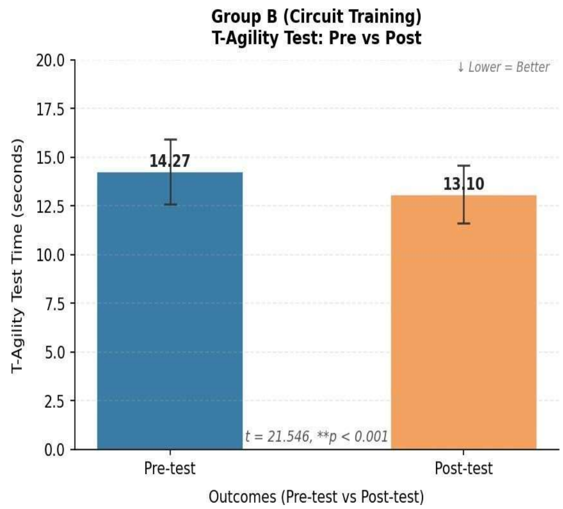


Figure 5. Group B - T-Agility Test: Pre vs Post times (seconds) +/- SD.

Between-Group Analysis

An independent-samples t-test was conducted to compare (a) post-test scores and (b) mean change scores between Group A (Plyometric Training) and Group B (Circuit Training).

Post-Test Score Comparison

Outcome	Group A Mean +/- SD	Group B Mean +/- SD	t-value	p-value	Significance
SAR (cm)	21.85 +/- 2.16	20.94 +/- 2.68	1.395	0.169	NS
AGT (sec)	12.30 +/- 1.66	13.10 +/- 1.49	1.894	0.0636	NS

Table 6. Post-test score comparison between Group A and Group B.

Table 6 compares absolute post-test scores between both groups. Neither outcome showed a significant between-group difference in final scores (SAR: p = 0.169, NS; AGT: p = 0.0636, NS), suggesting both groups reached broadly comparable performance levels post-intervention.

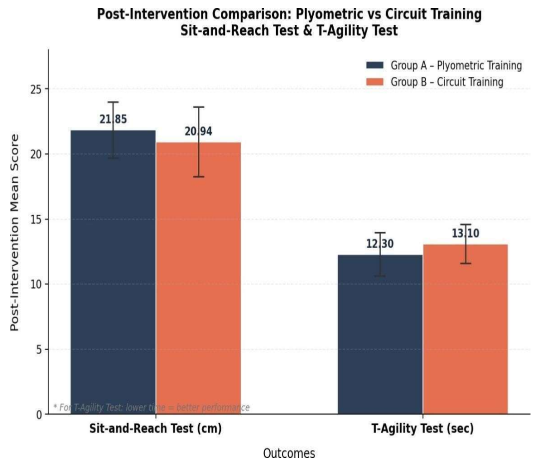


Figure 6. Post-Intervention Comparison: Plyometric vs Circuit Training across both outcomes.

Mean Change Score Comparison (Primary Between-Group Analysis)

Outcome	Group A Mean Change	Group B Mean Change	t-value	p-value	Significance
SAR (cm)	+3.193 +/- 0.535	+2.386 +/- 0.515	5.751	< 0.001	**
AGT (sec)	-1.450 +/- 0.386	-1.168 +/- 0.287	3.103	0.0030	**

Table 7. Mean change score comparison between Group A and Group B.

Table 7 presents mean change scores - the most sensitive indicator of training effect. For SAR, Group A improved by +3.193 cm vs +2.386 cm for Group B ($p < 0.001$, highly significant). For agility, Group A reduced time by 1.450 s vs 1.168 s for Group B ($p = 0.0030$), confirming plyometric training produced significantly superior improvements in both flexibility and agility.

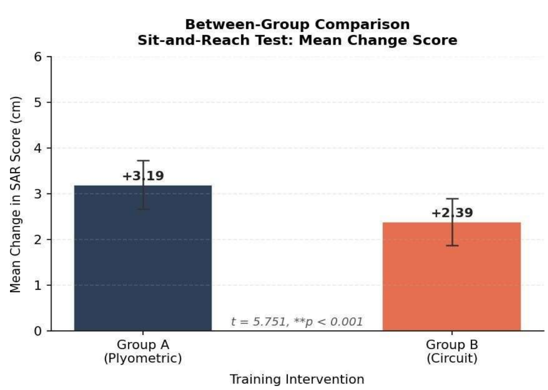


Figure 7. Between-group: Mean change in Sit-and-Reach score (cm).

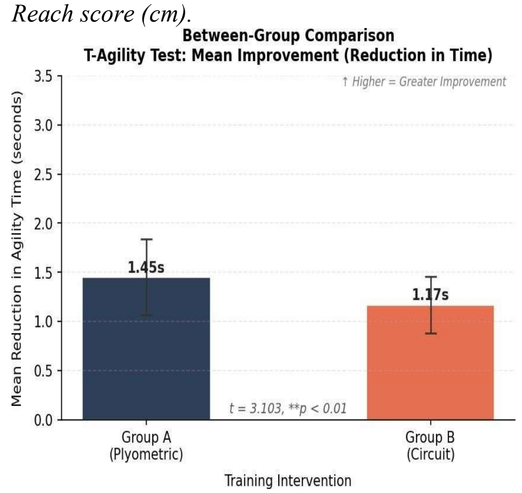


Figure 8. Between-group: Mean reduction in T-Agility time (seconds).

DISCUSSION

The aim of this study was to determine which of two six-week conditioning programmes - plyometric or circuit training - produces greater gains in flexibility and agility in recreational badminton players. Both programmes brought about statistically and clinically meaningful within-group improvements, yet plyometric training consistently produced larger changes across both outcomes. This pattern is consistent with the principle of training specificity, whereby adaptations are maximised when the physiological demands of training resemble those of the skill being developed.[14]

The larger flexibility gain in Group A (SAR +3.19 cm vs +2.39 cm in Group B) can be attributed to the mechanical demands characteristic of plyometric loading. During the ground-contact phase of exercises such as box jumps, depth jumps, and lateral bounds, the musculotendinous structures are subjected to rapid, high-amplitude eccentric stretch.[15] Repeated eccentric overload gradually increases the viscoelastic extensibility of the muscle-tendon unit over six weeks.[16] The rapid stretch rate during plyometric drills desensitises the Golgi tendon organs and raises the stretch reflex threshold, permitting greater muscle elongation before reflex contraction is triggered.[8] Over repeated training bouts, this leads to structural adaptations including increased sarcomere addition in series and greater tendon compliance.[10]

These flexibility findings are supported by Hassan et al.,[17] who recorded substantial SAR improvements in collegiate female badminton players following a structured plyometric programme. Similarly, Bhat et al.[5] documented concurrent gains in lower-limb flexibility and leg strength following plyometric training in badminton participants. Sunil et al.[18] further demonstrated that plyometric training yielded significantly greater flexibility improvements compared to Swiss ball training in recreational badminton players. Jam and Yadav[19] also noted improvements in flexibility and coordination among badminton and tennis players following selected exercises with a plyometric component.

Circuit training also produced a statistically robust flexibility gain (+2.39 cm); the smaller magnitude reflects the inherent limitations of this format for driving maximal flexibility adaptation. Circuit exercises are conducted at moderate intensity favouring cardiorespiratory and muscular endurance over peak eccentric loading.[9] The lower peak eccentric load means the stretch reflex threshold is not consistently challenged, and sarcomere adaptation is less pronounced.[21] Jayakumar et al.[22] confirmed meaningful flexibility improvements in a badminton cohort after circuit work, yet gains remained numerically inferior to those achieved by plyometric groups in parallel literature, consistent with the present results.

The greater agility improvement in Group A (AGT -1.45 s vs -1.17 s in Group B) follows logically from the neuromuscular mechanisms underlying plyometric adaptation. Box jumps, zig-zag hops, and lateral bounds directly target the reactive pre-activation patterns and reflex-potentiation pathways governing rapid momentum absorption and force redirection during changes of direction.[10] Repeated SSC loading enhances motor unit recruitment rate, inter-muscular co-ordination, and reactive ground-contact stiffness.[23] The short ground-contact durations demanded by plyometric drills train the nervous system to minimise the amortisation phase, which limits reactive agility speed in court sports.[24]

These observations are supported by Miller et al.,[25] who confirmed that a six-week plyometric programme notably shortened T-Agility Test times in collegiate athletes. Sheppard and Young[12] argued that truly effective agility training must target the reactive neuromuscular components of direction change. Asadi et al.[24] confirmed through meta-analysis that plyometric training produces significant improvements in change-of-direction speed with effect sizes proportional to SSC specificity. Thomas et al.[26] demonstrated plyometric techniques produced significantly greater muscular power and agility outcomes in youth soccer players than moderate-intensity training. Shah et al.[28] corroborated these findings in a badminton context, reporting significantly better agility and strength outcomes from plyometric versus circuit training in male badminton players - directly paralleling the present study's between-group agility difference.

The agility gains seen in the circuit training group reflect the well-established benefits of sustained high-intensity intermittent exercise on muscular endurance, anaerobic capacity, and movement economy.[21] However, circuit training does not replicate the brief ground-contact durations and rapid eccentric-to-concentric force reversals that define reactive agility in fast court sports.[29] Milanovic et al.[13] noted that generalised training programmes lacking sport-specific reactive components yield inferior agility outcomes even when overall fitness improves. Chaouachi et al.[31] demonstrated that agility-focused training with high-speed directional elements produced substantially greater improvements than matched-volume endurance-based circuit work in young athletes.

Practical Implications

From a sports physiotherapy standpoint, greater hamstring and lumbar flexibility reduces tensile loading on posterior-chain structures during the deep lunges and lateral reaches that badminton demands, thereby lowering muscle strain risk.[5] Enhanced agility translates to faster shuttle retrieval and improved proprioceptive stability during landing, each associated with reduced ankle and knee injury prevalence.[5,12] Short-duration structured training can produce meaningful injury-prevention adaptations,[32] and plyometric training has demonstrated broad applicability for improving explosive athletic performance across populations.[33] These findings support integrating progressive plyometric programmes as the primary conditioning tool in recreational badminton schedules, with circuit training retained as a complementary component.[34]

Limitations

This study has several limitations. The six-week timeframe does not permit conclusions about retention of gains after training ends, nor whether the between-group difference would grow or diminish with prolonged follow-up. The assessment battery was limited to two outcomes, leaving questions about lower-limb power, functional balance, and sport-specific endurance open. Participant recruitment via convenience sampling, combined with a sample restricted to healthy young recreational players, limits generalisability to elite, paediatric, or older groups. Subsequent research would benefit from longer observation periods, hybrid programme designs, and sample sizes adequate for sex- and age-stratified comparisons.

CONCLUSION

Six weeks of structured plyometric or circuit training produced statistically significant and clinically meaningful gains in hamstring and lumbar flexibility and multidirectional agility in recreational badminton players. Both approaches proved viable for this population. That said, plyometric training yielded considerably greater improvements across both measured outcomes, which supports its use as the preferred conditioning strategy when rapid gains in flexibility and agility are the priority. Coaches and physiotherapists working with recreational badminton players are encouraged to build progressive plyometric training into regular conditioning schedules. Circuit training should be retained as a complementary option that develops the underlying muscular and cardiovascular base. Future work examining longer durations, hybrid protocols, and long-term retention of adaptations will be needed to develop more refined guidance.

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