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Circuit Training-Induced Improvements in Performance-Related Bio Motor Abilities Among Ball Badminton Players

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ABSTRACT:

Purpose. The purpose of the present study was to investigate the effect of a structured circuit training programme on selected performance-related biomotor abilities among Ball Badminton players.

Material & Methods. Forty male Ball Badminton players aged between 18 and 25 years were randomly selected and equally assigned to two groups: an experimental group (EG = 20) and a control group (CG = 20). The experimental group participated in a structured circuit training programme for 12 weeks in addition to their regular activities, whereas the control group continued their routine activities without participating in any specialized training programme. The selected performance-related biomotor abilities were assessed before and after the intervention using standardized performance tests. The collected data were statistically analysed using Analysis of Covariance (ANCOVA) to determine the effects of the training programme while accounting for pre-test differences. Whenever significant F-ratios were observed, Scheffé's post hoc test was employed to identify specific differences between the experimental and control groups.

Results. ANCOVA revealed significant improvements in speed, explosive power, and muscular endurance in the experimental group compared with the control group after adjusting for baseline scores. The experimental group showed a favourable mean difference of 0.409 s in speed, 8.687 m in explosive power, and 7.987 repetitions/min in muscular endurance compared with the control group. Significant group effects were observed for speed, $F(1, 37) = 134.545$, $p < .001$, $\eta^2_p = .784$; explosive power, $F(1, 37) = 538.970$, $p < .001$, $\eta^2_p = .936$; and muscular endurance, $F(1, 37) = 18358.249$, $p < .001$,

$\eta^2_p = .998$. These findings demonstrate that the 12-week circuit training programme produced substantial improvements in selected performance-related biomotor abilities among Ball Badminton players.

Conclusions. The findings suggest that structured circuit training is an effective conditioning method for enhancing selected performance-related biomotor abilities among Ball Badminton players. Incorporating circuit training into regular sports conditioning programmes may help improve sport-specific physical fitness and contribute to enhanced athletic performance.

INTRODUCTION.

The birthplace of ball badminton is historically recognized as South India [16]. There are no authentic historical documents identifying the inventor or the exact origin of the game, but evidence suggests that the rulers of Thanjavur were playing the sport even before 1856. Over time, the game gradually spread across different parts of India, especially during the nineteenth century, when South Indian migrants introduced it to other regions [19]. Ball badminton is primarily a team sport and is played in various formats, including doubles and fives. In recent years, singles events have gained greater popularity, while mixed doubles competitions are also increasing steadily [10]. In addition to its competitive significance, ball badminton is an accessible recreational activity that encourages lifelong physical engagement, social interaction, and overall health. The game can be tailored to various age groups and fitness levels, making it suitable for both athletes and casual players. Regular participation improves cardiovascular fitness, neuromuscular coordination, balance, agility, and musculoskeletal function while promoting active lifestyles and decreasing sedentary behavior [2, 22]. Consequently, ball badminton holds substantial value as a recreational exercise that fosters health promotion and physical well-being. Ball badminton is a fast-paced and physically demanding sport that requires refined skill, quick reflexes, agility, accurate wrist control, and sound judgment from players [16]. Traditionally, the sport is played outdoors during daylight hours and is significantly influenced by weather conditions. To maintain fairness, regulations are designed to ensure equal environmental conditions for both teams. In modern times, indoor competitions under artificial lighting have become increasingly popular. States such as Tamil Nadu, Puducherry, Andhra Pradesh, and Karnataka frequently organize national-level tournaments under floodlights [16]. Competitive participation in ball badminton requires a high level of physical fitness, including speed, agility, muscular strength, flexibility, and aerobic-anaerobic endurance, to meet the demands of rapid directional changes, repeated accelerations, and sustained match performance [3]. Ball badminton differs from many other sports because it involves repeated explosive movements. Actions such as smashes and rapid rallies rely predominantly on anaerobic energy systems, whereas sustained rallies and recovery periods require aerobic efficiency. Therefore, in addition to technical and tactical preparation, comprehensive training programmes should focus on developing these essential physical qualities. Effective training programmes must be based on sound principles of sports conditioning and exercise science [6,12].

Although some consider ball badminton to be primarily skill-oriented, the modern version of the game clearly demands a high degree of physical conditioning. Powerful smashes, quick directional changes, rapid exchanges, and efficient net play require muscular strength, speed, flexibility, and precise neuromuscular coordination. To compete successfully, prevent injuries, and maintain consistent performance, players must possess sport-specific physical fitness. In this regard, structured conditioning methods such as circuit training (CT) may play an important role in enhancing player performance [15,23].

Circuit training is a systematic conditioning method consisting of a sequence of exercises targeting different muscle groups with minimal rest intervals between stations [23]. This method is particularly suitable for ball badminton players because it closely resembles the intermittent and high-intensity nature of the sport. Circuit training simultaneously develops several fitness components, including speed, muscular endurance, flexibility, and explosive power. Circuit training is a systematic conditioning method involving a series of exercises that target various muscle groups, with minimal rest intervals between each station [14]. Circuit training can improve sport-specific performance with shuttle runs, squat jumps, push-ups, lunges, medicine ball throws, and agility ladder drills. These exercises improve rapid direction changes, lower- and upper-body explosive power, neuromuscular coordination, and movement efficiency, resulting in faster court coverage, stronger smashes, better net play, and longer rallies. Progressive overload through gradual increases in training intensity, volume, or complexity promotes physiological adaptation, improving strength, power, speed, agility, and athletic performance [5,11,20].

From a rehabilitation perspective, enhancing biomotor abilities benefits not only sports performance but also promotes healthier movement patterns in recreational and daily activities. Improvements in muscular endurance, lower-limb power, flexibility, and neuromuscular coordination contribute to better joint stability, reduced excessive mechanical loading, and a lower risk of musculoskeletal injuries. As a result, structured circuit training can aid in injury prevention, enhance functional independence, and encourage ongoing participation in recreational sports and physical activities [2,10].

Literature review. Circuit training further enhances both aerobic and anaerobic energy systems, which are vital for ball badminton players. Anaerobic power is required for forceful strokes and explosive movements, while aerobic capacity supports recovery between rallies and prolonged match play. Enhanced muscular strength and physiological efficiency also contribute to injury prevention by strengthening muscles, tendons, and supportive structures. Consequently, integrating circuit training into regular practice sessions may improve both physical fitness and overall athletic performance in ball badminton players [9].

Previous studies have reported beneficial effects of physical conditioning programmes on badminton and ball badminton performance. Ma et al. (2024) observed that strength-based training interventions improved overall athletic performance among badminton players [13]. Similarly, Wang et al. (2025) demonstrated that resistance training positively influenced sport-specific performance characteristics in competitive badminton athletes [21]. Deng et al (2024) studied the impact of plyometric training (PT) on elite ball badminton players in Satara City. The top twenty male collegiate athletes, aged 17 to 19, were randomly selected. Physical fitness was assessed using the medicine ball throw (MBT) test for upper-body power and the vertical jump test (VJT) for lower limb explosive power. Participant homogeneity was confirmed, and they were divided into two groups of ten [4].

Research Gap & Aim. Although several studies have examined the effects of physical conditioning programmes, such as resistance training, plyometric training, and core strength exercises, on the performance of badminton players, there is limited research specifically addressing the impact of circuit training on performance-related biomotor abilities among ball badminton players. Previous investigations have predominantly focused on physiological variables, general fitness components, or athletes in traditional badminton, rather than on ball badminton players. Additionally, only a few studies have looked into the wider rehabilitative and recreational health benefits of circuit training, such as functional fitness, injury prevention, and ongoing participation in recreational sports. Consequently, this study aimed to assess the effectiveness of a structured circuit training programme on selected performance-related biomotor abilities in ball badminton players while also considering its potential contributions to musculoskeletal health and recreational physical activity.

MATERIAL & METHODS.

Study Design and participants. The present study adopted a simple randomized group experimental design to examine the effect of circuit training on performance-related biomotor abilities among Ball Badminton players. Forty subjects aged from 18 to 25 years old participated in the experiment and were classified into CG (n=20, who maintained normal practice without undergoing special training) and EG (n=20, who underwent a 12-week CT). As depicted in Figure 1, the subjects were given the pre-test prior to the experimental period, while the post-test was conducted after the completion of the 12-week program. The CONSORT flowchart illustrates the participant recruitment, allocation, follow-up, and analysis process of the study. Out of 50 participants assessed for eligibility, 40 met the inclusion criteria and were randomly assigned equally into the experimental and control groups (n = 20 each). All participants completed the intervention and post-test assessments, and the final analysis included all 40 participants. The study involved participants who had a minimum of two years of competitive ball badminton experience and engaged in regular training, defined as 3 to 5 sessions per week. All participants provided written informed consent and volunteered for the study. Individuals were excluded if they had recent musculoskeletal injuries, had undergone major surgery, or had cardiovascular, neurological, or other medical conditions that could impair physical performance. Additionally, those currently undergoing rehabilitation, participating in other structured training programs, or unable to complete the training regimen and assessments were also excluded.

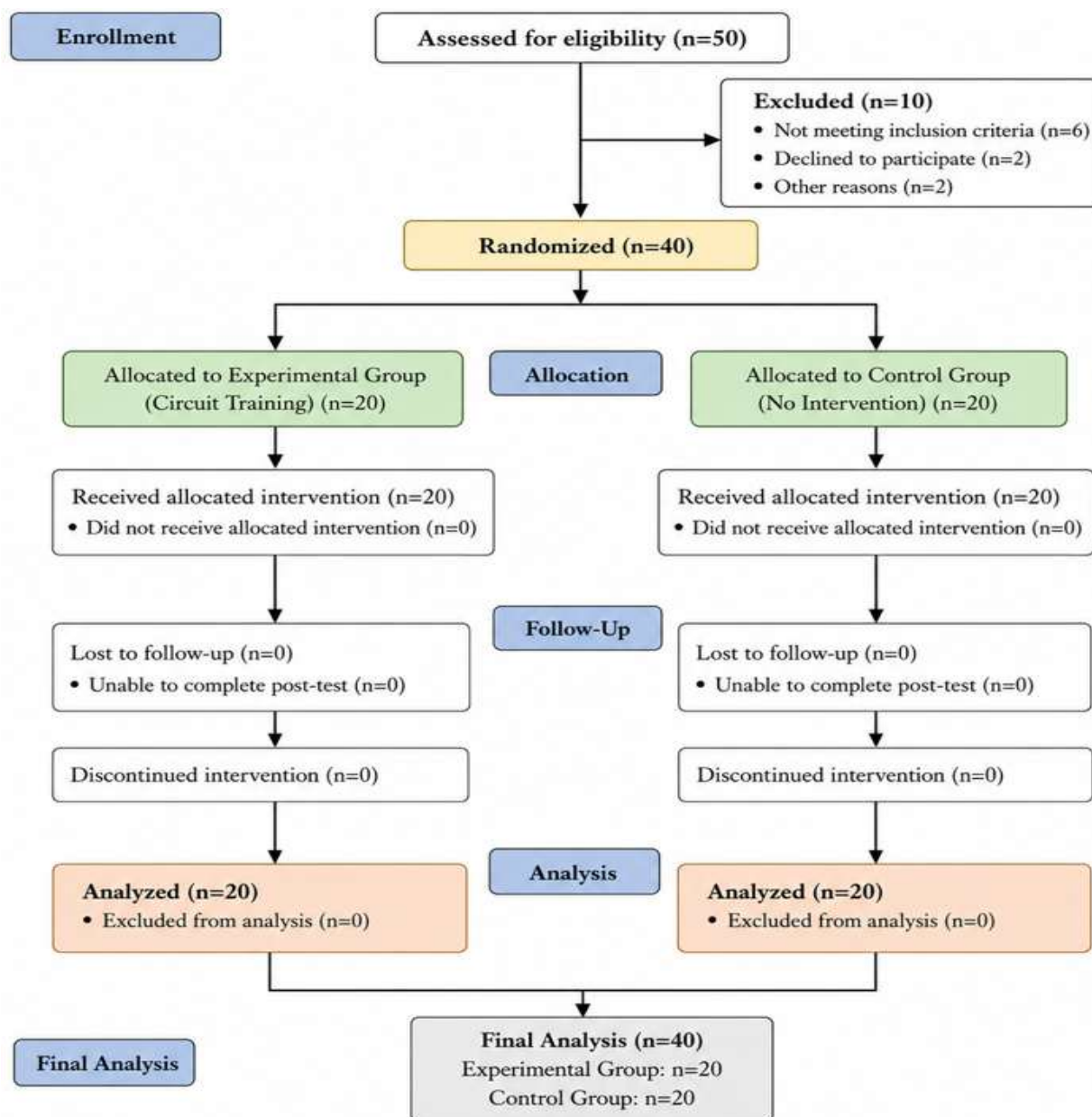


Figure 1. Consort Flow Chart for Participants Allocation

Training Protocol. To achieve improvements in some performance-related bio motor abilities among college-level male ball badminton players, an organized exercise program was devised by the researcher. Some important variables such as speed, explosive leg strength and muscle endurance were the main areas of emphasis of the exercise program. The aim was to increase the physical fitness and performance in selected games among the athletes. An exercise program was carefully planned and implemented by the investigator in accordance with these objectives. The EG underwent this exercise program for twelve weeks, where the sessions were held thrice weekly for an hour each session.

Circuit Training. During the entire course of the 12 weeks, the experimental groups were engaged in a standard CT program alongside their training routine. To cater for the physical and physiological demands of ball badminton, the training routine was designed based on information derived from textbooks, journals, websites, and consultation with experts. For three days per week, the two EG groups underwent their respective one-hour training programs. The CT program involved three to four sets of exercise lasting fifteen seconds, followed by rest periods lasting three to four minutes. Some of the exercises in the CT

program included push-ups, burpees, sit-ups, hurdle jumps, hop, squat, step-ups, dips, and walking lunges. Sessions were carried out from 3:00 p.m. to 4:00 p.m., and all participants were closely supervised to ensure proper technique and adherence, with an attendance rate of approximately 90%. The CG maintained their usual training schedule, primarily focused on technical drills and match play, with only limited aerobic work and no organized program designed to increase overall physical fitness. The detailed circuit training schedule for experimental group is presented in Table 1.

Table. 1 Circuit Training Schedule for 12 weeks

Weeks	Exercises	Sets	Work Intensity	Rest Between Exercises	Rest Between Circuits
1–3		3	Moderate (40–50% HRmax)	15 s	3–4 min
4–6	Push-ups, Burpees,	3	Moderate-to-vigorous (50–60% HRmax)	10 s	2–3 min
7–9	Sit-ups, Hurdles, Hopping, Squats,	4	Vigorous (60–65% HRmax)	15 s	3–4 min
10–12	Step-ups, Dips, Walking, Lunges.	4	Vigorous (65–70% HRmax)	10 s	2–3 min

PROGRAMMING SCHEDULE

EG went through the CT program for 12 weeks, three times a week, with each training session lasting around an hour. There were fitness trainers at hand in each of these sessions to ensure correct execution. The structure of the training was done like this: 10-minute dynamic stretch and jog to warm up the body in preparation for rigorous activity. Main activity (45 minutes): Circuit-style workouts involving bodyweight and functional training. These exercises target aspects such as strength, flexibility, speed, muscle endurance, and explosiveness.

The main exercises included pushups, burpees, sit-ups, hurdles, hops, squats, step-ups, dips, and lunges. It lasts for 15 seconds, followed by a 3–4-minute rest. Cool-down (5min): Static stretching and controlled breathing exercises to enhance recovery and flexibility. The CG maintained their usual training schedule, primarily focused on technical drills and match play, with only limited aerobic work and no organized program designed to increase overall physical fitness. To evaluate the intensity of exercise, it is determined by the Heart Rate. The calculation of Maximum Heart Rate (MHR) is essential. Maximum Heart Rate (MHR) = 220 – Age.

Variables and Testing Procedure. The selected performance-related biomotor abilities included speed, explosive power, and muscular endurance. Speed was assessed using a sprint test, explosive power was measured through the standing broad jump test, and muscular endurance was evaluated using the push-up test. Pre-test measurements were recorded before the commencement of the training programme, and post-test assessments were conducted after the completion of the 12-week intervention period.

Statistical Analysis. Normality and variance homogeneity assumptions were tested before the statistical analyses. The Shapiro–Wilk test showed that all study variables were normally distributed ($p > 0.05$). For all outcome variables, Levene's test showed that variance homogeneity between groups was satisfied ($p > 0.05$). After confirming the parametric test, the data Analysed using Analysis of Covariance (ANCOVA) to determine the adjusted post-test differences between the experimental and control groups while controlling pre-test scores.

Whenever significant F-ratios were obtained, Scheffé's post hoc test was applied to identify specific group differences. The level of significance was fixed at 0.05.

RESULTS

Table 3. Analysis of Covariance (ANCOVA) of Speed

	Sum of Squares	df	Mean Square	F	p	η^2_p	95% CI	
							Lower	Upper
Group	1.657	1	1.657	134.545	< .001	0.784	0.650	0.856
Speed pre	2.300	1	2.300	186.791	< .001	0.835	0.729	0.890
Residuals	0.456	37	0.012					

Table.3 shows that ANCOVA for speed. It's demonstrated a significant effect of the intervention on post-test speed performance after controlling for baseline speed. The analysis revealed a substantial group effect [$F(1, 37) = 134.545, p < .001$], indicating that the intervention significantly enhanced speed when compared to the comparison group. A large effect size ($\eta^2_p = 0.784$; 95% CI: 0.650–0.856) suggests that the intervention accounted for 78.4% of the variance in post-test speed scores after adjusting for pre-test performance. Additionally, post-test outcomes were significantly affected by baseline speed [$F(1, 37) = 186.791, p < .001$], exhibiting a large effect size ($\eta^2_p = 0.835$; 95% CI: 0.729–0.890). These findings indicate that the intervention effectively improves speed, regardless of initial performance levels.

Table.4 - ANCOVA for Muscular Endurance

	Sum of Squares	df	Mean Square	F	p	η^2_p	95% CI	
							Lower	Upper
Group	315.935	1	315.935	18358.249	< .001	0.998	0.997	0.999
EP pre	44.419	1	44.419	2581.074	< .001	0.986	0.976	0.991
Residuals	0.637	37	0.017					

ME- Muscular Endurance

Table.4 shows that ANCOVA for muscular endurance. After adjusting for baseline muscular endurance scores, the ANCOVA revealed a significant difference in post-test muscular endurance between the study groups. Participants who received the intervention demonstrated a notable improvement in muscular endurance [$F(1, 37) = 18358.249, p < .001$]. The large effect size ($\eta^2_p = 0.998$; 95% CI: 0.997–0.999) indicates that group membership accounts for most of the variance in the adjusted post-test muscular endurance scores. Additionally, the pre-test muscular endurance score served as a significant covariate [$F(1, 37) = 2581.074, p < .001$], with a partial eta squared of 0.986 (95% CI: 0.976–0.991), demonstrating a strong correlation between baseline and post-intervention performance. Overall, the intervention significantly enhanced muscular endurance beyond the initial differences observed at baseline.

Table.5- ANCOVA for Explosive Power

	Sum of Squares	df	Mean Square	F	p	η^2_p	95% CI	
							Lower	Upper
Group	750.601	1	750.601	538.970	< .001	0.936	0.893	0.893
EP pre	51.904	1	51.904	37.269	< .001	0.502	0.268	0.268
Residuals	51.528	37	1.393					

EP - Explosive Power

Table.5 shows that ANCOVA for explosive power. The intervention significantly influenced post-test explosive power after accounting for pre-test explosive power, as indicated by the ANCOVA analysis. A notable group effect [$F(1, 37) = 538.970, p$

< .001] suggests that the intervention group experienced a substantial improvement in explosive power compared to the comparison group. The intervention was responsible for 93.6% of the adjusted variance in post-test explosive power, which is reflected in the large effect size ($\eta^2_p = 0.936$). Additionally, pre-test explosive power had a significant effect on post-test performance [$F(1, 37) = 37.269, p < .001$], with a partial eta squared of 0.502, demonstrating the importance of baseline performance on the adjusted outcomes. These findings indicate that the intervention effectively enhanced explosive power while controlling for initial performance.

Table 6. Scheffé Post Hoc Analysis of Adjusted Post-test Mean Differences in Selected Bio motor Abilities

Variable	Groups Compared	Mean Difference	SE	95% CI for Mean Difference		p_{scheffe}
				Lower	Upper	
Speed (s)	EG vs CG	0.409	0.035	0.480	0.337	< .001 ***
Explosive Power (m)		8.687	0.374	9.445	7.929	< .001 ***
Muscular Endurance (push-ups/min)		7.987	0.059	8.107	7.868	< .001 ***

significant at *** $p < .001$

Table.6 shows that Scheffé post hoc analysis. Its revealed significant differences in performance variables between the experimental group (EG) and the control group (CG) following the intervention. The EG demonstrated superior speed performance, with a mean difference of 0.409 seconds ($SE = 0.035; p < .001$). In terms of explosive power, the EG surpassed the CG by 8.687 units ($SE = 0.374; p < .001$) and exhibited greater muscular endurance, averaging 7.987 more push-ups per minute ($SE = 0.059; p < .001$). Overall, circuit training resulted in statistically significant improvements in speed, explosive power, and muscular endurance, supported by narrow confidence intervals and highly significant p-values that affirm the robustness of these effects.

DISCUSSIONS

The significant improvement in speed observed after 12 weeks of circuit training aligns with recent findings reported by Ma et al. (2024), who demonstrated that integrated strength and conditioning programmes significantly enhanced sprint ability, agility, and movement efficiency among competitive badminton players [11]. Similarly, Wang et al. (2025) noted that resistance-based training improved lower-limb neuromuscular performance and sport-specific movement speed through increased motor-unit recruitment and an enhanced rate of force development [20]. The present findings reinforce these observations, indicating that the combination of repeated sprinting, multidirectional movements, and explosive exercises within circuit training effectively stimulates fast-twitch muscle fibres. This stimulation leads to improved acceleration and court movement in badminton players. Given that ball badminton involves rapid directional changes and repeated high-intensity efforts, these neuromuscular adaptations are particularly advantageous for sustaining performance throughout match play.

A significantly greater increase in speed was observed in the experimental group, possibly due to improved neuromuscular coordination, increased motor unit recruitment, and enhanced rate of force development through circuit-based exercises. Circuit training usually involves repeating sprinting, jumping, and rapid movement patterns that stimulate fast-twitch muscle fibers and improve movement efficiency. Such training done on a regular basis increases the ability of the muscles to generate force quickly, which directly helps improve speed performance. Previous research has demonstrated that circuit training increases anaerobic capacity and neuromuscular efficiency, resulting in improved sprint ability and movement quickness [9,13,18].

The increase in explosive power found in this study may be due to the repeated execution of dynamic and plyometric-type exercises that are part of circuit training. Explosive power depends greatly on the interaction of muscular strength with movement velocity. Circuit training enhances the efficiency of the phosphagen energy system, increases muscle fiber activation, and improves the use of elastic energy in the muscle-tendon complex. These physiological adaptations result in greater force production in shorter periods of time, which in turn improves explosive movements such as jumping and throwing. These

findings are consistent with previous studies reporting significant improvements in muscular power and anaerobic performance following resistance and plyometric training programs [4,5,11].

After the circuit training intervention, muscular endurance also improved significantly. This improvement may be related to increased oxidative capacity of skeletal muscle, improved local muscle blood flow, and delayed onset of fatigue due to repeated submaximal muscle contractions during training. Circuit training involves sustained muscular work with short rest intervals that increase the muscles' ability to resist fatigue and continue contracting repeatedly over time. The observed improvements in push-up performance may be attributed to adaptations such as increased mitochondrial density, improved lactate tolerance, and enhanced metabolic efficiency. Similar findings have been reported in studies emphasizing that circuit-based resistance training is an effective method for developing local muscular endurance because of the continuous and repetitive muscular activation it entails [9,13].

The observed improvement in explosive power aligns with Deng et al. (2024), highlighting significant gains in vertical jump and medicine-ball throw performance after plyometric training in collegiate badminton players. While Deng's intervention focused on plyometric exercises, both plyometric and circuit training enhance stretch-shortening cycle efficiency, neuromuscular coordination, and phosphagen energy function [13]. The enhanced explosive power in this study is likely due to the inclusion of squat jumps, medicine-ball throws, and multidirectional jumps in the circuit program. Circuit training also improved muscular endurance, supporting recent functional conditioning studies. According to Myers et al. (2015), Circuit-based resistance training with repeated submaximal contractions and short recovery periods improved muscular endurance and aerobic fitness. Structured circuit exercise programmes increased oxidative enzyme activity and metabolic efficiency, improving local muscular endurance and fatigue delay. These physiological adaptations may explain the improved push-up performance in this study, suggesting that circuit training builds muscular endurance for long Ball Badminton rallies [14].

Generally, the results of this study support the view that circuit training is an effective conditioning method for developing biomotor abilities. The experimental group showed significant improvements in speed, explosive power, and muscular endurance, suggesting that systematic circuit training induces positive physiological adaptations that enhance athletic performance and physical fitness. These findings are in agreement with previous investigations that reported beneficial effects of circuit and resistance training on physical performance variables among athletes and physically active individuals [8,17,18,20].

Strengths and Limitations of the Study. The present study has several strengths, including the use of a randomized group design, a well-structured 12-week circuit training program, and standardized testing procedures to assess biomotor abilities such as speed, explosive power, and muscular endurance. The inclusion of a control group enhanced the validity of the findings by allowing for a clear comparison between trained and untrained participants. Additionally, the application of appropriate statistical techniques, such as ANCOVA and Scheffé's post hoc test, bolstered the accuracy of the analysis and interpretation of results. However, the study also has certain limitations. The sample size was relatively small and restricted to male Ball Badminton players aged 18–25 years, which may limit the generalizability of the findings to other age groups, females, or athletes from different sports. Furthermore, factors such as dietary habits, recovery patterns, and lifestyle activities outside the training sessions were not controlled, and the long-term effects of circuit training were not assessed.

In addition to enhancing athletic performance, improvements in speed, muscular endurance, and explosive power can greatly influence recreational health and injury prevention. Enhanced neuromuscular coordination and movement efficiency diminish mechanical stress on joints, thereby reducing the likelihood of prevalent overuse injuries in racket sports. Circuit training can effectively enhance performance, facilitate rehabilitation, and encourage sustained participation in recreational physical activities.

CONCLUSION

The present study suggests that a systematic circuit training regimen considerably enhances speed, explosive power and muscular endurance among the Ball Badminton players. The results indicated that circuit training is a valid and feasible conditioning strategy for boosting performance related biomotor abilities and can be successfully included into regular sports training programs for better athletic performance.

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AUTHOR CONTRIBUTIONS

Ezhilarasan Manoharan: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Visualization, Writing – original draft, Writing – review and editing. **Asad Ali Khan D. Jaffar Ali Khan:** Conceptualization, Project administration, Resources, Supervision, Validation, Formal analysis, Funding acquisition, Writing – review and editing. **Sivarani Sivakozhundhu:** Conceptualization, Methodology, Project administration, Resources, Formal analysis, Funding acquisition. **Thamaraiselvi Saravanakumar:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Software, Validation, Visualization, Writing – original draft, Writing – review and editing.

CONFLICT OF INTEREST

The authors have no conflicts of interest in the material presented in this article.

ETHICAL APPROVAL & INFORMED CONSENT

All procedures were conducted in accordance with the Declaration of Helsinki and approved by Departmental Ethical Committee in Feb 2025. Written informed consent for participation and publication of anonymized clinical data was obtained from the participants.

AI POLICY

The authors declare that no generative AI was used in this manuscript.

DATA AVAILABILITY

The datasets utilized and analysed in this study can be obtained from the corresponding author upon reasonable request. All data necessary to assess the conclusions drawn in this paper are included within the paper itself.

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