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Effects of a Comprehensive Training Intervention on Physical, Technical, and Cognitive Performance in Collegiate Volleyball Outside Hitters: A Randomized Controlled Trial

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Abstract

Background and Aims: Outside hitters play a crucial role in the overall performance of a volleyball team. Modern competitive volleyball places relatively high demands on its technical and tactical proficiency, application ability, and physical fitness. In recent years, integrated training approaches based on the concept of holistic sports performance have attracted increasing attention; however, their effectiveness among collegiate volleyball players requires further empirical validation. This study aims to develop a comprehensive training program for university volleyball outside hitters and to evaluate its intervention effects on sport-specific performance.

Methodology: A combination of literature review, expert interviews, questionnaire survey, and experimental research methods was employed. A total of 28 male volleyball players from Yuncheng University (age: 20.83 ± 1.12 years) were selected and randomly allocated into an experimental group and a control group. Data analysis was conducted using independent samples t-tests and repeated measures analysis of variance (ANOVA). The intervention effects were evaluated based on a group × time interaction model, with Bonferroni correction applied for post hoc comparisons. The level of statistical significance was set at 0.05.

Results: The experimental group outperformed the control group in vertical reach, spiking speed, spiking accuracy, technical evaluation, and decision-making ability ($p < 0.05$), with most indicators reaching a highly significant level ($p < 0.001$) and effect sizes ranging from moderate to large. No statistically significant difference was found between groups in serve-reception ability ($p = 0.36$); however, a moderate effect size was observed ($d = 0.36$). Within-group time effect analysis indicated that physical fitness–related indicators showed greater improvements primarily in the later stages of the intervention, whereas technical and perceptual variables demonstrated more pronounced changes in the early phase. Although decision-making ability exhibited a significant main effect of time, the group × time interaction did not reach statistical significance ($p > 0.05$).

Conclusions: (1) The integrated training program developed in this study appears to enhance sport-specific performance in collegiate volleyball players to a certain extent, particularly in

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explosive power and technical indicators; however, these findings require further validation with larger samples. (2) Technical and perceptual abilities may respond more rapidly to training stimuli, whereas physical fitness improvements tend to follow a gradual progression; the stability of this temporal pattern warrants further investigation. (3) The effect of integrated training on decision-making ability remains inconclusive, and its underlying mechanisms as well as long-term effects need further exploration. (4) Due to limitations in sample size and intervention duration, as well as the incomplete control of potential confounding variables, the generalizability of the findings should be interpreted with caution.

Keywords: Comprehensive Training; College Students; Volleyball Athletes; Outside Hitter; Performance

Introduction

Modern competitive volleyball is characterized by its comprehensive, high-speed, and dynamic nature, placing greater demands on the coordinated development of multidimensional abilities, including physical fitness, technical skills, and cognitive abilities (Huang Hansheng, 2018; Ziv & Lidor, 2010). Research indicates that athletic performance is the result of the combined effects of physical fitness, technical execution, and situational decision-making ability. Among these, the outside hitter, due to high-frequency offensive tasks and involvement in complex tactics, has become a key position influencing match outcomes (Gabbett & Georgieff, 2007). However, traditional training has long separated physical and technical training, neglecting the interactive mechanisms between different ability dimensions, making it difficult to meet the demands of modern volleyball for comprehensive performance (Suchomel et al., 2016). Based on the principles of integrated training and situational learning, training should simultaneously develop physical, technical, and cognitive abilities within environments that closely replicate real match conditions, thereby enhancing the transfer of training outcomes to actual performance. However, among university athletes, the implementation of such integrated approaches remains constrained by factors such as prevailing coaching philosophies, individual variability, and limited training time due to academic schedules (Davids et al., 2013). Although previous studies have highlighted the importance of integrated training, systematic empirical evidence regarding the effects of multidimensional interventions and their integrated assessment for outside hitters in volleyball remains scarce. Therefore, this study developed a contextualized integrated training program and employed a randomized controlled design to systematically examine its impact on the physical, technical, and cognitive performance of college volleyball outside hitters, thereby providing empirical support for the theory of comprehensive training.

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Objectives

The objectives of this study are as follows:

1. To develop a comprehensive training program to enhance the outside hitter skills of college volleyball athletes.

2. To evaluate the effectiveness of the comprehensive training program on outside hitter skills.

Literature Review

A training program is a systematic plan designed to enhance athletic performance, typically comprising cycle, annual, and unit schedules to provide a structured pathway for the development of sport-specific abilities. Multidimensional training emphasizes the integration of strength, power, technical, and cognitive training within a single framework to promote the synergistic development of multidimensional abilities.

In modern volleyball, the outside hitter has evolved from a purely offensive role into a central position that integrates offense, defense, and tactical decision-making; their performance depends on the interaction of multiple factors, including physical fitness, technical skills, and cognitive abilities (Kioumourtzoglou et al., 2000). At the physical level, lower-body explosiveness and upper-body strength form the foundation for spiking and rapid movement (Martín-Hernández et al., 2024), while strength training can enhance the recruitment and firing frequency of motor units through neuromuscular adaptation, thereby improving movement efficiency (Suchomel et al., 2016). At the technical level, high-level spiking relies on the coordination of the kinetic chain, including takeoff timing, trunk rotation, and force transmission (Slovák et al., 2023).

Furthermore, improvements in neuromuscular capacity not only enhance the quality of movement execution but may also increase athletes' perceptual-decision-making efficiency during competition by reducing the load of movement control. Research indicates that elite athletes possess faster information processing and decision-making abilities in complex situations (Ribeiro et al., 2019), an advantage partly attributable to highly automated movement patterns and stable technical performance (Macquet, 2009). Psychological resilience further ensures decision-making stability by regulating stress responses (Daffin, 2019).

Although previous studies have examined volleyball performance from physical, technical, and cognitive dimensions separately, there remains a relative lack of research integrating the mechanisms underlying these three dimensions, particularly studies employing multidimensional assessments based on comprehensive training interventions. Therefore, examining the impact of comprehensive training on the multidimensional performance of outside hitters and addressing

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the gaps in existing research regarding mechanism integration and empirical validation has become an urgent priority.

Conceptual Framework

Comprehensive Training Mechanism Framework for Volleyball Outside Hitters

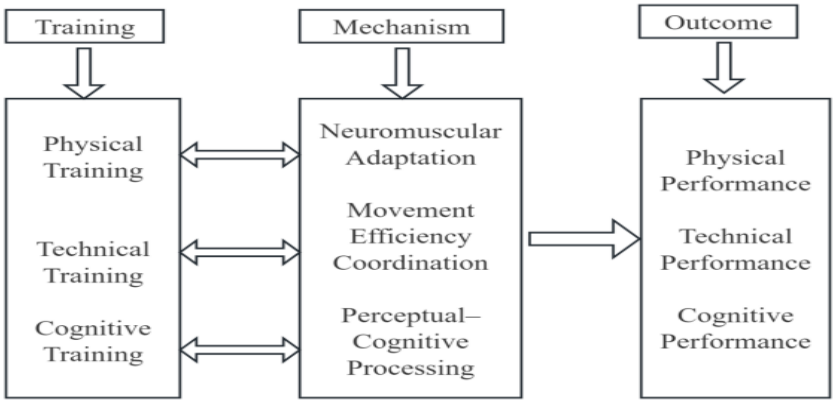


Figure 1 Research Framework

Methodology

This study targeted collegiate volleyball players in Shanxi Province, with 28 male athletes from Yuncheng University selected as participants. Based on predefined inclusion and exclusion criteria, participants were screened and then randomly assigned to either an experimental group or a control group to ensure baseline comparability.

Research instruments included an expert interview outline and evaluation questionnaires (IOC = 0.93–0.95) to assess the scientific validity and rationality of the training program. A pilot study (n = 6) was conducted before the formal experiment. The results indicated acceptable reliability (Cronbach's α = 0.82) and appropriate training loads, leading to minor refinements of the program.

The intervention lasted 12 weeks, with data collected at three time points: pre-test (Week 1), mid-test (end of Week 6), and post-test (end of Week 12). Measurements covered physical fitness, technical performance, and decision-making ability.

Data were analyzed using SPSS, with the significance level set at 0.05. Descriptive statistics (mean and standard deviation) were used to summarize the data. Independent samples *t*-tests were applied to examine between-group differences, while repeated measures ANOVA was used to assess changes over time. Bonferroni adjustments were conducted for post hoc comparisons. Effect sizes were reported using Cohen's *d* and partial eta squared ($P\eta^2$).

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Results

1. Program Overview and Theoretical Framework

This comprehensive training program is rigorously designed based on the empirical findings presented in Parts 1 and 2 of the study "Designing a Comprehensive Training Program to Improve Outside Hit Ability for College Volleyball Players." The program operates on an "Integrated Model" philosophy, fusing Technical, Physical, Decision-making, and psychological components within a unified training structure rather than in isolation.

2. Macrocycle Periodization (12 Weeks)

The 12-week macrocycle is divided into three distinct mesocycles, progressing from fundamental adaptation to complex integration and competitive optimization.

Table 1 Macro Training Plan for College Volleyball Outside Hitters

Phase	Mesocycle 1: Fundamental Ability and Adaptation	Mesocycle 2: Integrated Ability	Mesocycle 3: Game Ready and Optimization
Duration	Weeks 1–4	Weeks 5–8	Weeks 9–12
Primary Goal	Hypertrophy, movement automation, and basic cognitive cuing.	Power conversion, complex tactical scenarios, decision-making under load.	Max power maintenance, match simulation, pressure performance.
Physical Focus	General Strength and Stability	Explosive Power and Speed Strength	Speed, Agility, and Maintenance
Technical Focus	Skill Decomposition and Automation	Integration and Variation (Adjustment attacks)	Match Simulation and Error Correction
Cognitive Focus	Visual Cue Recognition	Decision Anticipation and Reaction	Live Decision Making and Tactics
Psychological Focus	Goal Setting and Relaxation	Imagery and Focus Regulation	Pressure Simulation and Resilience
Intensity	Moderate (60-70% 1RM)	High (75-85% 1RM)	High Competition Specific
Volume	High	Moderate	Low (Tapering)

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3. Comprehensive Training program intervention in the experimental group

1) Mean and standard deviation of the indicators of physical characteristics of the intervention subjects.

Table 2 shows that: Regarding age, the mean ± standard deviation for the control group was 20.85 ± 0.66, while for the experimental group it was 20.79 ± 1.48. For body weight, the mean ± standard deviation was 73.79 ± 8.54 kg in the control group and 70.93 ± 1.48 kg in the experimental group. For height, the mean ± SD in the control group was 1.80± 0.06 m, while in the experimental group it was 1.80 ± 0.05 m. For BMI, the mean ± SD in the control group was 22.23 ± 1.92, and in the experimental group it was 21.86 ± 1.63.

Table 2 The characteristics of the sample group

Variables	Control Group (n=14)	Experimental Group (n=14)
	M±SD	M±SD
Ages (years)	20.86±0.66	20.79±1.48
Weight (Kg)	73.79±8.54	70.93±6.36
Height (cm)	1.80±0.06	1.80±0.05
BMI	22.23±1.92	21.86±1.63

2) Comparative Analysis of Test Results: Between-group comparison of pretest, experimental, and control groups.

Table 3 The mean scores of the pretest Outside hitter ability for the experimental group (n=14) and the control group (n=14) were compared using an independent t-test.

Variables	Control group	Experimental group	95% CI		t	p
	M+ SD	M+ SD	lower	Upper		
Vertical jump (m)	2.97±0.03	2.99±0.04	-0.05	0.01	-1.66	0.11
Spike Speed (m/s)	15.16±0.43	15.04±0.33	-0.19	0.41	0.78	0.44
Spike Accuracy (score)	26.21±1.12	26.71±1.33	-1.45	0.45	-1.08	0.29
Technique Assessment (score)	72.71±1.98	73.93±2.56	-2.99	0.56	-1.41	0.17
Serve Reception (score)	13.21±1.71	12.64±1.22	-0.58	1.73	1.02	0.32
Decision-Making Ability	72.28±1.85	73.64±1.69	-2.74	0.02	-2.02	0.05

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Variables	Control group	Experimental group	95% CI		t	p
	M+ SD	M+ SD	lower	Upper		
(score)						
*p<.05						

Table 3 shows pretest phase intergroup comparisons revealed no statistically significant differences (p>0.05) between the experimental and control groups across all specialized physical fitness, technical, and cognitive metrics. Specifically, mean differences in peak speed, spike accuracy, spike technique scores, serve reception ability, and decision-making ability failed to reach significance levels. Regarding physical fitness metrics, no significant group differences were observed in vertical reach height or running vertical jump performance. Although minor mean differences existed in some indicators, overall performance remained within the same range.

Between-group comparison of post-test experimental and control groups

Table 4 The mean scores of the post-test of Outside hitter ability between the experimental group(n=14) and the control group(n=14) were compared using an independent t-test.

Variables	Control group	Experimental group	95% CI		t	p	Cohen's d
	M+ SD	M+ SD	lower	Upper			
Vertical jump (m)	3.04±0.05	3.16±0.03	-0.15	-0.09	-8.72	0.00*	3.28
Approach vertical jump (m)	3.13±0.14	3.22±0.06	-0.17	-0.01	-2.24	0.03*	0.83
Spike Speed (m/s)	16.29±0.42	17.21±0.91	-1.48	-0.36	-3.46	0.00*	1.28
Spike Accuracy (score)	32.07±1.33	34.14±1.01	-3.02	-1.12	-4.50	0.00*	1.71
Technique Assessment (score)	79.57±1.91	83.93±2.20	-5.96	-2.76	-5.60	0.00*	2.12
Serve Reception (score)	17.29±1.44	17.79±1.37	-1.59	0.59	-0.94	0.36	0.36
Decision-Making Ability (score)	76.43±1.65	78.86±1.92	-3.82	-1.04	-3.59	0.00*	1.36

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Variables	Control group	Experimental group	95% CI		t	p	Cohen's d
	M+ SD	M+ SD	lower	Upper			

*p<.05

The results of the independent samples *t*-test showed that, following the experimental intervention, the experimental group performed significantly better than the control group across multiple dimensions, including physical fitness, sport-specific technical performance, and cognitive ability.

In terms of physical fitness, the experimental group demonstrated a significantly higher standing vertical jump than the control group ($t = -8.72$, $p < 0.001$, $d = 3.28$). Regarding volleyball-specific technical performance, the experimental group showed significantly greater spike speed ($t = -3.46$, $p < 0.01$, $d = 1.28$) and spike accuracy ($t = -4.50$, $p < 0.001$, $d = 1.71$), both reflecting large effect sizes. In addition, technical movement scores were significantly improved ($t = -5.60$, $p < 0.001$, $d = 2.12$), indicating substantial optimization in movement quality and technical execution.

In terms of cognitive performance, the experimental group exhibited significantly better spiking decision-making ability than the control group ($t = -3.59$, $p < 0.01$, $d = 1.36$), suggesting that the intervention had a positive effect on perceptual processing and decision-making. However, no statistically significant difference was observed between the two groups in serve-receive ability ($t = -0.94$, $p = 0.36$, $d = 0.36$), indicating that the intervention had limited effects on defensive skills.

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Within-group comparisons of Outside Hitter Performance in the Experimental Group

Table 5 Mean comparison of Outside hitter ability within the experimental group (n=14) by using one-way ANOVA repeated measurement and Bonferroni post hoc

Dependent variables	Test	M.D	Std. E	p	F	p	Pη2
Vertical Jump (m)	Pretest vs Mid test	-0.09	0.01	0.001	89.23	0.001	0.82
	Pretest vs Post test	-0.16	0.01	0.001			
	Mid test vs Post test	-0.07	0.01	0.001			
Spike Speed (m/s)	Pretest vs Mid test	-0.13	0.23	1.00	58.08	0.001	0.75
	Pretest vs Post test	-2.17	0.23	0.001			
	Mid test vs Post test	-2.04	0.23	0.001			
Spike Accuracy (score)	Pretest vs Mid test	-3.79	0.45	0.001	139.33	0.001	0.88
	Pretest vs Post test	-7.43	0.45	0.001			
	Mid test vs Post test	-3.64	0.45	0.001			
Spike Technique Assessment (score)	Pretest vs Mid test	-4.50	0.91	0.001	60.26	0.001	0.76
	Pretest vs Post test	-10.00	0.91	0.001			
	Mid test vs Post test	-5.50	0.91	0.001			
Serve Reception (score)	Pretest vs Mid test	-2.71	0.44	0.001	68.47	0.001	0.78
	Pretest vs Post test	-5.14	0.44	0.001			
	Mid test vs Post test	-2.43	0.44	0.001			
Decision-Making Ability (score)	Pretest vs Mid test	-2.21	0.70	0.01	28.19	0.001	0.59
	Pretest vs Post test	-5.21	0.70	0.001			
	Mid test vs Post test	-3.00	0.70	0.001			

*p<.05

Table 5 shows that Based on the combined results of all indicators, the training intervention significantly improved the athletes' sport-specific physical fitness, technical performance, and decision-making ability. Spiking speed exhibited a significant time effect (F=58.08, p<0.001, Pη2=0.75), with the primary improvement occurring in the latter stages of training; spike accuracy (F=139.33, p<0.001, Pη2=0.88), technical evaluation of spikes (F=60.26, p<0.001, Pη2=0.76), and reception skills (F=68.47, p < 0.001, Pη2 = 0.78) all demonstrated sustained significant growth across all testing phases, with improvements in technical stability-related indicators occurring earlier than speed development. Decision-making ability also improved significantly (F = 28.19, p < 0.001, Pη2 = 0.59), indicating that comprehensive training has a positive impact on competitive

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cognition. The vertical reach exhibited significant time effects (Pη2 = 0.82 and 0.64), showing a progressive growth trend, with the vertical reach achieving a significant improvement in the later tests. Overall, all major variables reached large or very large effect sizes, indicating that this comprehensive training program not only significantly improved the specialized physical fitness and technical performance of outside hitters but also effectively promoted the development of their decision-making abilities in game situations.

Table 6 Interaction between time and group in the experimental and control groups

Variable	F	df	p	Pη^2
Vertical Jump(m)	52.07	1.37, 35.66	0.001	0.67
Spike Speed (m/s)	14.06	1.32,34.20	0.001	0.35
Spike Accuracy(score)	4.63	1.22,38.25	0.025	0.15
Spike Technique Assessment (score)	14.26	1.22, 31,80	0.001	0.35
Serve Reception(score)	3.05	1.48,38.34	0.073	0.11
Decision-Making Ability(score)	3.54	1.52, 39.57	0.050	0.12

A repeated-measures analysis of variance (ANOVA) using SPSS was conducted to examine the interaction effects between time and group for multiple indicators. Since some indicators did not meet the Mankiewicz-Shramek sphericity assumption, the Greenhouse–Geisser correction was applied, and the False Discovery Rate (FDR) method was used to control for multiple comparisons.

The results revealed that the time-by-group interaction effects for the Vertical Jump, Spike Speed, and Spike Technique Assessment measures were all statistically significant (all $p < 0.001$) and remained significant after correction. This indicates that the intervention significantly enhanced explosive power and technical execution ability. Additionally, Spike Accuracy ($p = 0.025$), Decision-Making Ability ($p = 0.050$), and Serve Reception ($p = 0.073$); these changes were marginally significant or showed a trend toward significance; however, they did not remain significant after multiple comparisons. Thus, the effects of the comprehensive training intervention on various performance indicators were selective: it significantly enhanced physical fitness and technical performance, while its impact on perception-decision-related indicators was relatively limited.

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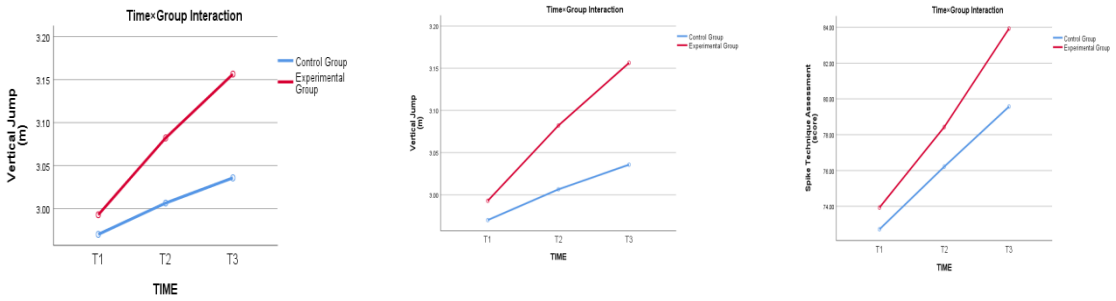


Figure 2 Trends in changes in the two groups' vertical Jump, spike speed, and spike movement assessment metrics at different time points

Conclusion

1. The comprehensive training program implemented may have a significant positive effect on the explosive power metrics of college volleyball players and demonstrate a cumulative effect that gradually increases over time. Notably, the phase of significant improvement in upper-body explosive power was concentrated in the later stages of training; however, these findings require further validation in interventions involving larger sample sizes.

2. Significant improvements in spiking accuracy, spiking technique evaluation, and reception metrics were observed as early as the initial training phase. This suggests that the refinement of technical skills in volleyball-specific training may precede the development of strength and speed; however, the stability of these improvements requires further verification.

3. The training intervention had a relatively limited effect on athletes' decision-making ability; the interaction between time and groups did not reach statistical significance, and the effect size was small. However, due to the lack of multi-scenario tasks and long-term follow-up data, the sustainability of this effect and its underlying mechanisms require further investigation.

Discussion

The comprehensive training program improved the explosive power, technical execution, and decision-making abilities of college volleyball outside hitters, with the experimental group showing significantly greater improvements than the control group. These findings suggest that an integrated "physical-technical-cognitive" training framework can effectively promote the multidimensional performance development of volleyball players.

In terms of physical fitness, the post-intervention standing reach test showed significant improvement, particularly during the later stages of training. This delayed progressive enhancement aligns with previous research indicating that explosive power development follows a cumulative adaptation process involving neuromuscular coordination, motor unit recruitment

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efficiency, and fast-twitch muscle fiber activation (Sander et al., 2013). Interventions based on speed and jump training yielded significantly greater improvements in jumping performance compared to traditional resistance training, attributed to optimized neural drive and force-velocity modulation (Silva et al., 2019). The results of this study corroborate these findings and indicate that sustained exposure to explosive and speed-oriented stimuli is key to establishing stable neuromuscular adaptations.

Spike velocity showed a significant increase primarily during the post-test phase, supporting the training principle that speed performance develops on a foundation of strength. Previous studies have demonstrated that strength training incorporating velocity-based monitoring allows precise load regulation through real-time feedback, enhancing the transfer of explosive power to sport-specific speed while reducing fatigue accumulation (Xiang et al., 2025). Furthermore, integrating physical conditioning into spike-related movement patterns may have enhanced the specificity of adaptations, supporting the notion that physical conditioning should directly serve technical execution (Zeng et al., 2023).

In contrast, technical indicators—specifically spiking accuracy and technical evaluation scores—showed significant improvements early in the intervention period, continued to increase, and exhibited large effect sizes. This temporal pattern suggests that technical adaptation precedes physical adaptation. Previous studies have also reported similar phenomena: skill-oriented training can rapidly improve technical performance, while changes in physical capacity occur later or show limited gains (Gabbett et al., 2006).

Furthermore, integrating neuromuscular elements such as balance, agility, and motor coordination may facilitate smooth transitions between the approach, takeoff, and ball contact phases, thereby enhancing overall technical efficiency. Previous research has confirmed that integrated neuromuscular training can improve movement quality and sport-specific skill performance (Hammami et al., 2018).

Notably, the comprehensive training program had a positive effect on decision-making ability, highlighting the value of integrating cognitive and psychological elements into physical and technical training. Research has demonstrated that decision-making ability is highly malleable, and structured perceptual-cognitive interventions can significantly improve tactical reaction speed and accuracy (Conejero Suárez et al., 2020). This intervention program emphasizes situational training and tactical simulations, allowing athletes to repeatedly experience the “perception-decision-execution” cycle in environments approximating competition, thereby promoting the automation of decision-making rules.

At the practical level, decision-making ability serves as a critical link between technical execution and competitive outcomes. Existing research indicates that in fast-paced team sports,

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decision-making quality is a more effective predictor of competitive performance than isolated physical attributes (McPherson & Kernodle, 2007). Therefore, improving decision-making ability can enhance offensive efficiency, allowing athletes to more accurately identify defensive gaps and select optimal spiking strategies. Furthermore, improved decision-making ability is associated with increased confidence and psychological resilience, which helps maintain performance stability during matches (Vestberg et al., 2012).

The comprehensive training program improved the explosive power, technical execution, and decision-making abilities of college volleyball outside hitters, with the experimental group showing significantly greater improvements than the control group. These findings indicate that an integrated "physical-technical-cognitive" training framework can effectively promote multidimensional performance development in volleyball players.

In terms of physical fitness, the post-intervention standing reach improved significantly, with particularly notable gains during the later training phases. This delayed, progressive enhancement aligns with previous research showing that explosive power development follows a cumulative adaptation process involving neuromuscular coordination, motor unit recruitment efficiency, and fast-twitch muscle fiber activation (Sander et al., 2013). Interventions based on speed and jump training yielded significantly greater improvements in jumping performance compared to traditional resistance training, attributed to optimized neural drive and force-velocity modulation (Silva et al., 2019). The results of this study corroborate these findings and suggest that sustained exposure to explosive and speed-oriented stimuli is key to establishing stable neuromuscular adaptations.

Spike velocity showed a significant increase primarily during the post-test phase, consistent with training theory that speed performance must be built upon a foundation of strength. Previous research indicates that velocity-based strength training enables precise load adjustment through real-time movement feedback, thereby enhancing the transfer of explosive power to sport-specific speed while minimizing fatigue accumulation (González-Badillo & Sánchez-Medina, 2010). Furthermore, integrating physical conditioning into spike-related movement patterns may have enhanced the specificity of adaptations, supporting the notion that physical conditioning should directly serve technical execution (Zeng et al., 2023).

In contrast, technical indicators, specifically spiking accuracy and technical evaluation scores, showed significant improvements early in the intervention period, with continued growth and large effect sizes. This temporal pattern suggests that technical adaptation precedes physical adaptation. Previous studies have reported similar phenomena: skill-oriented training can rapidly improve technical performance, while changes in physical capacity occur later or show limited gains (Gabbett et al., 2006). From the perspective of motor learning theory, this can be explained

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by the cognitive-association autonomous learning stage model: repeated sport-specific training accelerates the formation of motor patterns, enhances sensorimotor coupling, and stabilizes execution accuracy.

Furthermore, integrating neuromuscular elements such as balance, agility, and motor coordination may facilitate smooth transitions between the approach, takeoff, and ball contact phases, thereby enhancing overall technical efficiency. Previous research has confirmed that integrated neuromuscular training can improve movement quality and sport-specific performance (Hammami et al., 2018). This study further confirms that technical skills are highly training-sensitive, particularly when training is embedded in typical game situations with immediate feedback.

Notably, the comprehensive training program had a positive effect on decision-making ability, highlighting the value of integrating cognitive and psychological elements into physical and technical training. Research has demonstrated that decision-making ability is highly malleable, and structured perceptual-cognitive interventions can significantly improve tactical reaction speed and accuracy (Conejero Suárez et al., 2020). From the perspective of perceptual-motor coupling, elite athletes exhibit exceptional situational cue extraction abilities, enabling them to make rapid and appropriate responses under dynamic conditions (Williams & Ward, 2007). This intervention program emphasizes situational training and tactical simulations, allowing athletes to repeatedly experience the "perception-decision-execution" cycle in environments approximating competition, thereby promoting the automation of decision-making rules.

At the practical level, decision-making ability serves as a critical link between technical execution and competitive outcomes. Existing research indicates that in fast-paced team sports, decision-making quality is a more effective predictor of competitive performance than isolated physical attributes (McPherson & Kernodle, 2007).

Recommendation

This study suggests that college volleyball training should prioritize technical and cognitive training, incorporating competitive drills and situational simulations to enhance athletes' decision-making abilities and overall competitive performance. The study has several limitations, including a small sample size, a lack of objectivity in the assessment measures, and a short intervention period. Future research could expand the sample size, conduct long-term follow-ups, and utilize eye-tracking technology to quantify athletes' information processing and decision-making processes, thereby further optimizing the comprehensive training model.

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