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Effect of an Interactive Learning Programme on Motor Coordination and Serve Performance among Adolescent Tennis Players: A Controlled Pretest–Posttest Study in Al-Kut, Iraq

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Abstract. The tennis serve is a technically demanding skill that depends on a consistent ball toss, sequential segmental action along the kinetic chain and precise racket–ball contact. In many youth programmes, however, the serve is still taught mainly through blocked repetition with little task variation and limited structured feedback. This study examined the effect of an eight-week interactive learning programme on motor coordination and serve performance among adolescent tennis players. A two-group pretest–posttest design was adopted with 30 male players aged 14–16 years from a sports academy affiliated with the University of Wasit, Al-Kut, Iraq. Players were assigned to an experimental group (n = 15) that received interactive training or a control group (n = 15) that received conventional training; both groups completed 24 sessions of 60 minutes over eight weeks. The interactive programme combined variable visual targets, immediate knowledge of results, cue–response tasks and game-based peer scoring. Motor coordination was measured with a nine-target Wall-Target Reactive Test (0–100) and serve performance with a composite of accuracy, speed and technique (0–50). The groups were comparable at baseline. At posttest, the experimental group scored higher than the control group in coordination (mean difference = 17.13 points, 95% CI 14.16–20.10, $t(28) = 11.80$, $p < .001$, $d = 4.31$) and in serve performance (mean difference = 11.66 points, 95% CI 9.28–14.04, $t(28) = 10.05$, $p < .001$, $d = 3.67$), with the largest component gains in technique and accuracy. Structured interactive practice appears to be a useful complement to conventional serve instruction for adolescent players. The very large effect sizes, near-ceiling technique scores and absence of retention testing, however, call for cautious interpretation and independent replication.

Keywords: Interactive Learning, Tennis Serve, Motor Coordination, Augmented Feedback, Constraints-Led Approach, Adolescent Athletes.

1. Introduction

Tennis places continuous demands on the perceptual and motor systems. Players must read the flight of the ball, organise fast multi-joint actions and adjust them to changing spatial and temporal conditions. Among the strokes of the game, the serve holds a special position. It is the only stroke a player initiates under relatively stable conditions, yet it is also one of the most complex to learn, because it requires a repeatable ball toss, an efficient transfer of momentum from the legs through the trunk to the racket arm and accurate contact at the highest point of the swing (Elliott, 2006; Reid et al., 2008). Since every point begins with a serve, the quality of this stroke has a direct bearing on match outcomes at all levels of play.

How the serve is taught matters as much as how often it is practised. Research on motor learning has shown that the organisation of practice, the type and timing of feedback, the goals given to the learner and the direction of attention all shape the acquisition of technical skill (Schmidt et al., 2019; Wulf, 2013). In many youth academies, including those in Iraq, serve instruction still relies largely on shadow swings and repeated serving to a fixed target under coach demonstration. This approach provides volume but offers little variation, few decisions for the learner and limited information about the outcome of each attempt.

Interactive learning offers an alternative. In an interactive practice environment, target locations, visual cues and scoring rules can be manipulated so that players must adapt their movement to changing task goals while receiving immediate information about success. Such environments are consistent with the constraints-led approach, which views skilled movement as emerging from the interaction of individual, task and environmental constraints (Newell, 1986; Renshaw et al., 2019), and with representative learning design, which seeks to preserve the link between perception and action found in performance settings (Pinder et al., 2011). The evidence for related practice manipulations is, however, mixed. Systematic reviews of contextual interference show that benefits observed in laboratory tasks are smaller and less consistent in applied sport settings (Ammar et al., 2023; Czyż et al., 2024a, 2024b).

Few controlled studies have examined interactive serve instruction in adolescent players, and almost none have been conducted in Iraqi sports academies, where training resources and coaching traditions differ from those described in most published work. Adolescence is also a period in which coordination and technical skill are particularly responsive to well-designed practice (Lloyd & Oliver, 2012). Against this background, the present study investigates the effect of an eight-week interactive learning programme, compared with conventional training, on motor coordination and serve performance among adolescent tennis players in Al-Kut, Iraq.

1.1 Research Questions

- To what extent does an interactive learning programme improve motor coordination among adolescent tennis players compared with conventional training?
- To what extent does an interactive learning programme improve serve performance among adolescent tennis players compared with conventional training?
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- Which components of serve performance (accuracy, speed and technique) change most following interactive training?

1.2 Research Hypotheses

The following null hypotheses were tested at the .025 level of significance (Bonferroni-adjusted for two primary outcomes):

$H_0$1: There is no significant difference in posttest motor coordination scores between players trained with the interactive programme and those trained conventionally.
$H_0$2: There is no significant difference in posttest serve performance scores between players trained with the interactive programme and those trained conventionally.

1.3 Justification of the Study

The study is justified by the practical need to improve the quality of technical instruction in youth tennis while keeping coaching methods affordable and evidence-based. The serve is usually the first stroke in which young players develop persistent technical faults, and once these faults are automated, they are difficult to correct. An approach that improves both coordination and serve execution during adolescence may therefore have lasting value for player development.

Coaches and physical education teachers: The findings provide information on how variable targets, immediate feedback and game-based scoring can be organised within ordinary training sessions.

Players: Interactive tasks may increase engagement and give learners clearer information about the results of their movements.
Academy administrators and curriculum planners: The study indicates where investment in simple instructional equipment may be justified within sports academies and colleges of physical education.

Researchers: The study adds controlled data from an under-represented context and identifies measurement and design issues that future studies should address.

2. Literature Review

2.1 Conceptual Clarification

2.1.1 Interactive Learning

In this study, interactive learning refers to a practice environment in which the learner responds to changing task information and receives immediate outcome information that can be used to adjust subsequent attempts. Its main elements are variable task goals (for example, changing target locations), perceptual cues that call for a response, augmented feedback in the form of knowledge of results, and game-like scoring that sustains engagement. Interactive learning is not defined by technology. The same principles can be applied with electronic light systems or with coloured targets, coach signals and partner scoring.

2.1.2 Motor Coordination

Motor coordination is the spatial and temporal organisation of body segments to achieve a movement goal under given task constraints. In the tennis serve, coordination involves the timing of lower-limb drive, trunk rotation and upper-limb acceleration so that energy is transferred efficiently along the kinetic chain (Kovacs & Ellenbecker, 2011; Reid et al., 2008). In field settings, coordination is commonly assessed with tasks that combine accuracy and speed of response. Such tasks capture only part of the construct and should not be taken as direct measures of neural adaptation.

2.1.3 Serve Performance

Serve performance is the observable quality of the serve as expressed in where the ball lands (accuracy), how fast it travels (speed) and how well the movement pattern conforms to accepted technical criteria (technique). Composite scores that combine these three dimensions are common in coaching practice because each dimension alone gives an incomplete picture of serving effectiveness (Abrams et al., 2011; Kovacs & Ellenbecker, 2011).

2.2 Theoretical Framework

Three bodies of theory underpin the design of the interactive programme. The first is the constraints-led approach and ecological dynamics. Newell (1986) proposed that

movement patterns emerge from the interaction of constraints acting on the individual, the task and the environment. Coaches can therefore guide learning by manipulating task and environmental constraints rather than prescribing a single ideal technique (Chow et al., 2016; Renshaw et al., 2019). Variable targets and response cues are examples of such manipulations, encouraging players to explore functional movement solutions that remain linked to the information available in play (Pinder et al., 2011).

The second concerns augmented feedback and attentional focus. Knowledge of results tells the learner about the outcome of a movement, whereas knowledge of performance describes the movement itself. The guidance hypothesis holds that frequent, immediate feedback can enhance performance during practice but may encourage dependence if it is not gradually withdrawn (Salmoni et al., 1984). Reviews of visual, auditory and multimodal feedback confirm that timing, frequency and modality influence both acquisition and retention (Sigrist et al., 2013). Research on attention indicates that an external focus on the effect of a movement, such as a target, generally supports learning more than an internal focus on body parts (Wulf, 2013). The OPTIMAL theory adds that enhanced expectancies and learner autonomy contribute to learning alongside external focus (Wulf & Lewthwaite, 2016).

The third is contextual interference. Shea and Morgan (1979) showed that random practice can depress performance during acquisition but improve retention and transfer compared with blocked practice. Later syntheses have qualified this effect. Ammar et al. (2023) found no consistent benefit of high contextual interference in sport practice, while Czyż et al. (2024a, 2024b) reported retention and transfer benefits that were strongest in laboratory settings and varied considerably across applied studies. These findings suggest that variability should be introduced deliberately and that its effects on applied skills cannot be assumed.

Taken together, these perspectives predict that an interactive programme should improve performance on tasks that share its demands, but they also warn that immediate posttest gains are not the same as durable learning or transfer to match play.

2.3 Review of Related Studies

Biomechanical studies have established that the tennis serve is a whole-body action in which lower-limb drive and trunk rotation contribute substantially to racket speed and influence the loading of the shoulder (Elliott, 2006; Reid et al., 2008). Kovacs and Ellenbecker (2011) proposed an eight-stage model of the serve that coaches can use to evaluate technique from preparation through to follow-through, and Abrams et al. (2011) reviewed motion-analysis evidence on the flat, slice and kick serves, highlighting the importance of coordinated segment sequencing for both performance and injury prevention.

Studies on instructional manipulations in tennis are fewer. Keller et al. (2021) compared attentional instructions and augmented feedback during serving in elite players and found that displaying serve speed produced immediate increases in velocity, whereas an external attentional focus alone did not consistently outperform an internal focus. Farrow and Reid (2010) showed that scaling the court and ball to the learner increased the number of hitting opportunities and successful outcomes for young beginners, illustrating how task modification can shape skill acquisition in children. Beyond tennis, the meta-analyses cited above indicate that variable practice yields mixed results in field settings and that delayed retention and transfer tests are needed before claiming learning effects (Ammar et al., 2023; Czyż et al., 2024a, 2024b).

Most of this evidence comes from adult or elite players, laboratory tasks or short single-session protocols. Controlled multi-week interventions with adolescent players are scarce, and no published study, to the authors' knowledge, has examined interactive serve instruction in Iraqi sports academies. The present study addresses this gap by comparing an eight-week interactive programme with conventional training in adolescent players in Al-Kut.

3. Research Methodology

3.1 Research Design

The study adopted a two-group pretest–posttest experimental design. One group received the interactive learning programme (experimental group, EG) and the other received conventional serve training (control group, CG). Motor coordination and serve performance were measured before and after the eight-week intervention period.

3.2 Population and Sample

The population comprised adolescent male tennis players registered at a sports academy affiliated with the University of Wasit in Al-Kut, Wasit Governorate, Iraq. Players were eligible if they were aged 14–16 years, had at least 12 months of regular tennis training and were medically cleared for physical activity. Thirty players who met these criteria were included.

3.3 Group Assignment

The 30 players were randomly assigned to the EG (n = 15) or the CG (n = 15). All participants completed the programme and both test sessions.

3.4 Intervention Programme

Both groups trained three times per week for eight weeks (24 sessions), with each session lasting 60 minutes. The two groups therefore received the same training volume and differed only in the way serve practice was organised.

Experimental group. The EG followed an interactive programme organised in four two-week phases (Table 3.1).

Sessions used visual targets of graded difficulty placed in the service box, immediate knowledge of results after each serve, coach feedback, and stimulus–response tasks in which players had to react to a visual cue before or during serving. Tasks were presented in a game format with peer scoring to sustain motivation. The four instructional elements (structured repetition, variable target goals, immediate outcome feedback and peer scoring) were delivered together, so their individual contributions cannot be separated.

Control Group: The CG followed the academy's conventional programme, consisting of shadow swings, serves to a fixed target and coach-guided repetition with verbal correction.

Table 3.1: Structure of the Eight-Week Interactive Programme for the Experimental Group

Weeks	Instructional focus	Main interactive activities
1–2	Familiarisation with cue recognition and serve targets	Visual-cue recognition; orientation to nine target zones; target-directed serving
3–4	Variable target placement and feedback	Alternating target locations; cue-triggered serving; immediate result feedback
5–6	Combined serve and response-cue tasks	Serve-to-cue transitions; variable-response drills; partner feedback
7–8	Consolidation and game-based target selection	Integrated target games; progressive challenge; serve-placement consolidation

Source: *Researchers' Training Plan.*

Table 3.2: Outcome Measures, Score Ranges and Procedures

Measure	Score range	Procedure
Motor coordination (WTRT)	0–100	Nine target zones on a wall; player positioned 3 m from the wall; scores combine hit accuracy and response to visual cues
Serve accuracy	0–20	Ten serves to predetermined target zones in the service box
Serve speed	0–15	Ball speed recorded with a radar gun and converted to a 15-point scale
Serve technique	0–15	Rated by three experienced tennis coaches using a technical rubric; mean rating used
Serve performance (total)	0–50	Sum of accuracy, speed and technique

Note: *WTRT = Wall-Target Reactive Test.*

3.5 Instruments for Data Collection

Motor coordination. Coordination was assessed with the Wall-Target Reactive Test (WTRT). Nine numbered target zones were marked on a wall, and the player stood 3 m from the wall. On each trial the player had to strike the ball to the target indicated by a visual cue. The total score ranged from 0 to 100 and reflected both the accuracy of target hits and the response to the cues. Serve performance. Serve performance was assessed with a 50-point composite. Accuracy (0–20) was scored from ten serves directed at predetermined target zones in the service box. Speed (0–15) was measured with a radar gun and converted to a 15-point scale. Technique (0–15) was rated independently by three experienced coaches using an observational rubric, and the mean of the three ratings was used.

3.6 Validity and Reliability of the Instruments

The test battery was selected because each component reflects a demand of the serving task described in the biomechanical and coaching literature (Kovacs & Ellenbecker, 2011; Reid et al., 2008). Test–retest reliability was examined in a pilot sample of ten players not included in the main study. Intraclass correlation coefficients for the two tests were 0.89 and 0.92, indicating good to excellent reliability (Koo & Li, 2016).

3.7 Method of Data Collection

Pretests were administered in the week before the intervention and posttests in the week after the final session. The same test procedures were used on both occasions.

3.8 Method of Data Analysis

Data were summarised as means and standard deviations. Baseline equivalence was examined with independent-samples *t* tests on age, height, body mass, training experience and pretest scores. Within-group change was described as absolute and percentage gain from pretest to posttest. Between-group differences at posttest were tested with independent-samples *t* tests (equal variances assumed, $df = 28$) and reported as mean differences with 95% confidence intervals. Welch's correction for unequal variances led to identical conclusions. Effect sizes were expressed as Cohen's *d* using the pooled standard deviation,

with 0.2, 0.5 and 0.8 regarded as small, medium and large (Cohen, 1988; Lakens, 2013). Because two primary outcomes were tested, the significance level was adjusted to α = .025 (Bonferroni). Because participant-level scores were not available for this analysis, baseline-adjusted differences were approximated from the group summary statistics using the analysis of covariance (ANCOVA) model with pretest score as covariate (Vickers & Altman, 2001). As this model requires the within-group pretest–posttest correlation (r), which was not reported, the adjusted estimates were computed across a plausible range of r = 0.30–0.90 as a sensitivity analysis. Analyses were performed with Python 3 (SciPy library).

3.9 Ethical Considerations

The study was approved by the Ethics Committee of the College of Physical Education and Sports Sciences, University of Wasit (approval no. ws sport.233-2025, dated 5 January 2025) before recruitment. Because all participants were minors, written informed consent was obtained from parents or legal guardians and verbal or written assent from each player. Participation was voluntary, players could withdraw at any time without consequence, and all data were coded and analysed anonymously.

4. Results and Discussions

This section presents the results in line with the research questions and hypotheses. Baseline characteristics are described first, followed by the pretest–posttest results for motor coordination and serve performance and the component analysis of serve performance.

4.1 Characteristics of Participants and Baseline Equivalence

Table 4.1: Characteristics of Participants and Baseline Scores by Group (n = 30)

Variable	EG (n = 15) Mean ± SD	CG (n = 15) Mean ± SD	$t(28)$	p	d
Age (years)	15.20 ± 0.81	15.40 ± 0.74	−0.71	.486	−0.26
Height (cm)	168.50 ± 4.20	169.10 ± 3.95	−0.40	.690	−0.15
Body mass (kg)	61.20 ± 5.15	62.00 ± 4.85	−0.44	.665	−0.16
Training experience (months)	14.50 ± 2.10	14.20 ± 2.35	0.37	.715	0.13
Motor coordination, pretest (0–100)	54.20 ± 4.12	53.80 ± 4.35	0.26	.798	0.09
Serve performance, pretest (0–50)	22.50 ± 2.85	23.10 ± 2.90	−0.57	.572	−0.21

Source: *Field Data. EG = experimental group; CG = control group.*

Table 4.1 shows that the two groups were closely matched before the intervention. Differences in age, height, body mass and training experience were small and non-significant (all $p > .48$), as were differences in pretest coordination and serve scores ($p = .798$ and $p = .572$, respectively). The standardised differences were all below 0.30. Non-significant baseline tests do not prove equivalence, but the closeness of the means and standard deviations indicates that the groups started from a similar level.

4.2 Research Question One: Effect on Motor Coordination

Table 4.2: Pretest and Posttest Scores for Motor Coordination and Serve Performance by Group

Outcome	Group	Pretest Mean ± SD	Posttest Mean ± SD	Gain	Gain (%)
Motor coordination (0–100)	EG	54.20 ± 4.12	78.53 ± 3.85	+24.33	+44.9
	CG	53.80 ± 4.35	61.40 ± 4.10	+7.60	+14.1
Serve performance (0–50)	EG	22.50 ± 2.85	41.26 ± 3.10	+18.76	+83.4
	CG	23.10 ± 2.90	29.60 ± 3.25	+6.50	+28.1

Source: *Field Data.*

Table 4.3: Between-Group Comparison of Posttest Scores

Outcome	Mean difference (EG − CG)	95% CI	$t(28)$	p	Cohen's d
Motor coordination	17.13	14.16 to 20.10	11.80	< .001	4.31
Serve performance	11.66	9.28 to 14.04	10.05	< .001	3.67

Note: *Independent-samples t tests with pooled variance; α = .025 (Bonferroni). Welch-corrected tests gave the same conclusions.*

Table 4.4: Sensitivity Analysis of Baseline-Adjusted (ANCOVA) Posttest Differences across Assumed Pretest–Posttest Correlations

Outcome	Assumed *r*	Adjusted difference (EG − CG)	95% CI	*F*(1, 27)	Partial η^2
Motor coordination	0.30	17.02	14.12 to 19.92	145.2	0.84
	0.50	16.94	14.31 to 19.57	174.6	0.87
	0.70	16.87	14.70 to 19.04	254.5	0.90
	0.90	16.79	15.47 to 18.12	677.0	0.96
Serve performance	0.30	11.86	9.53 to 14.18	109.5	0.80
	0.50	11.99	9.88 to 14.10	135.9	0.83
	0.70	12.12	10.38 to 13.86	204.3	0.88
	0.90	12.26	11.19 to 13.32	560.4	0.95

Note: *Estimates derived from group means and standard deviations assuming a common within-group pretest–posttest correlation; all $p < .001$.*

Both groups improved their coordination scores over the eight weeks, but the size of the improvement differed markedly. The EG gained 24.33 points (44.9%), whereas the CG gained 7.60 points (14.1%), a difference in gains of 16.73 points (Table 4.2). At posttest, the EG scored 17.13 points higher than the CG (95% CI 14.16–20.10, $t(28) = 11.80$, $p < .001$), and the standardised difference was very large ($d = 4.31$; Table 4.3). Hypothesis $H_0 1$ was therefore rejected. Adjusting for pretest scores barely changed this estimate: across assumed pretest–posttest correlations of 0.30 to 0.90, the ANCOVA-adjusted difference ranged from 16.79 to 17.02 points, and the lower confidence limit never fell below 14 points (Table 4.4).

This result is consistent with the constraints-led view that changing task goals and perceptual cues encourages players to search for and stabilise effective coordination patterns (Newell, 1986; Renshaw et al., 2019). It should be noted, however, that the WTRT shares some features with the EG training tasks, particularly the use of target zones and visual cues. Part of the advantage may therefore reflect greater familiarity with the test format rather than a broader improvement in coordination, a point taken up in the discussion.

4.3 Research Question Two: Effect on Serve Performance

The same pattern appeared for serve performance. The EG improved by 18.76 points (83.4%) compared with 6.50 points (28.1%) in the CG, a difference in gains of 12.26 points (Table 4.2). At posttest the EG scored 11.66 points higher than the CG (95% CI 9.28–14.04, $t(28) = 10.05$, $p < .001$, $d = 3.67$; Table 4.3). Hypothesis $H_0 2$ was therefore rejected. The baseline-adjusted difference remained between 11.86 and 12.26 points across all assumed correlations (Table 4.4), so the conclusion does not depend on the unknown pretest–posttest correlation. Figure 1 presents the group means at both time points.

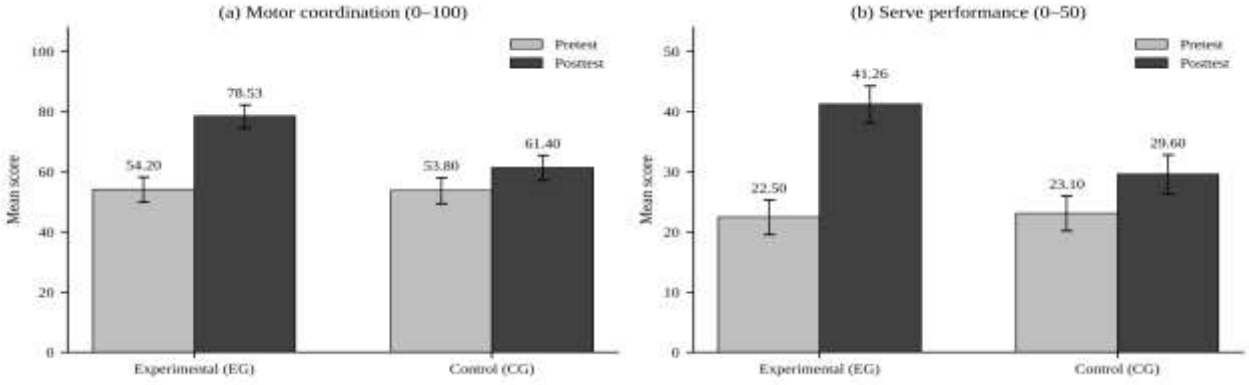


Figure 1: Mean (± SD) pretest and posttest scores for (a) motor coordination and (b) serve performance in the experimental (EG) and control (CG) groups.

These findings agree with Keller et al. (2021), who found that immediate outcome feedback produced rapid improvements in server performance, and with the broader evidence that external targets help direct the learner's attention to the effects of movement (Wulf, 2013). The present intervention differed from that study in the age and level of the players and in its eight-week duration, so the comparison is conceptual rather than quantitative.

4.4 Research Question Three: Components of Serve Performance

Table 4.5: Serve Performance Components in the Experimental Group (n = 15)

Component (maximum)	Pretest mean	Posttest mean	Absolute gain	Relative gain (%)
Accuracy (20)	8.40	15.60	+7.20	+85.7
Speed (15)	8.10	11.50	+3.40	+42.0
Technique (15)	6.00	14.16	+8.16	+136.0
Total (50)	22.50	41.26	+18.76	+83.4

Source: *Field Data.*

Technique showed the largest absolute and relative improvement (+8.16 points; +136.0%), followed by accuracy (+7.20 points; +85.7%), while speed improved least (+3.40 points; +42.0%). This ordering fits the design of the programme, which emphasised target-directed serving and feedback on outcome rather than maximal velocity. Speed depends more heavily on strength, body size and maturation, which are less likely to change substantially within eight weeks (Lloyd & Oliver, 2012). The posttest technique mean (14.16 of a possible 15) lies close to the maximum of the scale, so a ceiling effect is likely, and the technique gain may underestimate the true differences between players at the upper end.

5. Discussion of Findings

This study examined whether an eight-week interactive learning programme would improve motor coordination and serve performance among adolescent tennis players compared with conventional training. The results showed that both groups improved, but the interactive group improved substantially more on both outcomes, with the largest serve gains in technique and accuracy.

The direction of these findings is consistent with the theoretical basis of the programme. Variable targets and response cues altered the task constraints from serve to serve, requiring players to adapt their toss, body action and racket path to changing goals (Newell, 1986; Pinder et al., 2011; Renshaw et al., 2019). Immediate knowledge of results gave players information they could use on the next attempt (Salmoni et al., 1984; Sigrist et al., 2013), and visible targets directed attention to the outcome of the movement rather than to body parts (Wulf, 2013). The game-based scoring may also have supported motivation and expectancies of success, which the OPTIMAL theory identifies as contributors to learning (Wulf & Lewthwaite, 2016). Because these elements were delivered together and none of them was measured separately, the study cannot identify which element was responsible for the gains.

The size of the effects requires particular comment. Standardised differences of 4.31 and 3.67 are far larger than those usually reported in motor learning interventions, and the meta-analytic literature on practice variability reports small or inconsistent effects in applied settings (Ammar et al., 2023; Czyż et al., 2024a, 2024b). Several features of the present study may have inflated the observed differences. The coordination test resembled the EG training tasks; technique scores approached the ceiling of the rating scale; the standard deviations were small, which enlarges standardised effects even when absolute differences are moderate; and it has not been confirmed whether technique raters were blind to group allocation. The absolute differences of about 17 and 12 points, together with their confidence intervals, are therefore a more informative summary of the findings than the effect sizes alone.

The study also measured performance immediately after the programme. Improved performance at the end of practice is not equivalent to learning, which is shown by delayed retention, nor to transfer to match play (Czyż et al., 2024a, 2024b; Schmidt et al., 2019). The present results indicate a short-term advantage on the assessment tasks; whether this advantage persists and carries over to competitive serving remains to be tested.

Developmental factors should also be considered. Adolescence is a period of rapid change in body dimensions, strength and coordination (Lloyd & Oliver, 2012). The groups were similar in age, height, body mass and training experience, but biological maturation was not assessed, and differences in maturity status could affect speed-related scores in particular.

From a practical standpoint, the programme does not require costly equipment. Its principles can be applied with coloured targets, coach-given visual signals and structured partner scoring, which makes it feasible for academies and schools with limited budgets, including those in Iraq. Such low-cost versions should, however, be evaluated in their own right rather than assumed to produce the same effects as programmes using electronic target systems.

6. Limitations

The study has several limitations. The sample was small (n = 30), male only and drawn from a single academy, which limits generalisation. Baseline-adjusted (ANCOVA) estimates were approximated from summary statistics across a range of assumed pretest–posttest correlations rather than computed from individual scores; although the conclusions were stable across that range, a full ANCOVA on participant-level data remains preferable (Vickers & Altman, 2001). Serve component scores were reported for the experimental group only. In addition, the method of random sequence generation, the detailed scoring rules of the coordination test, the speed-conversion scale and the technique rubric were not fully documented, and assessors were not confirmed to be blind to group allocation, which limits replication and leaves room for assessment bias. Biological maturation, coach attention and practice outside the programme were not controlled, and no retention or match-play transfer test was conducted.

7. Conclusion

This study examined the effect of an eight-week interactive learning programme on motor coordination and serve performance among adolescent tennis players at a sports academy in Al-Kut, Iraq. Using a two-group pretest–posttest design with 30 players, it found that players who trained with variable visual targets, immediate outcome feedback, cue–response tasks and game-based scoring achieved markedly higher posttest scores in both coordination and serve performance than players who followed conventional training. Within serve performance, technique and accuracy improved most, and speed least.

These results suggest that interactive practice is a promising complement to conventional serve instruction in youth tennis. Given the unusually large effects, the near-ceiling technique scores, the similarity between the coordination test and the training tasks and the absence of retention testing, the findings should be regarded as preliminary evidence of short-term improvement rather than proof of durable learning. Replication with larger and more diverse samples, baseline-adjusted analysis and delayed retention and transfer tests is needed before firm recommendations can be made.

8. Recommendations

Based on the findings of the study, the following recommendations are made:

Integration into Coaching Programmes: Tennis coaches and academy directors should consider incorporating variable target serving, immediate outcome feedback and game-based scoring into regular serve instruction as a complement to, not a replacement for, conventional technical coaching.

Low-Cost Implementation: Academies and physical education departments with limited resources can apply the same principles with coloured targets, coach signals and partner scoring.

Gradual Reduction of Feedback: Coaches should progressively reduce the frequency of augmented feedback to encourage players to rely on their own error detection.

Coach Education: Colleges of physical education and sports sciences should include constraints-led and interactive practice design in coach and teacher preparation programmes.

Future Research: Future studies should use larger samples that include female players and different skill levels, assess biological maturation, blind assessors to group allocation, use coordination tests that differ from the training tasks, apply baseline-adjusted analysis and include delayed retention and match-play transfer tests.

9. Contribution to Knowledge

This study provides controlled data on interactive serve instruction among adolescent tennis players in Iraq, a context that is largely absent from the published literature. It shows how principles from the constraints-led approach, augmented feedback and attentional focus can be combined into a practical eight-week programme, and it identifies the measurement and design features, such as test–task similarity, ceiling effects and the need for retention testing, that future studies of interactive learning in sport should address.

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