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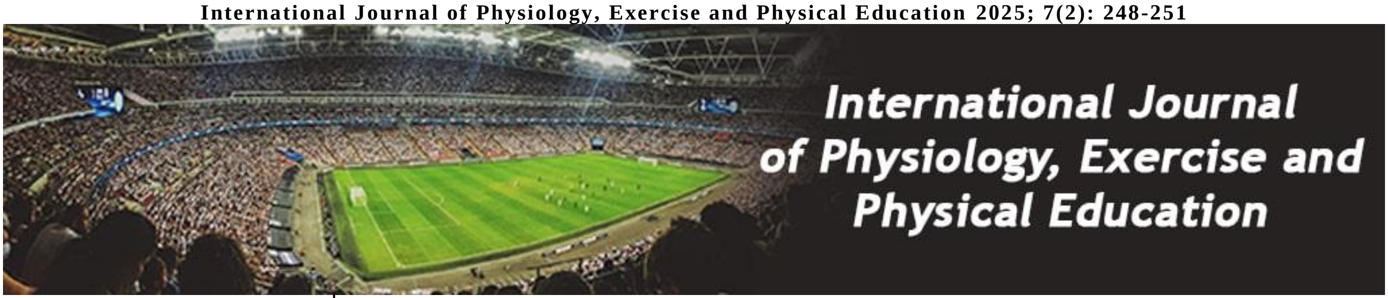

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An experimental investigation into the differential effects of anaerobic, interval, and combined training package on physiological efficiency among volleyball players

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Abstract
The present study aimed to investigate the differential effects of anaerobic, interval, and combined training packages on selected physiological efficiency variables among intercollegiate volleyball players. Thirty-six male volleyball players aged 18 to 25 years from Thoothukudi District, Tamil Nadu, India, were randomly assigned to three groups: Anaerobic Training Group (ATG), Interval Training Group (ITG), and Combined Training Group (CTG), each consisting of twelve participants (n = 12). The experimental period lasted 8 weeks, with three training sessions per week. Physiological variables such as Forced Vital Capacity (FVC), Maximum Voluntary Ventilation (MVV), and Tidal Volume (TV) were measured using a digital spirometer. Data were analyzed using paired sample 't'-tests, Analysis of Covariance (ANCOVA), and Scheffé's post-hoc test at a 0.05 significance level. The results revealed significant improvements in all physiological parameters across the three training groups. Among them, the Combined Training Group (CTG) demonstrated superior gains in FVC, MVV, and TV compared to the Anaerobic and Interval Training Groups. The findings suggest that integrating anaerobic and interval training components produces more comprehensive adaptations by enhancing both aerobic endurance and anaerobic power systems. Therefore, combined training can be recommended as an effective approach for improving physiological efficiency and performance among volleyball players.

Keywords: Anaerobic training, interval training, combined training, physiological efficiency, volleyball players

Introduction

Volleyball is an intermittent, high-intensity team sport characterized by explosive movements such as spiking, blocking, jumping, and rapid directional changes. These actions require a well-developed integration of both anaerobic and aerobic energy systems to sustain performance throughout extended rallies and matches [1]. In modern competitive volleyball, physical conditioning has become a decisive factor influencing performance, endurance, and recovery. Consequently, the design of effective training programs that enhance both physiological efficiency and game-specific performance has gained significant research attention. Anaerobic training primarily develops the body's capacity to perform short-duration, high-intensity efforts by increasing phosphagen and glycolytic energy pathway efficiency. It improves muscular strength, power output, and lactic acid tolerance attributes essential for quick jumps, spikes, and short sprints [2]. Interval training, on the other hand, strategically alternates periods of intense activity and recovery, allowing athletes to improve cardiovascular endurance, oxygen uptake, and fatigue resistance while maintaining high performance levels during repeated bouts of effort [3]. In recent years, researchers have emphasized combined training a method integrating both anaerobic and interval components to simultaneously enhance muscular power and aerobic capacity [4]. Such hybrid programs have shown promise in improving not only the physiological efficiency of athletes but also their recovery rate and match endurance.

Despite the growing popularity of combined training models in other sports, their direct effects on volleyball players' physiological parameters remain under-explored.
Therefore, the present study aims to experimentally examine the differential effects of anaerobic, interval, and combined training packages on selected physiological variables among volleyball players. Understanding these effects may guide coaches and trainers in optimizing conditioning programs to maximize performance outcomes and minimize fatigue during competitive play.

Materials and Methods

Research Design

The present study employed an experimental design to examine the differential effects of anaerobic, interval, and combined training packages on selected physiological efficiency variables among volleyball players. A pre-test and post-test randomized group design was used, wherein subjects were assigned to four groups: Anaerobic Training Group (ATG), Interval Training Group (ITG) and a Combined Training Group (CTG). Each training intervention was implemented over an 8-week period, with three sessions per week, excluding match practice days.

Participants

The study sample consisted of 40 male volleyball players (n = 36) aged between 18 and 24 years, who were actively engaged in collegiate-level volleyball training programs. The participants were randomly divided into four equal groups (n = 12 per group). All subjects were medically screened and found to be free from cardiovascular, metabolic, or musculoskeletal disorders that could interfere with training or data collection. Prior to the experiment, written informed consent was obtained from all participants.

Training Protocols

Anaerobic Training Group (ATG)

The ATG followed a regimen emphasizing short, high-intensity exercises targeting anaerobic energy systems. The program included repeated sprints, plyometric drills (e.g., depth jumps, bounding), and high-load resistance training with work-to-rest ratios of 1:5. Each session lasted approximately 45 minutes, focusing on explosive movements essential for volleyball actions such as spiking and blocking [5].

Interval Training Group (ITG)

The ITG underwent aerobic-interval training designed to improve cardiovascular endurance and recovery efficiency. Each session involved alternating bouts of high-intensity running (80-90% H R max.) and low-intensity recovery jogs (50-60% HR max.), typically organized in 4-6 sets of 3-minute work intervals with 90 seconds of recovery [6].

Combined Training Group (CTG)

The CTG received a hybrid training intervention integrating elements of both anaerobic and interval training. The protocol alternated between high-intensity plyometric and sprint drills and moderate-intensity endurance intervals within a single session. This approach aimed to enhance both aerobic and anaerobic capacities, maximizing physiological efficiency and overall performance [7].

Variables Measured

The physiological efficiency variables Forced Vital Capacity (FVC), Maximal Voluntary Ventilation (MVV) and Tidal Volume (TV) are assessed using a digital spirometer, expressed in ml/mins. Pre-test and post-test scores were recorded under standardized conditions to ensure reliability.

Statistical Analysis

The collected data were analyzed using Analysis of Variance (ANOVA) to determine significant differences among the four groups. When significant F-ratios were found, Scheffé's post hoc test was applied to identify intergroup differences. Statistical significance was set at $p<0.05$. Descriptive statistics, including means and standard deviations, were also computed to interpret the results.

Results

Results on Forced Vital Capacity (FVC)

Table 1: Summary of mean and paired sample t-test for pre- and posttests on Forced Vital Capacity (ml/min)

Group	Pretest Mean	Posttest Mean	't' value
Anaerobic Training Group (ATG)	3.63	3.66	5.75*
Interval Training Group (ITG)	3.63	3.64	4.69*
Interval Training Group (ITG)	3.66	3.69	7.42*

Significant at 0.05 level, table value with df = 11 is 2.20.

The obtained 't' values (5.75, 4.69, and 7.42) are greater than the table value (2.20), indicating that all three training methods significantly improved Forced Vital Capacity among volleyball players.

Table 2: Analysis of covariance on Forced Vital Capacity (FVC) (ml/min)

Source of Variance	Sum of Squares	df	Mean Square	F-ratio	η^2
Between Groups	0.004	2	0.002	13.96*	0.466
Within Groups	0.005	32	0.00015		

Significant at 0.05 level; table value with df (2, 32) = 3.30.

The adjusted posttest means were 3.66 (ATG), 3.65 (ITG), and 3.68 (CTG). Since the obtained F-ratio (13.96) exceeded the table value (3.30), significant differences existed among the groups.

Table 3: Scheffé's post hoc test on Forced Vital Capacity (FVC)

Comparison	Mean Difference	Required CI	Result
ATG vs ITG	0.01*	0.01	Significant
ATG vs CTG	0.02*	0.01	Significant
ITG vs CTG	0.03*	0.01	Significant

The pairwise comparisons reveal significant differences among all training groups. The Combined Training Group (CTG) showed superior improvement compared to both ATG and ITG.

Results on Maximum Voluntary Ventilation (MVV)

Table 4: Summary of mean and paired sample t-test for pre- and posttests on Maximum Voluntary Ventilation (MVV) (ml/min)

Group	Pretest Mean	Posttest Mean	't' value
Anaerobic Training Group (ATG)	127.9	130.9	35.00*
Interval Training Group (ITG)	128.0	129.9	23.00*
Interval Training Group (ITG)	127.5	131.4	47.00*

Significant at 0.05 level; table value with df = 11 is 2.20.*

All three training programs significantly improved Maximum Voluntary Ventilation (MVV) performance.

Table 5: Analysis of covariance on Maximum Voluntary Ventilation (MVV) (ml/min)

Source of Variance	Sum of Squares	df	Mean Square	F-ratio	η^2
Between Groups	23.93	2	11.97	154.97*	0.901
Within Groups	2.62	32	0.082		

Significant at 0.05 level; table value with df(2, 32) = 3.30.

The adjusted posttest means were 130.7 (ATG), 129.7 (ITG), and 131.7 (CTG). The F-ratio of 154.97 indicates a highly significant difference among groups.

Table 6: Scheffé's post hoc test on Maximum Voluntary Ventilation (MVV)

Comparison	Mean Difference	Required CI	Result
ATG vs ITG	0.01*	0.96	Significant
ATG vs CTG	0.01*	0.96	Significant
ITG vs CTG	0.02*	0.96	Significant

The CTG demonstrated superior gains in MVV compared to both ATG and ITG

Results on Tidal Volume

Table 7: Summary of mean and paired sample t-test for pre- and posttests on Tidal Volume (TV) (ml/min)

Group	Pretest Mean	Posttest Mean	't' value
Anaerobic Training Group (ATG)	1.82	1.84	6.78*
Interval Training Group (ITG)	1.82	1.84	23.00*
Interval Training Group (ITG)	1.82	1.86	49.00*

Significant at 0.05 level; table value with df = 11 is 2.20.

All three training programs significantly enhanced Tidal Volume (TV).

Table 8: Analysis of covariance on Tidal Volume (TV) (ml/min)

Source of Variance	Sum of Squares	df	Mean Square	F-ratio	η^2
Between Groups	0.004	2	0.002	55.12*	0.775
Within Groups	0.001	32	0.000035		

Significant at 0.05 level; table value with df(2, 32) = 3.30.

The adjusted posttest means were 1.84 (ATG), 1.84 (ITG), and 1.86 (CTG), showing statistically significant improvement across groups.

Table 9: Scheffé's post hoc test on Tidal Volume (TV)

Comparison	Mean Difference	Required CI	Result
ATG vs ITG	0.00	0.22	Not Significant
ATG vs CTG	0.02	0.22	Not Significant
ITG vs CTG	0.02	0.22	Not Significant

Although the Combined Training Group had the highest mean, the differences were not statistically significant at the 0.05 level.

Discussion

The present study examined the differential effects of anaerobic, interval, and combined training programs on selected physiological efficiency variables namely, Forced Vital Capacity (FVC), Maximum Voluntary Ventilation (MVV), and Tidal Volume (TV) among intercollegiate volleyball players. The findings revealed that all three training modalities significantly improved these physiological variables, with the Combined Training Group (CTG) demonstrating superior performance across most parameters.

Forced Vital Capacity (FVC)

The significant improvements observed in Forced Vital Capacity following anaerobic, interval, and combined training interventions indicate that these methods effectively enhance pulmonary function. The Combined Training Group showed the greatest increase in FVC compared to Anaerobic and Interval Training groups. This improvement can be attributed to the synergistic effect of combining high-intensity and endurance components, which optimize both respiratory muscle strength and lung capacity. These findings are consistent with previous research by [8], who reported that mixed training protocols enhance both forced vital capacity and respiratory endurance among athletes. Similarly, [9] found that high-intensity interval training elicits positive adaptations in both aerobic and anaerobic energy systems, thereby improving ventilatory efficiency. Furthermore, that volleyball training involving intermittent explosive efforts contributes to superior ventilatory responses due to repeated bouts of high-intensity activity [10].

Maximum Voluntary Ventilation (MVV)

The results demonstrated that Maximum Voluntary Ventilation significantly improved across all groups, with the Combined Training Group showing the highest adjusted post-test mean (131.7 ml/min). This indicates a substantial enhancement in the ability of the respiratory muscles to sustain high levels of ventilation. The superior performance of the combined training group aligns with the principles of periodization [11], which emphasize the integration of multiple energy systems for optimal physiological adaptation. Previous studies have shown that both anaerobic sprint training and aerobic conditioning contribute to increased ventilatory capacity and efficiency [12]. Similarly, Ghosh reported that endurance athletes exhibit greater MVV values due to continuous respiratory muscle engagement, while the inclusion of anaerobic intervals further enhances respiratory strength and tolerance to fatigue [13].

Tidal Volume (TV)

Tidal Volume improved significantly after training in all three experimental groups. Although no significant pairwise differences were observed in post-hoc comparisons, the Combined Training Group exhibited slightly higher mean values, suggesting a cumulative benefit from integrating multiple training stimuli. This pattern supports the findings of Plowman and Smith, who noted that combined training interventions enhance both static and dynamic lung volumes by improving alveolar ventilation and respiratory muscle coordination [14]. Additionally, Kenney, Wilmore, and Costill highlighted that structured exercise programs, especially those involving both endurance and strength elements, lead to increased respiratory efficiency and lung compliance [15], thus improving Tidal Volume performance.

Conclusion

The results of this study reinforce the effectiveness of combining anaerobic and interval components to enhance physiological efficiency among volleyball players. Combined training appears to yield the most comprehensive adaptations due to its capacity to stimulate both aerobic endurance and anaerobic power systems simultaneously. These findings echo the observations of Sheppard and Young who emphasized that volleyball performance relies on both explosive power and sustained respiratory efficiency [16].

In summary, the Combined Training Package (CTG) proved to be the most beneficial intervention for improving Forced Vital Capacity, Maximum Voluntary Ventilation, and Tidal Volume. The inclusion of both anaerobic and interval elements likely maximized respiratory muscle conditioning and systemic oxygen utilization, leading to superior overall physiological efficiency in volleyball athletes.

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