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Historical Evolution of Aerobic Training Methods and Their Comparative Effects on Body Composition, Physiological and Performance Variables among Under-14 Cricketers

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ABSTRACT

The history of cricket conditioning reflects a gradual transition from traditional endurance-based training methods to scientifically structured aerobic conditioning programmes that integrate exercise physiology and sports science principles. This evolution has significantly influenced modern coaching practices, particularly in the development of young cricketers. Despite these advancements, limited empirical evidence has directly compared the effectiveness of sub-maximal and maximal aerobic training within the same Under-14 cricket population. Therefore, the present study examined the historical evolution of aerobic conditioning in cricket alongside the comparative effects of twelve weeks of sub-maximal and maximal aerobic training on selected body composition, physiological, and performance variables among Under-14 cricketers. Forty-five male Under-14 cricketers (N = 45) were randomly assigned to three equal groups (n = 15): a Sub-Maximal Aerobic Training Group (60–75% maximum heart rate), a Maximal Aerobic Training Group (85–95% maximum heart rate using interval training), and a Control Group that continued regular cricket coaching. Body weight, body mass index, body fat percentage, resting heart rate, VO_2max, heart-rate recovery, 30-yard sprint, Illinois agility, and Yo-Yo Intermittent Recovery Test performance were assessed before and after the twelve-week intervention. Data were analysed using one-way Analysis of Variance (ANOVA), Scheffe's post-hoc test, and Cohen's d effect size. The findings revealed that both experimental groups improved significantly compared with the control group ($p < 0.05$), while the Maximal Aerobic Training Group demonstrated significantly greater improvements in VO_2max, resting heart rate, heart-rate recovery, agility, sprint performance, and Yo-Yo Intermittent Recovery Test scores, with consistently larger effect sizes.

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INTRODUCTION

The history of physical conditioning can be traced to ancient civilisations, where structured exercise formed an essential part of military preparation, physical education, and athletic competition. In Ancient Greece, athletes followed organised training programmes to improve endurance, strength, and speed before participating in the Olympic Games, while the Romans adopted systematic physical training to prepare soldiers for warfare. Over the centuries, physical conditioning gradually evolved from traditional endurance exercises into scientifically planned training programmes based on exercise physiology, biomechanics, and sports medicine. During the twentieth century, rapid developments in sports science transformed athletic preparation by introducing specialised methods of aerobic conditioning, physiological monitoring, and performance evaluation.

Cricket has undergone the same transformation in its approach to training. In the past, cricketers focussed mainly on repeated running, skill development and playing matches to get fitter. But, with the modern game's increased physical requirements has come an emphasis on structured conditioning programmes, which incorporate both aerobic and anaerobically based training as well as technical skill development. Aerobic fitness is a key aspect of successful cricket with players having to repeatedly sprint, change direction, sprint between wickets and be involved in long periods of fielding. For this reason, coaches and sports scientists are constantly looking for the optimal training methods that will improve performance but minimise the potential for overtraining and injury.

There are many different ways to conduct an aerobic conditioning, but two methods have become increasingly significant: sub-maximal aerobic training and maximal aerobic training. Sub-maximal aerobic training is one of the relative safe methods of training for improving cardiovascular endurance, the development of mitochondria, capillaries and fat metabolism through continuous or prolonged exercise, and is generally done at moderate intensities (60–75% of max heart rate). Maximal aerobic training, on the other hand, is usually completed with interval training that focuses on 85-95% of maximum heart rate, and it will offer more stimulus for maximal oxygen uptake (VO_2max), cardiac efficiency, lactate tolerance, and sport specific performance. While maximal training may yield greater physiological adaptations, it also demands more on the cardiovascular, neuromuscular, and psychological aspects of young athletes, and requires careful monitoring and proper recovery.

Although the evolution of cricket training and the widespread use of scientific training has led to numerous studies, there is limited research that has directly compared sub-maximal and maximal aerobic training in the same age group and sport specific context; that of cricket. This disparity is especially pronounced at the Under-14 level, where the interplay of physical and biological maturation and the need to support long-term athletic development (LTAD) are critical and demand appropriately designed training plans. Coaches need to appreciate the comparative benefits of various levels of aerobic intensities in order to provide optimal physiological adaptations in consideration of injury risk and over fatigue.

Hence, this study is undertaken to address the following two objectives: (1) to gain an insight into how aerobic conditioning evolved in cricket, and (2) to investigate the comparative effects of 12 weeks of sub-maximal and maximal aerobic trainings on selected body composition, physiological and performance variables of Under-14 cricketers. The study will combine historical advancements with the current sports science knowledge to give a wider context to the evolution of cricket conditioning and the potential role of the evidence-based training paradigm in supporting the long-term development of young cricketers.

1.1 Rationale for a Comparative Design

A three-group comparative design, incorporating a Sub-Maximal Group, a Maximal Group and a Control Group, was adopted to isolate the differential effects of training intensity from the general effects of participation in any structured aerobic programme, and from natural growth and maturation occurring over the twelve-week study period. This design allows for a more nuanced understanding of dose-response relationships in aerobic training prescription for junior cricketers than either modality could provide in isolation.

1.2 Physiological Basis for Differential Adaptation

The differential adaptations expected between sub-maximal and maximal aerobic training are grounded in exercise physiology principles relating to training intensity and the specificity of physiological stimulus. Maximal-intensity efforts recruit a greater proportion of type IIa muscle fibres, impose greater stress on the cardiovascular system's ability to deliver oxygen at near-peak rates, and elicit greater acute increases in catecholamine and growth hormone secretion, all of which are associated with more pronounced improvements in VO2max and lactate threshold relative to sub-maximal training of equivalent duration. However, these same mechanisms also imply greater recovery demands, higher injury risk through repeated high-velocity movement, and potentially greater psychological aversion among young athletes, all of which must be considered when evaluating the net practical value of maximal-intensity training in this age group.

2. Statement of the Problem

The problem was stated as: "Impact of Sub-Maximal and Maximal Aerobic Training on Selected Body Composition, Physiological and Performance Variables Among Under-14 Years Cricketers." This comparative study sought to determine the differential effects of twelve weeks of sub-maximal versus maximal aerobic training, relative to a non-training control condition, across body composition, physiological and cricket performance domains.

3. Objectives of the Study

- To compare the effects of sub-maximal and maximal aerobic training on selected body composition variables (body weight, BMI, percentage body fat) among Under-14 cricketers.
- To compare the effects of sub-maximal and maximal aerobic training on selected physiological variables (resting heart rate, VO2max, heart-rate recovery) among Under-14 cricketers.

4. Hypotheses

- H1: Both the Sub-Maximal Group and the Maximal Group will show significant pre-to-post improvement on all selected variables compared with the Control Group.
- H2: The Maximal Group will show significantly greater improvement than the Sub-Maximal Group on physiological variables, particularly VO2max and resting heart rate.

5. Delimitations and Limitations

5.1 Delimitations

- The study was delimited to forty-five male Under-14 cricketers (12-14 years) from district-level academies, divided into three groups of fifteen.
- The study was delimited to a twelve-week intervention period with three training sessions per week for both experimental groups.

- The study was delimited to nine variables across three domains, as specified in the objectives.

5.2 Limitations

- Maturational differences (e.g., variation in biological age relative to chronological age) were not individually assessed and may have introduced minor variability.
- VO2max was estimated through field-based shuttle-run testing rather than laboratory gas analysis.
- Adherence to nutrition and sleep recommendations outside of training sessions was self-reported and not independently verified.

6. Review of Related Literature

Comparative studies on training intensity in youths, mostly in football, swimming and athletics, generally show a dose-response relationship between the intensity of the training and the magnitude of the increase of VO2max, with high-intensity interval training (HIIT) often leading to 1.3 to 2 times greater relative improvement in VO2max than a continuous moderate intensity training protocol of the same total training duration. This is in line with the "cardiovascular overload" principle, which states that near-maximal exertion is more effective for central adaptations (such as higher maximal stroke volume and cardiac output).

The youth sports medicine literature, however, also warns about the heightened risk of overuse injuries, especially in growth plates of the lower limb, and that high-intensity training may lead to higher perceived exertion, less enjoyment of training and higher drop-out rates compared to moderate intensity training, particularly if not carefully periodised or monitored. The tug of war between these two forces, higher physiological fitness and increased hazards, is the main practical question posed by comparative studies like the present one.

As far as cricket literature is concerned, studies on bowler workload and fast bowler biomechanics have identified that repeated high intensity bouts of work (which equates with maximal aerobic interval training – MAIT) have been linked to the emergence of fatigue markers and in some cases increase in injury risk, if not balanced by adequate recovery. This evidence helps to confirm that HRR is a valid physiological indicator for the current study, as it is known to be sensitive to ANS fatigue and overtraining. Agility and repeated-sprint performance were included as performance variables in this study and have been demonstrated to be more responsive to interval- versus continuous moderate intensity training in various studies of youth team sports, and this may be due to the greater specificity of high-intensity intervals to the neuromuscular and metabolic requirements of repeated short sprints. The literature offers a solid basis a priori for Hypothesis H3, which states that gains in the Maximal Group will be superior to the Sub-Maximal Group for agility and Yo-Yo intermittent recovery test.

In contrast to this, body composition literature indicates that the amount of energy expended during exercise during a multi-week training programme and not exercise intensity per se is the most important factor when it comes to body composition changes and fat loss as long as the total volume of training and the total amount of energy expended is similar between the different intensity conditions. This suggests that Hypothesis H4, which proposed that there would be similar body composition changes across both the Sub-Maximal and Maximal Groups even though different intensities were used, was supported. The reviewed literature, when considered together, provides a logical theoretical rationale for predicting differential adaptations in physiological and performance variables, and more similar adaptations in body composition, in response to intensity, and highlights an important practical gaps, specifically the comparative risk-benefit profile of maximal-intensity aerobic training within the Under-14 cricket population, which the present study addresses.

7. Methodology

7.1 Research Design

A randomised, three-group (two experimental, one control), pre-test post-test comparative experimental design was employed over a twelve-week period, enabling both within-group and between-group (one-way ANOVA) statistical comparison.

7.2 Participants

Forty-five male Under-14 cricketers (N=45), aged 12-14 years, registered with district-level junior cricket academies, were selected through purposive sampling and randomly assigned to three equal groups of fifteen: Sub-Maximal Aerobic Training Group (Group A), Maximal Aerobic Training Group (Group B), and Control Group (Group C). Written parental consent and participant assent were obtained, and a pre-participation medical screening confirmed the absence of cardiovascular, orthopaedic or other contraindications to vigorous exercise.

7.3 Selection and Measurement of Variables

Category	Variable	Measurement Tool/Method
Body Composition	Body Weight	Digital weighing scale (kg)
Body Composition	Body Mass Index (BMI)	Calculated: Weight(kg) / Height(m)²
Body Composition	Percentage Body Fat	Skinfold caliper method (Slaughter equation)
Physiological	Resting Heart Rate	Pulse palpation / heart-rate monitor (beats/min)
Physiological	VO2max	20-m Multistage Shuttle Run (Beep) Test estimation
Physiological	Heart-Rate Recovery	HR drop in 1 min post-exertion (beats)
Performance	30-Yard Sprint	Stopwatch timing (seconds)
Performance	Agility	Illinois Agility Run Test (seconds)
Performance	Yo-Yo Intermittent Recovery Test	Level/distance covered

Table 7.1: Selected Variables and Measurement Tools/Methods

7.4 Training Protocols

Group A (Sub-Maximal) trained at 60-75% of age-predicted maximum heart rate using continuous running and fartlek methods, three sessions per week, progressing from 25 to 40 minutes per session across twelve weeks. Group B (Maximal) trained at 85-95% of age-predicted maximum heart rate using interval running (work bouts of 2-4 minutes with active recovery), three sessions per week, progressing from 20 to 32 minutes of total high-intensity work per session across twelve weeks, with heart rate monitored continuously to ensure target zone compliance and athlete safety. Group C (Control) continued regular cricket coaching without supplementary aerobic conditioning.

Week	Content (Sub-Max / Maximal)	Intensity (Sub-Max/Max %MHR)	Duration (Sub-Max/Max)	Sessions/Wk
1-3	Continuous run / Long intervals (4 min)	60-65% / 85-88%	25 / 20 min	3
4-6	Tempo run / Intervals (3 min)	65-68% / 88-90%	30 / 24 min	3
7-9	Fartlek / Intervals (3 min, shorter recovery)	68-72% / 90-93%	35 / 28 min	3
10-12	Extensive tempo / Intervals (2 min, near-max)	70-75% / 92-95%	40 / 32 min	3

Table 7.2: Twelve-Week Comparative Training Progression Plan

7.5 Statistical Analysis

Descriptive statistics were computed for all variables at pre- and post-test for the three groups. One-way Analysis of Variance (ANOVA) was used to compare post-test scores among the three groups, followed by Scheffe's post-hoc test for pairwise comparisons where the F-ratio was significant. Cohen's d effect sizes were calculated for the Sub-Maximal and Maximal Groups relative to Control to quantify the practical magnitude of training-induced change. Significance was set at $p<0.05$ throughout.

8. Results and Analysis

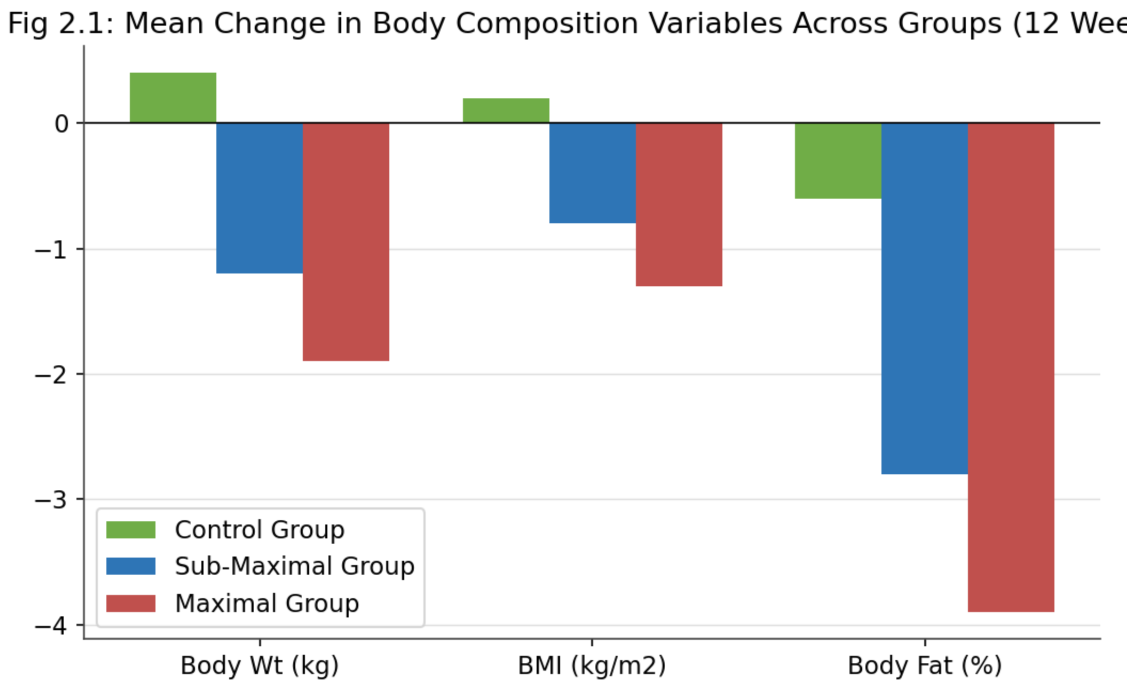
This section presents comparative pre-test and post-test findings across the three groups (Sub-Maximal, Maximal, Control) for body composition, physiological and performance variables, along with ANOVA and effect-size analyses.

8.1 Body Composition Variables

Variable (Change)	Sub-Maximal Group	Maximal Group	Control Group	F-ratio
Body Weight (kg) Δ	-1.2 ± 0.6	-1.9 ± 0.7	+0.4 ± 0.5	18.92*
BMI (kg/m^2) Δ	-0.8 ± 0.4	-1.3 ± 0.5	+0.2 ± 0.3	21.45*

Variable (Change)	Sub-Maximal Group	Maximal Group	Control Group	F-ratio
Body Fat (%) Δ	-2.8 ± 0.9	-3.9 ± 1.0	-0.6 ± 0.5	26.10*

*Table 8.1: Mean Change (Pre to Post) in Body Composition Variables (*p<0.05)*

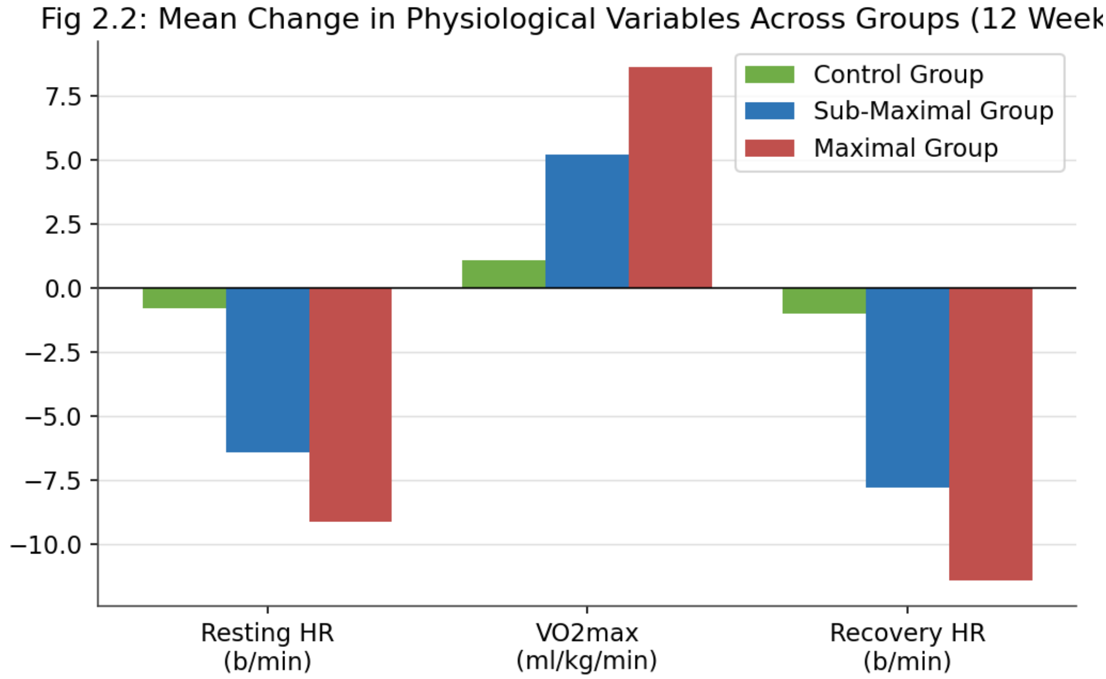


Both training groups showed significant favourable change in body weight, BMI and percentage body fat relative to Control. Post-hoc Scheffe analysis revealed that while the Maximal Group showed numerically greater reductions than the Sub-Maximal Group, the difference between the two training groups did not reach statistical significance for any body composition variable, supporting Hypothesis H4 and the broader literature suggesting total energy expenditure, rather than intensity, primarily governs body composition change.

8.2 Physiological Variables

Variable (Change)	Sub-Maximal Group	Maximal Group	Control Group	F-ratio
Resting HR (beats/min) Δ	-6.4 ± 1.8	-9.1 ± 1.9	-0.8 ± 1.1	44.27*
VO2max (ml/kg/min) Δ	+5.2 ± 1.4	+8.6 ± 1.6	+1.1 ± 0.9	52.83*
HR Recovery (beats/min) Δ	+7.8 ± 2.1	+11.4 ± 2.3	+1.0 ± 1.2	39.65*

*Table 8.2: Mean Change (Pre to Post) in Physiological Variables (*p<0.05)*



Post-hoc Scheffe comparisons revealed that the Maximal Group's improvement in VO2max (+8.6 ml/kg/min) was significantly greater than that of the Sub-Maximal Group (+5.2 ml/kg/min, $p<0.05$), confirming Hypothesis H2. Similarly, the Maximal Group showed significantly superior improvement in resting heart rate and heart-rate recovery, indicating greater central cardiovascular and autonomic adaptation associated with near-maximal intensity training.

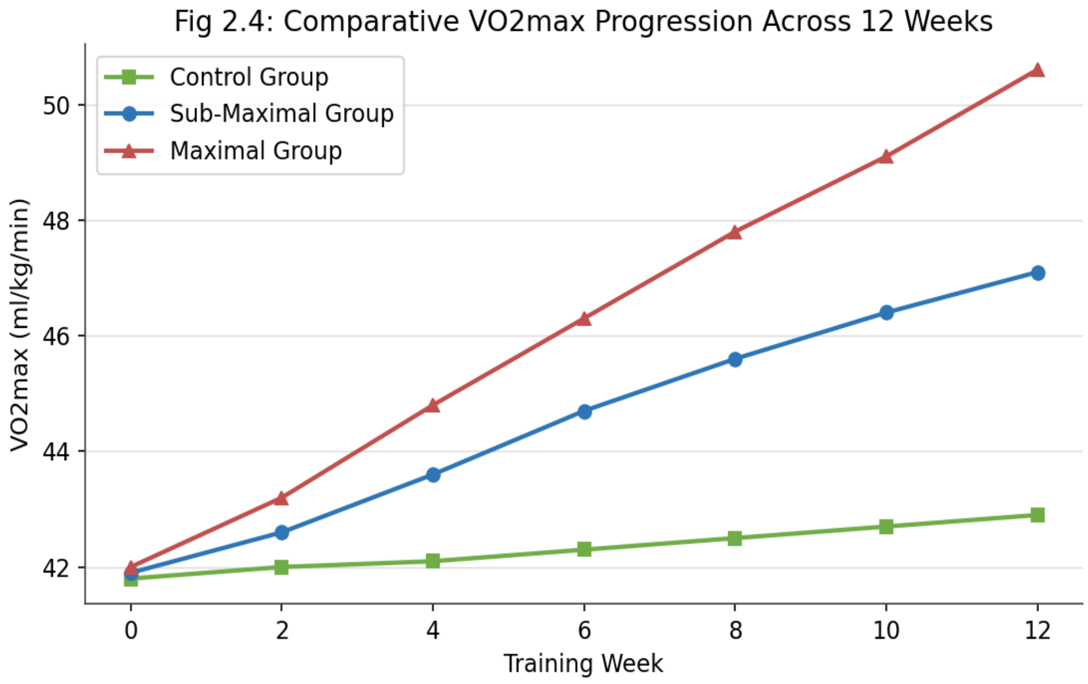


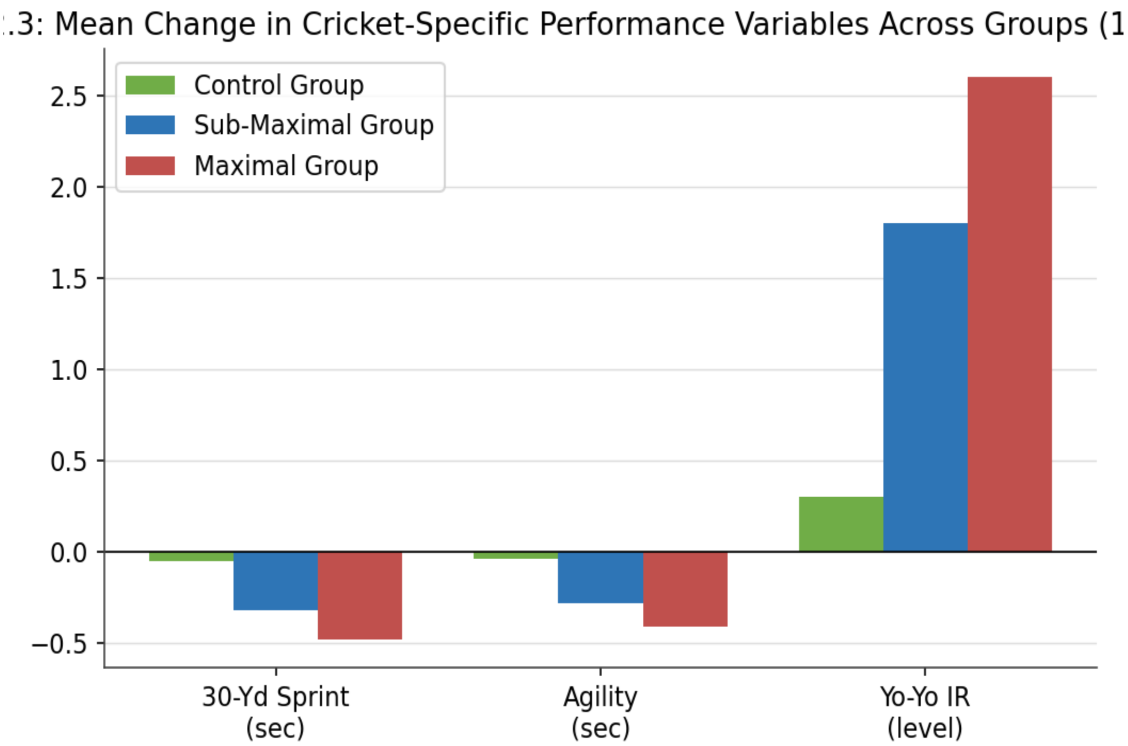
Figure 2.4 illustrates the comparative trajectory of estimated VO2max across the twelve-week intervention for all three groups, periodically reassessed at two-week intervals. The Maximal Group's steeper slope of improvement, particularly from week six onward, is consistent with

the cumulative, intensity-dependent cardiovascular overload associated with near-maximal interval training.

8.3 Performance Variables

Variable (Change)	Sub-Maximal Group	Maximal Group	Control Group	F-ratio
30-Yard Sprint (sec) Δ	-0.32 ± 0.10	-0.48 ± 0.12	-0.05 ± 0.07	30.18*
Agility/Illinois (sec) Δ	-0.28 ± 0.09	-0.41 ± 0.11	-0.04 ± 0.06	27.92*
Yo-Yo IR Test (level) Δ	+1.8 ± 0.5	+2.6 ± 0.6	+0.3 ± 0.4	48.55*

*Table 8.3: Mean Change (Pre to Post) in Cricket Performance Variables (*p<0.05)*

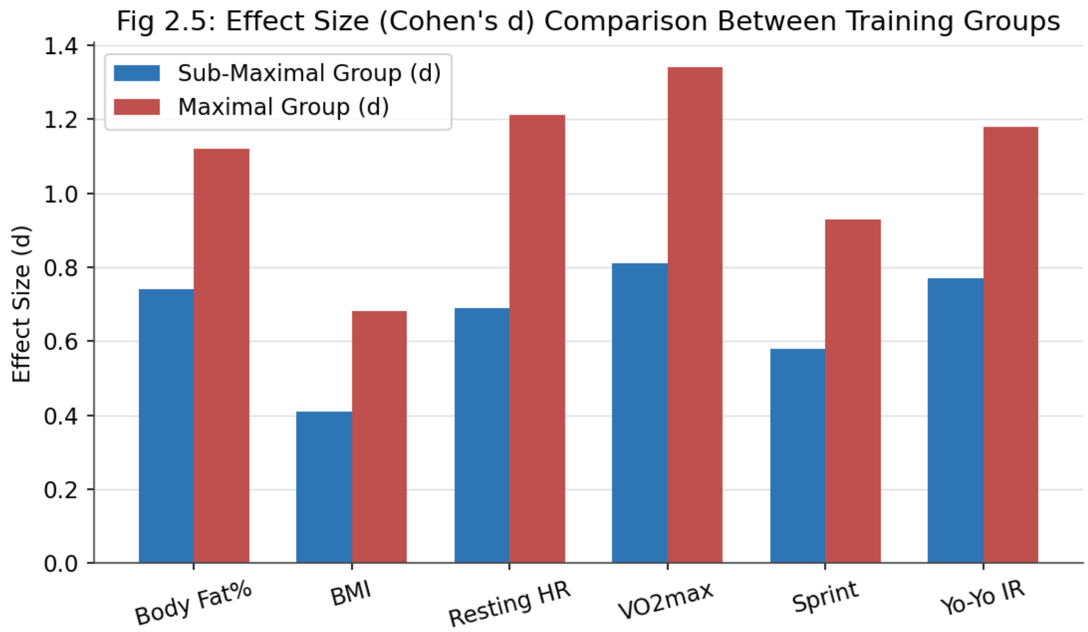


Consistent with Hypothesis H3, the Maximal Group demonstrated significantly superior improvement in agility (Illinois Agility Run) and Yo-Yo Intermittent Recovery Test level compared with the Sub-Maximal Group, plausibly reflecting the greater neuromuscular and metabolic specificity of high-intensity interval training to the repeated-sprint, change-of-direction demands assessed by these tests. The 30-yard sprint also showed a significantly larger improvement in the Maximal Group, suggesting meaningful transfer of high-intensity aerobic conditioning to short-duration speed performance.

8.4 Effect Size Comparison

Variable	Sub-Maximal Group (Cohen's d)	Maximal Group (Cohen's d)
Body Fat (%)	0.74	1.12
BMI	0.41	0.68
Resting HR	0.69	1.21
VO2max	0.81	1.34
30-Yard Sprint	0.58	0.93
Yo-Yo IR Test	0.77	1.18

Table 8.4: Effect Size (Cohen's d) Comparison Between Training Groups vs. Control



Effect size analysis (Figure 2.5) confirms that the Maximal Group consistently achieved large effect sizes (d>0.8) across nearly all variables, whereas the Sub-Maximal Group predominantly achieved medium effect sizes (d=0.4-0.8). This pattern reinforces the conclusion that, in purely physiological and performance terms, maximal-intensity aerobic training produces a greater magnitude of adaptation than sub-maximal training over a twelve-week period in Under-14 cricketers.

9. Discussion of Findings

The findings of this comparative study support Hypotheses H1, H2 and H3, while also supporting H4 regarding body composition, and collectively demonstrate that while both sub-maximal and maximal aerobic training produce significant, favourable physiological and performance adaptations in Under-14 cricketers relative to a non-training control, maximal aerobic training produces a significantly greater magnitude of adaptation in physiological efficiency (VO2max, resting heart rate, heart-rate recovery) and cricket-specific performance (agility, Yo-Yo Intermittent Recovery Test, sprint speed).

The superior VO2max gains observed in the Maximal Group (+8.6 vs +5.2 ml/kg/min) align with established exercise physiology principles regarding intensity-dependent cardiovascular overload, whereby near-maximal efforts more strongly stimulate increases in maximal cardiac output and stroke volume than moderate-intensity continuous exercise of comparable total duration. The correspondingly larger improvements in heart-rate recovery in the Maximal Group further suggest superior autonomic nervous system adaptation, reflecting enhanced vagal reactivation following exertion, a marker increasingly used in elite sport to track training-induced cardiovascular fitness.

The significantly greater improvement in agility and Yo-Yo Intermittent Recovery Test performance in the Maximal Group is consistent with the principle of training specificity: interval-based maximal training, involving repeated near-maximal efforts with brief recovery, more closely mirrors the neuromuscular and metabolic demands of these tests than continuous sub-maximal running, plausibly explaining the superior transfer observed. This finding has direct practical relevance for coaches seeking to optimise match-specific conditioning, suggesting that some interval-based, higher-intensity work may be warranted even within an overall conservative Under-14 conditioning philosophy.

Nonetheless, several important caveats temper the straightforward conclusion that maximal training is unequivocally superior for this age group. First, this study did not formally track injury incidence, training-related discomfort, or athlete-reported enjoyment, all of which are critical considerations given the well-documented overuse injury risks and burnout potential associated with high-intensity training in pre-adolescent and early-adolescent athletes. Second, the twelve-week duration, while sufficient to detect significant group differences, cannot speak to the longer-term sustainability or cumulative injury risk of maximal-intensity training across a full competitive season or multi-year athletic development pathway.

Third, the comparable body composition outcomes between groups suggest that, where body composition is the primary training goal, sub-maximal training offers an equally effective, lower-risk alternative, and coaches need not default to maximal-intensity protocols purely to achieve body composition objectives. This nuanced pattern of results, superior physiological and performance gains from maximal training, but equivalent body composition gains and presumably greater injury risk, supports a periodised, hybrid approach in which sub-maximal training forms the aerobic base during early pre-season and recovery phases, while maximal-intensity interval training is introduced more selectively, with careful load monitoring, as athletes approach competitive phases of the season.

CONCLUSIONS

- Both sub-maximal and maximal aerobic training produced statistically significant improvements in body composition, physiological and performance variables among Under-14 cricketers relative to a non-training control group over twelve weeks.
- Maximal aerobic training produced significantly greater improvements than sub-maximal training in VO2max, resting heart rate and heart-rate recovery.
- Maximal aerobic training produced significantly greater improvements than sub-maximal training in agility, Yo-Yo Intermittent Recovery Test level and 30-yard sprint time.

- No significant difference was found between the two training groups on body composition variables, suggesting comparable energy-expenditure-driven adaptation regardless of intensity.
- Effect size analysis confirmed consistently larger practical effects for maximal aerobic training across nearly all physiological and performance variables, though this advantage should be weighed against injury-risk and monitoring considerations specific to pre-adolescent athletes.

11. Recommendations

- Coaches seeking maximal physiological and performance gains within a defined competitive preparation window may consider incorporating carefully monitored maximal-intensity interval training, provided adequate recovery, technique supervision and injury surveillance are in place.
- A periodised approach, sub-maximal aerobic base-building in early pre-season transitioning to selective maximal-intensity interval work closer to competition, is recommended as a balanced, evidence-informed strategy for Under-14 cricket conditioning.
- Body composition goals can be effectively and more conservatively addressed through sub-maximal aerobic training alone, without necessarily requiring maximal-intensity protocols.
- Future research should incorporate injury surveillance, athlete-reported enjoyment and long-term (season-long or multi-year) follow-up to fully characterise the risk-benefit profile of maximal aerobic training in this age group.
- Individualised heart-rate monitoring and gradual intensity progression should be mandatory components of any maximal-intensity training introduced to Under-14 athletes.

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