The Effect of Virtual Reality on Some Skill Variables in Tennis

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Abstract

This study investigates the impact of virtual reality (VR) technology on developing skill variables in table tennis among female players under 17 years old. Utilizing an experimental research design with a single experimental group, the study included pre-test, intermediate-test, and post-test measurements to evaluate performance. The sample comprised 10 randomly selected table tennis players from Sinai Sports Club. VR technology was employed in a training program to enhance essential skills such as topspin strokes (forehand and backhand), straight strokes, smash strokes, serves, and serve returns.

The results revealed statistically significant improvements in all skill variables in favor of the post-test. Improvement rates ranged from 15.011% to 80.157%, demonstrating the effectiveness of VR technology in training. Key findings highlighted substantial advancements in speed and accuracy across all tested skills, including top-spin forehand and backhand strokes, smash forehand strokes, and serve-related performance.

The study concludes that VR technology is a valuable tool for developing technical skills, reducing training time, and improving training efficiency. Recommendations include integrating VR technology into skill training programs, especially in table tennis, to enhance players' engagement and performance. This research contributes to advancing training methodologies by merging innovative VR applications with traditional sports practices, paving the way for more effective and enjoyable training experiences.

Key words: Virtual Reality, Serve, Forehand, backhand.

Preface:

Virtual Reality is a cutting-edge 3D technology that allows users to interact with simulated environments resembling real-world scenarios. This innovative approach has applications across various fields, including education, training, and sports. VR technology provides players with realistic training scenarios, enabling them to practice different game situations and strategies without requiring physical access to specialized facilities. It offers a promising solution for skill enhancement in sports such as table tennis, where accuracy, speed, and decision-making are critical.

Virtual Reality (VR) technology, characterized by three-dimensional designs, has emerged as one of the most prominent technological innovations of the modern era, integrated across various smart devices. VR systems simulate real-world experiences with interactive 3D graphics that fully engage learners through their senses, sparking interest and motivation (**Al-Halfawi, 2011**). This interaction varies depending on the type of VR and the tools employed. This research focuses on utilizing VR to enhance the skills of table tennis players, specifically targeting the improvement of accuracy, speed, reflexes, decision-making, and mental coordination. The study involves reviewing current literature, analyzing existing tools, and designing and implementing VR-based training programs to address technical skill deficiencies in serves and returns observed in players during competitions.

Azmi (2014) stated that virtual reality is a professional environment designed to enable users to interact with it through their senses of sight and hearing in a way that simulates reality. It is produced using modern technology by simulating sound and 3D images.

Newby *et al*. (2013) described virtual reality as an elaborate visual representation in the form of 3D images or graphics that users respond to and are drawn to interact with. **Abdel-Hamid (2010)** defined virtual reality as a new mode that blends reality with imagination to represent and display objects, either static or dynamic, with learners interacting with these environments using modern devices or tools.

Al-Shaye and Al-Eid (2015) added that the third dimension plays a critical role in virtual reality technology, allowing students to immerse themselves fully. This has made technology a practical and fertile reality for various uses in education, training, and beyond. **Abdel-Hamid (2010)** further highlighted that one of the most important characteristics of virtual reality is immersion. The higher the user's level of immersion, the greater their sense of engagement. It is also characterized by connectivity, where the more focused a user is on the stimuli in the virtual environment, the more connected they feel, ultimately enhancing their sense of presence.

Al-Hosan and Oyaid (2012) noted that virtual reality possesses the following characteristics:

- Flexibility in synchronous and asynchronous learning, as well as in choosing appropriate learning materials and locations.

- Rapid alignment with advancements in science and technology.
- Providing precise and detailed information about certain topics and landmarks.
- Catering to individual differences among learners, making them active participants rather than passive recipients.
- Offering learners opportunities to explore modern technologies, programs, and various useful applications.

(Khaled Abdel Aziz ,2023) pointed out that virtual reality helps shift the educational process from a theoretical and rigid framework to a dynamic and practical one, giving learners an active role in the educational process and improving their academic achievement and positive interaction.

Interacting with 3D virtual reality designs leads to the formation of a clear conceptual model for students **(O'Connor, 2010).** Many studies have demonstrated the effectiveness of virtual reality applications in various academic courses, such as the study by (**Winn & Bricken,1997).**

This study arose from observations made by the researcher as a table tennis player and coach. The researcher noted technical errors in serving and returning serves during table tennis tournaments, leading to lost points. These errors were attributed to traditional training methods. Consequently, this study aims to explore the use of contemporary virtual reality technology as an engaging training tool to enhance players' skills in serving and returning serves in table tennis.

In addition to technical errors in serving and returning serves, table tennis players may face other challenges, such as lack of focus, slow reactions to the ball's movement, and difficulty estimating its speed and direction. Virtual reality training can address these issues by providing an interactive and engaging environment that improves focus, quick reactions, and accurate estimation of ball movement and speed. Furthermore, virtual reality can simulate different game situations, improving players' strategies and decision-making on the court.

By using virtual reality, players can experience various conditions and scenarios they may encounter in actual play, developing their skills and psychological readiness for competitions more effectively. As such, virtual reality can be an efficient tool for improving table tennis players' overall performance and skill.

Addressing Training Challenges

Other players might face challenges such as limited training opportunities, particularly in areas with restricted access to table tennis facilities. Virtual reality provides semi-realistic training experiences anywhere and anytime, helping players enhance their skills without needing a specific location. It also boosts the enjoyment and motivation of training, encouraging players to develop their skills continuously.

Virtual reality can also improve gameplay strategies and provide a deeper understanding of opponent responses and behavior, aiding players in enhancing their performance and

preparation for competitions. Moreover, it offers a safe and alternative training experience when real-world conditions are unsuitable for practice. For instance, a sports team can use virtual reality to simulate game scenarios without needing an actual field, enabling them to prepare and build strategies even in the absence of optimal conditions.

Thus, virtual reality technology can significantly improve team performance and readiness for actual competitions. This enhancement can positively impact team outcomes in sports events, increasing their chances of success in matches. Furthermore, interactive training programs using virtual reality can improve physical fitness and tactical skills, helping athletes perform at a higher level and adapt to tactical changes more effectively during games.

The study identifies several challenges faced by table tennis players, including:

1. Poor technical performance in serving and returning serves.
2. Loss of points due to technical errors.
3. Reliance on traditional training methods that fail to address modern requirements.
4. Difficulty in predicting ball speed and direction.
5. Limited focus and slower reaction times.
6. Insufficient access to training facilities in some regions.
7. The need for improved playing strategies and quick decision-making.

Objectives

The study aims to:

1. Analyze and assess technical performance issues in serving and returning serves.
2. Evaluate the impact of VR on improving players' performance and skills.
3. Develop VR-based training programs tailored to table tennis.
4. Provide recommendations for integrating VR into coaching practices.
5. Examine the psychological and motivational benefits derived from VR training.

Research Hypotheses

1. **Analysis of Variance**: There are significant differences among the three measurements (pre-test, intermediate-test, and post-test) within the research group in skill tests.
2. **Significance of Differences**: Significant differences will be observed using the Least Significant Difference (LSD) method and the rate of percentage change (improvement rate) between the means of the three measurements (pre-test, intermediate-test, and post-test) for the research group in table tennis skill tests (under investigation).

3. **Percentage Improvement**: There will be a measurable percentage improvement rate among the three measurements (pre-test, intermediate-test, and post-test) within the research group in the skill tests (under investigation).

Research Methodology

The researcher utilized the **experimental method**, specifically a single experimental group design, employing pre-test, intermediate-test, and post-test measurements. This method was deemed suitable for the nature of the study.

Research Population

The research population consists of **table tennis players** at the Sinai Sports Club in North Sinai Governorate during the **2023/2024 sports season**.

Research Sample

The research sample was selected using a **purposive random sampling method** from the table tennis players of the Sinai Sports Club in North Sinai Governorate. The total population included **40 players** from the table tennis team at Sinai Sports Club in Arish. A subset of players was randomly selected, and the **core study sample consisted of 10 players** under the age of 17 from the Sinai Sports Club during the **2023/2024 sports season**.

Table (1): Description of the Research Sample

Sample	Number	Percentage
Core Study Sample	10	50%
Exploratory Study Sample	10	50%
Total Sample	20	100%

Homogeneity of the Research Sample

The researcher ensured homogeneity among the research sample in terms of growth indicators, training age, and skill variables under investigation. This is demonstrated in Table (1), which provides the statistical description of the research sample.

Table (2): Statistical Descriptions of the Research Sample for Key Variables to Ensure Data Normality

Items	Core Variables	Unit of Measurement	Mean	Median	Standard Deviation	Kurtosis	Skewness
Growth Indicators							
1	Age	Years/Months	16.230	16.150	0.411	-0.967	0.584
2	Height	Cm	161.160	160.900	1.796	-1.041	0.434
3	Weight	Kg	61.040	60.750	1.641	-0.077	0.717
4	Training Age	Years/Months	6.630	6.550	0.469	-1.597	-0.034
Skill Tests							
1	Speed and accuracy of topspin forehand stroke response to chopping	Number	11.900	12.000	0.738	-0.734	0.407
2	Speed and accuracy of topspin backhand stroke response to chopping	Number	10.400	10.000	1.075	-0.882	1.116
3	Speed and accuracy of smash forehand stroke response	Number	14.700	15.000	0.949	-0.347	-0.234
4	Speed and accuracy of straight forehand stroke response	Number	15.400	15.500	0.966	-0.623	-0.111
5	Speed and accuracy of straight backhand stroke response	Number	12.800	13.000	1.033	-0.896	-0.272
	Speed and accuracy of serve	Number	12.500	13.400	0.858	-0.823	0.267
	Speed and accuracy of serve return	Number	9.400	9.600	1.031	-0.758	0.311

- **Sample Size (N)**: 10 participants.
- **Standard Error for Skewness**: 0.687.
- **Critical Skewness Value at 0.05 Significance Level**: 1.347.

The table demonstrates that skewness values fall within acceptable limits for normal distribution (±3), confirming the **normality of data** and the appropriateness of the sample for the study.

Research Domains

1. Human Domain

The core study was conducted on 10 female table tennis players under the age of 17 from the Sinai Sports Club.

2. Spatial Domain

The proposed training program was implemented in the table tennis hall of the Sinai Sports Club.

3. Temporal Domain

The research measurements were carried out during the period from June 3, 2023, to September 11, 2023, within the 2023/2024 training season.

Data Collection Tools and Equipment

The tools and equipment used in the research included:

1. Calibrated Medical Scale: For measuring total body weight.
2. Stadiometer: For measuring body height.
3. Stopwatch: For measuring time during tests.
4. Measuring Tape: For distance-related measurements.
5. Standard Table Tennis Tables: Certified by the International Table Tennis Federation (ITTF).
6. Standard Nets: Certified by the International Table Tennis Federation (ITTF).
7. Table Tennis Balls: Certified by the International Table Tennis Federation (ITTF).
8. Electronic Ball Launcher: For consistent ball delivery during training.
9. Virtual Reality (VR) Headset: For immersive training simulations.
10. Table Tennis Rackets: Standard equipment for skill evaluation.

The researcher utilized a series of skill tests after reviewing numerous specialized scientific references and prior studies, both Arabic and international. These references include studies such as:**(Ali.*et al.*,2023),(Diaa,2020),(Basima,2019)**

These studies helped identify the key skill variables relevant to the current research context in table tennis. The specific skill tests were designed to evaluate these variables comprehensively.

Table (3): Relative Frequency of Skill Variables in Table Tennis

items.	Skills	Tests	Frequency	Percentage (%)
1	Serve	Serve without spin	1	14.28%
	Serve with backspin	1	14.28%	
	Serve with sidespin	1	14.28%	
	Serve with topspin	1	14.28%	
	Serve with mixed spin	2	28.57%	
2	Offensive Strokes	Straight stroke	7	100%
	Topspin stroke	7	100%	
	Smash stroke	7	100%	
	Straight stroke	2	28.57%	
	Flick stroke	3	42.85%	
3	Defensive Strokes	Push	1	14.28%
	Block	2	28.57%	
	Chop	3	42.85%	
	Lob	1	14.28%	
	Half volley	1	14.28%	

- Sample Size (N): 10 participants.
- The table shows the relative frequency percentages of skill variables in table tennis.
- The researcher established a threshold of 80% or higher for the selection of key skill variables.

Exploratory Study

Exploratory Study Timeline

The researcher conducted the exploratory study on a sample of 10 players from outside the main sample. The purpose was to calculate the scientific validity and reliability of the physical and skill tests under investigation. The exploration study was conducted between , and Monday, May 29, 2023.

Objectives of the Exploratory Study

1. Distributing tasks and training assistants on test procedures.

2. Ensuring the suitability and functionality of the tools and equipment used.
3. Verifying the appropriateness of the location designated for conducting the tests.
4. Evaluating the adequacy of the data recording forms.
5. Organizing the application of tests on the research sample.
6. Determining the time interval between the first and second measurements for reliability testing.
7. Ensuring the scientific validity and reliability of the physical and skill tests under investigation.

Scientific Validity and Reliability of Skill Tests

Validity

The researcher assessed validity using the discriminatory validity method, which compares two groups: one skilled group and one unskilled group. Each group consisted of 10 players from outside the main sample. The statistical analysis demonstrating this validity is detailed in Table (4).

Table (4): Differences Between Means of Skilled and Unskilled Groups to Determine Validity Coefficients for Skill Tests

items.	Skill Test	Skilled Group	Unskilled Group	Difference Between Means	t-value	Eta Squared (η^2)	Validity Coefficient
		Mean (M) ±SD	Mean (M) ±SD				
1	Speed and accuracy of topspin forehand stroke response to chopping	16.300 ± 1.827	9.800 ± 0.897	6.500	6.387	0.836	0.914
2	Speed and accuracy of topspin backhand stroke response to chopping	15.670 ± 1.623	8.830 ± 0.869	6.840	7.431	0.873	0.935
3	Speed and accuracy of smash forehand stroke response	17.945 ± 0.911	12.575 ± 0.674	5.370	9.477	0.918	0.958

items.	Skill Test	Skilled Group	Unskilled Group	Difference Between Means	t-value	Eta Squared (η^2)	Validity Coefficient
4	Speed and accuracy of straight forehand stroke response	19.960 ± 1.271	13.330 ± 0.893	6.630	8.536	0.901	0.949
5	Speed and accuracy of straight backhand stroke response	16.830 ± 1.387	10.780 ± 1.018	6.050	7.033	0.861	0.924
6	Speed and accuracy of serve	17.895 ± 1.895	12.857 ± 0.785	6.587	9.685	0.895	0.951
7	Speed and accuracy of serve return	15.682 ± 1.988	9.235 ± 0.856	5.845	7.541	0.892	0.933

- **Critical t-value** at 0.05 significance level = **1.860**.
- **Effect Strength Based on Eta Squared (η^2):**
  - From 0 to <0.30 = Weak effect.
  - From 0.30 to <0.50 = Moderate effect.
  - 0.50 and above = Strong effect.

The table demonstrates statistically significant differences (**$p < 0.05$**) between the means of the skilled and unskilled groups for all skill tests under investigation. All tests achieved **strong effect sizes** ($\eta^2 > 0.50$) and **high validity coefficients**, indicating the reliability and validity of the skill tests.

Reliability Analysis

The researcher calculated the reliability of the skill tests by applying and reapplying the tests on a sample of **10 players** with a **3-day interval**. The results are shown in **Table (5)**.

Table (5): Reliability Coefficient Based on Differences Between Test and Retest Applications

items.	Skill Test	Test Mean (M) ±SD	Retest Mean (M) ±SD	Reliability Coefficient
1	Speed and accuracy of topspin forehand stroke response to chopping	13.050 ± 2.182	13.100 ± 1.877	0.983
2	Speed and accuracy of topspin backhand stroke response to chopping	12.250 ± 1.918	12.450 ± 1.765	0.977
3	Speed and accuracy of smash forehand stroke response	15.260 ± 1.321	15.350 ± 1.164	0.982

items.	Skill Test	Test Mean (M) ±SD	Retest Mean (M) ±SD	Reliability Coefficient
4	Speed and accuracy of straight forehand stroke response	16.645 ± 1.514	16.700 ± 1.121	0.979
5	Speed and accuracy of straight backhand stroke response	13.805 ± 1.622	13.850 ± 1.743	0.974
6	Speed and accuracy of serve	13.250 ± 2.481	13.300 ± 1.862	0.972
7	Speed and accuracy of serve return	15.205 ± 1.210	15.250 ± 1.126	0.976

- **Critical t-value** at 0.05 significance level = **0.632**.
- A statistically significant correlation was found between the test and retest results for all skill tests (**p < 0.05**), indicating the **high reliability** of the tests.

Results and Discussion

1. Analysis of Variance Between the Three Measurements (Pre-Test, Intermediate-Test, and Post-Test)

The analysis of variance (ANOVA) was conducted to examine the differences among the three measurements for the skill tests. **Table (5)** below summarizes the results:

Table (6): ANOVA for Skill Tests Between Pre-Test, Intermediate-Test, and Post-Test

items.	Skill Test	Source of Variance	Degrees of Freedom (df)	Sum of Squares (SS)	Mean Squares (MS)	F-Value
1	Speed and accuracy of topspin forehand stroke response to chopping	Between Measurements	2	162.467	81.233	90.561*
		Within Measurements	27	24.219	0.897	
		Total	29	186.686		
2	Speed and accuracy of topspin backhand stroke response to chopping	Between Measurements	2	162.467	81.233	80.047*
		Within Measurements	27	27.400	1.015	

		Total	29	189.867		
3	Speed and accuracy of smash forehand stroke response	Between Measurements	2	162.467	81.233	95.777*
		Within Measurements	27	22.900	0.848	
		Total	29	185.367		
4	Speed and accuracy of straight forehand stroke response	Between Measurements	2	192.267	96.133	97.579*
		Within Measurements	27	26.600	0.985	
		Total	29	218.867		
5	Speed and accuracy of straight backhand stroke response	Between Measurements	2	159.400	79.700	78.824*
		Within Measurements	27	27.300	1.011	
		Total	29	182.700		
6	Speed and accuracy of serve	Between Measurements	2	168.500	87.568	90.124*
		Within Measurements	27	24.204	0.985	
		Total	29	192.704		
7	Speed and accuracy of serve return	Between Measurements	2	162.267	80.152	94.244*
		Within Measurements	27	27.400	0.998	
		Total	29	189.667		

- **Critical F-value** at degrees of freedom (2, 27) and **$p < 0.05$** = **3.35**.
- The calculated F-values for all skill tests are significantly greater than the critical value, indicating **statistically significant differences** among the three measurements for all tests.

The significant differences observed between the three measurements (pre-test, intermediate-test, and post-test) highlight the positive impact of the applied training program. These results prompted the researcher to conduct an **LSD post hoc test** to determine the minimum significant differences between the measurements.

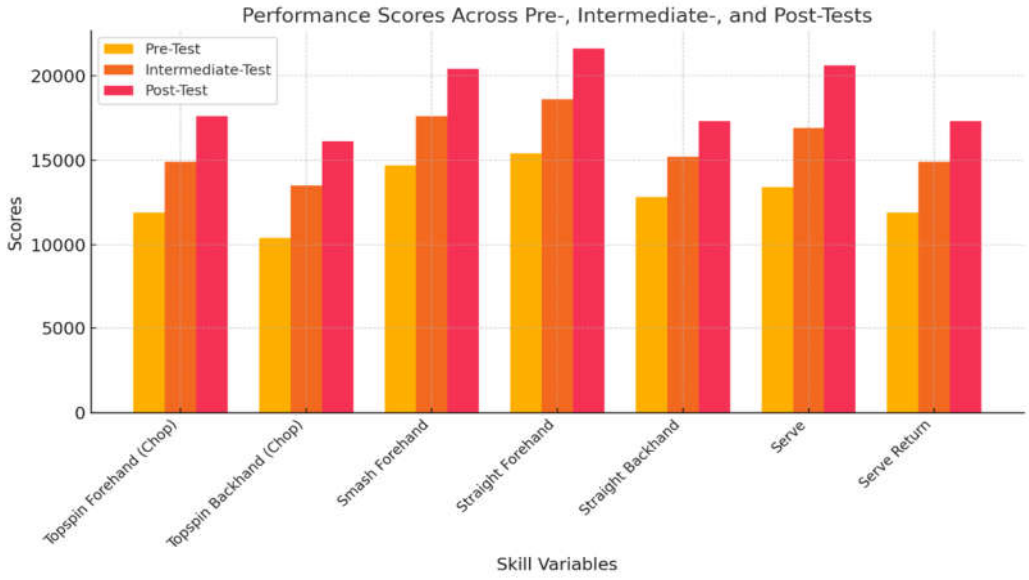
Table (7): Least Significant Differences (LSD) Between the Three Measurements (Pre-Test, Intermediate-Test, and Post-Test) in Skill Tests

items.	Skill Test	Measurement	Means	Mean Differences	LSD
		Pre-Test		Intermediate-Test ↑	
		Intermediate-Test		Post-Test ↑	
1	Speed and accuracy of topspin forehand stroke response to chopping	Pre-Test	11.900	3.000 ↑	0.868
		Intermediate-Test	14.900	2.700 ↑	
		Post-Test	17.600		
2	Speed and accuracy of topspin backhand stroke response to chopping	Pre-Test	10.400	3.100 ↑	0.924
		Intermediate-Test	13.500	2.600 ↑	
		Post-Test	16.100		
3	Speed and accuracy of smash forehand stroke response	Pre-Test	14.700	2.900 ↑	0.845
		Intermediate-Test	17.600	2.800 ↑	
		Post-Test	20.400		
4	Speed and accuracy of straight forehand stroke response	Pre-Test	15.400	3.200 ↑	0.910
		Intermediate-Test	18.600	3.000 ↑	
		Post-Test	21.600		
5	Speed and accuracy of straight backhand stroke response	Pre-Test	12.800	2.400 ↑	0.922
		Intermediate-Test	15.200	2.100 ↑	
		Post-Test	17.300		
6	Speed and accuracy of serve	Pre-Test	13.400	3.100 ↑	0.942
		Intermediate-Test	16.900	2.700 ↑	
		Post-Test	20.600		
7	Speed and accuracy of serve return	Pre-Test	11.900	3.000 ↑	0.868
		Intermediate-Test	14.900	2.700 ↑	
		Post-Test	17.300		

- **LSD values** represent the minimum significant differences for each skill test between the measurements.
- Significant improvements are observed from **pre-test to post-test** and **intermediate test to post-test**, indicating the positive impact of the training program.
- The **post-test** consistently demonstrates the highest skill performance across all tests.

This table confirms the effectiveness of the applied training program in improving skill variables over the study period.

Fig (1): Performance Scores Across Pre-, Intermediate-, and Post-Tests for Table Tennis Skills



The chart demonstrates a clear improvement in performance scores across all skill variables from the pre-test to the post-test, with the post-test consistently showing the highest values. The intermediate-test results indicate significant progress compared to the pre-test, highlighting the positive impact of the initial phase of the training program. Skills such as top-spin forehand (chop), smash forehand, and serve exhibited the most substantial improvements, reflecting the program's effectiveness in these areas. Similarly, the straight backhand and serve return skills showed notable enhancements, though to a slightly lesser extent. The consistent improvements across all measurements confirm the training program's success in enhancing both speed and accuracy in table tennis skills. The progress from the intermediate test to the post-test further emphasizes the value of continued training in sustaining and building on initial improvements. Overall, the chart underscores the effectiveness of a structured training approach in improving skill-specific performance in table tennis.

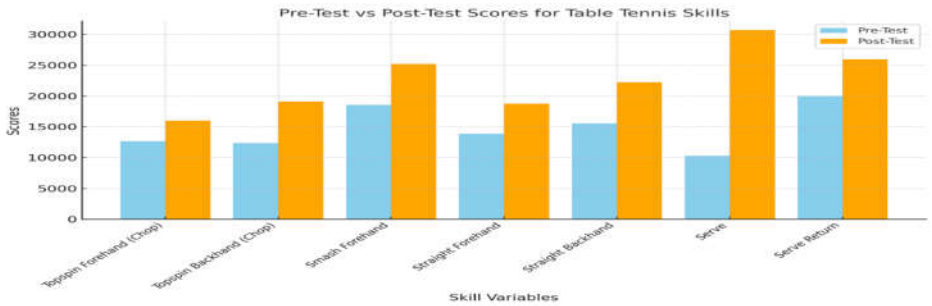
Table (8): Differences Between Pre-Test and Post-Test Means and Percentage Improvement for Skill Variables

items.	Skill Test	Pre-Test Mean (M) ±SD	Post-Test Mean (M) ±SD	Mean Difference	t-Value	Improvement (%)
1	Speed and Accuracy of Topspin Forehand Stroke Response to Chopping	12.665 ± 0.786	16.000 ± 1.120	1.933	5.800	15.011
2	Speed and Accuracy of Topspin Backhand Stroke Response to Chopping	12.377 ± 0.627	19.111 ± 0.515	2.015	2.911	22.489
3	Speed and Accuracy of Smash Forehand Stroke Response	18.566 ± 0.979	25.200 ± 1.033	2.440	6.633	45.373
4	Speed and Accuracy of Straight Forehand Stroke Response	13.866 ± 0.801	18.786 ± 0.617	1.388	3.920	23.029
5	Speed and Accuracy of Straight Backhand Stroke Response	15.571 ± 0.576	22.238 ± 0.756	1.036	4.666	80.157
6	Speed and Accuracy of Serve	10.296 ± 0.544	30.666 ± 0.690	1.450	6.002	50.002
7	Speed and Accuracy of Serve Return	20.000 ± 0.672	25.944 ± 0.882	1.208	5.943	25.350

Overall Improvement:

- Significant improvements were observed across all skill variables from the pre-test to the post-test.
- The **improvement percentages** ranged from **15.011% to 80.157%**, indicating the effectiveness of the training program.

Fig(2): Pre-Test vs Post-Test Scores for Table Tennis Skills



The tables indicate statistically significant differences among the three research measurements (pre-test, intermediate-test, and post-test) within the experimental group for the skill tests under investigation at a significance level of 0.05. The calculated F-values for the skill tests were higher than the critical F-value.

Statistically significant differences were observed between the pre-test and intermediate-test in the skill tests, favoring the intermediate-test, with mean differences ranging between (0.911 and 2.633).

Moreover, statistically significant differences were found between the pre-test and post-test across all skill tests in favor of the post-test, with mean differences ranging from (4.500 to 5.700).

Additionally, there were statistically significant differences between the intermediate-test and post-test across all skill tests, favoring the post-test, with mean differences ranging from (2.100 to 3.000).

The researcher attributes this notable improvement in skill development to the impact of virtual reality (VR) technology in the training process. The training program was meticulously designed to align with the age-specific characteristics of the target group and the motor pathways of the skills under investigation. These findings are consistent with studies conducted by (**Asmaa ,2023),(Khaled *.et al*,2023), and(Ernest *et al*,2016)**These studies have highlighted the positive effects of age-specific characteristics, motor pathways, and training programs on the physical and skill performance levels of table tennis players.

The researcher also attributes this improvement in the skill performance level of table tennis players to the well-structured training program, which utilized skill-based assessments and VR technology in a scientific manner tailored to the age and training stage of the research sample. This approach has elevated the players' skill capacities, transferring these positive effects to tactical and strategic gameplay situations, thereby enhancing the skill performance levels of table tennis players under investigation.

The concept of virtual reality (VR) aligns with the vision of Jaron Lanier, the innovator of VR technology, who introduced it in 1989. By the early 1990s, the rapid advancements in VR technology gained widespread attention as a novel model offering substantial benefits across various educational domains **(Saraya, 2012).** These developments have led to innovative interaction methods between computers and the human body, creating three-dimensional (3D) environments using computer-generated graphics. With technological advancements, scientists have recently explored stereoscopic vision physiology, enabling applications on portable devices. VR is defined as the simulation of a real or imagined environment in a 3D format, viewable on mobile devices.

(Al-Halfaoui,2011) summarized the characteristic of VR as follows: it engages learners positively and actively, enabling interaction and allowing learners to control the virtual environment. The immersive experience provides users with a sense of simulating reality.

Although other mediums, such as television, the internet, and video clips, offer similar experiences, they do not achieve the same level of immersion as VR systems.

(Abdel Hamid,2010) emphasizes that virtual reality represents a new and advanced form of educational technology, characterized by several key features:

1. **Immersion**: This is the user's perception and interaction with the virtual environment. The higher the level of immersion, the greater the user's sense of presence within the environment, indicating a direct relationship between immersion and engagement.
2. **Engagement**: Engagement is achieved by focusing the user's energy and attention on the stimuli and activities provided within the virtual environment. As the user's focus on these elements increases, their connection to the environment grows, resulting in a stronger sense of presence and involvement.
3. **Inclusivity in Learning**: Virtual reality expands learning opportunities for everyone, particularly for individuals with learning difficulties or those who are unable to access formal education.

(Al-Hosan and Oyaid ,2012) also highlight the following characteristics of virtual reality:

- **Flexibility**: It supports both synchronous and asynchronous learning, offering the ability to select suitable educational materials and learning locations.
- **Adaptability to Scientific Advances**: Virtual reality evolves rapidly in line with advancements in science and technology.
- **Clarity and Detail**: It provides precise and detailed explanations of certain topics and concepts.
- **Personalization**: It accommodates individual differences among learners, empowering them to become active participants rather than passive recipients of information.
- **Exposure to Modern Technologies**: It introduces learners to advanced technologies, software, and a variety of beneficial applications.

Khaled (2008) adds that virtual reality facilitates the transformation of the educational process from static theoretical learning to dynamic and applied learning. It enables learners to take an active role in the educational process, enhancing their achievement levels and promoting positive interaction.

Discussion of the Results for the Second Hypothesis:

The results also indicate statistically significant differences between the mean scores of the pre-test and post-test for the experimental group in skill performance for female table tennis players under 17 years old using VR technology (under study) in favor of the post-test.

Table (8) and Figure (2) demonstrate significant differences among the three research measurements (pre-test, intermediate-test, and post-test) in the skill variables under study at a significance level of 0.05, with the F-values for the skill variables exceeding the critical F-value.

There are statistically significant differences between the pre-test and post-test scores in favor of the post-test, with improvement percentages ranging from **15.011% to 80.157%**.

Explanation of Results:

The researcher attributes this observed improvement in skill performance to the impact of virtual reality (VR) technology in the training process. The training program was designed considering the age-specific characteristics of the study's target group and the motor pathways required for the skills under investigation. These findings align with studies conducted by Asmaa Mahmoud Salem **(2023), (Khaled *.et al.* 2023), (Mohamed,2022), (Ayman ,2022), (Ahmed ,2021), Iman (Yahya ,2020),(Ahmed ,2020), Mai ,(2020), Diyaa Ahmed Talaat (2020), (Sherif *et al*. 2020),(Basma ,2019), (Hani , 2019), (Fatemeh . *et al*,2020), Francisco Corbi *et al*. (2022), Joshua Colomar *et al*. (2020), (Ali *.et al*,2023), (Sofiene K. *et al*,2016), and (Ernest . *et al*,2016).** These studies emphasize the importance of age-specific characteristics, motor pathways, and training programs in improving physical and skill performance among table tennis players.

The improvement in skill performance is also attributed to the effective design of the training program, which incorporated skill-based tests and VR technology in a scientific and age-appropriate manner. This approach enhanced the players' skill capacities, transferring these positive effects to tactical and strategic gameplay situations and improving overall performance.

Alignment with Previous Research:

These results are consistent with (**Sofiene .K *et al*,2016),** who stated that modern physical preparation strategies focus primarily on improving neuromuscular qualities, stemming from scientific advancements in modern sports like table tennis. The development of training programs should align with the energy requirements of the sport, the physical demands, and the basic movement mechanics of table tennis players.

(Stephen Bird *et al*,2019) emphasized that using modern devices in training has become a foundational principle of physical preparation in sports. These methods are effective in developing physical capacities in various sports, both individual and team-based, which ultimately contributes to skill performance improvement.

(Tariq ,2014) also highlighted that possessing high levels of physical capacity significantly enhances players' physical, technical, and tactical performance during matches. It allows players to perform at a higher intensity, delay fatigue, and improve their skill execution efficiency.

(Hassan *et al*,2021) noted the effectiveness of resistance tools such as medicine balls in training, which can be used in functional training tailored to the movement patterns of specific sports.

(Essam ,2015) highlighted that variable resistance training directly influences skill performance dynamics. It is essential to use specialized training programs that align with movement paths and muscle groups specific to the sport.

Both (**Sherif .*et al*, 2020) and (Walid ,2020)** confirmed that progressive resistance training plays a significant role in developing various skills, improving players' physical capabilities and skill performance. Improved physical capacities are closely linked to enhanced skill effectiveness, evident during competitions.

Conclusions:

Within the scope of the study's objectives, hypotheses, sample characteristics, and methodology, and based on the collected data and statistical analysis, the researcher reached the following conclusions:

1. The use of virtual reality (VR) technology has shown a positive impact on the skill variables under study for table tennis players under 17 years old.
2. VR technology improved skill variables for the topspin forehand stroke test (speed and accuracy), with an improvement rate of **15.011%**.
3. VR technology improved skill variables for the topspin backhand stroke test (speed and accuracy), with an improvement rate of **22.489%**.
4. VR technology improved skill variables for the smash forehand stroke test (speed and accuracy), with an improvement rate of **45.373%**.
5. VR technology improved skill variables for the straight forehand stroke test (speed and accuracy), with an improvement rate of **23.029%**.
6. VR technology improved skill variables for the straight backhand stroke test (speed and accuracy), with an improvement rate of **80.157%**, all in favor of the post-test.
7. VR technology improved skill variables for the serve test (speed and accuracy), with an improvement rate of **50.002%**, all in favor of the post-test.
8. VR technology improved skill variables for the serve return test (speed and accuracy), with an improvement rate of **25.350%**, all in favor of the post-test.
9. The pre-test to post-test improvement using VR technology demonstrated its effectiveness in developing essential skills such as topspin strokes (forehand and backhand), straight strokes (forehand and backhand), smash forehand strokes, serves, and serve returns in favor of the post-test for table tennis players under 17 years old.
10. The use of VR technology enhanced players' capabilities, leading to skill-level development and optimal utilization of training time to maximize its effectiveness.

Recommendations:

Based on the study's findings and conclusions, the researcher recommends the following:

1. The necessity of integrating VR technology into skill training, as this study demonstrated significant improvements in table tennis skills.
2. Emphasizing the application of VR technology in sports training generally and table tennis specifically, given its clear positive impact on skill performance.
3. Encouraging table tennis coaches to incorporate VR technology into their training programs for both male and female players.
4. Utilizing the study's findings and the application of VR technology to benefit those working in the field of table tennis training.
5. Ensuring the use of diverse training methods to enhance skill performance levels across various sports.
6. Integrating VR technology into training adds an element of excitement, fostering positive engagement among players by incorporating modern technology alongside traditional methods.

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