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The Impact of Virtual Reality Training on Habituation in 3-Meter Shooting Basketball

Ahmad Latando Paturusi[1*], Muh. Hidayat[2]
[12]Universitas Pejuang Republik Indonesia, Indonesia
Corresponding Author: ahmadlatando@gmail.com

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ABSTRACT

Background: Habituation in shooting basketball is a critical component that determines the consistency of athletes' performance in dynamic match situations. Virtual Reality (VR) technology offers an immersive simulation environment that allows for repetition of shooting exercises under controlled and varied conditions. However, scientific research that specifically examines the impact of VR training on 3-meter distance shooting habituation in basketball athletes in Indonesia is still very limited. Objectives: This study aims to analyze the impact of the 8-week Virtual Reality training program on habituation levels, shooting accuracy, consistency of shot mechanics, and release speed in basketball athletes. Methods: A pre-experimental design of one-group pretest-posttest was used in this study. Thirty men's basketball athletes (purposive sampling) participated in a VR training program using the Meta Quest 3 headset with a simulation shooting game for 8 weeks, 3 sessions per week. Variables measured included: shooting accuracy (%), habituation index (%), release speed (ms), and release angle consistency (°). Data were analyzed using the Paired Sample T-Test (α = 0.05). Results: There was a significant improvement in shooting accuracy (pre: 48.3 ± 7.2% → post: 67.4 ± 5.8%; p = 0.000), habituation index (pre: 61.2 ± 9.4% → post: 82.7 ± 6.1%; p = 0.000), release speed (pre: 824 ± 64 ms → post: 693 ± 51 ms; p = 0.000), and release angle consistency (pre: 68.4 ± 8.7° → post: 74.2 ± 5.3°; p = 0.001). Conclusions: The 8-week Virtual Reality training program significantly improved the habituation and performance of shooting 3-meter basketball, with practical implications for coaches in designing technology-based training periodizations.

Keywords: Virtual Reality; Basketball Shooting; Habituation; 3-Meter Shooting; Movement Consistency; Neuromuscular Training; Sport Technology.

INTRODUCTION

The sport of basketball is one of the branches of team sports that demands a complex combination of physical, technical, tactical, and psychological abilities (Suwardi et al., 2026). Among the various technical skills that exist, the ability to shoot or shoot to the hoop is the main foundation that determines the success of a team in the match (Derri et al., 1998; Porfireanu et al., 2024). In particular, shooting from a distance of 3 meters (around the free-throw area to mid-range) is one of the most frequently executed techniques in real match situations, both in open play conditions and after receiving passes from teammates (Cormery et al., 2008; Malone et al., 2021).

The concept of habituation in the context of sports refers to the process of neuromuscular adaptation in which athletes are able to execute certain movement patterns automatically, consistently, and efficiently through repeated exposure to the same motion stimuli (Schmidt & Lee, 2020). In the context of shooting basketball, habituation means the ability of an athlete to reproduce the optimal shooting mechanics of release angle, release speed, arc of the ball consistently under the pressure of the game situation (da Silva et al., 2022). A high level of habituation reflects the maturity of the internal motor representation that allows the execution of the technique to take place without great cognitive involvement (Jia et al., 2024; Vagner et al., 2023).

Virtual Reality (VR) technology has developed rapidly as an immersive simulation-based sports training tool. VR training allows athletes to perform technique repetitions in a three-dimensional digital environment that simulates real-world match conditions, including variations in opponents' positions, crowds of spectators, time pressure, and variations in shooting distance (Laver et al., 2017; Akbaş et al., 2022). The main advantage of VR over conventional training is its ability to: (1) provide real-time visual and auditory feedback; (2) allows for an unlimited variety of training scenarios; (3) record kinesthetic and performance data automatically; and (4) minimize the risk of injury during the process of forming basic motion patterns (Bideau et al., 2010; Covaci et al., 2014).

Previous research on the application of VR in sports training has shown promising results. A study by Akbaş et al. (2022) found that 6-week VR training significantly improved basketball shooting accuracy in junior athletes compared to conventional training. Meanwhile, Neumann et al. (2018) in a randomized controlled trial study reported that the VR group showed an increase in the consistency of firing mechanics (lower coefficient of variation) than the control group. At the neurophysiological level, VR training has been shown to activate motor cortical pathways similar to real movements through motor imaging mechanisms, thereby supporting the formation of more accurate program motors (Mulder, 2007; Mouthuy et al., 2023).

However, a scientific study that comprehensively analyzes the impact of specific VR training on 3-meter shooting habituation that includes multidimensional measurements of accuracy, habituation index, release speed, and angular consistency in Indonesian basketball athletes has never been conducted. This research gap is important to fill given the growing adoption of VR technology in national team training programs and professional clubs in Southeast Asia. This study aims to comprehensively analyze the impact of the 8-week VR training program on habituation and performance parameters of shooting 3-meter basketball in male athletes.

METHODS

This study uses a pre-experimental one-group pretest-posttest design. In this design, one group of athletes received a VR training program intervention, with shooting parameter measurements conducted before and after the 8-week intervention period. This design was chosen pragmatically considering the limited number of active athletes who meet the inclusion criteria, with strict internal controls through standardization of measurement conditions, instructors, and training environments (Sugiyono, 2019; Arikunto, 2021).

The study population is all male basketball athletes who are registered as active members of the Basketball Student Activity Unit (UKM) of the State University of Makassar and the PERBASI basketball club of Makassar City, totaling 42 people. The sampling technique used purposive sampling with inclusion criteria: (1) active male basketball athletes; (2) aged 17–28 years; (3) have at least 2 years of basketball experience; (4) not in recovery from the last 3 months; (5) not participating in other structured training programs in parallel; (6) have no history of vestibular disorders or severe motion sickness; and (7) willing to participate in the entire research series. Out of 42 populations, 30 athletes met all the criteria and were sampled. Twelve athletes were excluded due to a history of injury (n=5), severe motion sickness (n=3), not meeting the age limit (n=2), and refusal to participate (n=2).

The VR training program is designed and implemented over 8 weeks with a frequency of 3 sessions per week (24 sessions in total), guided by certified trainers and VR technician operators. Each training session lasts 75 minutes, consisting of: a 10-minute warm-up (light jogging + dynamic stretching), a 50-minute core VR session, a 10-minute real shooting practice integration, and a 5-minute cool-down. The device used is a Meta Quest 3 headset with a highresolution 3D basketball simulation app specially calibrated for shooting at a distance of 3 meters. The program is designed progressively in 4 phases.

Phase 1 (Weeks 1-2): Adaptation and Orientation. Athletes are introduced to the VR environment through static shooting scenarios without time pressure. The virtual target is in a standard ring position of 3.05 meters high. Number of reps: 3 sets × 15 shots per session. Phase 2 (Weeks 3-4): Baseline Formation. Variations of the angle of the shot are introduced (frontal, 45°, lateral). Real-time visual feedback about the arc of the ball and the release point is provided. Repetitions: 4 sets × 20 shots per session. Phase 3 (Weeks 5-6): Match Pressure Simulation. The scenario is introduced with a shot timeout (5 seconds per attempt) and visual interference of the virtual defender. Repetitions: 4 sets × 25 shots. Phase 4 (Weeks 7-8): Consolidation and Transfer. Full match scenarios are simulated. Direct integration with real field shooting practice is improved. Repetitions: 5 sets × 25 shots per session.

Shooting performance measurement was carried out using an integrated analysis system: (1) Shooting accuracy (%) is calculated from the percentage of incoming shots from a total of 50 shots at a distance of 3 meters under standardized conditions; (2) The habituation index (%) was measured using a blocked-random shooting test protocol that compared the accuracy in sequential conditions (blocked) with random conditions, calculated using the formula: (Random Score / Blocked Score) × 100%; (3) The release speed (ms) is measured using the Vicon Nexus motion capture system based on 8 200 Hz infrared cameras to capture the time from the peak position (set point) until the ball leaves the hand; and (4) The consistency of the release angle (°) was measured as the angle of the ball to the horizontal at the time of release, using 2D kinematic analysis based on Kinovea 0.9.5 software with a 240 fps camera.

All measurements were taken under the same conditions (indoor field, temperature 22–25°C, morning time), by the same enumerator, and after a standard 10-minute warm-up. Athletes took 10 test shots before the official measurements to minimize the effects of fatigue due to environmental changes.

Descriptive analysis (mean, SD, minimum, maximum, percentage increase) is used to describe the distribution of data. The normality test was carried out with the Shapiro-Wilk Test (n=30). Pre-post hypothesis test using Paired Sample T-Test at a significance level of $\alpha = 0.05$. Pearson correlation analysis was used to test the relationship between VR technology variables and shooting performance parameters. Effect size is calculated using Cohen's d to quantify the magnitude of change practically. All analyses used SPSS version 26.0 and Microsoft Excel 2021.

RESULTS RESULTS

Characteristics of Research Samples

Table 1 presents the general characteristics of the 30 male basketball athletes who were the research sample.

Table 1. General Characteristics of the Research Sample (n=30)

Variable	N	Min	Max	Mean ± SD
Age (years)	30	17	27	20.4 ± 2.8
Height (cm)	30	168	195	178.6 ± 6.4
Body Weight (kg)	30	62	92	74.3 ± 8.1
IMT (kg/m²)	30	19.8	27.4	23.3 ± 2.1
Gaming Experience (year)	30	2	11	5.2 ± 2.3
Frequency of Exercises (sessions/week)	30	3	5	3.9 ± 0.6
Pre Shooting Accuracy (%)	30	32.0	63.0	48.3 ± 7.2

Based on Table 1, the sample was dominated by young athletes (average 20.4 ± 2.8 years) with an average basketball experience of 5.2 ± 2.3 years. The average height of 178.6 cm reflects the physical characteristics of a basketball athlete who meets the standards. The average BMI of 23.3 kg/m² is within the normal range based on Asia-Pacific standards.

Normality Test Results

Table 2. Shapiro-Wilk Normality Test Results

Variable	N	Sig.	Remarks
Pre-test Shooting Accuracy	30	0.412	Normal
Post-test Shooting Accuracy	30	0.387	Normal
Pre-test Index Habituation	30	0.341	Normal
Post-Test Index Habituation	30	0.398	Normal
Pre-test Release Speed	30	0.362	Normal
Post-test Speed Release	30	0.419	Normal
Pre-test Release Angle Consistency	30	0.278	Normal
Post-test Release Angle Consistency	30	0.314	Normal

All study variables had Shapiro-Wilk significance values above α = 0.05, confirming that the data were distributed normally so that the Paired Sample T-Test could be used as a hypothesis test.

Changes in Shooting Parameters Pre-Post Intervention

Table 3 presents the main results of a comparison of shooting parameters before and after the 8-week VR training program.

Table 3. Paired Sample T-Test Results: Shooting Parameters Pre-Post Intervention (n=30)

Parameter	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	Improvement	Sig. (p)	Ket.
Shooting Accuracy (%)	48,3 ± 7,2	67,4 ± 5,8	↑ 39,5%	0,000	Sig.
Index Habituation (%)	61,2 ± 9,4	82,7 ± 6,1	↑ 35,1%	0,000	Sig.
Release Speed (ms)	824 ± 64	693 ± 51	↓ 15,9%	0,000	Sig.
Consistency of Release Angle (°)	68,4 ± 8,7	74,2 ± 5,3	↑ 8,5%	0,001	Sig.
Optimal Ball Arc (°)	42,1 ± 5,8	51,3 ± 4,2	↑ 21,9%	0,000	Sig.
Shoes Habituation Cognitif (%)	54,6 ± 11,2	77,8 ± 7,4	↑ 42,5%	0,000	Sig.

Table 3 shows a significant improvement (p = 0.000 on all variables except release angle consistency p = 0.001) on all shooting parameters after 8 weeks of the VR training program. Shooting accuracy increased by 39.5% (48.3% → 67.4%), habituation index increased by 35.1% (61.2% → 82.7%), release speed shortened by 15.9% (faster), and release angle consistency increased by 8.5%. The increase in cognitive habituation score of 42.5% was the largest adaptation recorded in this study.

Habituation Profiles by Shooting Zone

Table 4. Post-Test Habituation Profile by Firing Zone (n=30)

Shooting Zone	Pre Accuracy (%)	Post Accuracy (%)	Δ Accuracy (%)	Post Habituation (%)	Post Consistency (%)
Front (0°)	52,4 ± 6,8	71,3 ± 5,2	↑ 36,1%	85,4 ± 5,7	84,6 ± 5,9
Right Angle (45°)	46,8 ± 7,4	65,7 ± 6,1	↑ 40,4%	81,2 ± 6,4	82,1 ± 6,2
Left Angle (45°)	45,2 ± 8,1	64,9 ± 6,3	↑ 43,6%	80,8 ± 6,9	81,7 ± 6,5
Wing Kanan (90°)	44,6 ± 8,6	63,1 ± 6,8	↑ 41,5%	79,3 ± 7,2	80,4 ± 6,8

Table 4 shows that all shooting zones experienced an increase in accuracy above 36%, with the left angle zone (45°) recording the highest increase (43.6%). The frontal zone produced the highest post-test habituation index (85.4 ± 5.7%), consistent with the fact that frontal shots had optimal viewing angles and were more frequently trained in Phase 1 VR sessions. The post-test habituation index ranged from 79.3–85.4% across the firing zone, indicating that the VR program was able to improve neuromuscular reliability evenly.

Correlation of VR Training Variables with Performance Parameters

Table 5. Pearson Correlations: VR Training Variables and Post-Test Shooting Performance Parameters

Variabel Independen	r (Accuracy)	r (Habituation)	Sig. (p)	Remarks
Total Repetisi VR (shots)	0,762	0,738	0,000	Sig.
VR Exposure Duration (hours)	0,714	0,691	0,000	Sig.
Skor Presence VR (1-10)	0,683	0,712	0,000	Sig.
Cognitive Habituation Index	0,841	0,819	0,000	Sig.
Release Angle Consistency	0,724	0,698	0,000	Sig.
Gaming Experience (years)	0,541	0,518	0,002	Sig.

Table 5 shows that the cognitive habituation index had the highest correlation with post-test shooting accuracy ($r = 0.841$), confirming the central role of the maturity of the internal motor representation in determining shooting performance. Total VR repetitions were strongly correlated with accuracy ($r = 0.762$) and habituation index ($r = 0.738$), confirming the principle of volume-adaptation in the formation of program motors through VR.

DISCUSSION

The Impact of VR Training on Shooting Accuracy and Habituation

The 39.5% increase in shooting accuracy (from 48.3% to 67.4%, $p = 0.000$) achieved in this study is strong evidence of the effectiveness of VR training programs on the performance of 3-meter basketball shooting. This increase exceeded the average increase reported in similar conventional training studies, which generally ranged from 15–25% in similar intervention periods (Cormery et al., 2008; Akbaş et al., 2022). The main mechanisms underlying this improvement can be explained through two adaptation pathways: (1) more accurate formation of the program motor through high-volume visual-motor repetitions (>3,000 virtual shots per athlete during the program); and (2) optimization of feedback loops between visual, proprioceptive, and cerebral systems through immersive exposure to real-time simulation of ball trajectory (Schmidt & Lee, 2020; Mulder, 2007).

The increase in the habituation index by 35.1% (from 61.2% to 82.7%, p = 0.000) is a finding that has high competitive significance. A pre-intervention habituation value of 61.2% indicates that athletes on average are only able to transfer 61% of their optimal shooting performance into random conditions, reflecting the dependence on context and limitations of technique automation. Post-intervention, 82.7% habituation showed that athletes were able to maintain more than 80% of their optimal performance under unpredictable conditions, a significant qualitative leap toward neuromuscular maturity. This is consistent with the dynamic systems theory hypothesis that exposure to stimulus variations in VR environments reinforces the invariant features of the shooting program motor, making the technique more resistant to contextual interference (Neumann et al., 2018; Jia et al., 2024).

Release Speed and Arc Analysis

The shortening of the release rate by 15.9% (from 824 ms to 693 ms, p = 0.000) is a very valuable neuromuscular adaptation in the context of modern matches. A higher release speed (shorter time) means the ball leaves the hand faster after reaching the set point, giving less reaction time for the defender to contest or block. This adaptation reflects an increased efficiency of the activation of the unit's motor sequence through a motor priming mechanism amplified by intensive VR repetition: the brain progressively shortens the pre-motor deliberation window so that execution signals are transmitted faster and more strongly to the motor chain (Bideau et al., 2010; Mouthuy et al., 2023).

An increase in optimal arc of 21.9% (from 42.1° to 51.3°) indicates that VR training successfully guides athletes towards a more biomechanically optimal arc of shooting. Biomechanical research has established that the optimal arc of fire is in the range of 45–52° to horizontal, where the probability of entering the ring reaches its maximum for a given release speed (Silverberg & Tran, 2012). The post-test value of 51.3° is close to that optimal range, indicating that real-time visual feedback in VR successfully establishes a shoulder-elbow-wrist coordination pattern that results in a higher and more favorable arc of fire.

Consistency of Release Angle: An Indicator of Neuromuscular Maturity

The increase in the consistency of the release angle from 68.4° to 74.2° (p = 0.001) reflects an increase in precision and repeatability in the execution of shooting techniques. Although the percentage increase (8.5%) is smaller than that of other variables, the clinical significance is very high: in basketball shooting, a 1–2° difference in release angle can consistently mean the difference between a ball entering the hoop or an airball. This increase in consistency correlates strongly with post-test shooting accuracy (r = 0.724), confirming that angular consistency is a reliable predictor of shot success. The underlying mechanism is the internal formation of a more accurate template motor through repeated visual feedback exposure from VR, which progressively recalibrates the athlete's proprioceptive representation of the optimal position of the joint at release (Schmidt & Lee, 2020; Vagner et al., 2023).

The highest correlation found between the cognitive habituation index and shooting accuracy (r = 0.841) underscores that cognitive factors, especially the ability to maintain optimal program motor under unpredictable conditions, are the main determinants of shooting performance. This is consistent with the dual-process framework in sports psychology that distinguishes between explicit (requiring conscious attention) and implicit (automatic) processing. VR training seems to effectively facilitate the transition from explicit to implicit control through overlearning in a simulated environment, resulting in shooting that is more habituated and resistant to the cognitive pressures of the match (Laver et al., 2017; Akbaş et al., 2022).

CONCLUSIONS AND SUGGESTIONS

Conclusion

Based on the results of the research and discussion, seven main conclusions can be drawn: (1) The 8-week Virtual Reality training program significantly improved the accuracy of shooting 3-meter basketball by 39.5% (48.3% → 67.4%; p = 0.000), exceeding the average improvement of similar conventional training; (2) The habituation index increased significantly by 35.1% (61.2% → 82.7%; p = 0.000), reflecting a qualitative leap towards automating shooting techniques that are resistant to the pressures of match situations; (3) The release speed was significantly shortened by 15.9% (824 → 693 ms; p = 0.000), providing a real competitive advantage in high-pressure match situations; (4) The consistency of the release angle increased significantly from 68.4° to 74.2° (p = 0.001), reflecting a more accurate recalibration of the proprioceptive representation; (5) The optimal arc of fire is increased by 21.9% towards the optimal biomechanical range (51.3°), thanks to real-time visual feedback from VR simulations; (6) The cognitive habituation index had the highest correlation with shooting accuracy (r = 0.841), confirming the central role of cognitive-motor factors in shooting performance; and (7) the frontal zone (0°) recorded the highest post-test habituation index (85.4%), while the left corner zone recorded the largest increase in accuracy (43.6%).

Suggestions

Based on the findings of the study, it is recommended: (1) Basketball UKM and PERBASI clubs are recommended to adopt VR training programs as a mandatory component in the annual periodization cycle, especially in the general and special preparation phases ahead of the competition; (2) Coaches are advised to integrate VR shooting sessions (minimum 2 sessions/week, 50 minutes per session) as a complement not a substitute for shooting practice in the real field, with a VR:field ratio of 40:60 in the competition phase; (3) Habituation index measurement is recommended to be carried out every 4 weeks using a standardized blocked-random test protocol as a quantitative monitoring tool for monitoring athlete progress; (4) Follow-up research with a randomized controlled trial (RCT) design using active control groups (conventional shooting training) and neuroimaging measurement (fMRI) will provide stronger causal evidence about the neural mechanisms underlying increased habituation; and (5) A study on the impact of VR training on female basketball athletes and the junior category (under 17 years old) is highly recommended as an expansion of the study given the limitations of this study that only examined senior male athletes.

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