International Journal of Educational Review, Law & Social Sciences (IJERLAS)

International Journal of Educational Review, Law And Social Sciences (IJERLAS Journal) | ISSN (e): 2808-487X
Volumes 5 No. 6 (2025)

Training-Induced Adaptations: A Comparative Study of Aerobic Capacity, Muscular Endurance, and Cricket-Specific Performance in Adolescent Athletes

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Received	: 01 August 2025	Published	: 01 October 2025
Revised	: 20 August 2025	DOI	: https://doi.org/10.54443/ijerlas.v5i6.4198
Accepted	: 23 September 2025	Link Publish	: https://radjapublika.com/index.php/IJERLAS

Abstract

This study investigates training-induced adaptations in aerobic capacity, muscular endurance, and cricket-specific performance among adolescent athletes aged 13–18 years. A randomized controlled trial was conducted with 60 male and female cricketers assigned to three groups: aerobic training (AT), resistance training (RT), or combined training (CT) for 12 weeks. Aerobic capacity was assessed via VO2max testing, muscular endurance through push-up and plank tests, and cricket-specific performance via batting accuracy, bowling speed, and fielding agility drills. Results indicated significant improvements in VO2max ($p < 0.01$) for the AT group compared to RT, with CT showing moderate gains. Muscular endurance improved significantly in the RT and CT groups ($p < 0.05$), particularly in upper-body strength. Cricket-specific performance, notably bowling speed and fielding agility, showed the greatest improvement in the CT group ($p < 0.01$), suggesting synergistic effects of combined training. No significant differences were observed in batting accuracy across groups. These findings highlight the efficacy of tailored training protocols in enhancing physiological and sport-specific outcomes in adolescent cricketers. The results have implications for designing age-appropriate training programs to optimize performance and support talent development in cricket. Further research should explore long-term adaptations and include diverse populations.

Keywords: ***Adolescent athletes, aerobic capacity, muscular endurance, cricket performance, training adaptations, sports physiology, VO2max, resistance training, combined training, talent development.***

Introduction

Since it affects both short-term performance and long-term athletic potential, the physiological development of teenage athletes is an important topic of research in sports science. Rapid physical, hormonal, and neuromuscular changes that occur during adolescence, which usually lasts from 13 to 18 years of age, make this population particularly receptive to training interventions (Armstrong & McManus, 2017). Understanding how training regimens impact these qualities is crucial for maximizing performance and promoting talent development in sports like cricket, which require a blend of muscular strength, aerobic endurance, and sport-specific skills. In order to fill a gap in the literature about the relative effectiveness of various training modalities in this age group, this study compares training-induced adaptations in aerobic capacity, muscular endurance, and cricket-specific performance in adolescent athletes.Cricket is a physically taxing sport that calls for a combination of muscular endurance for repetitive motions like bowling, explosive power for batting and sprinting, and aerobic fitness for extended fielding (Noakes & Durandt, 2000). Optimal oxygen uptake (VO2max), a common indicator of aerobic capacity, is essential for maintaining performance over extended games, especially in Test cricket formats where players may be active for several hours (Johnstone & Ford, 2010). According to studies, aerobic exercise can raise VO2max by boosting cardiovascular efficiency and mitochondrial density. Because of their developing physiologies, adolescents frequently show more flexibility in these adaptations (Baquet et al., 2003). For example, aerobic training programs lasting 8–12 weeks significantly increased VO2max in adolescents by 5–15%, depending on intensity and frequency, according to a meta-analysis conducted by Baquet et al. (2003).In cricket, muscular endurance—which is the capacity to maintain repeated muscle contractions over time—is equally important, especially for bowlers who frequently execute high-intensity actions (Stretch et al., 2000). Because of their continued neuromusculardevelopment, adolescents respond strongly to resistance training, which has been demonstrated to improve muscular endurance by increasing motor unit recruitment and muscle fiber efficiency (Faigenbaum et al., 2009). According to a 2009 study by Faigenbaum et al., adolescents who received 8 weeks of resistance training saw a 20–30% increase in muscular endurance during exercises like push-ups and sit-ups, with the benefits carrying over to tasks specific to their sport. It is still unclear how much of these improvements translate into cricket-specific abilities like fielding agility or bowling accuracy.Technical Abilities like batting, bowling, and fielding are all part of cricket-specific performance, which calls for a blend of athleticism and sport-specific techniques. Although resistance and aerobic training increase overall fitness, it is unclear how these training methods directly affect cricket-specific results, especially in teenagers (Woolmer et al., 2008). For instance, Bartlett (2003) observed that fielding drills enhanced young cricket players' agility and reaction time; however, it is unclear how combining aerobic and resistance training would affect these abilities. By addressing both energy systems and neuromuscular demands, combined training that incorporates resistance and aerobic exercises may have synergistic benefits and result in better sport-specific outcomes (Leveritt et al., 1999). There are, however, few studies comparing these training methods in teenage cricket players; Instead, most of the research focuses on adult athletes or single-modality interventions. Adolescents' distinct physiological traits, such as growth spurts and hormonal shifts, call for specialized training methods.

Generalized adult training regimens are not the best because pubertal development affects muscle mass, aerobic capacity, and recovery rates (Armstrong & McManus, 2017). For example, testosterone spikes during puberty promote muscle growth in response to resistance training; however, overtraining may cause harm to developing musculoskeletal systems (Lloyd et al., 2016). Additionally, teenagers may not be as motivated or as committed to their trainingas adults, so engaging and sport-specific programs are necessary to keep them involved (Fraser-Thomas et al., 2008). Given its complex physical requirements and growing emphasis on early talent identification, cricket, a sport with rising youth participation worldwide, offers an excellentsetting for researching these adaptations (Stretch et al., 2000). Few studies have systematically compared the effects of aerobic, resistance, and combined training on both physiological and sport-specific outcomes in cricket, despite the growing body of research on adolescent athletes. The literature currently in publication frequently concentrates on individual outcomes, like strength or VO2max, without discussing how they interact or relate to performance (Johnstone & Ford, 2010; Faigenbaum et al., 2009). Furthermore, although a lot of research has been done been done on adult cricket players, the distinct developmental stage of adolescents calls for further study in order to guide evidence-based training methods. By investigating the effects of various training regimens on adolescent athletes' aerobic capacity, muscular endurance, and cricket-specific performance, this study seeks to close this knowledge gap and offer guidance to coaches and sports scientists.

Objectives of the Study

1. To compare the effects of aerobic training, resistance training, and combined training on aerobic capacity, muscular endurance, and cricket-specific performance in adolescent cricketers aged 13–18 years over a 12-week intervention period.
2. To determine the extent to which improvements in aerobic capacity and muscular endurance contribute to enhanced cricket-specific skills, such as batting accuracy, bowling speed, and fielding agility, in adolescent athletes.

Hypotheses of the Study

1. Aerobic training will result in significantly greater improvements in aerobic capacity (VO2max) compared to resistance training, while combined training will yield intermediate improvements in adolescent cricketers.
2. Combined training will lead to significantly greater enhancements in cricket-specific performance (e.g., bowling speed and fielding agility) compared to aerobic or resistance training alone, due to synergistic effects on both aerobic capacity and muscular endurance.

Methods

60 teenage cricket players, both male and female, between the ages of 13 and 18, were selected from nearby cricket academies for this randomized controlled trial. They had to have played competitive cricket for at least a year and not have suffered any recent injuries. For 12 weeks, participants were divided into three groups (n=20 each) at random and

given three 60-minute sessions per week under the supervision of certified coaches: aerobic training (AT), resistance training (RT), or combined training (CT). The CT group alternated aerobic and resistance training, the RT group performed strength exercises (such as push-ups and squats) at 60–80% 1RM, and the AT group ran-based exercises at 70–85% HR max. Pre- and post-intervention tests were used to measure aerobic capacity using VO2max on a treadmill, muscular endurance using push-up and plank tests, and cricket-specific performance using batting accuracy (target-hitting task), bowling speed (radar gun), and fielding agility (shuttle-run drill). Every test was carried out with standardized tools, and its validity and reliability had already been established. Two-way ANOVA was used to compare group and time effects, and post-hoc Tukey tests and effect sizes (Cohen's d) were calculated. The threshold for significance was set at $p < 0.05$. Participants' and guardians' informed Consent was obtained, and ethical approval was acquired.

Analysis

Table 1: Baseline Characteristics of Participants by Training Group

Variable	Aerobic Training (AT) (n=20)	Resistance Training (RT) (n=20)	Combined Training (CT) (n=20)
Age (years)	15.2 ± 1.3	15.4 ± 1.2	15.3 ± 1.4
Height (cm)	165.8 ± 6.5	166.2 ± 7.1	165.5 ± 6.8
Weight (kg)	58.4 ± 5.2	59.1 ± 5.6	58.7 ± 5.4
BMI (kg/m²)	21.3 ± 1.8	21.5 ± 1.9	21.4 ± 1.7
Training Experience (years)	2.1 ± 0.8	2.2 ± 0.7	2.1 ± 0.9
Sex (Male/Female)	12/8	13/7	12/8

Source: Computed From Primary Data

Table 1 shows that the aerobic training (AT), resistance training (RT), and combined training (CT) groups were well-matched at baseline, with no significant differences in age (15.2–15.4 years), height (165.5–166.2 cm), weight (58.4–59.1 kg), BMI (21.3–21.5 kg/m²), training experience (2.1–2.2 years), or sex distribution (12–13 males, 7–8 females per group). The lack of significant differences ($p > 0.05$) ensures that any post-intervention outcomes are attributable to the training protocols rather than baseline disparities, establishing a robust foundation for comparing group responses to the 12-week intervention.

Table 2: Pre- and Post-Intervention Aerobic Capacity (VO2max)

Group	Pre-Intervention	Post-Intervention	Change (%)	p-value	Effect Size (Cohen's d)
Aerobic Training (AT)	42.5 ± 4.2	48.3 ± 4.5	13.6	<0.001	1.34
Resistance Training (RT)	42.8 ± 4.0	43.5 ± 4.1	1.6	0.412	0.17
Combined Training (CT)	42.6 ± 4.3	46.2 ± 4.4	8.5	<0.01	0.83

Source: Computed From Primary Data

Table 2 indicates that the AT group achieved the greatest improvement in VO2max (13.6%, $p < 0.001$, $d = 1.34$), followed by the CT group (8.5%, $p < 0.01$, $d = 0.83$), while the RT group showed minimal change (1.6%, $p = 0.412$, $d = 0.17$). The significant between-group differences (AT vs. RT, $p < 0.001$; AT vs. CT, $p < 0.05$) suggest that aerobic-focused training is most effective for enhancing aerobic capacity in adolescent cricketers, with combined training providing moderate benefits, likely due to its partial aerobic component.

Table 3: Pre- and Post-Intervention Muscular Endurance

Group	Test	Pre-Intervention	Post-Intervention	Change (%)	p-value	Effect Size (Cohen's d)
Aerobic Training (AT)	Push-ups	22.4 ± 5.1	24.1 ± 5.3	7.6	0.082	0.33
	Plank (s)	65.2 ± 12.3	68.7 ± 12.8	5.4	0.134	0.28
Resistance Training (RT)	Push-ups	23.1 ± 4.9	29.8 ± 5.2	29.0	<0.001	1.31
	Plank (s)	66.4 ± 11.9	82.3 ± 12.5	23.9	<0.001	1.29
Combined Training (CT)	Push-ups	22.8 ± 5.0	28.2 ± 5.4	23.7	<0.001	1.03
	Plank (s)	65.8 ± 12.1	78.9 ± 12.7	19.9	<0.01	1.05

Source: Computed From Primary Data

Table 3 reveals that the RT group exhibited the largest gains in muscular endurance, with push-up repetitions increasing by 29.0% ($p < 0.001$, $d = 1.31$) and plank hold time by 23.9% ($p < 0.001$, $d = 1.29$). The CT group also showed significant improvements (push-ups: 23.7%, $p < 0.001$, $d = 1.03$; plank: 19.9%, $p < 0.01$, $d = 1.05$), while the AT group had non-significant changes (push-ups: 7.6%, $p = 0.082$; plank: 5.4%, $p = 0.134$). Between-group comparisons confirm that RT and CT significantly outperformed AT ($p < 0.01$), indicating that resistance-based training is critical for enhancing muscular endurance in this population.

Table 4: Pre- and Post-Intervention Cricket-Specific Performance.

Group	Test	Pre-Intervention	Post-Intervention	Change (%)	p-value	Effect Size (Cohen's d)
Aerobic Training (AT)	Batting Accuracy (%)	68.5 ± 8.2	70.2 ± 8.4	2.5	0.214	0.21
	Bowling Speed (km/h)	105.3 ± 7.1	107.1 ± 7.3	1.7	0.156	0.25
	Fielding Agility (s)	12.8 ± 1.4	12.3 ± 1.3	-3.9	<0.05	0.37
Resistance Training (RT)	Batting Accuracy (%)	69.1 ± 8.0	70.8 ± 8.3	2.5	0.198	0.21
	Bowling Speed (km/h)	106.2 ± 6.9	110.5 ± 7.0	4.0	<0.01	0.62
	Fielding Agility (s)	12.7 ± 1.5	12.1 ± 1.4	-4.7	<0.01	0.41
Combined Training (CT)	Batting Accuracy (%)	68.8 ± 8.1	70.5 ± 8.5	2.5	0.204	0.20
	Bowling Speed (km/h)	105.9 ± 7.0	112.4 ± 7.2	6.1	<0.001	0.91
	Fielding Agility (s)	12.9 ± 1.4	11.8 ± 1.3	-8.5	<0.001	0.80

Source: Computed From Primary Data

Table 4 demonstrates that the CT group achieved the most substantial improvements in cricket-specific performance, with bowling speed increasing by 6.1% ($p < 0.001$, $d = 0.91$) and fielding agility improving by 8.5% ($p < 0.001$, $d = 0.80$). The RT group showed moderate gains (bowling speed: 4.0%, $p < 0.01$, $d = 0.62$; fielding agility: 4.7%, $p < 0.01$, $d = 0.41$), while the AT group had smaller improvements (bowling speed: 1.7%, $p = 0.156$; fielding agility: 3.9%, $p < 0.05$). Batting accuracy showed minimal, non-significant changes across all groups (2.5%, $p > 0.05$). These findings suggest that combined training optimizes sport-specific outcomes, particularly for dynamic tasks like bowling and fielding.

Table 5: Between-Group Statistical Comparisons

Outcome	AT vs. RT (p-value)	AT vs. CT (p-value)	RT vs. CT (p-value)
VO2max (mL/kg/min)	<0.001	<0.05	<0.01
Push-ups (repetitions)	<0.001	<0.01	0.142
Plank (seconds)	<0.001	<0.01	0.178
Batting Accuracy (%)	0.876	0.912	0.934
Bowling Speed (km/h)	<0.05	<0.01	<0.05
Fielding Agility (s)	0.214	<0.01	<0.05

Source: Computed From Primary Data

Table 5 summarizes that the AT group significantly outperformed RT in VO2max ($p < 0.001$), while CT showed intermediate improvements (AT vs. CT, $p < 0.05$; RT vs. CT, $p < 0.01$). For muscular endurance, RT and CT significantly surpassed AT ($p < 0.01$), with no significant difference between RT and CT ($p > 0.05$). In cricket-specific performance, CT outperformed both AT and RT in bowling speed and fielding agility ($p < 0.05$), while batting accuracy showed no significant group differences ($p > 0.05$). These results highlight the specificity of training effects, with AT enhancing aerobic capacity, RT and CT improving muscular endurance, and CT excelling in sport-specific performance.

Results

the 12-week intervention produced different training-induced adaptations in the adolescent cricket players (13–18 years old) in the aerobic training (AT), resistance training (RT), and combined training (CT) groups (n=20 each). ensured by baseline characteristics that revealed no significant differences in age, height, weight, BMI, training experience, or sex distribution ($p > 0.05$) (Table 1). of aerobic capacity, the AT group had the biggest increase in VO2max (13.6%, $p < 0.001$), followed by CT (8.5%, 0.01), and RT had the least change (1.6%, $p = 0.412$) (Table 2). was a significant improvement in muscular endurance in the RT group (push-ups: 29.0%, $p < 0.001$; plank: 23.9%, $p < 0.001$) and CT group (push-ups: 23.7%, $p < 0.001$; plank: 19.9%, $p < 0.01$), but not in the AT group (push-ups: 7.6%, $p = 0.082$; plank: 5.4%, $p = 0.134$) (Table 3). to cricket-specific performance, the CT group increased their bowling speed (6.1%, $p < 0.001$) and fielding agility (8.5%, $p < 0.001$) the most, followed by RT (bowling speed: 4.0%, $p < 0.01$; fielding agility: 4.7%, $p < 0.01$) and AT (bowling speed: 1.7%, = 0.156; fielding agility: 3.9%, $p < 0.05$). There superiority of AT in VO2max ($p < 0.001$ vs. RT), the advantage of RT and CT in muscular endurance ($p < 0.01$ vs. AT), and the superiority of CT in bowling speed and fielding agility ($p < 0.05$ vs. RT and AT) were all confirmed by between-group comparisons (Table 5). There were no reported dropouts or missing data.

Discussion

The findings from this 12-week randomized controlled trial on adolescent cricketers (aged 13–18 years) demonstrate distinct training-induced adaptations across aerobic training (AT), resistance training (RT), and combined training (CT) groups, aligning with the study's objectives and hypotheses. The significant improvement in VO2max in the AT group (13.6%, $p < 0.001$) compared to RT (1.6%, $p = 0.412$) and CT (8.5%, $p < 0.01$) supports prior research indicating that aerobic training enhances mitochondrial biogenesis and cardiovascular efficiency, particularly in adolescents due to their physiological plasticity (Baquet et al., 2003). Conversely, RT and CT markedly improved muscular endurance (push-ups: 29.0% and 23.7%; plank: 23.9% and 19.9%, respectively, $p < 0.01$), consistent with Faigenbaum et al. (2009), who noted neuromuscular adaptations from resistance training in youth. The CT group's superior gains in cricket-specific performance, particularly bowling speed (6.1%, $p < 0.001$) and fielding agility (8.5%, $p < 0.001$), suggest synergistic effects of combining aerobic and resistance training, as proposed by Leveritt et al. (1999). The lack of significant changes in batting accuracy across groups ($p > 0.05$) may reflect the skill's reliance on technical proficiency rather than physiological improvements (Stretch et al., 2000). These results underscore the value of tailored training for adolescent cricketers, with CT offering optimal sport-specific benefits. Limitations include the short intervention duration and male-dominated sample, potentially limiting generalizability. Future research should explore longitudinal effects and include more female athletes to enhance applicability. These findings inform evidence-based training programs for youth cricket, emphasizing combined protocols for holistic performance enhancement.

Conclusion

This 12-week randomized controlled trial demonstrated that aerobic training (AT), resistance training (RT), and combined training (CT) elicited distinct adaptations in adolescent cricketers aged 13–18 years. AT significantly enhanced aerobic capacity (VO2max, 13.6%), RT and CT improved muscular endurance (push-ups: 29.0% and 23.7%; plank: 23.9% and 19.9%), and CT yielded the greatest gains in cricket-specific performance (bowling speed: 6.1%; fielding agility: 8.5%). Batting accuracy showed no significant changes across groups, suggesting its reliance on technical skills. These findings highlight the efficacy of combined training for optimizing both physiological and sport-specific outcomes in adolescent cricketers, offering practical implications for designing age-appropriate training programs to support talent development. Future research should investigate long-term effects and include more diverse populations to enhance generalizability.

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