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Effect Of Isolated and Combined Circuit Training and Plyometric Training on Motor Fitness, Physiological and Skill Related Performance Variables Among High School Girls Volleyball Players

[1]DASARI RAMADEVI , [2]M. SIVA SANKAR REDDY

[1]Research Scholar in Physical Education, Department of Physical Education, Sri Venkateswara University, Tirupati, Andhra Pradesh, India.

[2]Director, Department of Physical Education, Research Supervisor, DPE, Sri Venkateswara University, Tirupati, Andhra Pradesh, India.

ABSTRACT

The purpose of this study was to investigate the effects of isolated circuit training, isolated plyometric training, and combined circuit and plyometric training on selected motor fitness, physiological, and skill-related performance variables among high school girls volleyball players. Sixty female volleyball players aged 14 to 17 years were randomly selected and equally divided into four groups: Group I (Circuit Training), Group II (Plyometric Training), Group III (Combined Training), and Group IV (Control). The experimental groups underwent a structured twelve-week training programme, five sessions per week. Motor fitness variables assessed included speed, agility, muscular strength, explosive power, and flexibility. Physiological variables included resting heart rate, vital capacity, and cardiovascular endurance. Skill-related variables comprised serving accuracy, spiking, setting, and passing. Pre-test and post-test data were collected and analysed using Analysis of Covariance (ANCOVA). Results indicated significant improvements in all selected variables across the three experimental groups compared to the control group. The combined training group demonstrated the greatest improvements in all variables, suggesting that a combined approach to circuit and plyometric training yields superior adaptations in motor fitness, physiological capacity, and volleyball-specific skills among high school girls.

Keywords: Circuit Training, Plyometric Training, Motor Fitness, Physiological Variables, Volleyball Skills, High School Girls.

1. INTRODUCTION

Volleyball is a dynamic, high-intensity team sport that demands a comprehensive blend of motor fitness, physiological efficiency, and technical skill. At the high school level, where physical development is at a critical juncture, appropriate training methodologies can profoundly influence long-term athletic performance and overall health. The increasing competitiveness of school-level volleyball necessitates that coaches and physical educators adopt scientifically validated training programmes that holistically develop young athletes.

Physical conditioning programmes designed for volleyball players must address multiple performance dimensions simultaneously. Speed, agility, explosive power, muscular endurance, and flexibility are considered the principal motor fitness components critical to volleyball performance. From a physiological standpoint, improvements in resting heart rate, vital capacity, and cardiovascular endurance directly translate into better

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on-court performance and faster recovery between rallies. Moreover, skill-related variables such as serving accuracy, spiking effectiveness, setting precision, and passing consistency form the technical backbone of competitive volleyball.

Circuit training is a well-established conditioning methodology involving sequential performance of multiple exercises targeting different muscle groups with minimal rest intervals. It is particularly effective for developing muscular endurance, cardiovascular fitness, and general motor fitness simultaneously. Plyometric training, on the other hand, focuses on developing explosive power through stretch-shortening cycle movements such as box jumps, depth jumps, and bounding exercises. These explosive movements directly replicate the biomechanical demands of volleyball actions including jumping, spiking, and rapid directional changes.

While both circuit training and plyometric training have been individually investigated in sport science literature, limited research has explored their combined effects, particularly among female high school volleyball players. The present study addresses this research gap by examining and comparing the isolated and combined effects of these two training modalities on a comprehensive range of motor fitness, physiological, and skill-related performance variables.

2. REVIEW OF LITERATURE

Extensive research has established the efficacy of circuit training and plyometric training across various sports and populations. A selective review of relevant studies provides the theoretical framework for the present investigation.

Demorest and Landry (2003) conducted a comprehensive review of strength and conditioning programmes for young athletes and concluded that structured resistance and plyometric training significantly enhanced explosive power, speed, and agility without adverse effects on developing musculoskeletal systems when properly supervised.

Maffiuletti et al. (2002) examined the effects of combined electrostimulation and plyometric training on jumping ability and sprint performance in elite basketball players. Their findings demonstrated substantial improvements in countermovement jump height and 10-metre sprint time, highlighting the synergistic potential of combined training approaches.

Chimera et al. (2004) investigated the effects of plyometric training on muscle activation strategies and performance in female athletes. Results indicated significant improvements in neuromuscular control, explosive power, and lower extremity coordination, with implications for injury prevention in female volleyball players.

Markovic (2007) conducted a meta-analysis of plyometric training studies and found that plyometric interventions consistently produced significant gains in vertical jump performance, sprinting speed, and agility across diverse athletic populations. The analysis also noted that training programmes exceeding eight weeks

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produced the most robust adaptations.

Fatouros et al. (2000) explored the interrelationship between plyometric training intensity and training-induced adaptations in jumping performance. They demonstrated a dose-response relationship between training volume and explosive power gains, with moderate-to-high intensity plyometric programmes producing superior outcomes.

Stojanovic and Kostic (2002) specifically examined circuit training effects on physiological parameters in female athletes and reported significant improvements in maximal oxygen uptake, resting heart rate, and vital capacity following an eight-week circuit training intervention, underscoring the cardiovascular benefits of this training modality.

Trajkovic et al. (2012) investigated the effects of a six-week plyometric training programme on volleyball-specific skills among junior players. Their results demonstrated significant improvements in spiking power, serving velocity, and jump height, confirming the sport-specificity of plyometric adaptations for volleyball performance.

3. METHODOLOGY

3.1 Participants

Sixty female high school volleyball players aged between 14 and 17 years were purposively selected from government high schools in Salem District, Tamil Nadu, India. All participants had a minimum of one year of volleyball experience and were free from any musculoskeletal injuries or medical conditions that could affect training participation. Written informed consent was obtained from participants' parents or guardians, and the study was approved by the Institutional Ethics Committee.

3.2 Experimental Design

A randomised pre-test post-test control group experimental design was employed. Participants were randomly assigned to four equal groups of fifteen players each:

Group I: Circuit Training Group (CTG)

Group II: Plyometric Training Group (PTG)

Group III: Combined Circuit and Plyometric Training Group (CPTG)

Group IV: Control Group (CG) – No structured training intervention

3.3 Training Protocols

All three experimental groups trained for twelve weeks, five sessions per week, with each session lasting approximately 60 to 75 minutes including warm-up and cool-down phases.

Circuit Training Protocol: The circuit consisted of ten stations targeting major muscle groups: push-

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ups, sit-ups, squat jumps, lateral shuffles, medicine ball throws, step-ups, triceps dips, agility ladder drills, core planks, and skipping. Each station was performed for 45 seconds with 15-second transition intervals. Three to five circuit rounds were completed per session with progressive overload applied fortnightly.

Plyometric Training Protocol: The programme included box jumps, depth jumps, broad jumps, lateral bounds, single-leg hops, hurdle hops, tuck jumps, and approach jumps mimicking volleyball spiking mechanics. Volume progressed from 80 to 200 foot contacts per session over twelve weeks, with intensity progressively increased from low to high-intensity plyometric exercises.

Combined Training Protocol: The combined group performed circuit training exercises in the first half and plyometric drills in the second half of each session. Total session volume was carefully managed to avoid overtraining, with the circuit component comprising five stations and plyometric volume starting at 60 foot contacts, progressively increasing to 150 per session.

3.4 Variables and Measurement Tools

Table 1: Variables and Measurement Instruments

Variable Category	Variable	Test/Instrument
Motor Fitness	Speed	50-metre Dash (seconds)
Motor Fitness	Agility	Illinois Agility Run Test (seconds)
Motor Fitness	Muscular Strength	Grip Dynamometer (kg)
Motor Fitness	Explosive Power	Standing Broad Jump (cm)
Motor Fitness	Flexibility	Sit and Reach Test (cm)
Physiological	Resting Heart Rate	Digital Pulse Oximeter (bpm)
Physiological	Vital Capacity	Spirometer (litres)
Physiological	Cardiovascular Endurance	600-metre Run/Walk Test (min)
Skill-Related	Serving Accuracy	AAHPERD Volleyball Serve Test
Skill-Related	Spiking	Volleyball Spike Accuracy Test
Skill-Related	Setting	Brady Volleyball Skill Test (Wall Volley)
Skill-Related	Passing	Volleyball Forearm Pass Accuracy Test

3.5 Statistical Analysis

Data collected from pre-tests and post-tests were analysed using Analysis of Covariance (ANCOVA) with the pre-test scores as covariates to control for initial differences between groups. Where significant F-ratios were obtained, Scheffe's post-hoc test was applied to identify specific between-group differences. The level of significance was set at $p < 0.05$ for all statistical tests. All analyses were performed using SPSS Version 26.0.

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4. RESULTS AND DISCUSSION

4.1 Motor Fitness Variables

Table 2 presents the adjusted post-test means and F-ratios for motor fitness variables across all four groups. Analysis of covariance revealed significant main effects for all motor fitness variables.

Table 2: ANCOVA Summary for Motor Fitness Variables (Adjusted Means)

Variable	CTG (Adj. Mean)	PTG (Adj. Mean)	CPTG (Adj. Mean)	CG (Adj. Mean)	F-Ratio	Sig.
Speed (sec)	8.12	8.04	7.89	8.67	14.32	0.001*
Agility (sec)	16.43	16.27	15.98	17.21	11.87	0.001*
Str. (kg)	24.81	25.34	26.78	22.14	18.64	0.001*
Power (cm)	161.4	164.2	171.6	148.3	22.19	0.001*
Flexibility (cm)	28.47	27.93	30.62	24.16	16.75	0.001*

* Significant at $p < 0.05$ level. CTG = Circuit Training Group; PTG = Plyometric Training Group; CPTG = Combined Training Group; CG = Control Group.

The ANCOVA results revealed that all three experimental groups demonstrated significant improvements in speed, agility, muscular strength, explosive power, and flexibility compared to the control group. The combined training group (CPTG) consistently produced the highest adjusted post-test means for explosive power (171.6 cm), muscular strength (26.78 kg), and flexibility (30.62 cm). For speed and agility, where lower values indicate better performance, the CPTG also recorded the most favourable scores (7.89 seconds and 15.98 seconds respectively).

The superior improvements in explosive power observed in the CPTG can be attributed to the synergistic effect of plyometric exercises stimulating fast-twitch muscle fibre recruitment alongside the muscular endurance and coordination benefits conferred by circuit training. These findings are consistent with Markovic's (2007) meta-analytical conclusions and Trajkovic et al.'s (2012) sport-specific findings in volleyball players.

4.2 Physiological Variables

Table 3: ANCOVA Summary for Physiological Variables (Adjusted Means)

Variable	CTG	PTG	CPTG	CG	F-Ratio	Sig.
Resting HR (bpm)	72.14	73.56	70.28	78.91	19.43	0.001*
Vital Cap. (L)	2.84	2.73	3.01	2.41	17.28	0.001*
Cardio. Endurance (min)	3.42	3.51	3.21	4.18	21.67	0.001*

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* Significant at p < 0.05 level.

Significant improvements in all physiological variables were recorded across experimental groups. Resting heart rate demonstrated the greatest reduction in the CPTG (70.28 bpm), followed by CTG (72.14 bpm) and PTG (73.56 bpm), compared to the control group (78.91 bpm). Vital capacity showed the most pronounced enhancement in the CPTG (3.01 litres), consistent with the cardiovascular demands of combined high-intensity training. Cardiovascular endurance, measured by the 600-metre run/walk test, improved significantly in the CPTG, which recorded the lowest time (3.21 minutes), indicating superior aerobic adaptation.

The cardiac adaptations observed—particularly the reduction in resting heart rate—reflect increased stroke volume and enhanced parasympathetic nervous system tone resulting from sustained aerobic conditioning embedded within the circuit training component. The significant improvement in vital capacity in the CPTG suggests that the sustained respiratory demands of combined training stimulated respiratory muscle strengthening and improved pulmonary function, supporting findings by Stojanovic and Kostic (2002).

4.3 Skill-Related Performance Variables

Table 4: ANCOVA Summary for Volleyball Skill Variables (Adjusted Means)

Variable	CTG	PTG	CPTG	CG	F-Ratio	Sig.
Serving Accuracy	18.34	19.12	21.67	14.28	24.51	0.001*
Spiking (score)	16.42	17.89	19.74	12.63	28.34	0.001*
Setting (score)	17.28	16.94	18.83	13.41	19.76	0.001*
Passing (score)	18.71	17.93	20.14	13.87	22.48	0.001*

* Significant at p < 0.05 level.

The analysis of volleyball-specific skill variables revealed highly significant differences between groups for all four skills assessed. The combined training group recorded the highest adjusted means across all skill measures: serving accuracy (21.67), spiking (19.74), setting (18.83), and passing (20.14). These results clearly indicate that the CPTG benefited from the combined neuromotor and physiological adaptations that translated directly into enhanced technical skill execution.

The PTG demonstrated superior spiking scores (17.89) compared to the CTG (16.42), which aligns with the established relationship between explosive power and spiking effectiveness. The approach jump mechanics refined through plyometric training directly improve the biomechanical efficiency of spiking. Conversely, the CTG showed marginally better passing and setting scores compared to PTG, which may be attributed to the enhanced muscular control, coordination, and body awareness developed through multi-station circuit training.

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4.4 Post-hoc Analysis

Scheffe's post-hoc test was applied to identify specific pairwise differences between groups. Results confirmed that the CPTG differed significantly from all other groups on all variables ($p < 0.05$). The CTG and PTG also differed significantly from the control group on all variables. However, the difference between CTG and PTG was statistically significant only for explosive power and spiking accuracy ($p < 0.05$), while other variables did not reach statistical significance between these two training groups, suggesting comparable yet distinct training effects.

Table 5: Scheffe's Post-hoc Comparison — Selected Variables

Comparison	Speed	Explosive Power	Vital Capacity	Spiking
CTG vs PTG	NS	S*	NS	S*
CTG vs CPTG	S*	S*	S*	S*
PTG vs CPTG	S*	S*	S*	S*
CTG vs CG	S*	S*	S*	S*
PTG vs CG	S*	S*	S*	S*
CPTG vs CG	S*	S*	S*	S*

S* = Significant at $p < 0.05$; NS = Not Significant.

5. DISCUSSION

The findings of the present study substantiate the hypothesis that both isolated and combined circuit and plyometric training produce significant adaptations in motor fitness, physiological, and volleyball-specific skill variables among high school girls. The hierarchical superiority of combined training observed across all dependent variables merits detailed discussion.

The improvements in explosive power across all three experimental groups can be mechanistically explained through distinct pathways. Plyometric training facilitates neural adaptations including improved rate of force development, enhanced motor unit synchronisation, and optimised stretch-shortening cycle utilisation. Circuit training contributes through hypertrophic adaptations, improved intramuscular coordination, and enhanced metabolic efficiency. When combined, these complementary mechanisms appear to produce additive and potentially synergistic effects, explaining the superior outcomes in the CPTG.

The significant improvement in cardiovascular endurance observed in all experimental groups, with the CPTG demonstrating the greatest gains, is particularly relevant for volleyball performance. Matches can extend over multiple sets, requiring sustained aerobic capacity for optimal recovery between rallies and maintenance of technical execution under fatigue. The aerobic base developed through circuit training, combined with the high-intensity oxygen demand of plyometric training, appears to create a robust cardiovascular adaptation that

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surpasses either modality in isolation.

The translation of physical fitness improvements into enhanced volleyball skills observed in this study is consistent with the principle of training specificity. Improved explosive power directly augments jump height during spiking and blocking. Enhanced agility facilitates faster movement to pass and set the ball in defensively challenging positions. Superior cardiovascular endurance enables maintenance of technical precision throughout prolonged match conditions. The CPTG's superior skill performance therefore represents not merely an additive effect but an integrated neuro-physiological adaptation that comprehensively prepares volleyball players for competitive demands.

Gender-specific considerations are also pertinent in interpreting these results. Female athletes generally exhibit greater muscular imbalances between quadriceps and hamstrings, and plyometric training has been demonstrated to address these imbalances through enhanced eccentric loading and landing mechanics. The significant flexibility improvements recorded in the CPTG may also reflect gender-responsive adaptations to the integrated training stimulus, as flexibility training components embedded within the circuit positively influenced overall musculotendinous compliance.

6. CONCLUSIONS

Based on the findings of the present investigation, the following conclusions are drawn:

1. Twelve weeks of circuit training, plyometric training, and combined circuit-plyometric training each produced significant improvements in selected motor fitness variables including speed, agility, muscular strength, explosive power, and flexibility among high school girls volleyball players compared to the control group.

2. All three training modalities significantly improved physiological variables including resting heart rate, vital capacity, and cardiovascular endurance, with the combined training group demonstrating the most pronounced adaptations.

3. Volleyball-specific skill performance in serving accuracy, spiking, setting, and passing was significantly enhanced in all experimental groups, with the combined circuit and plyometric training group recording the highest skill scores.

4. The combined circuit and plyometric training programme was superior to either isolated modality in developing all selected variables, suggesting that the integration of these complementary training approaches produces synergistic adaptive responses that are particularly beneficial for high school girls volleyball players.

5. Coaches and physical educators working with high school female volleyball players are encouraged to incorporate combined circuit and plyometric training programmes within their seasonal conditioning plans to maximise comprehensive physical and technical development.

7. RECOMMENDATIONS

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Based on the conclusions of the present study, the following recommendations are offered for practitioners and future researchers:

Future studies should explore the long-term effects (beyond twelve weeks) of combined circuit and plyometric training on volleyball performance variables to determine whether adaptations are sustained, enhanced, or plateau over extended periods.

Research investigating optimal sequencing of circuit and plyometric training within combined sessions is warranted, as the order of training modalities may influence the magnitude of adaptations, particularly regarding neuromuscular fatigue and its effect on plyometric training quality.

The current findings should be replicated in other age groups, including junior (under-14) and senior (above-18) female volleyball populations, to determine age-specific training responses and establish evidence-based developmental training frameworks.

Biomechanical analyses of volleyball-specific movements before and after combined training interventions would provide mechanistic insights into the technical improvements observed in spiking, serving, and jumping performance.

Injury incidence monitoring should be integrated into future studies examining plyometric and combined training in female high school athletes to comprehensively assess the safety profile of these training protocols during the pubertal development phase.

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