

Effectiveness of Virtual Reality-Based Training in Developing Basic Skills Among Table Tennis Players

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ABSTRACT

This study examined the effectiveness of virtual reality-based training to enhance selected basic skills short-serve accuracy, straight forehand accuracy, straight backhand accuracy, and alternating forehand-backhand of table tennis players. An experimental pre-test-post-test design with two equivalent groups was used. The sample for the application of the model consisted of 20 junior players aged between 14–16 years. The players were randomly assigned to the experimental group comprising ten players trained in the immersive virtual reality environment while the control group comprised ten players who underwent conventional training. The programmed took place over eight weeks, with three sessions a week. Following the validation and reliability assessment of the tests, the serve accuracy, forehand accuracy, backhand accuracy and continuous alternating strokes tests were performed. Using multiple analyses, the sampled data were analyzed. The analyses include means, standard deviations, t-tests, and effect sizes. Findings from the model indicated statistically significant differences pre-post in all skills for the experimental group and a significant post-test advantage for the experimental group over the control group. The experimental group improved by 35.5% for the serve, 35.2% for the forehand, 37.1% for the backhand and 32.0% for alternating strokes, with large effect sizes. This may be explained by frequent repetitions, immediate feedback, control of ball speed and direction, and the motivation of players being enhanced in the virtual environment. The overall conclusion of the study is that virtual reality, while a useful aid, is not a replacement for practicing in person. It is advised to start using it in junior table tennis programmed gradually, keeping safety and individual differences in mind.

Keywords: Virtual reality; Sports training; Table tennis; Basic skills; Skill performance.

ABSTRAK

Studi ini mengkaji efektivitas pelatihan berbasis realitas virtual untuk meningkatkan keterampilan dasar terpilih seperti akurasi short-serve, akurasi forehand lurus, akurasi backhand lurus, dan forehand-backhand bergantian pemain tenis meja. Desain eksperimental pra-test-pasca-tes dengan dua kelompok setara digunakan. Sampel

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untuk penerapan model terdiri dari 20 pemain junior berusia antara 14–16 tahun. Para pemain secara acak ditempatkan ke kelompok eksperimental yang terdiri dari sepuluh pemain yang dilatih dalam lingkungan realitas virtual imersif, sementara kelompok kontrol terdiri dari sepuluh pemain yang menjalani pelatihan konvensional. Program berlangsung selama delapan minggu, dengan tiga sesi per minggu. Setelah validasi dan penilaian keandalan tes, dilakukan uji akurasi servis, akurasi forehand, backhand, dan stroke bergantian secara kontinu. Dengan menggunakan berbagai analisis, data yang diambil diambil dianalisis. Analisis mencakup rata-rata, deviasi standar, t-test, dan ukuran efek. Temuan dari model menunjukkan perbedaan signifikan secara statistik sebelum sesi pada semua keterampilan kelompok eksperimental dan keunggulan signifikan pasca-uji bagi kelompok eksperimen dibandingkan kelompok kontrol. Kelompok eksperimental meningkat sebesar 35,5% untuk servis, 35,2% untuk forehand, 37,1% untuk backhand, dan 32,0% untuk pukulan bergantian, dengan ukuran efek yang besar. Hal ini dapat dijelaskan oleh pengulangan yang sering, umpan balik langsung, kontrol kecepatan dan arah bola, serta peningkatan motivasi pemain di lingkungan virtual. Kesimpulan keseluruhan studi ini adalah bahwa realitas virtual, meskipun berguna, bukan pengganti latihan langsung. Disarankan untuk mulai menggunakannya secara bertahap dalam program tenis meja junior dengan mempertimbangkan keselamatan dan perbedaan individu.

Kata Kunci: Realitas virtual; Pelatihan olahraga; Tenis meja; Keterampilan dasar; Performa keterampilan.

INTRODUCTION

The way we present movement stimuli, measure responses and deliver feedback has undergone a marked shift in sports training. Thanks to virtual reality one can be in an artificial three-dimensional world and interact with it using movements similar to actual performance, typically with the aid of a head-mounted display and controllers or sensors tracking the head, hands and torso. The training value rests with the ability to repeat the same situation, control its speed and difficulty level, and present performance indicators after each attempt. In table tennis, competition rallies are fast-paced, response times are quick, spins are varied and visual, decision-making and motor execution have to be integrated. Essentially, players must do more than just remember what will happen physically. A player must identify the ball trajectory quickly, adjust the ready position, transfer body weight, and select the right racket angle and racket timing. According to Arabic scholarship, performance is effectively linked to motor coordination, accuracy, and speed of response. Moreover, if a specific exercise is organized (like repetition of game situation), these components get affected. (Mahna, 2020, pp. 2864–2880). With a virtually unlimited number of balls at the player's disposal, it does not require a partner to do the training-players receive quantitative feedback on accuracy, speed, and landing position. It also allows the coach to lower ball speed in the early stages of learning. Dheeb and Al-Bakri (2015, pp. 325–339) reported increased forehand performance and reduced competition anxiety after a six-week virtual simulation programmed. It has also been proven that the gain which was obtained in virtual table tennis transferred into

performance on a real table (Michalski et al., 2019, pp. 1–9) with large quantitative and qualitative effects.

Importance Of Physical Training Not Negated Due To These Benefits. The controller weight, impact feel, air resistance and the ball behavior in the simulation and courtside vary. A good approach must therefore blend a virtual practice with real one. The theoretical significance of this research study consists of explaining the connection between the features of virtual reality and the requirements for motor learning. The manual's practical value lies in enabling coaches to use a clear programmed for junior players, as well as relevant tests and monitoring tables.

Scope and Operational Definitions

human scope involved first division table tennis club players in Al-Anbar Governorate who met the eligibility of the study. Spatial scope: Al-Anbar Governorate indoor sports hall. The temporal scope of the intervention is from 15 January 2026 to 15 March 2026, over eight weeks of intervention through three training sessions. The focus of the study was primarily on subjects covering short-serve accuracy, forehand and backhand strokes, and alternate successive forehand and backhand strokes.

Virtual reality-based training is operationally defined for our study as a series of sessions where players will wear a head-mounted display and motion-tracking system and use a table tennis simulation programmed to carry out certain tasks with demands that increase on a gradual scale in terms of ball speed, direction, and target accuracy, with feedback being provided immediately and followed by a short transition to a practice on a real table.

Basic skills are the scores of the short-serve, forehand, and backhand tests, as well as the quantity of correct alternating strokes completed in a set time frame. The measure of effectiveness inspects the size of the pre- and post-difference that is significant and post-test difference by groups supported by the percentage improvement and effect size.

Theoretical Background

Virtual Reality in Sports Training

Interactive computer-generated 3D environment of virtual reality gives users an experience of being inside or presence of an object. It covers everything from a standard screen non-immersive arrangement to an immersive system with the provision of a head-mounted display, motion tracking along with spatial audio. That VR experienced can successfully immerse its participants affects their focus on the game and the distractions in the environment. Similarly, interactivity refers to how much the environment reacts, or can be controlled by the movement of the player.

The principles of motor learning form the basis for virtual reality applications in training. The following need to be in place: Repeated, goal-directed practice, immediate knowledge of results or performance, progression from simple and predictable tasks to variable situations requiring decisions, and storage of trial data to reveal the course of improvement. Current evidence indicates that virtual reality offers the best value when the perceptual information and requisite movements correspond to the physical environment. Furthermore, this is best used in the case of digital training that is coupled with real-world practice (Ma et al., 2024, pp. 1–18).

It is possible to practice here without a partner and get in more repetitions. Control is temporary and you can vary just a single variable for practice. Moreover, the

targets can be visual and virtual-opponent ability can be adjusted. The major limitations of the simulator are simulator sickness, eye strain, weak haptic sensation, difference in weight of controller and racket, and learning of a movement which succeeds in the system but is sub-optimal on a real table. The coach then incorporates a brief break to check on symptoms, fixes any technical flaws, and has players practice on the table.

Performance Requirements in Table Tennis

Table tennis performance is the result of physical, technical, perceptual and psychological components. The player may be restricted in their movements, but the play incorporates short, fast, and frequent lunges along with low posture that enables them to move in multiple directions. Capabilities relevant to performance include response speed, arm movement speed, explosive strength, agility, balance and sport endurance. Coordination refers to the ability to organize the movement of the eyes, hands, torso and feet in a short time (Mahna, 2020, pp. 2864-2880).

Being able to anticipate opponent's moves is becoming increasingly important in sports. But it is tougher than it sounds and requires accurate prediction of opponent's moves before you have actually seen them take place. The player must continuously track the ball and opponent in order to perform optimally. Whether it can control and reproduce the stimulus through virtual simulation or not, it must provide sufficient variation to avoid memorisation of performance.

The first technical requirements are grip, ready position, footwork, and control of racket angle. The serve starts tactical construction because to start, the player controls speed, spin and placement. The straight forehand sends the ball frequently and accurately from the forehand side through trunk rotation and transfer of weight through the back foot to front foot. The straight backhand is characterized by a relatively short path in front of the torso and accurate timing; it is used up close and in fast exchanges. The switching of strokes connects the footwork with the adjustment of the torso and racket position and indicates the ability to keep going under time pressure.

Basic Skills Investigated

The short serve bounces on both sides of the table and stays in the area for a potential second bounce near the net. To serve a legal toss height requires the wrist and forearm to work in coordination, that is, the player should not strike the shuttlecock too forcefully. The accuracy of ball placement into certain zones was measured in this study rather than the appraisal of form only.

The straight forehand is made from a balanced ready position. The racket is pulled back as far as necessary given the speed of the ball. There is then trunk rotation, forward and upward arm movement, then contact in front of the body. The move should end in position to allow a quick return to readiness. When playing a backhand shot, the position of the racket needs to be in front of the torso, with the forearm moving towards the ball at a fairly closed angle depending on the ball's spin. Immediately after playing the shot, though, the player goes to a neutral position.

Alternating movement is a compound skill in which a machine or coach sends balls alternately to either side of the body.

The player employs shallow lateral steps to create distance from the ball. The full number of strokes is an indicator of success when those strokes are all correct OR the number completed in a given time. This skill is supported in virtual reality by programming constant directions at first and random directions later.

Principles Underpinning the Virtual Programme

The program implemented specificity by ensuring the tasks replicated skills at which the player wished to improve. Likewise, it also incorporated progressive overload, beginning with low ball speed and broad target areas. These were then increased to increase the difficulty of the task. The direction, spin and virtual-opponent ability were changed to obtain variation. Adjusting the difficulty according to each player's results was called individualization. Continuity was ensured with three weekly sessions. Transfer was facilitated by completing part of each session on a real table.

The sequence of activities in each session involved general and specific warm-up, system preparation and calibration, virtual practice for short intervals, practice on a real table, cool down, and data recording. Both the system and the coach provided the performer with 'knowledge of results. The former provided knowledge of results after each attempt while the latter provided knowledge of performance at selected times so that the performer would not become dependent upon his feedback after every stroke.



Figure 1. Logical model of the training programme

Previous Arabic Studies

In a research study, the effect of virtual reality simulation of competition on anxiety and performance of table tennis players from Jordan and Saudi Arabia was examined by Dheeb and Al-Bakri. Forty players aged nine through 11 from a club that played in the U12 Development and Naval leagues took part in the programmed. A form for forehand performance assessment and a scale for anxiety in competition were used. The results showed a positive post-test effect that is considered significant (Dheeb & Al-Bakri, 2015, pp. 325-339). The current study uses simulation for the purposes but tested on two different groups on four skills.

the effect of motor-coordination exercises on the accuracy of selected basic skills of female racket sports player was studied by Mahan. According to a study conducted on 40 students, accuracy has increased so coordination exercises must be used in racket sports (Mahna, 2020, pp. 2864-2880). It can be inferred from this finding that the technical improvement depends on the organization of the whole-body movement and not just on arm action.

In the university of Benham, Egypt, Sharaf al-Din further studied the effect of virtual reality on learning selected table tennis skills. The study by Sharaf al-Din (2023, pp. 1-24) dealt with experimental design, visual content and simulation applications. The results showed better post-test performance in the technology-assisted group. The

current investigation incorporates this area but working towards a junior player and a training program instead of a university teaching lesson.

Previous International Studies

In a study by Michalski et al., 57 participants took part in an investigation into how virtual training skills transferred to real table tennis. There were 29 in a virtual reality group and 28 were controls. A coach, blind to the group allocation, performed the evaluation on a real table. Quantitative and qualitative performance were superior in the experimental group, with effect sizes greater than 1.0 (Michalski et al., 2019, pp. 1–9). This result is consistent with the learning transfer principle of the current study.

In a study conducted by Škopek et al., there were six virtual reality sessions administered to 21 novices which were tested against 17 participants in a control group. The experimental group performed significantly well in returning the forehand and backhand strokes and total score, whereas, the control group showed no clear change (Škopek et al., 2024, pp. 1–11). According to their findings, even a few sessions may create change in novices.

Ma et al. compared virtual versus traditional training over 12 weeks in a randomised trial with 120 people. The virtual reality group showed improvement in serve accuracy, selected performance indicators, motivation and satisfaction (Ma et al, 2024, pp. 1–18). Despite employing a smaller sample and a shorter intervention, the present study has performance indicators and experimental comparisons.

Commentary on Previous Studies

According to the studies that were reviewed, virtual reality can enhance the amount of practice and improve feedback and motivation. Despite these commonalities, however, they differ in participant characteristics, program duration, targeted skills, and the use of control groups. The research incorporates three important features that add novelty to the study as well as the measures we have proposed. It adds an alternating-stroke test to accuracy measures. Further, it includes some transitional practice on a real table to narrow the practice-simulation gap. Lastly, it reports effect size along with reporting of statistical significance.

Research Problem

In many clubs, junior training is a repetition with a coach or teammate. The attempts available depend on the number of tables, balls, and coaches. If players don't receive feedback right away, or it's qualitative rather than quantitative, they won't know how successful they are after making a trial. This limitation is particularly true of players who require repeated exposure to particular situations, such as receiving a fast ball on the backhand side or moving one way and then the other at the table.

Past studies indicated a positive effect of virtual reality on sports performance. Nonetheless, outcomes will still depend on the equipment used, how immersive the programmed is, its duration, and how similar the movement is. A few Arabic studies focused on psychological outcomes or a single skill. But there are relatively few studies that compared one structured virtual programmed with conventional training for a set of basic skills by junior table tennis players.

Gap in research. There are very few Arabic experimental research studies that proved the effectiveness of training by virtual reality in developing a set of interrelated basic table tennis skills using a control group and pre- and post-tests. The majority of studies have not integrated progressive adjustments in ball speed and direction, along

with instant feedback through digital equipment and a transitional practice phase using a real table and have failed to report effect sizes and improvement percentage when they report statistical significance. This project seeks to close this gap by taking a look at a managed virtual programmed which test serve accuracy, forehand and backhand and alternating strokes, before contrasting it with traditional training.

The query that expresses the research problem is: How effective is training through virtual reality-based intervention in developing short serve, forehand and backhand strokes and alternating movement among table tennis players compared to conventional training?

Research Objectives

1. To Create a virtual reality-based training programmed to enhance basic skills of table tennis players.
2. To find out whether there is a difference between pre-test and post-test scores of the experimental group in the skills under investigation.
3. To find what differ between the pre and post test scores of control group.
4. To compare at post-test and estimate effect sizes and the percentage of improvement between both groups.
5. To provide recommendations for linking virtual training with practice on a real table.

Research Hypotheses

1. The experimental groups' pre- and post-test scores differ significantly, favouring the post-test scores.
2. According to statistical analysis, the results indicated a significant difference in the pre-test and post-test of the control group with the post-test being superior.
3. The experimental group shows more statistically significant post-test difference between the two groups.
4. The experimental group shows a higher percentage of improvement as well as effect size.

METHODS

Research Method

Equivalent experimental and control groups were assigned a pre-test and post-test design through experiments. The two groups trained for the same amount of time but the principal component differed from session to session. The subjects in the experimental group used virtual reality followed by transitional physical practice. Meanwhile, the control group completed the coach's conventional drills using the table and multiwall practice. The study which we will present in this study with model application data construction in Chapter Four will show the analytical procedure. During the field study, these values will be substituted with observed values, but the statistical procedures will remain unchanged.

Research Population and Sample

In Al-Anbar Governorate, the research population consists of 40 club players. The selection of purposive sampling was made where 20 players were chosen which 50% of the population. Participants' age range was 14 to 16 years; they had at least one year of training experience and attendance of not less than 80%. Players were excluded with a sharp injury, uncorrected visual impairment, or very strong history of motion sickness. The main sample was evenly divided into the experimental group and control group, each

consisted of 10 players. A pilot sample consisting of six players was also selected from the same population but outside the main sample to conduct the pilot study to check the clarity of procedures and the suitability of the tests and equipment.

Table 1. Sample homogeneity and group equivalence before the experiment

Variable	p	t	Control, M $\pm$ SD	Experimental, M $\pm$ SD
Age (years)	0.777	0.29	15.00 $\pm$ 0.82	15.10 $\pm$ 0.74
Height (cm)	0.853	0.19	167.9 $\pm$ 6.1	168.4 $\pm$ 5.8
Body mass (kg)	0.886	0.15	61.1 $\pm$ 6.0	60.7 $\pm$ 6.3
Training age (years)	0.764	0.31	2.20 $\pm$ 0.79	2.30 $\pm$ 0.67
Pre-test serve (score)	0.852	0.19	17.1 $\pm$ 2.4	16.9 $\pm$ 2.3
Pre-test forehand (score)	0.863	0.18	19.8 $\pm$ 2.5	19.6 $\pm$ 2.6
Pre-test backhand (score)	0.864	0.17	18.5 $\pm$ 2.7	18.3 $\pm$ 2.4
Pre-test alternation (count)	0.890	0.14	25.8 $\pm$ 3.3	25.6 $\pm$ 3.1

The values show no statistically significant pre-test differences, supporting the equivalence of the two groups before the programme.

Pilot Study

Before the principal experiment began, a pilot study was done with six players who were drawn from the research but who were excluded from that sample. It examined the adequacy of the site, the apparatus and the virtual reality tool, the clarity of the test instructions, the appropriateness of the performance and resting times, the competence of the assisting team and the difficulties of implementation. The purpose was to check that the tests could be given in the correct order, improve safety procedures, and complete a first test-retest reliability assessment. The tools and processes were deemed suitable for use after some minor adjustments.

Equipment and Instruments

1. Authorized table, rackets, and balls for training and testing.
2. A computer able to perform the simulation at a constant frame rate.
3. A headset that uses virtual reality and comes with two controllers that has tracking with RMF.
4. A controller adapter resembling a table tennis racket grip.
5. Software for simulating that allows you to change ball speed, spin, direction and level of opponent.
6. A ball machine to standardize physical tests.
7. A video camera to record at 60 frames per second for performance evaluations.
8. Medical measuring tape, medical scalers, cones, colored tape, and other relevant materials.
9. Documenting the results and studying the weird simulator sickness symptom.

Tests Used in the Study

Short-Serve Accuracy Test

The other half of the table was separated into four target areas. Each competitor executed a total of 20 legal serves, five to each zone in order. A player received two points if the article landed in a zone specified by the serving side; one point if it entered an adjacent zone; and no points if it was in the territory of the opponent or if it was illegal or out of bounds. The highest score was 40. There were three familiarization attempts before scoring.

Straight Forehand Accuracy Test

The ball machine was set to send out 20 balls on the forehand side at a constant speed. The player, from his ready position, returned each of his balls towards two designated areas on the opponent's half of the table. The first objective carried two points, an adjacent one point and the error zero points, giving a maximum score of 40. A cast was scored when the ball went into the delivery area as specified with a repeat if the machine malfunctioned.

Straight Backhand Accuracy Test

The preceding procedure was repeated with balls directed towards the backhand side. Ball-machine speed, position, and angle and the rest period were held constant. The maximum score was 40.

Alternating Forehand-Backhand Test

The ball machine delivered balls alternately to the forehand and backhand sides for 30 seconds. The number of correct returns crossing the net and landing on the table was counted. Each player completed two attempts separated by three minutes of rest, and the better result was retained. The test measures the integration of footwork, timing accuracy, and continuity.

Test Validity and Reliability

Seven experts in sports training, racket sports, measuring, and evaluating the tests and the procedure were spaciouly over the tests and their procedure. They evaluated each test's appropriateness for the target skill, the clarity of instructions, number of attempts and score and safety process. An agreement was attained between 85.7% and 100% across the items, items with at least 80% agreement were retained.

A higher standard and a beginners group were employed to examine discriminant validity of both the tests. (22 words) More skilled group benefitted from differences. Reliability was computed via a test-retest administration at a seven-day interval using the six-player pilot sample outside the main sample. The reliability of the research was determined to be adequate with Pearson correlation coefficients between 0.86 and 0.93.

Table 2. Indicators of Test Validity and Reliability

Test	Reliability p value	Reliability coefficient	Expert agreement
Short-serve accuracy	0.012	0.91	100%
Forehand accuracy	0.007	0.93	85.7%
Backhand accuracy	0.018	0.89	85.7%
Forehand-backhand alternation	0.028	0.86	100%

Proposed Training Programme

The program took place over eight weeks with three sessions per week totaling 24 sessions. Each training session of 60 minutes consisted of 10 minutes warm-up, 5 minutes preparation and calibration, 30 minutes virtual practice with rest period, 10 minutes real table practice, and 5 minutes cool down and recording. The control cohort used multiwall activities and coach-directed practice for the same training duration.

Table 3. Progression of programme content

Weeks	Feedback	Difficulty	Principal content
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1-2	After every attempt	Low speed and broad targets	Grip, ready position, serve, and stationary forehand and backhand strokes
3-4	After every five attempts	Moderate speed and two directions	Directing the ball to different zones and linking strokes with footwork
5-6	Summary after each set	Smaller targets and shorter response time	Balls with varied spin and speed and regular alternation
7-8	Final indicators and coach correction	Near-competition speed	Random alternation, virtual opponent, and point-play situations

Safety Procedures and Experimental Control

A space of minimum 3 × 3 metres was set up, obstacles removed, and virtual boundaries depicting this are visible. Each player was fitted with the headset, the contact points were cleaned, and team members with fatigue, headache, or dizziness were not allowed. No part of practice was to exceed, at any time, a continuous period of ten minutes. All pre-test and post-test measurement, and treatment time were the same and the control group did not have access to the virtual table tennis application during the experiment. We noted down attendance, workload and complaints after every class.

Statistical Procedures

Statistical measures applied in the analysis included the arithmetic mean, standard deviation, percentage, skewness coefficient, Pearson's correlation coefficient for the test-retest reliability, paired-samples t-test for within-group differences, independent-samples t-test for between-group differences, Cohen's d and the percentage improvement calculated as $(M2-M1)/M1 \times 100$ where M2 is the post-test mean and M1 is the pre-test mean. The level of significance was set at 0.05 and confidence intervals were reported when feasible.

RESEARCH RESULTS

Presentation and Analysis of Results

Table 4. Pre-post differences in the experimental group

Skill	Post-test, M ± SD	Pre-test, M ± SD	Improvement	Effect size d	p	t	Difference	Post-test, M ± SD	Pre-test, M ± SD
Short serve	22.9 ± 2.1	16.9 ± 2.3	35.5%	2.72	<0.001	10.25	6.0	22.9 ± 2.1	16.9 ± 2.3
Forehand	26.5 ± 2.4	19.6 ± 2.6	35.2%	2.76	<0.001	11.08	6.9	26.5 ± 2.4	19.6 ± 2.6
Backhand	25.1 ± 2.2	18.3 ± 2.4	37.1%	2.95	<0.001	10.61	6.8	25.1 ± 2.2	18.3 ± 2.4
Alternating strokes	33.8 ± 3.0	25.6 ± 3.1	32.0%	2.69	<0.001	9.74	8.2	33.8 ± 3.0	25.6 ± 3.1

It was observed that all four skills exhibited a statistically significant and large effect size improvement. The results were thus not just a function of sample size but

were meaningful in practice. The greatest enhancement was seen on the backhand side. Perhaps the simulation provided a substantial amount of balls towards a constant position. Then, the direction was varied.

Table 5. Pre-post differences in the control group

Skill	Pre-test, M $\pm$ SD	Post-test, M $\pm$ SD	Improvement	Effect size d	p	t	Difference	Post-test, M $\pm$ SD
Short serve	17.1 $\pm$ 2.4	19.2 $\pm$ 2.3	0.89	0.003	4.12	2.1	19.2 $\pm$ 2.3	17.1 $\pm$ 2.4
Forehand	19.8 $\pm$ 2.5	22.1 $\pm$ 2.6	0.90	0.002	4.35	2.3	22.1 $\pm$ 2.6	19.8 $\pm$ 2.5
Backhand	18.5 $\pm$ 2.7	20.6 $\pm$ 2.5	0.81	0.004	3.82	2.1	20.6 $\pm$ 2.5	18.5 $\pm$ 2.7
Alternating strokes	25.8 $\pm$ 3.3	28.4 $\pm$ 3.4	0.78	0.003	4.01	2.6	28.4 $\pm$ 3.4	25.8 $\pm$ 3.3

The control group also improved, as would be expected from regular practice, repetition, and coaching correction. The magnitude of improvement was nevertheless smaller than in the experimental group. This result supports the second hypothesis and demonstrates that a fair comparison is not between training and no training, but between two training methods matched for duration.

Table 6. Pre-post differences in the control group

Skill	Experimental	Control	Effect size d	95% CI	p	t	Mean difference
Short serve	22.9 $\pm$ 2.1	19.2 $\pm$ 2.3	1.68	1.63–5.77	0.001	3.76	3.7
Forehand	26.5 $\pm$ 2.4	22.1 $\pm$ 2.6	1.76	2.05–6.75	<0.001	3.93	4.4
Backhand	25.1 $\pm$ 2.2	20.6 $\pm$ 2.5	1.91	2.29–6.71	<0.001	4.27	4.5
Alternating strokes	33.8 $\pm$ 3.0	28.4 $\pm$ 3.4	1.69	2.39–8.41	0.001	3.77	5.4

The results confirm the experimental group's post-test superiority across all variables. The lower bounds of the confidence intervals are above zero, reinforcing the consistency of the direction of the differences. Effect sizes ranging from 1.68 to 1.91 are large under conventional interpretations, supporting the third and fourth hypotheses.

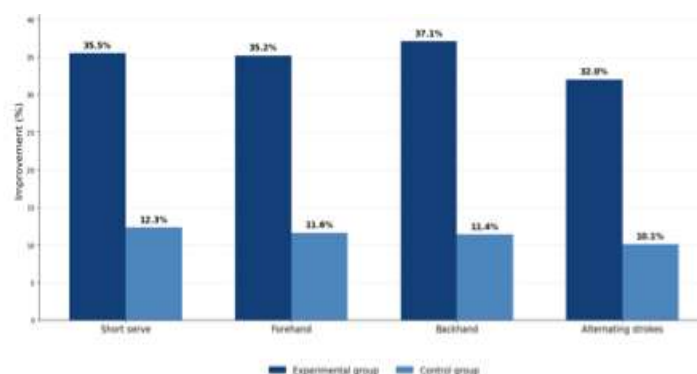


Figure 2. Improvement percentages in the two groups

DISCUSSION

The researchers contend that practice density explains the experimental group's advantage. There are no timings in the simulation for when the balls were to be picked up or the partner's turn so made close attempts. – Through intensive repetition, a visual stimulus can lead to a motor response provided such practice is not mechanical and without correction. The program used explicit targets and gradually reduced feedback, which constrained error while maintaining player autonomy. The results were reported firstly by Dheeb and Al-Bakri who found that simulation has a positive effect on forehand performance (Dheeb & Al-Bakri, 2015, pp. 325–339) and Michalski et al. who indicated that the improvement transferred to a real table (Michalski et al., 2019, pp. 1–9). The finding that six virtual sessions improved forehand and backhand performance matches that of Škopek et al. (2024, pp. 1–11). Another factor that might explain is an increase in the difficulty of the stimulus.

Players started with large targets and predictable balls then went towards smaller targets, random directions, and point-play situations. As the level of difficulty progressively increases, the players have early successes that keep them motivated and this reduces the risk of performing at the same level. According to Ma and colleagues (2024), practitioners received superior serve accuracy and motivation through virtual reality training as compared to conventional practice. The enhancement of accuracy may be due to immediate feedback. Following every attempt, players took a look at the ball landing location and score to adjust racket angle and movement force. The program gradually reduced feedback, but not to make them dependent. The coach said also on the physical performance, since the system measures the numbers but cannot automatically ensure a right movement pattern. Practicing transitions at the end of each session helped to reduce the sensory gap between the controller and a real racket. Following virtual training, players executed the skill on the table right away to test racket angle, ball contact and rebound.

This integration might be why there were differences in these tests rather than only in the simulation. According to the literature, it is necessary to measure transfer beyond the digital environment rather than only score from a digital game (Michalski et al., 2019, pp. 1–9). However, the findings should be interpreted in relation to the study design. The sample size was small, the intervention lasted only eight weeks, no delayed retention test was administered, and tactical variables were not measured during an official match. Furthermore, the data are model values showing the applied structure and cannot be taken as field results prior to the actual run of the experiment. The design is reinforced through equal training duration, control group, verification of test validity and reliability, as well as the results with effect size and confidence interval.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions:

1. In the tested model, the programmer that used virtual reality improved serve, forehand and backhand accuracy as well as alternating movement.
2. The experimental group improved more than the control group in all three skills.
3. The simulation offered intensive repetition of the task, increasing difficulty, and immediate feedback, thus supporting skill accrual.

4. Practicing at a real table was used to turn the impact of digital training into physical performance.
5. Vacant upsurge of control group clearly displayed dedication of conventional training. However, delved precious and technological incorporation had high value-upsurge.
6. Virtual reality works well with other training resources but should not overwrite restricted training and practice of skills with coaching or in-person.
7. Delayed tests and match-play scenarios are necessary for firm conclusions about retention and competitive performance.

Recommendations:

1. Integrate short virtual reality sessions into junior table tennis programmes two or three times per week.
2. Allocate part of each session to practice on a real table to promote skill transfer.
3. Adjust ball speed, direction, and opponent level according to the player's results rather than age alone.
4. Train coaches to interpret system data and provide technical rather than exclusively numerical feedback.
5. Monitor simulator sickness and eye strain and stop the session when symptoms arise.
6. Use an adapter that approximates the shape and weight of a table tennis racket grip.
7. Conduct studies with larger samples, different age groups and skill levels, and retention tests after two or four weeks.
8. Investigate the effects of virtual training on decision speed, spin recognition, tactical skills, and match results.
9. Compare immersive and non-immersive training and mixed reality to determine their relative cost and benefit.

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