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Effect of Motor Learning Strategies Based on Mental Imagery in Improvement Motor Coordination of the Backhand Stroke Among Young Tennis Players

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Abstract

The purpose of this study was to explore the effectiveness of a mental imagery program on backhand stroke coordination by young tennis players. We used a quasi-experimental design with a pre-test post-test and two groups; an experimental group of 12 male (14-16 y) & control group of 12, male players from the same age category. The experimental group underwent a six-week mental imagery intervention (three sessions of 30 minutes/session). These sessions stressed on imagining movements from first and third person perspectives, emphasizing details and promoting awareness of body movements. In contrast, the control group continued its usual training activities and did not perform any mental imagery task. Motor coordination was measured with the Körperkoordination für Kinder (KTK) test and movement analysis was recorded using high-speed video filming. Statistical data were collected using descriptive statistics, paired and independent t-tests, as well as effect size value. A significant improvement for the experimental group could also be found in neuromuscular coordination, (Pre-Test: 45.33 ± 3.21; Post-test: 51.75 ± 2.88; t = -8.45, p <.001, d = 2.32), while no change appeared within the control group (Pre-test: 44.91 ± 3.47; Post-test: 45.30 ± 3.55; t =.65, p =.53, d =.11). Between-group differences persisted in favor of the experimental group [post-test (t = 5.78, p < 0.001, d = 1.87)]. These results suggest structured mental imagery possessing strong potential to act as a means for improving motor performance in tennis, and possibly other skill sports.

Keywords: motor skills, mental imagery, tennis, psychomotor performance.

Introduction

Motor learning is a foundational domain within movement and exercise sciences, concerned with the processes through which individuals acquire, retain, and transfer motor skills as a result of structured practice (Cumming & Williams, 2012). Among the emerging approaches in this field, mental imagery has shown particular promise as an effective performance-enhancement strategy. It involves the cognitive simulation of movements in the absence of physical execution, enabling the refinement of motor patterns and neural activation associated with skilled performance (Guillot & Collet, 2008). Such a claim would be justified by research demonstrating improvement in variables such as accuracy, timing and motor co-ordination that are related to sport (1,2).

Tennis backhand serves are one of the most difficult motor skills, which demand perfect coordination between upper and lower limbs and a good neuromuscular function (3). The physical principle is already clear which supports the strong association with tennis practiced since childhood, emphasizing how young tennis players have difficulty in combining technical and physical training when there are high demands on their time or when fatigue and injury risk impede physical practice in space. In this regard, mental imagery stands out as a promising alternative which may increase motor memory and control without any physical activity (4,5). In tennis, experimental work has shown that the implementation of structured sessions of mental imagery indeed produced increased levels of overall back-hand accuracy and neuromuscular coordination in young players (3,6). Furthermore, Ali et al. (2023) have drawn attention to the fact that mental imagery is affected by the participant's ability and somatosensory input, e.g., holding a racket during mental imagery, which increases all sensory-motor induced representation in time and space of the movement (7). These results highlight the potential of mental imagery as a partial substitute for physical practice, both theoretically and practically, particularly during the early stages of motor skill acquisition or under physical constraints (8).

Even though there is an increasing attention to the role of mental imagery in sports training, a common suggestion has been its implementation in combination with physical practice, thereby limiting the possibility for isolating the independent influence of mental imagery on motor coordination. Moreover, there is scarce evidence on the direct effects of mental imagery training on the coordination in backhand stroke among young tennis players. This lack of the literature indicates that a study testing how effective motor imagery is, as a technique separate from motor performance tasks to improve motor coordination was needed.

This study aims to examine the effectiveness of mental imagery as a motor learning strategy in enhancing the motor coordination of the backhand stroke among young tennis players. It seeks to compare pre- and post-intervention performance following a structured mental imagery training program that emphasizes cognitive rehearsal of movement without any physical involvement, and to identify its impact on motor memory and neuromuscular integration indicators.

It is hypothesized that a systematic mental imagery training program will significantly improve the motor coordination of the backhand stroke among young tennis players compared to pre-training performance. It is also expected that these improvements will be associated with positive changes in motor memory and neuromuscular responses, even in the absence of physical practice.

The importance of the present study would be to contribute to developing scientific knowledge regarding mental imagery as an educational and training tool relative to physical practice in tennis, also, because it can be a suitable or even successful alternative or supplement. The results could provide coaches with scientific methods to develop low-load, cognitive-based training strategies aimed at improving motor performance and coordination in young athletes. Finally, the present finding adds to the general understanding of motor learning by applying cognitive and neuromuscular views on improving performance using non-physical training methods.

The sample comprised young tennis players, aged 14-16 years, who attended the Specialized School of Baghdad and had similar levels of physical and motor skills before starting the intervention. The study was performed from August 2025 to October 2026 and involved pre-test training, executing of the mental imagery program, and post-tests. The experiments were performed at Specialized School in Baghdad, that provided a controlled and appropriate testing situation for measurements and training since the environmental conditions are kept consistent.

Methodology

Research Design

The research adopted quasi experimental design with pretest and posttest equivalent group; there were two groups the experiment group and the control group. We aimed to evaluate the effects of a six-week mental imagery program on motor coordination in the backhand stroke technique in young tennis athletes. The main purpose of this study was to control the influences between mental imagery and physically practicing and effectiveness compared to no intervention with control group.

Participants

Study sample Twenty-four young male tennis players were included in this study aged from 14 to16 years who were attending the Specialized School for Tennis in Baghdad. Subjects were randomly assigned to two groups of equal size, an experimental group (n = 12) who underwent the mental imagery programmed and a control group (n = 12) that continued their usual training with no further experimentation. Participants were selected purposefully based on the following inclusion criteria: regular participation in tennis training, comparable physical and motor levels, and absence of any injuries or health conditions that could affect performance. Written informed consent was obtained from all participants and their guardians prior to the commencement of the study.

Before initiating the experimental intervention, pre-tests were conducted for both the experimental and control groups to ensure their statistical equivalence in the main study variable. The results of the independent samples t-test indicated no statistically significant differences between the two groups in the measured variable, suggesting that the groups were homogeneous at the starting point as shown in table 1. Therefore, any subsequent differences in outcomes can be attributed solely to the effect of the structured mental imagery program rather than to any initial disparities between the participants.

Table 1. *Statistical Equivalence Between the Experimental and Control Groups*				
Variable	**Experimental Group**	**Control Group**	**t-value**	**p-value**
Neuromuscular Coordination (KTK Test)	45.33 ± 3.21	44.91 ± 3.47	0.32	0.75*
*: Non-Significant at p >0.05				

Instruments and Tools

The use of validated and standardized tools guaranteed the reliability of evaluation for motor coordination in this study. The Mental Imagery Training Procedure was developed on existing theoretical and empirical bases, and consistently applied 30 minutes per session three times a week for six weeks. The intervention incorporated increasing amounts of internal and external attentional focus strategies where the latter was combined with the explicit intent of improving neuromuscular control and maximizing temporal organization of movement in response to demands from an externally focused task (3,9). Motor proficiency was also assessed with a short version of the Körperkoordinationstest für Kinder (KTK) to provide a well-known quantitative score for neuromotor fitness in children. It is composed of four basic motor activities (e.g., walking on a beam, vertical jump, horizontal jump, lateral transfer over boxes) and already adapted test to measure coordination between upper and lower limbs during tennis backhand stroke performance (10). In addition, moving images were filmed using high-speed video recording to capture and extensively measure kinetic and kinematic values for the biomechanics of the badminton backhand stroke including joint range-of-motion (RoM), limb velocity, inter-limb timing.

Procedures

Structured scientific method was used in this study having pre-test, intervention and posttest phases for experimental group as well as control groups. All participants were tested in the same way before the intervention to evaluate motor coordination (MC) and backhand performance, using tests that are valid and reliable. Motor coordination was measured by the KTK test, which assesses the integration of upper and lower limbs with emphasis on timing, spatial control and movement accuracy (10). A full analysis of the backhand stroke involved high-speed video recording of joint angles at elbow, shoulder and hip, arm velocity and inter-limb coordination all recorded at 240 frames/s.

The experimental group underwent a six-week mental imagery intervention, three times weekly for approximately 30 min. Sessions were conducted in a quiet room at Baghdad Specialized School to reduce potential interruption. Subjects were comfortably seated and, under the supervision of an experienced coach, selected spoken instructions and tapede material. The training conditions included different types of images: internal image (i.e., where players mentally generated the body sensations relative to the movement of their hand, wrist and arm during the backhand stroke), external image (i.e., where they imagined themselves from an outside perspective performing a backhand stroke with particular attention to the coordination between their upper-lower limbs), and focused attention to technical aspects (e.g., racket angle at ball impact and follow through) in order to produce more accurate/economic movements.

From a task consisting of isolated limb movements in weeks 1-2, participants then put themselves in readiness -- through visualizing the total stroke sequence in weeks 3-6 for cues to timing and coordination. Participants, for example, were asked to imagine the fluid swinging of the racket while simultaneously ensuring that both hips and shoulders were aligned so force would be maximally exerted.

The control group was trained using their usual tennis training programme, three 90-minute sessions per week of physical drill work, technical practice and match play, without mental imagery intervention. This method was used to assure a valid comparison where only the influence of the imagery program would be measured.

Post-test used the same procedures as those of pre-test conditions, with instruments held in the same manner to assess changes in motor-coordination and backhand performance. Uniform testing conditions were ensured in the controlled environment of the Specialized School. The weekly intervention was rationally designed, as described in the Table 2.

Table 2. *Weekly Mental Imagery Training Program for Backhand Stroke Coordination*

Week	Sessions per Week	Session Duration	Session Content	Primary Objective
1	3	30 min	Introduction to the basics of mental imagery, initial mental guidance for the backhand stroke, and focus-attention drills	Adaptation to imagery and development of basic motor awareness
2	3	30 min	Internal imagery practice focusing on hand, wrist, and arm movement	Strengthening neuromuscular coordination of upper limbs
3	3	30 min	External imagery to visualize full-body movement, integrating upper and lower limbs	Improving inter-limb coordination
4	3	30 min	Combination of internal and external imagery with focus on timing and temporal coordination	Enhancing timing accuracy and movement precision
5	3	30 min	Advanced imagery drills for full-sequence visualization, attention to technical details	Increasing smoothness and neuromuscular efficiency
6	3	30 min	Comprehensive review of all imagery techniques, full integration of internal and external imagery	Consolidating motor coordination and optimizing overall performance

The control group continued to follow their routine tennis training schedules over the 6 weeks, without experimental interference. This method served to provide a balanced level of comparison between the two groups and avoid any confounding influence on analyzing the partial effects regarding the mental imagery program.
After completion of the 6-week training program, post-tests were conducted for both groups in same situation and instruments as pre-test. These tests aimed to measure the extent of improvement in motor coordination and backhand, which allowed an objective comparison between experimental and control groups.

Statistical Analysis
Descriptive statistics and Chi-square tests were performed using SPSS (Version 26). Mean and standard deviations were computed for all variables as descriptive statistics to summarize group performance. Independent-samples t-tests were used to compare baseline characteristics of the experimental and control groups. Paired-samples t-tests were used to evaluate within-group differences from pre-test to post-test. Cohen’s d was calculated for estimating effect sizes and its magnitude of the intervention. P-values ≤ 0.05 were considered significant for all tests.

Result

Table 3. *Descriptive Statistics and Within-Group Comparisons for Neuromuscular Coordination*					
Group	**Pre-Test (M ± SD)**	**Post-Test (M ± SD)**	**t-value**	**p-value**	**Cohen's d**
Experimental	45.33 ± 3.21	51.75 ± 2.88	8.45	0.000*	2.32
Control	44.91 ± 3.47	45.30 ± 3.55	0.65	0.53	0.11
*Significant at p ≤ 0.05					

Table 4. *Independent-Sample t-Test for Between-Group Comparisons*				
Comparison	**Post-Test Mean**	**t-value**	**p-value**	**Cohen's d**
Experimental vs. Control	51.75 vs 45.30	5.78	0.000*	1.87
*Significant at p ≤ 0.05				

Table 5. *Descriptive Statistics and Within-Group Comparisons for Video Analysis*						
Group	**Metric**	**Pre-Test (M ± SD)**	**Post-Test (M ± SD)**	**t-value**	**p-value**	**Cohen's d**
Experimental	Elbow Joint Angle (Degrees)	125.4 ± 8.2	132.7 ± 6.5	-4.12	0.002*	1.01
	Limb Velocity (m/s)	3.8 ± 0.5	4.3 ± 0.4	-3.87	0.003*	0.94
	Inter-Limb Temporal Coordination (s)	0.12 ± 0.03	0.08 ± 0.02	4.56	0.000*	1.15
Control	Elbow Joint Angle (Degrees)	126.1 ± 7.8	126.1 ± 7.9	0.02	0.98	0.00
	Limb Velocity (m/s)	3.9 ± 0.6	3.9 ± 0.6	0.15	0.88	0.00
	Inter-Limb Temporal Coordination (s)	0.11 ± 0.03	0.11 ± 0.03	0.10	0.92	0.00
*Significant at p ≤ 0.05						

Discussion

Our results point out a strong and easily measurable effect of the Mental Imagery program proposed in the present intervention on complex neuromuscular coordination during execution of an effective BH stroke in young tennis players. In contrast, the control group that did not complete any formal mental training showed no tangible improvement over six weeks. This sharp discrepancy vigorously endorses that imagery is an efficient cognitive-motor training device for potentiating skill acquisition and performance in youth athletes.

The better results shown by the experimental group, would be related to the intensified mental rehearsal that reinforces the link between motor representations and movements execution. Mental rehearsal seems to facilitate the activation and synchronization of the motor-planning areas of our brain, allowing for increased accuracy during motor-pathway engagement (9,11). Imagery also enables athletes to mentally practice movement patterns without physical execution that leads to the programming of motor elements, spatial and temporal coordination, and the sharpening of mental representations involved in complex skill (12,13). In the current investigation, however, imagery-based training enabled players to effectively concentrate on the co-ordination of upper and lower limb movements a crucial element for performing a powerful backhand stroke (14,15).

The systematic approach of the programme that starts with simple guided exercises along with advancing to full-sequence visualisations in combination awareness and adding attention is also consistent with motor-learning theory and cognitive simulation. This deliberate mental practice seems to have a dramatic effect not only in the quality of the movement itself, but also on neuromuscular timing and coordination (16, 17), especially when movements are complex and require precise limb synchronization. However, the control group's changes were not so big as to be significant among whom there was regular physical training. This finding is consistent with the idea that standard physical training alone cannot maximize coordination in some respects, and an integrative use of physical and mental forms of training could be more effective.

These findings back up earlier research showing that mental practice can significantly enhance physical training, particularly for young athletes who are still developing their cognitive skills and visual-motor connections (18). After the mental imagery program, where players mentally rehearsed the timing, posture, and smoothness of their backhand strokes, they likely built stronger sensorimotor connections. This led to the generalization of imagery practice to performance itself. The type of reasoning described above therefore not only permit mental practice to be considered as a "psychological trick" but also it is proved at neurophysiological level that can provoke the same changes in a motor coordination, that can be objectively measured, this way (3,15).

Overall, this study allows those that develop training programs for tennis instruct other specific skills to incorporate mental imagery protocols, specifically in the case of young athletes and more so when complex skills involving precise coordination and synchronization between limbs are involved. Furthermore, they demonstrate the value of applying a cognitive and physical combined training strategy to improve youth sport skill acquisition and performance.

Limitations

several limitations should be considered. First, the small sample size (n=24) may limit generalizability, necessitating larger samples in future studies. Second, the modified KTK test, while practical, may not fully capture tennis-specific coordination demands. Third, the study included only male players aged 14–16 years, potentially limiting applicability to female players or other age groups. Fourth, the laboratory-based mental imagery intervention is somewhat limited in respect to simulating real training grounds that may present distractions. Moreover, the control group received standard training (sessions of 90 min) which in duration and intensity differed from the experimental intervention (sessions of 30 min), potentially causing interferences with the outcomes. Lastly, the video analysis has been limited to a subset of kinematic parameters; including electromyography (EMG) data might provide more extensive information on local neuromuscular effects. It is important that future lines of research address these limitations by sampling populations more representative of the general population and employing sport-specific assessments.

Conclusions

The present study established that the mental imagery package had some effect on improving neuromechanical coordination related to backhand stroke performance in young tennis players. Altered movement timing, smoothness and interlimb coordination in the untrained limb of participants in the intervention group were also significantly different to those of the control group. These findings add to the growing evidence that MI can be an effective cognitive motor tool, supplementing physical practice with respect to learning complex motor skills.

Recommendations

It was recommended that coaches and sport instructors should include in their day-to-day practice transferring-verbal imagery-designed sessions, gradually moving from simple rehearsal to visualization of the full sequence. Verbal Instructions and Practice for Upper-Limb Motor Skill Training During Rehabilitative Interventions Extremity Deficit Synergies Motor Imagery-Verbal Suggestions as Applied to Motor Skill Practice can be Combined with Mental Imagery-Constrained Movement Therapy to Promote Greater Opportunities for Enhanced Outcome Monitoring. Furthermore, similar interventions should be tested in other sports and age categories towards a better club or performance management coordination.

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