Effect of Circuit Training with and Without External Resistance in Combination with Skill-Based Conditioning on Selected Game-Specific Fitness and Skills of Under-19 Badminton Players

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Abstract:
This study investigated the differential effects of circuit training with and without external resistance, when combined with skill-based conditioning, on selected game-specific fitness parameters (agility, speed, explosive power) and badminton
skills (short serve accuracy, smash power, net play precision) of under-19 badminton players. Forty-five male under-19 badminton players (mean age 17.2 ± 0.8 years) were randomly assigned to three groups: Circuit Training with External Resistance (CT+R), Circuit Training without External Resistance (CT-R), and a Control Group (CG) that followed their regular badminton training. All three groups underwent a 12-week training program, with the experimental groups incorporating circuit training (either with or without resistance) alongside their regular skill-based badminton practice.
Pre- and post-tests were conducted to assess agility (T-test), speed (30-meter sprint), explosive power (standing long jump), short serve accuracy (number of successful serves within target), smash power (smash velocity using radar gun), and net play precision (number of successful drop shots within target). The results revealed statistically significant improvements in agility, speed, explosive power, short serve accuracy, smash power, and net play precision in both the CT+R and CT-R groups compared to the CG. Furthermore, the CT+R group showed significantly greater improvements in speed and explosive power compared to the CT-R group.
However, no significant differences were observed between the two circuit training groups for agility and the selected badminton skills. These findings suggest that both circuit training protocols, when integrated with skill-based conditioning, are effective in enhancing game-specific fitness and skills in young badminton players. The addition of external resistance in circuit training appears to provide an added advantage for improving speed and explosive power.

Keywords: Badminton, Circuit Training, External Resistance, Skill-Based Conditioning, Game-Specific Fitness, Badminton Skills, Under-19 Players.

Introduction:
Badminton is a high-intensity intermiflent sport demanding a unique blend of physical fitness components

such as agility, speed, explosive power, and endurance, coupled with precise technical skills like serving, smashing, and net play (Cabello Manrique & González-Badillo, 2003). For under-19 players transitioning to higher levels competition, optimizing both their physical conditioning and technical proficiency is crucial for success. Traditional badminton training often involves extensive on-court practice focusing on skill development. However, incorporating structured off-court conditioning programs can significantly enhance the physical aflributes necessary for improved game performance (Chin et al., 2014). Circuit training, characterized by a series of exercises performed in succession with minimal rest, has been shown to be an effective method for developing multiple fitness components simultaneously (Geflman & Pollock, 1981).
The inclusion of external resistance in circuit training can further augment strength and power development, potentially leading to greater improvements in speed and explosive movements crucial in badminton (Suchomel et al., 2016). However, the effectiveness of circuit training with and without external resistance, when specifically combined with skill-based badminton conditioning, on the game-specific fitness and skills of young players warrants further investigation. Therefore, this study aimed to compare the effects of a 12-week circuit training program with and without external resistance, integrated with regular skill-based badminton training, on selected game-specific fitness parameters (agility, speed, explosive power) and badminton skills (short serve accuracy, smash power, net play precision) of under-19 male badminton players.

Literature Review:
Previous research has highlighted the importance of various fitness components in badminton performance. Agility is essential for court coverage and quick directional changes (Abián-Vicén et al., 2013), while speed is critical for reacting to shots and covering the court efficiently (Phomsoupha & Laffaye, 2015). Explosive power in the legs and arms is fundamental for jumping, lunging, and executing powerful strokes like the smash (Yüksel et al., 2017).
Circuit training has been demonstrated to improve cardiovascular fitness, muscular endurance, strength, and power in various athletic populations (Anderson et al., 2010). Studies have also shown the benefits of circuit training for badminton players, leading to improvements in agility, speed, and power (Chin et al., 2014; Ismail et al., 2017).
The use of external resistance in training has been extensively studied for its impact on strength and power development (Suchomel et al., 2016). While resistance training is often incorporated into badminton conditioning programs, research specifically comparing circuit training with and without external resistance in conjunction with skill-based practice on game-specific outcomes in young badminton players is limited.
Skill-based conditioning, which involves incorporating fitness exercises that mimic the movements and demands of the sport, is considered crucial for translating fitness gains into improved game performance (Mujika, 2000). Combining general fitness training like circuit training with specific badminton skill practice is hypothesized to be more effective than either approach alone.
This study builds upon existing literature by specifically examining the differential effects of circuit training with and without external resistance, when integrated with regular on-court skill training, on a comprehensive set of game-specific fitness and skill parameters relevant to under-19 badminton players.

Methodology:

Participants:

Forty-five male under-19 badminton players (mean age 17.2 ± 0.8 years, mean height 1.75 ± 0.06 m, mean weight 65.3 ± 5.7 kg) from local badminton academies were recruited for the study. Participants had at least three years of badminton playing experience and were actively involved in regular badminton training (3-4 sessions per week). Wriflen informed consent was obtained from the participants and their parents/guardians prior to their participation. Participants were randomly assigned to one of three groups:

- **Circuit Training with External Resistance (CT+R) Group (n=15):** Participated in a circuit training program incorporating external resistance exercises in addition to their regular badminton training.
- **Circuit Training without External Resistance (CT-R) Group (n=15):** Participated in a circuit training program using bodyweight exercises in addition to their regular badminton training.
- **Control Group (CG) (n=15):** Continued their regular badminton training program without any additional circuit training.

Procedures:

The study employed a pre-test post-test control group design. Baseline measurements for all selected fitness and skill parameters were taken one week prior to the commencement of the training program. The 12-week training intervention was conducted three times per week, with each session lasting approximately 60 minutes
for the experimental groups (30 minutes of circuit training followed by their regular badminton practice). The control group continued with their usual badminton training schedule. Post-tests for all parameters were conducted within one week following the completion of the 12-week training program, using the same protocols as the
pre-tests.

Training Programs:

- **Circuit Training Programs (CT+R and CT-R):** Both circuit training programs consisted of 6-8 stations targeting major muscle groups and incorporating movements relevant to badminton. Each circuit was performed for 3 rounds with 60 seconds of work at each station followed by 60 seconds of rest between stations and 2 minutes of rest between rounds. The exercises were progressed in terms of intensity (load or repetitions) over the 12 weeks.
  - **CT+R Group:** Included exercises such as squats with dumbbells, lunges with dumbbells, bench press, overhead press, bent-over rows with dumbbells, calf raises with weights, medicine ball throws, and resisted sprints. The initial resistance was set at 60-70% of their estimated 1 repetition maximum (1RM) and progressively increased.
  - **CT-R Group:** Included bodyweight exercises such as squats, lunges,
push-ups, pull-ups (assisted if needed), calf raises, burpees, jumping jacks, and mountain climbers. Exercise intensity was progressed by increasing repetitions or reducing rest periods.
- **Control Group (CG):** Continued their regular badminton training program, which typically included on-court drills focusing on stroke technique, footwork paflerns, game simulations, and light conditioning exercises.
- **Skill-Based Conditioning (Integrated into both experimental groups):** Both the CT+R and CT-R groups incorporated short bursts of badminton-specific movements and drills within their circuit

training sessions or immediately following. These included shadow badminton drills mimicking a flacking and defensive movements, shuffle cock pickups with agility focus, and short court sprints.

Data Collection:

- **Agility:** T-test was used to measure agility, with the time taken to complete the course recorded in seconds.
- **Speed:** 30-meter sprint test was conducted, and the time taken to cover the distance was recorded in seconds.
- **Explosive Power:** Standing long jump test was performed, and the longest distance jumped (in centimetres) out of three trials was recorded.
- **Short Serve Accuracy:** Players performed 10 short serves aimed at a designated target area in the front service box. The number of successful serves landing within the target area was recorded.
- **Smash Power:** Players performed 10 overhead smashes directed towards a designated target area. The velocity of each smash was measured using a radar gun (Stalker Sport 2), and the average velocity (in km/h) was recorded.
- **Net Play Precision:** Players performed 10 drop shots from the backcourt aimed at a designated target area near the net. The number of successful drop shots landing within the target area was recorded.

Statistical Analysis:

Descriptive statistics (mean and standard deviation) were calculated for all variables at pre- and post-tests for each group. A two-way repeated measures analysis of variance (ANOVA) was used to analyze the interaction effect of group (CT+R, CT-R, CG) and time (pre-test, post-test) on the measured variables. Where significant interaction effects were found, Bonferroni post-hoc tests were used to determine the specific differences between groups and time points. The alpha level for statistical significance was set at $p < 0.05$.

Results:

The descriptive statistics for all measured variables at pre- and post-tests for each group are presented in Table 1.

Table 1: Descriptive Statistics (Mean ± SD) for Pre- and Post-Test Variables

Variable	Group	Pre-Test	Post-Test
Agility (seconds)	CT+R	10.85 ± 0.32	10.42 ± 0.25*
	CT-R	10.91 ± 0.35	10.50 ± 0.28*
	CG	10.88 ± 0.30	10.82 ± 0.29
Speed (30m, seconds)	CT+R	4.32 ± 0.15	4.10 ± 0.12*#
	CT-R	4.35 ± 0.14	4.18 ± 0.13*
	CG	4.33 ± 0.16	4.30 ± 0.15
Explosive Power (cm)	CT+R	245.6 ± 12.5	262.3 ± 14.1*#

	CT-R	243.8 ± 11.9	255.1 ± 13.3*
	CG	244.5 ± 12.1	246.2 ± 11.8
Short Serve Accuracy (#)	CT+R	6.2 ± 1.1	7.8 ± 1.0*
	CT-R	6.1 ± 1.0	7.5 ± 0.9*
	CG	6.3 ± 1.2	6.5 ± 1.1
Smash Power (km/h)	CT+R	85.4 ± 3.8	91.2 ± 4.1*
	CT-R	84.9 ± 3.5	90.1 ± 3.9*
	CG	85.1 ± 3.7	85.8 ± 3.6
Net Play Precision (#)	CT+R	5.9 ± 0.9	7.3 ± 0.8*
	CT-R	5.8 ± 0.8	7.1 ± 0.7*
	CG	6.0 ± 1.0	6.2 ± 0.9

*Significantly different from pre-test ($p < 0.05$)
#Significantly different from CT-R group at post-test ($p < 0.05$)

The two-way repeated measures ANOVA revealed significant interaction effects (Group x Time) for agility ($F(2, 42) = 10.52$, $p < 0.001$), speed ($F(2, 42) = 15.87$, $p < 0.001$), explosive power ($F(2, 42) = 12.34$, $p < 0.001$), short serve accuracy ($F(2, 42) = 8.76$, $p < 0.001$), smash power ($F(2, 42) = 7.91$, $p < 0.001$), and net play precision ($F(2, 42) = 9.12$, $p < 0.001$).
Post-hoc analysis showed that both the CT+R and CT-R groups demonstrated significant improvements ($p < 0.05$) in all measured fitness and skill parameters from pre- to post-test. The CG showed no significant changes in any of the variables over the 12-week period.
Furthermore, the CT+R group exhibited significantly greater improvements in speed ($p < 0.05$) and explosive power ($p < 0.05$) compared to the CT-R group at the post-test. However, no significant differences were found between the CT+R and CT-R groups for agility, short serve accuracy, smash power, and net play precision.

Discussion:
The findings of this study indicate that a 12-week circuit training program, both with and without external resistance, when combined with regular skill-based badminton training, is effective in improving selected game-specific fitness components (agility, speed, explosive power) and badminton skills (short serve accuracy, smash power, net play precision) in under-19 male badminton players. The control group, which only continued their regular badminton training, showed no significant improvements in any of the measured variables, highlighting the positive impact of incorporating circuit training.
The significant improvements observed in agility in both experimental groups can be aflributed to the dynamic nature of circuit training exercises, which often involve multi-directional movements and changes in direction, mimicking the demands of badminton footwork. The enhanced speed in both groups likely resulted from the overall conditioning effect of circuit training, improving lower body power and coordination.
The CT+R group demonstrated significantly greater improvements in speed and explosive power compared to the CT-R group. This suggests that the inclusion of external resistance in circuit training

provides an added stimulus for developing strength and power, which are crucial for generating faster movements and more explosive actions on the court. These findings align with previous research emphasizing the benefits of resistance training for enhancing speed and power in athletes (Suchomel et al., 2016).

Both circuit training protocols led to significant improvements in the selected badminton skills. The enhanced physical fitness likely contributed to improved technical execution and consistency. For instance, increased leg power could allow players to achieve befler positioning for serves and smashes, while improved agility could facilitate befler court coverage for net play. The integration of skill-based conditioning within the circuit training sessions might have further facilitated the transfer of fitness gains to sport-specific skills.

Interestingly, no significant differences were observed between the CT+R and CT-R groups in terms of improvements in agility and the selected badminton skills. This suggests that while external resistance provides an advantage for speed and explosive power, bodyweight circuit training combined with skill-based conditioning is equally effective in enhancing agility and the specific technical skills assessed in this study. This could be due to the fact that the specific movements and coordination required for these skills might be adequately addressed through bodyweight exercises and the integrated skill-based drills.

Conclusion:

This study demonstrates that both circuit training with and without external resistance, when implemented in conjunction with skill-based conditioning, are effective strategies for enhancing game-specific fitness and selected badminton skills in under-19 male badminton players. The inclusion of external resistance in circuit training appears to provide an additional benefit for improving speed and explosive power. However, bodyweight circuit training combined with skill-based conditioning is equally effective in improving agility and the specific badminton skills assessed.

Practical Implications:

The findings of this study have practical implications for coaches and trainers working with young badminton players. Incorporating circuit training, either with or without external resistance, alongside regular badminton practice can be a valuable approach to improve both physical fitness and technical skills. Coaches should consider the specific training goals and available resources when deciding whether to include external resistance in circuit training programs. For players aiming for significant gains in speed and explosive power, resistance-based circuit training may be more beneficial. However, bodyweight circuit training combined with skill-based drills offers a viable and effective alternative for improving overall game-specific fitness and skills, particularly when access to resistance training equipment is limited.

Limitations and Future Directions:

This study was limited to male under-19 badminton players from a specific region. Future research could explore the effects of these training protocols on female players and different age groups. Additionally, investigating the long-term effects of these training programs on performance and injury risk would be valuable. Further studies could also examine the optimal combination of circuit training and skill-based conditioning parameters, such as training volume, intensity, and exercise selection, to maximize training

adaptations in badminton players. Finally, exploring the role of other training modalities, such as plyometrics or eccentric training, in enhancing
badminton-specific fitness and skills could provide further insights for optimizing training programs.

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