



## A quasi-experimental study on the effectiveness of circuit training for improving aerobic capacity in female cricketers

*Un estudio cuasiexperimental sobre la eficacia del entrenamiento en circuito para mejorar la capacidad aeróbica en jugadoras de críquet*

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### Abstract

**Background:** Physical fitness, sleep quality, and activity levels are critical for cricket performance, yet evidence on effective training strategies for female players remains limited. Circuit training may improve these parameters but has not been extensively studied in this population.

**Purpose:** To investigate the effects of a four-week circuit training program on aerobic fitness, sleep quality, and physical activity levels in female cricket players.

**Methods:** Sixty national-level players (18–25 years) were randomly assigned to an intervention group (circuit training + regular practice) or a control group (regular practice). Assessments included Yo-Yo Intermittent Recovery Test Level-1 (YYIRT1) for distance, estimated VO<sub>2</sub> max, Pittsburgh Sleep Quality Index (PSQI), and International Physical Activity Questionnaire (IPAQ). Pre- and post-intervention data were analyzed using two-way repeated measures ANOVA.

**Results:** Significant group × time interactions were observed for YYIRT1 distance ( $F(1,58) = 26.87, p < 0.001, \eta^2 = 0.32$ ), VO<sub>2</sub> max ( $F(1,58) = 18.52, p < 0.001, \eta^2 = 0.24$ ), PSQI ( $F(1,58) = 6.74, p = 0.012, \eta^2 = 0.10$ ), and IPAQ ( $F(1,58) = 7.91, p = 0.007, \eta^2 = 0.12$ ). Post hoc comparisons confirmed significant improvements in the intervention group, while the control group showed no changes.

**Conclusion:** A four-week circuit training program effectively enhances aerobic capacity, sleep quality, and physical activity levels in female cricketers. These findings support integrating circuit training into cricket conditioning programs and warrant further investigation through longer interventions with objective intensity monitoring.

### Keywords

Aerobic capacity; VO<sub>2</sub> max; circuit training; cardiorespiratory fitness.

### Resumen

**Antecedentes:** La condición física, la calidad del sueño y los niveles de actividad son factores críticos para el rendimiento en el críquet, sin embargo, la evidencia sobre estrategias de entrenamiento efectivas para jugadoras sigue siendo limitada. El entrenamiento en circuito puede mejorar estos parámetros, pero no ha sido ampliamente estudiado en esta población.

**Objetivo:** Investigar los efectos de un programa de entrenamiento en circuito de cuatro semanas sobre la condición aeróbica, la calidad del sueño y los niveles de actividad física en jugadoras de críquet.

**Métodos:** Sesenta jugadoras de nivel nacional (18–25 años) fueron asignadas aleatoriamente a un grupo de intervención (entrenamiento en circuito + práctica regular) o a un grupo de control (práctica regular). Las evaluaciones incluyeron la Prueba Yo-Yo de Recuperación Intermittente Nivel 1 (YYIRT1) para la distancia, el VO<sub>2</sub> máx estimado, el Índice de Calidad del Sueño de Pittsburgh (PSQI) y el Cuestionario Internacional de Actividad Física (IPAQ). Los datos pre y post intervención se analizaron mediante un ANOVA de medidas repetidas de dos factores.

**Resultados:** Se observaron interacciones significativas grupo × tiempo para la distancia del YYIRT1 ( $F(1,58) = 26.87, p < 0.001, \eta^2 = 0.32$ ), el VO<sub>2</sub> máx ( $F(1,58) = 18.52, p < 0.001, \eta^2 = 0.24$ ), el PSQI ( $F(1,58) = 6.74, p = 0.012, \eta^2 = 0.10$ ) y el IPAQ ( $F(1,58) = 7.91, p = 0.007, \eta^2 = 0.12$ ). Las comparaciones post hoc confirmaron mejoras significativas en el grupo de intervención, mientras que el grupo de control no mostró cambios.

**Conclusión:** Un programa de entrenamiento en circuito de cuatro semanas mejora de manera efectiva la capacidad aeróbica, la calidad del sueño y los niveles de actividad física en jugadoras de críquet. Estos hallazgos respaldan la integración del entrenamiento en circuito en los programas de acondicionamiento para el críquet y justifican investigaciones adicionales mediante intervenciones más prolongadas con monitoreo objetivo de la intensidad.

### Palabras clave

Capacidad aeróbica; VO<sub>2</sub> máx; entrenamiento en circuito; aptitud cardiorrespiratoria.

## Introduction

A player is considered physically fit if they can sprint, jump, change directions quickly, and move all of their joints without experiencing undue weariness (Haskell et al., 2007). It includes both skill-related and health-related elements, including strength, flexibility, cardiovascular endurance, muscular endurance, and body composition, all of which have an impact on general health (Adami et al., 2010).

Because it increases overall capability, lowers the chance of injury, and improves reliability, physical fitness is essential for cricket players to perform at their best (Smita Wagh et al., 2022). Cricket demands a combination of strength and technique, testing players' mental and physical limits (Noakes & Durandt, 2000). The player's role and the game type determine the fitness requirements. For example, quick bowlers need to be more fit than opening batsmen, and one-day cricket requires higher levels of fitness than Test matches (Ahamad et al., 2015; Orchard et al., 2005).

Cricket is a sport that places multifaceted physical and psychological demands on athletes, requiring a combination of strength, endurance, coordination, and mental resilience (Noakes & Durandt, 2000). Physical fitness plays a pivotal role in ensuring consistent performance, reducing the risk of injury, and enhancing an athlete's capacity to meet these challenges (Smita Wagh et al., 2022). However, the physiological demands of cricket are not uniform; they vary significantly depending on the player's role and the format of the game. For example, one-day cricket is more physically demanding than Test matches, and fast bowlers typically require higher fitness levels than opening batters due to the intense, repetitive nature of their role (Ahamad et al., 2015; Orchard et al., 2005).

Among the various components of physical fitness, cardiorespiratory endurance is particularly important in cricket. It enables athletes to sustain high-intensity efforts throughout extended periods of play, whether sprinting between wickets, covering ground in the field, or maintaining bowling pace over long spells (Christie et al., 2008; Vickery et al., 2018). A widely adopted and effective strategy to improve cardiorespiratory fitness is circuit training. This One method combines resistance and aerobic exercises in a structured, continuous sequence that engages multiple muscle groups and energy systems. Circuit training enhances overall physical conditioning and aligns well with the dynamic and multidimensional demands of cricket (Fitrian et al., 2023; Khattak et al., 2020).

Despite the practical advantages of circuit training, its evidence base in cricket remains limited. A recent systematic review and meta-analysis of circuit-based interventions across sports reported consistent improvements in aerobic capacity, muscular endurance, and body composition, but highlighted that cricket-specific applications are scarce (Ramos-Campo et al., 2021; Mahalingam et al., 2024; Saibya et al., 2024). Most cricket-related conditioning research has focused on fast bowlers or male players (M. Kumar, 2016; Anitha et al., 2018), leaving a gap in understanding how female cricketers respond to such programs. Addressing this gap is critical, as sex-based physiological and recovery differences may influence adaptations to training (Santos et al., 2022; Shephard, 2000).

Furthermore, circuit training is recognized for its efficiency and adaptability. It allows coaches to train multiple athletes simultaneously, even under time or equipment constraints, making it a practical choice for team-based sports (Heinrich et al., 2012; Nandagopal et al., 2019). Physiologically, it has been shown to improve oxygen uptake, muscular strength, anaerobic and aerobic endurance, flexibility, and coordination—key attributes for cricket-specific performance (Maiorana et al., 2000; Marín-Pagán et al., 2020). Although circuit training has been investigated in male athletes across sports such as football, kabaddi, and volleyball, cricket research has predominantly centered on male populations, with female athletes underrepresented (Anitha et al., 2018; Kumar et al., 2023; Kumar, 2016; Mahalingam et al., 2024; Ramos-Campo et al., 2021; Saibya et al., 2024). This imbalance underscores the need for targeted studies in women's cricket to establish evidence-based conditioning protocols.

Sleep quality and physical activity levels are emerging determinants of athletic performance and recovery. Poor sleep has been linked to impaired cognitive function, slower recovery, and increased injury risk in athletes (Fullagar et al., 2015; Samuels, 2008). The Pittsburgh Sleep Quality Index (PSQI) is a widely used tool for assessing subjective sleep quality, while the International Physical Activity Questionnaire (IPAQ) evaluates habitual activity levels and energy expenditure. Despite their relevance, there is limited research exploring how training interventions in cricket affect these parameters, particularly in female populations.



In Bangladesh, women's cricket has grown rapidly over the past decade, with the national team competing regularly in ICC tournaments and grassroots participation expanding (Bangladesh Cricket Board, 2022). However, despite this growth, there remains a lack of published research on evidence-based conditioning strategies tailored to the unique physiological demands of Bangladeshi female cricketers. Existing performance reports emphasize technical and tactical preparation, but systematic evaluation of structured training interventions is absent, leaving strength and conditioning programs to rely largely on adaptations from men's cricket or other sports.

Therefore, in addition to evaluating aerobic capacity, the present study also assessed sleep quality (PSQI) and physical activity level (IPAQ) to determine whether a four-week circuit training program could induce favorable adaptations beyond cardiorespiratory fitness. To capture a more holistic view of athlete well-being, the present study also included sleep quality and physical activity as secondary outcomes. Sleep quality, assessed through the Pittsburgh Sleep Quality Index (PSQI), has been directly linked to recovery, injury risk, and performance consistency in athletes (Fullagar et al., 2015; Hamlin et al., 2021). Similarly, habitual activity levels measured by the International Physical Activity Questionnaire (IPAQ) provide insight into training load and recovery balance beyond structured sessions (Alnawwar et al., 2023). While exploratory in nature, including these outcomes allows for a broader assessment of how circuit training might influence both performance and wellness dimensions in female cricketers.

It was hypothesized that participants undergoing the circuit training intervention would demonstrate significantly greater improvements in Yo-Yo IR1 distance,  $VO_2$  max, sleep quality, and physical activity levels compared to those in the control group.

This study not only evaluates the efficacy of circuit training in enhancing aerobic capacity among female cricketers but also contributes to the broader sports science literature by emphasizing the need for gender-responsive, cricket-specific conditioning strategies. By offering practical, evidence-based insights for coaches and performance staff, the findings aim to support the continued development of women's cricket in Bangladesh and elevate its presence on the international stage.

## Method

### *Participants*

Sixty national-level female cricket players aged 18–25 years voluntarily participated in the study. Participants were recruited based on their performance in the domestic cricket league and were actively engaged in regular cricket training at the time of the study. All participants provided written informed consent prior to participation.

#### *Inclusion Criteria*

Participants were included if they met the following criteria: (i) female cricket players aged 18–25 years; (ii) national-level or elite domestic players with a minimum of two years of competitive playing experience; (iii) participation in at least ten official competitive matches during the previous season; (iv) medically cleared to engage in high-intensity physical training; and (v) free from musculoskeletal injury or illness during the six months preceding the study.

#### *Exclusion Criteria*

Participants were excluded if they: (i) had any current injury or medical condition limiting full participation; (ii) were using medications or supplements known to affect cardiovascular performance or sleep patterns; (iii) participated in additional structured physical conditioning programs outside regular cricket practice during the study period; or (iv) failed to attend more than 10% of the prescribed training sessions.

### *Criterion measure*

The primary outcome variable of this study was cardiorespiratory fitness among adolescent female cricket players. This was assessed using the Yo-Yo Intermittent Recovery Test Level-1 (YYIRT1), a validated field test for measuring aerobic capacity in team sports. The total distance covered during the test



was recorded as an indicator of endurance performance. Additionally, maximal oxygen uptake ( $\text{VO}_2\text{max}$ ) was estimated from the total distance using the following equation:

$$\text{VO}_2 \text{ Max (mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}) = \text{IR1 distance (m)} \times 0.0084 + 36.4$$

### *Calibration and Standardization of Testing Equipment*

All testing procedures were standardized across pre- and post-intervention assessments. The YYIRT1 was conducted on the same playing surface under similar environmental conditions (time of day, temperature, and humidity). Distance markers were measured using calibrated measuring tapes, and standardized audio signals were delivered using the same sound system at a fixed volume. Questionnaires were administered in a quiet, controlled environment to ensure consistent conditions across assessments.

### *Secondary Outcome Variables*

Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI), a validated instrument for evaluating sleep patterns and disturbances in athletes. Lower scores indicate better sleep quality. Physical activity level was measured using the International Physical Activity Questionnaire (IPAQ-Short Form), which estimates total weekly energy expenditure (MET-minutes/week). Both assessments were conducted at baseline (pre-test) and immediately following the intervention (post-test).

### *Experimental design*

#### *Randomization and Allocation Procedure*

Following baseline assessments, participants were allocated to either an intervention group ( $n = 30$ ) or a control group ( $n = 30$ ) using a computer-generated simple random allocation sequence created in Microsoft Excel by an independent researcher not involved in recruitment, testing, or training supervision. A 1:1 allocation ratio was used. Block or stratified randomization was not applied because participants were relatively homogeneous in terms of age, competitive level, and training background. Allocation concealment was ensured through the use of sequentially numbered, sealed, opaque envelopes, which were opened only after completion of all baseline measurements, thereby minimizing selection and allocation bias.

#### *Blinding (Shielding) Procedures*

Due to the nature of the exercise-based intervention, participant blinding was not feasible, as individuals were aware of their involvement in the circuit training program. However, several measures were implemented to reduce potential performance and observer bias. Outcome assessors conducting the YYIRT1 and administering questionnaires were not informed of participants' group allocation during pre- and post-testing. Participants were instructed not to disclose their group assignment to assessors. In addition, data analysis was performed using anonymized group codes, ensuring partial blinding at the statistical analysis stage. However, outcome assessors were not informed of participants' group allocation during pre- and post-testing. Participants were instructed not to disclose their group assignment to assessors. Additionally, data analysis was conducted using anonymized group codes to reduce analytical bias.

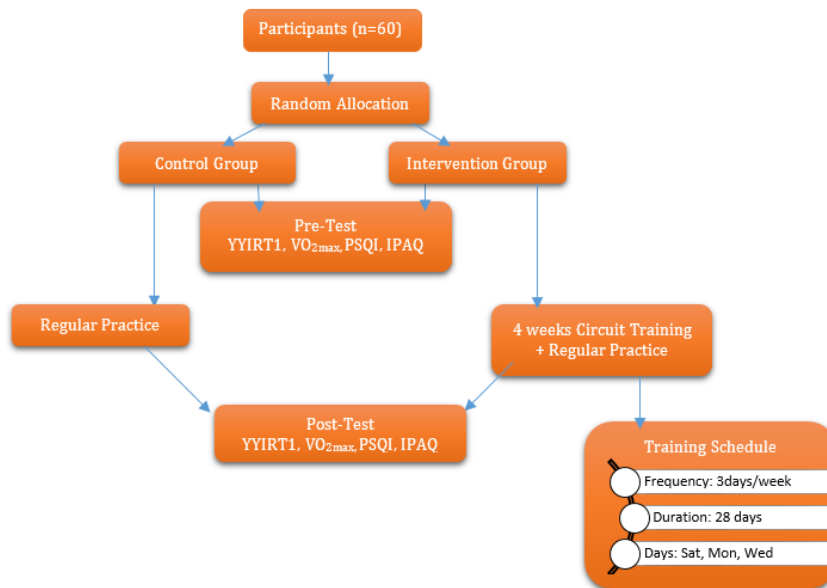
#### *Control of Potential Confounding Variables*

Several potential confounding variables were identified and reasonably controlled in line with the quasi-experimental design. Prior training history was standardized by including only national-level players with similar competitive experience and ongoing participation in regular cricket training. Participants were instructed to maintain their usual training schedules throughout the intervention, and no additional structured conditioning programs were permitted.

Nutritional status was not experimentally manipulated; however, participants received standardized instructions to maintain their habitual diet and to avoid nutritional supplements, ergogenic aids, or major dietary changes during the study period. Recovery-related factors were partially controlled by instructing participants to avoid strenuous physical activity for at least 24 hours before testing sessions and to maintain consistent sleep routines. Sleep quality and habitual physical activity were monitored

using validated questionnaires (PSQI and IPAQ) to account for lifestyle- and recovery-related influences on performance outcomes.

Figure 1. The study design layout



## Power Analysis

An a priori power analysis was conducted using G\*Power (version 3.1) to determine the required sample size. For a two-way repeated measures ANOVA with two groups (intervention vs. control) and two measurements (pre-test and post-test), assuming a medium effect size ( $f = 0.25$ ), an alpha level ( $\alpha$ ) of 0.05, and a desired power ( $1-\beta$ ) of 0.80, the minimum required sample size was 34 participants. Our final sample of 60 participants (30 per group) exceeded this requirement, ensuring sufficient statistical power to detect meaningful effects. The details of the power analysis are summarized in Table 1.

Tabla 1. Power Analysis for Sample Size Determination

Parameter	Value / Assumption	Note
Statistical test	Two-way repeated measures ANOVA	Group $\times$ Time interaction
Groups	2 (Intervention, Control)	
Measurements per subject	2 (Pre-test, Post-test)	
Effect size ( $f$ )	0.25 (medium)	Cohen's benchmarks
Alpha ( $\alpha$ )	0.05	Conventional threshold
Desired power ( $1-\beta$ )	0.80	Standard in sports science
Minimum required sample	34 participants	G*Power 3.1 calculation
Final sample size	60 participants (30 per group)	Exceeded requirement, ensuring sufficient power

## Ethical considerations

The study followed the Declaration of Helsinki guidelines and was approved by the Ethical Review Committee, Faculty of Biological Science and Technology, Jashore University of Science and Technology (Ref: ERC/FBST/JUST/2023-161, Date: 09/05/23). Written informed consent was obtained from all participants. Data were anonymized, stored securely, and reported in aggregate form. Participation was voluntary, with the right to withdraw at any time.

## Procedure for collecting data

Data collection was conducted in two phases: pre-test (baseline) and post-test (following the four-week intervention). All assessments were carried out under standardized conditions to ensure reliability.

### 1. Scheduling and Participant Preparation:

- The pre-test phase was conducted one week prior to the start of the circuit training intervention.
- Participants were instructed to maintain their usual diet and training routine and to avoid strenuous exercise 24 hours before testing.
- The post-test phase was conducted within two days after completing the final training session.

### 2. Primary Outcome Measurements:

- Yo-Yo Intermittent Recovery Test Level-1 (YYIRT1):

The test was performed on a 20-meter course with an additional 5-meter recovery zone, following standard protocols. Participants ran between markers at increasing speeds dictated by audio signals until exhaustion. The total distance covered was recorded, and  $VO_2$  max was estimated using the equation:

$VO_2$  Max ( $mL \cdot kg^{-1} \cdot min^{-1}$ ) = IR1 distance (m)  $\times$  0.0084 + 36.4 Testing conditions (surface, temperature, time of day) were kept consistent across pre- and post-test sessions.

### 3. Secondary Outcome Measurements:

- Pittsburgh Sleep Quality Index (PSQI):

Participants completed the PSQI questionnaire to assess subjective sleep quality over the previous month. The same instrument was administered during both pre- and post-test phases to monitor changes attributable to the intervention.

- International Physical Activity Questionnaire (IPAQ–Short Form):

This questionnaire was administered alongside PSQI to evaluate weekly physical activity levels (MET-min/week). Standard scoring guidelines were followed to calculate total energy expenditure.

### 4. Intervention Implementation:

- The experimental group performed a supervised four-week circuit training program (three sessions per week) in addition to their regular cricket practice, while the control group continued only with regular practice.
- To minimize external influences, no extra physical training sessions were permitted during the intervention period.

### 5. Post-test Phase:

- The post-test assessment mirrored the pre-test procedures, ensuring identical protocols.
- All data were recorded by trained staff to minimize measurement error.

### Training Program for Circuits:

For four weeks, there were three sessions of the circuit training program per week. A 15–20 minute warm-up preceded each session, which was followed by aerobic and anaerobic capacity-enhancing exercises. Each week, the workouts and recuperation periods were gradually changed to push the participants and raise their level of fitness. The training sessions targeted specific energy systems, ensuring the players developed endurance and strength throughout the program. Detail plan of circuit training (Sperlich et al., 2017) has been presented in table 2 below:

Table 2. Circuit training Program

Week	Session (Day)	Exercises	Series	Work : Rest
1	Saturday	Burpees → Skipping → Pull-ups → One-legged squats → Leg levers → Push-ups → 7-min shuttle run	6	30 s each exercise : 30 s rest; 2 min rest between series
	Monday	Run → Burpees → Leg levers → Lunges → Isometric squat → Rows → Plank	3	30–60 s per exercise : 30–60 s rest; 2 min rest between series
	Wednesday	Burpees → One-legged squats → Push-ups → Crunches	5	30 s each : 30 s rest
2	Saturday	Sprint → Isometric squat → One-legged squats → Sumo squat → Push-ups → Rows → Plank → Skipping	3	45–60 s each : 30 s rest

	Monday	Isometric pull-up + Run → Squat jumps + Run → Rows → Burpees → Lunges → Leg levers	10 (short circuits) + 3 (long circuits)	20–60 s work : 30 s rest
	Wednesday	Run → Inchworms	3–5	60 s run : 30 s rest
3–4	Saturday	Jump squats → Isometric squat → Burpees → One-legged squats → Iron mikes → Skipping → 10-min shuttle run	2	60 s each : 30 s rest
	Monday	Pull-ups → Jump rope → Push-ups → Leg levers → Rows → Burpees → 9-min run	3	60 s each : 30 s rest
	Wednesday	Jumping jacks → Skipping → Squats → Burpees → Plank → Lunges → 15-min run	3	30–180 s each : 30 s rest

### Analytical procedure

All statistical analyses were conducted using IBM SPSS Statistics software (version 26). Descriptive statistics (mean ± standard deviation) were calculated for all variables, including YYIRT1 distance, VO<sub>2</sub> max, PSQI scores, and IPAQ scores. The Shapiro–Wilk test was applied to examine the normality of the data distributions, and all variables met the assumptions for parametric testing. Homogeneity of variances was confirmed using Levene’s test.

To evaluate the effects of the intervention, a two-way repeated measures analysis of variance (ANOVA) was performed with time (pre-test vs. post-test) as the within-subject factor and group (experimental vs. control) as the between-subject factor. The primary outcomes analyzed were total distance covered in YYIRT1 and estimated VO<sub>2</sub> max, while PSQI and IPAQ served as secondary outcomes. The primary focus of the analysis was the time × group interaction, which determined whether changes over time differed significantly between the experimental and control groups.

Where significant interaction effects were identified, post hoc pairwise comparisons with Bonferroni correction were applied to detect specific differences within and between groups. Effect sizes were calculated using partial eta squared ( $\eta^2$ ) to interpret the magnitude of effects, with values of 0.01, 0.06, and 0.14 indicating small, medium, and large effects, respectively (Field, 2013). Statistical significance was set at  $p < 0.05$  for all tests.

Table 3 of the Shapiro-Wilk test indicates that the data for Vo2Max and distance measurements were normally distributed for all groups during the pre-test and post-test periods.

Table 3. Tests of Normality (Shapiro-Wilk)

	Group	Vo <sub>2</sub> Max			Distance		
		Statistic	df	Sig.	Statistic	df	Sig.
Pre-Test	IG	.965	30	.838	.965	30	.838
	CG	.828	30	.052	.823	30	.058
Post-Test	IG	.948	30	.643	.948	30	.642
	CG	.805	30	.057	.805	30	.057

## Results

Table 4 summarizes the mean age, height, weight, and Body Mass Index (BMI) of the subjects categorized into intervention group (IG) and control group (CG). The table reveals that the mean height and weight were slightly higher for IG than the CG group.

Table 4. Descriptive statistics (Mean ± SD) for demographic and anthropometric characteristics of the intervention and control groups at baseline.

Parameters	Intervention Group		Control Group	
	Mean	SD	Mean	SD
Age (Yrs)	23.50	±5.52	23.40	±4.14
Height (m)	1.53	±.068	1.56	±.032
Weight (Kg)	54.15	±3.63	53.50	±4.55
BMI (Kg/m <sup>2</sup> )	21.32	±1.91	21.79	±1.79

To investigate group differences over time, a two-way repeated measures ANOVA (table 5) was conducted for both the Yo-Yo Intermittent Recovery Test Level-1 (Yo-Yo IR1) distance and estimated VO<sub>2</sub> max.



There was a significant interaction effect between time (pre- vs. post-test) and group (experimental vs. control) for both outcomes. For Yo-Yo IR1 distance, the interaction effect was statistically significant ( $F(1, 58) = 26.87, p < .001, \text{partial } \eta^2 = .32$ ), indicating that the experimental group experienced significantly greater improvements than the control group. Similarly, for  $\text{VO}_2 \text{ max}$ , the interaction effect was also significant ( $F(1, 58) = 18.52, p < .001, \text{partial } \eta^2 = .24$ ), confirming a greater improvement in the experimental group. These results reinforce the effectiveness of the four-week circuit training intervention in enhancing aerobic capacity in female cricketers.

Table 5. Results of two-way repeated measures ANOVA examining group  $\times$  time interaction for Yo-Yo IR1 distance and  $\text{VO}_2 \text{ max}$

Variable	Group	Pre-test (Mean $\pm$ SD)	Post-test (Mean $\pm$ SD)	F	p	Partial $\eta^2$	Post Hoc Summary
Yo-Yo IR1 Distance (m)	Experimental	896.4 $\pm$ 175.2	1372.3 $\pm$ 195.1	26.87	< .001	0.32	Significant improvement in IG; CG no change; between-group difference at post-test significant
	Control	902.7 $\pm$ 160.8	976.5 $\pm$ 165.7				
$\text{VO}_2 \text{ max}$ (ml/kg/min)	Experimental	38.5 $\pm$ 3.1	46.3 $\pm$ 3.4	18.52	< .001	0.24	Significant improvement in IG; CG no change; between-group difference at post-test significant
	Control	38.2 $\pm$ 2.9	39.6 $\pm$ 3.0				

Figure 2 Presents a spaghetti plot of individual pre- and post-intervention scores for both groups, showing consistent improvements in most IG participants:

Figure 2. Spaghetti Plot illustrating the improvement in distance covered in the Yo-Yo Intermittent Recovery Test (YYIRT1) before and after the four-week circuit training intervention in each group.

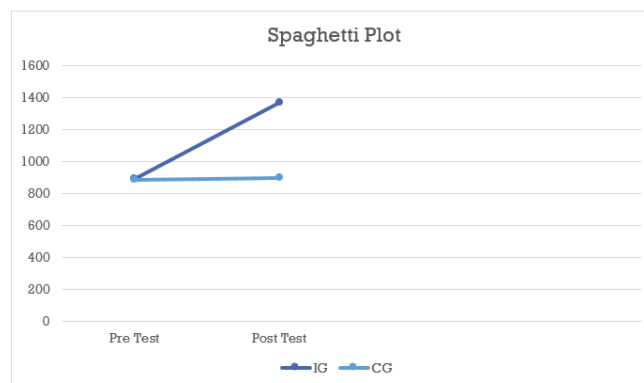
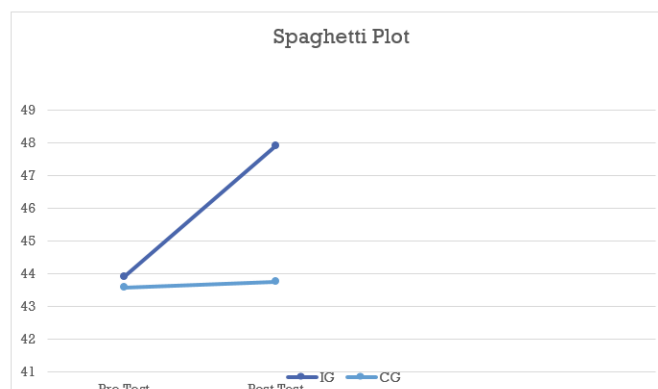


Figure 3 illustrates  $\text{VO}_2 \text{ max}$  changes across playing roles (batters, bowlers, all-rounders) in both groups:

Figure 3. Spaghetti plot showing  $\text{VO}_2 \text{ max}$  improvements in batters, bowlers, and all-rounders in IG and CG after training.



The table 6 revealed significant improvements in both sleep quality (PSQI) and physical activity levels (IPAQ) in the experimental group following the four-week circuit training program. As presented in Table X, there was a significant time  $\times$  group interaction for PSQI scores ( $F(1,58) = 6.74, p = 0.012, \eta^2 = 0.10$ ), indicating that sleep quality improved substantially in the intervention group compared to the control group. Post hoc comparisons confirmed that PSQI scores decreased significantly from pre- to post-test in the experimental group ( $p < 0.01$ ), while no significant change was observed in the control group. Additionally, post-test PSQI scores were significantly lower in the intervention group than in the control group ( $p < 0.01$ ).

Similarly, IPAQ scores demonstrated a significant time  $\times$  group interaction ( $F(1,58) = 7.91, p = 0.007, \eta^2 = 0.12$ ). Post hoc analysis revealed a significant increase in weekly physical activity levels in the intervention group ( $p < 0.01$ ), whereas the control group showed no meaningful change ( $p > 0.05$ ). Furthermore, post-test IPAQ scores were significantly higher in the intervention group compared to the control group ( $p < 0.01$ ). These findings suggest that circuit training not only improved aerobic capacity but also contributed to enhanced sleep quality and increased habitual physical activity levels.

Table 6. Secondary Outcome Measures (PSQI and IPAQ) Pre- and Post-Intervention with Post Hoc Comparisons

Variable	Group	Pre-test (Mean $\pm$ SD)	Post-test (Mean $\pm$ SD)	F (1,58)	p-value	Partial $\eta^2$	Post Hoc Comparison
PSQI (score)	Experimental	7.2 $\pm$ 1.5	4.8 $\pm$ 1.3	6.74	0.012	0.10	Pre vs. Post IG: Significant decrease ( $p < 0.01$ ); CG: No change; IG vs. CG Post: Significant difference ( $p < 0.01$ )
	Control	7.1 $\pm$ 1.4	7.0 $\pm$ 1.3				
IPAQ (MET-min/week)	Experimental	2870 $\pm$ 420	3540 $\pm$ 460	7.91	0.007	0.12	Pre vs. Post IG: Significant increase ( $p < 0.01$ ); CG: No change; IG vs. CG Post: Significant difference ( $p < 0.01$ )
	Control	2855 $\pm$ 430	2890 $\pm$ 440				

## Discussion

This research focused on the impact of a four-week circuit training program on the cardiorespiratory fitness of female cricket players from Bangladesh. It addresses a significant gap in the sport science literature, particularly concerning female athletes from cricket. The main findings show that circuit training increases aerobic capacity, indicated by significant gains in total distance covered in the Yo-Yo Intermittent Recovery Test Level-1 (YYIRT1) and estimated  $VO_2$  max in the intervention group (IG) as opposed to the control group (CG) which showed minimal change. These findings reflect and expand upon earlier circuit training research in that they highlight the effectiveness of circuit training in improving female cricketers' cardiovascular fitness.

In addition to the increases in aerobic fitness, the intervention positively affected sleep quality, physical activity level, and sustained sleep behaviors, indicated by the significant change of lower PSQI scores and higher IPAQ scores. The likely reasons for enhanced sleep quality included improved recovery and training readiness. In the context of the current study, enhanced conditioning ensured high engagement levels with training routines. These findings support prior research that has noted the effectiveness of exercise training in improving sleep and physical activity levels in athletes (Alnawwar et al., 2023; Fullagar et al., 2015; Hamlin et al., 2021). The inclusion of these measures underscores the multifaceted benefits of circuit training, extending beyond cardiorespiratory fitness to encompass broader aspects of athlete well-being.

The noted gains in YYIRT1 distance and  $VO_2$  max are consistent with prior research confirming the benefits of high-intensity circuit and interval training on an athlete's aerobic fitness. The effects of high-intensity interval training on aerobic power and endurance are well-documented (Buchheit & Laursen, 2013; Weston et al., 2014). Particularly, the work of Darmo Umar and Tomoliyus (2018) and Muryadi et al. (2022) documented marked improvements in aerobic fitness after circuit training in team sport athletes, which supports our results (Darmo Umar & Tomoliyus, 2018). In a similar vein, Saibya et al. (2024) reported recently the benefits of circuit training, noting enhanced cardiovascular fitness and intermittent exercise performance, which underscores the versatility of such approaches across athletic training (Saibya et al., 2024).



The results demonstrate statistically significant group  $\times$  time interaction effects for both YYIRT1 distance ( $F(1, 58) = 26.87, p < .001, \text{partial } \eta^2 = .32$ ) and  $\text{VO}_2 \text{ max}$  ( $F(1, 58) = 18.52, p < .001, \text{partial } \eta^2 = .24$ ). These results are strong evidence that the observed changes in aerobic fitness are the result of the circuit training intervention, rather than general training or external factors. This finding addresses limitations of prior research where improvements could not definitively be linked to the training intervention due to inadequate statistical analyses (e.g., lack of interaction tests). Our approach strengthens causal inferences and aligns with the recommendations by Harold et al. (2013) and Fatma Hilal et al. (2024) on the necessity of rigorous statistical methodologies to discern training effects in applied sports science research.

The primary measurement YYIRT1 (Yo-Yo Intermittent Recovery Test Level-1) has been used to measure aerobic fitness for many years and it has been shown that it can measure fitness levels that require interval training due to its sensitivity and specificity. Krustup et al., (2003) studied its assessment in soccer and cricket and proved that YYIRT1 has a high correlation with endurance performance in these sports which require repeated bursts of high-intensity effort with short breaks in between. . Bobby & Badhan (2023) studied YYIRT1's effectiveness on women cricketers and pointed out that it helps to assess training changes and forecast performance during competitions. Our study also confirmed its effectiveness in women cricketers and we support its use in field-based, low-cost fitness evaluation.

This study also illustrates the importance of physiological changes going alongside specific cricket training for women which has rarely been researched. Female athletes are distinguished by their physiological and hormonal makeup which changes the way they may react to training (Santos et al., 2022; Shephard, 2000). For example, women as opposed to men, have a delayed recovery rate and different patterns of nutrients and energy use, muscle fibres, and even cellular structure such as myocytes (Ruby & Robergs, 1994).

Tailoring training interventions to accommodate these differences can maximize performance gains while reducing injury risk and overtraining. Our study contributes to this emerging discourse by providing empirical evidence that female cricketers benefit significantly from structured circuit training, thus supporting calls for more sex-specific sport science research and training program development (Bobby et al., 2025).

From a practical perspective, the findings have significant implications for coaching and athlete development in women's cricket, particularly in contexts with limited access to sophisticated training equipment or facilities. Circuit training offers a versatile, time-efficient method that can be adapted to various fitness levels and resource constraints (Santos et al., 2022). By improving aerobic fitness, players can better sustain performance during prolonged matches, recover more quickly between high-intensity efforts, and reduce fatigue-related errors, all critical factors in competitive cricket (Noakes & Durandt, 2000). Thus, integrating circuit training into routine conditioning programs can enhance overall team performance and individual player longevity.

### **Limitation**

Despite these promising findings, several limitations should be acknowledged. First, the study lacked objective (e.g., heart rate monitoring, blood lactate concentration) and subjective (e.g., rating of perceived exertion) measures to quantify the intensity of the circuit training sessions. This limitation restricts the ability to confirm whether training consistently reached the targeted aerobic thresholds known to elicit  $\text{VO}_2 \text{ max}$  adaptations. Second, while the four-week intervention was sufficient to produce measurable improvements, its relatively short duration limits conclusions about long-term adaptations and sustainability of benefits. Third, the sample was restricted to national-level female cricketers from Bangladesh, which may limit generalizability to other populations or levels of play. Finally, while PSQI and IPAQ provided valuable insights into sleep and activity levels, these self-reported measures may be subject to recall bias.

Future studies should incorporate objective workload monitoring, extend the intervention duration, and explore additional performance and recovery metrics, including hormonal markers, sleep tracking devices, and psychological assessments. Expanding research to diverse cohorts will further clarify the broader applicability of circuit training in enhancing both performance and well-being among female athletes.



## Conclusions

The results of the study reveals that four-week circuit training program significantly improves aerobic fitness, sleep quality, and physical activity levels in female cricket players compared to regular practice alone. The intervention led to substantial gains in Yo-Yo IR1 performance and VO<sub>2</sub> max, alongside marked reductions in PSQI scores and increases in IPAQ scores, indicating enhanced recovery and engagement with training routines. These findings highlight circuit training as a practical, time-efficient, and highly effective conditioning method for female cricketers, particularly in resource-limited settings. Incorporating such evidence-based training strategies into women's cricket programs may optimize player performance and overall well-being. Future research with longer intervention periods, objective workload monitoring, and larger, more diverse samples is recommended to strengthen these conclusions and expand their applicability.

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