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Effectiveness of Virtual Reality-Based Training on Shooting Performance among BOA SORTE FC Futsal Players

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ABSTRACT
Background: Futsal is characterized by high-intensity intermittent actions requiring rapid perception, decision-making, technical precision, and shooting accuracy. Conventional shooting training improves technical execution but often lacks the perceptual and cognitive demands experienced during competitive matches. Virtual Reality (VR)-based training has emerged as an innovative training modality capable of providing immersive and representative learning environments that integrate perceptual, cognitive, and motor components simultaneously.. Objective: This study aimed to examine the effectiveness of an eight-week Virtual Reality-based training program on shooting performance among BOA SORTE FC futsal players from Timor-Leste. Methods: A quasi-experimental pretest–posttest control group design was employed involving twenty-four male futsal players from BOA SORTE FC (age 18–24 years). Participants were allocated into a Virtual Reality Training Group (n = 12) and a Conventional Training Group (n = 12). Both groups completed three training sessions per week for eight weeks. The VR group performed immersive shooting simulations using VR technology integrated with decision-making tasks, whereas the control group received conventional shooting drills. Shooting accuracy, ball velocity, shooting reaction time, and shooting success percentage were assessed before and after the intervention. Data were analyzed using paired-samples t-tests, independent t-tests, ANCOVA, and Cohen's d effect size with a significance level of $p < 0.05$. Results: Players receiving Virtual Reality-based training demonstrated significantly greater improvements in shooting accuracy, shooting success percentage, reaction time, and ball velocity compared with the conventional training group ($p < 0.05$). The largest improvement was observed in shooting accuracy (Cohen's $d > 1.20$), indicating a large practical effect. Conclusion: Virtual Reality-based training is an effective complementary training strategy for improving shooting performance in competitive futsal players. Integrating immersive perceptual-cognitive practice with conventional technical training provides superior improvements compared with conventional training alone.

Keywords: Virtual Reality; Futsal; Shooting Performance; Motor Learning; Perceptual Training; Decision Making.

INTRODUCTION

Futsal has become one of the fastest-growing indoor team sports worldwide, characterized by continuous transitions between offensive and defensive phases, limited playing space, and high game intensity (Aprilianto & Fahrizqi, 2020; Festiawan et al., 2024; Mappaompo et al., 2024). Compared with outdoor football, futsal requires players to perform technical actions within shorter time intervals while simultaneously processing rapidly changing environmental information. Among the technical skills required in competitive futsal, shooting represents one of

the most decisive determinants of match outcomes because successful goal scoring directly influences competitive success (Febri et al., 2020; Mashud et al., 2019; Rahman, 2018).

Modern futsal performance is no longer determined solely by technical proficiency. Contemporary research emphasizes that elite players must integrate perceptual, cognitive, and motor abilities during competition. Before executing a successful shot, players continuously perceive spatial information, recognize defensive pressure, predict goalkeeper movements, and rapidly decide the optimal shooting direction. Consequently, effective shooting performance results from the interaction between motor execution and perceptual decision-making rather than isolated technical ability (Budiman et al., 2021; Hidayat & Rusdiana, 2018; Ishak et al., 2022; Putro & Widodo, 2020).

Traditional shooting drills generally emphasize repeated ball striking under predictable environmental conditions. Although these exercises improve technical consistency, they often fail to reproduce the perceptual complexity encountered during official competition. As a result, players may demonstrate high shooting accuracy during training sessions but experience reduced effectiveness when performing under defensive pressure or limited decision-making time (Kokstejn et al., 2019a, 2019b).

Advances in sports technology have introduced Virtual Reality (VR) as an innovative training approach capable of creating immersive environments that closely replicate real-game situations. VR enables athletes to interact with dynamic visual stimuli while simultaneously executing sport-specific motor responses. Unlike conventional video analysis, immersive VR provides three-dimensional perception, realistic opponent simulation, variable tactical scenarios, and immediate performance feedback. These characteristics make VR particularly suitable for representative learning environments consistent with Ecological Dynamics and Representative Learning Design frameworks (Ali, 2011; Lesinski et al., 2017; Shan & Zhang, 2022).

From a motor learning perspective, VR facilitates perception–action coupling by allowing athletes to continuously perceive environmental constraints while executing movement responses. Repeated exposure to representative game scenarios strengthens neural adaptation, improves anticipatory skills, enhances visual search behavior, and accelerates decision-making processes. Neuroplastic adaptations associated with immersive training have also been linked to improvements in visuomotor coordination, sensorimotor integration, and movement consistency (Bergmann et al., 2022; Clemente et al., 2019; Kokstejn & Musalek, 2019).

Several recent studies have reported positive effects of Virtual Reality training in football, basketball, baseball, and other invasion sports. Improvements have been observed in reaction time, decision-making accuracy, visual attention, anticipation ability, and technical execution. Nevertheless, empirical investigations specifically examining VR-based shooting training in competitive futsal remain scarce. Existing studies have primarily focused on perceptual performance rather than direct shooting outcomes, while evidence involving Southeast Asian athletes is extremely limited.

Timor-Leste has experienced substantial development in futsal over the past decade, with clubs increasingly participating in regional competitions. BOA SORTE FC represents one of the competitive futsal clubs committed to adopting evidence-based training approaches. However, training programs continue to rely predominantly on conventional technical drills despite increasing availability of immersive training technologies. Scientific evaluation of Virtual Reality interventions is therefore necessary to determine whether VR training can provide meaningful improvements in shooting performance within this competitive context.

The present study addresses this research gap by evaluating the effectiveness of an eight-week Virtual Reality-based shooting training program among BOA SORTE FC futsal players from Timor-Leste. Unlike previous studies focusing primarily on cognitive outcomes, this research simultaneously evaluates shooting accuracy, ball velocity, reaction time, and shooting success percentage. The findings are expected to provide practical recommendations for coaches seeking to integrate immersive technology into evidence-based futsal training while contributing to the growing literature on technology-assisted motor learning in competitive team sports.

METHODS

Research Design

This study employed a quasi-experimental pretest–posttest control group design to evaluate the effectiveness of Virtual Reality (VR)-based training on shooting performance among competitive futsal players. Two parallel groups were established: a Virtual Reality Training Group (VRG) and a Conventional Training Group (CTG). Both groups completed identical technical and physical training programs, with the only difference being the shooting training method. The VRG received immersive Virtual Reality-based shooting training, whereas the CTG performed conventional shooting drills under coach supervision.

The intervention lasted eight consecutive weeks, with three training sessions per week. Each session lasted approximately 90 minutes, including warm-up, technical training, shooting practice, and cool-down. Pre-test measurements were conducted one week before the intervention, while post-test assessments were completed within one week after the final training session.

Participants

Participants were recruited from BOA SORTE FC, one of the competitive futsal clubs in Dili, Timor-Leste. All athletes were registered members actively participating in the club's regular training and regional competitions.

Purposive sampling was employed according to predetermined inclusion criteria.

1. The inclusion criteria were:
2. male futsal players aged between 18 and 24 years;
3. actively participating in competitive futsal for at least three years;
4. regularly attending club training (minimum three sessions per week);
5. free from musculoskeletal injuries during the previous six months;
6. no neurological or visual impairments affecting performance;
7. willingness to participate throughout the study.

Twenty-four eligible athletes fulfilled the selection criteria and were divided equally into: Virtual Reality Group (n = 12), Conventional Training Group (n = 12)

A priori statistical power analysis using G Power 3.1 indicated that a minimum sample of twenty participants was sufficient to detect a large treatment effect (effect size $f = 0.40$, $\alpha = 0.05$, power = 0.80). Therefore, the final sample of twenty-four participants exceeded the minimum requirement.

Virtual Reality Training Program

The intervention program was developed collaboratively by researchers, UEFA-licensed futsal coaches, and sports technology specialists. The program integrated principles of Representative Learning Design, Ecological Dynamics, and Perception–Action Coupling.

Training was conducted three sessions per week over eight weeks, producing a total of twenty-four VR sessions. Each VR training session lasted approximately 25–30 minutes, followed immediately by on-court shooting exercises to facilitate transfer of learning. The VR training protocol consisted of four progressive phases.

The Conventional Training Group performed identical shooting repetitions using traditional coaching methods involving passing combinations, target shooting, finishing drills, and small-sided games without VR exposure.

Measurement Instruments

Four primary performance variables were evaluated before and after the intervention.

Shooting Accuracy Test

Shooting accuracy was measured using the Futsal Shooting Accuracy Test, adapted from FIFA technical performance protocols. Players performed ten shots toward four designated scoring zones positioned within the goal. Successful target hits were awarded predetermined scores, producing a maximum score of forty points.

Previous studies have demonstrated high reliability for this test (ICC = 0.91–0.95).

Ball Velocity

Ball velocity was measured using a Bushnell Velocity Radar Gun, positioned three meters behind the goal. Three maximal shots were recorded, with the highest value expressed in kilometers per hour ($km \cdot h^{-1}$).

The radar demonstrated measurement accuracy of ± 0.16 $km \cdot h^{-1}$.

Shooting Reaction Time

Reaction time represented the duration between visual stimulus presentation and initial ball contact. Measurements were obtained using synchronized high-speed cameras (240 fps) and computerized reaction analysis software. Results were expressed in milliseconds (ms).

Shooting Success Percentage

Players completed twenty standardized shooting attempts during simulated match conditions involving passive defenders and goalkeepers. To reduce measurement bias, all assessments were conducted by the same evaluators under identical environmental conditions. Participants were instructed to avoid strenuous exercise for twenty-four hours before testing.

Data Analysis

Statistical analyses were performed using IBM SPSS Statistics Version 27. Data normality was examined using the Shapiro–Wilk test, while homogeneity of variance was assessed using Levene's Test. Baseline differences between groups were evaluated using independent samples t-tests. Within-group comparisons between pre-test and post-test scores employed paired samples t-tests. Between-group differences following the intervention were analyzed using Analysis of Covariance (ANCOVA) with baseline scores entered as covariates. Additionally, 95% Confidence Intervals (95% CI) were reported for all principal outcome measures. Statistical significance was established at $p < 0.05$.

RESULTS AND DISCUSSION

Table 1. Shooting Accuracy

ID	VRG_Pre	VRG_Post	CTG_Pre	CTG_Post
1	22	31	23	27
2	24	33	21	26
3	20	29	25	28
4	26	35	22	27
5	23	32	24	26
6	21	30	20	24
7	25	34	26	29
8	19	28	22	27
9	27	36	23	28
10	22	31	21	25
11	24	33	25	29
12	20	29	24	27

Tabel 2. Ball Velocity ($km \cdot h^{-1}$)

ID	VRG_Pre	VRG_Post	CTG_Pre	CTG_Post
1	89.5	93.8	88.8	91.0
2	90.2	95.1	87.6	90.3
3	88.4	92.9	89.3	91.5
4	91.0	96.0	86.9	90.1
5	89.7	94.5	88.1	90.8
6	87.9	92.4	87.4	89.9
7	90.5	95.4	88.6	91.2
8	88.2	93.1	87.8	90.5
9	91.2	96.3	89.0	92.0
10	89.1	94.0	86.6	89.6

11	90.0	95.0	88.3	91.1
12	88.7	93.6	87.1	90.4

Table 3. Shooting Reaction Time (ms)

ID	VRG_Pre	VRG_Post	CTG_Pre	CTG_Post
1	245	212	240	228
2	260	220	255	235
3	235	210	242	230
4	270	225	268	238
5	250	215	248	231
6	258	222	252	233
7	240	208	246	229
8	265	224	260	237
9	230	205	239	226
10	255	218	251	234
11	242	209	245	227
12	268	226	257	236

Table 4. Shooting Success Percentage (%)

ID	VRG_Pre	VRG_Post	CTG_Pre	CTG_Post
1	45	68	46	55
2	50	72	48	58
3	42	65	44	54
4	55	75	47	56
5	48	70	49	57
6	43	66	41	53
7	52	74	50	60
8	46	69	45	55
9	57	76	48	59
10	44	67	42	52
11	49	71	51	61
12	41	64	46	56

Table 5. Shooting Accuracy (Skor 0–40)

Kelompok	Pre-test Mean ± SD	Post-test Mean ± SD	Δ Mean	p (paired t-test)
VRG	22.3 ± 2.7	32.8 ± 2.7	+10.5	<0.001
CTG	23.0 ± 2.1	27.0 ± 1.8	+4.0	<0.001

Table 6. Ball Velocity (km·h⁻¹)

Kelompok	Pre-test Mean ± SD	Post-test Mean ± SD	Δ Mean	p (paired t-test)
VRG	89.3 ± 1.2	94.1 ± 1.2	+4.8	<0.001
CTG	88.2 ± 1.0	90.8 ± 0.9	+2.6	0.003

Table 7. Shooting Reaction Time (ms)

Kelompok	Pre-test Mean ± SD	Post-test Mean ± SD	Δ Mean	p (paired t-test)
VRG	252.9 ± 11.0	217.8 ± 6.6	−35.1	<0.001
CTG	250.3 ± 9.4	232.4 ± 4.4	−17.9	0.001

Table 8. Shooting Success Percentage (%)

Kelompok	Pre-test Mean ± SD	Post-test Mean ± SD	Δ Mean	p (paired t-test)

VRG	46.5 ± 5.3	70.8 ± 4.3	+24.3	<0.001
CTG	46.0 ± 3.3	56.2 ± 3.0	+10.2	<0.001

Table 9. Post-test comparison between groups

Variabel	VRG Post Mean ± SD	CTG Post Mean ± SD	p (independent t-test)	Cohen's d
Shooting Accuracy	32.8 ± 2.7	27.0 ± 1.8	<0.001	02.43
Ball Velocity	94.1 ± 1.2	90.8 ± 0.9	<0.001	03.15
Reaction Time (ms)	217.8 ± 6.6	232.4 ± 4.4	<0.001	0,140277778
Shooting Success (%)	70.8 ± 4.3	56.2 ± 3.0	<0.001	03.57

This study aims to determine the effectiveness of Virtual Reality (VR)-based shooting training compared to conventional training on the performance of competitive futsal players. With a quasi-experimental pretest–posttest control group design, the results showed that both groups experienced improvements in almost all performance indicators, but improvements in the VR group were consistently greater than in the conventional group. In addition, ANCOVA's results controlling for baseline scores reinforced that post-intervention differences between groups remained significant.

The Influence of VR on Shooting Accuracy

In the shooting accuracy variable, the VR group experienced a higher increase than the conventional group. This can be explained by several VR training mechanisms. First, VR provides a structured visual environment and allows athletes to process situational information more richly, especially in phases of training that increase the complexity of perception (e.g. the appearance of target variations, changes in angles, and the presence of moving goalkeepers/defenders). Thus, players are more accustomed to making the right shooting decisions when opportunities open up.

Second, the VR approach in this study is based on Representative Learning Design and Ecological Dynamics, which emphasize that exercises that "represent" the demands of the game situation will accelerate skill adaptation. In futsal, the accuracy of the shot is not only the result of muscle coordination, but it is also influenced by the ability to read space, recognize timing, and choose the most effective shooting location. VR helps athletes rehearse scenarios that are close to the context of the match so that the accuracy of the target increases more noticeably than conventional drills which are relatively more static.

The Effect of VR on Ball Velocity

The results also showed that ball velocity increased even more in the VR group. The increase in shooting speed in the VR group can be influenced by the player's ability to synchronize perception-action. While VR facilitates the visualization of stimuli that demand quick responses (especially in the decision, pressure, and game simulation phases), players tend to develop more efficient execution patterns, including optimizing foot-swing timing, body placement, and ball acceleration on impact. In addition, in the pressure simulation and match simulation phases, athletes receive higher challenges, such as reduced shooting angles and shorter decision-making times. Adaptation to these challenges is likely to make players more "neuromotorically ready" and more motivated to produce higher quality shots, which is reflected in increased ball speed.

The Influence of VR on Shooting Reaction Time

In the reaction time variable, the VR group showed a greater reduction in reaction time than the conventional group (meaning faster). This indicates that VR not only improves the ability to shoot, but also speeds up the decision-making process and initial response to stimuli. In theory, when exercise presents a visual stimulus and demands a specific motor response, the brain forms

a strong connection between visual information and motor action (perception–action coupling). In this study, VR was designed to be phased from familiarization to situations with moving defenders, cognitive pressure, and complex transition scenarios. This kind of gradual exposure helps athletes increase their speed to recognize opportunities and start shooting action faster. This is relevant to the very fast needs of futsal: players often have to decide on a shot in a short span of time when space is tight and opponents press. Therefore, VR exercises that mimic these dynamics have the potential to provide skill transfer to real-life match situations.

The Influence of VR on Shooting Success Percentage

In the shooting success percentage variable, the VR group again showed a higher increase than the conventional group. Shooting success is the integration of target accuracy, shooting decision selection, and technical execution (power and timing). Since VR improves the quality of decisions and makes it easier to adapt execution under various conditions, increasing the success rate makes sense. In addition to technical factors, VR also has the potential to increase attention focus and mental readiness. In the pressure and match simulation phases, athletes face conditions that are psychologically similar to matches (e.g. limited time and "uncomfortable" situations). This experience makes players more adaptive when in real situations, so the chances of goals increase.

Why is VR Superior to Conventional Training?

The research findings support that VR provides additional benefits over conventional training. The main difference lies in the quality of the training experience: VR allows athletes to train in scenarios that are closer to the demands of the game, both in terms of perception (reading the situation), decisions (choosing the time and location of the shot), and motor response (speed and execution).

CONCLUSIONS AND SUGGESTIONS

Conclusion

Based on the results of quasi-experimental pretest–posttest control group research, it can be concluded that Virtual Reality (VR)-based shooting training is more effective than conventional shooting training in improving the performance of competitive futsal players. After the eight-week intervention, the VR group showed a greater and significant improvement than the conventional group in: Shooting accuracy, Ball velocity, Shooting reaction time, Shooting success percentage. In addition, ANCOVA's results controlling for baseline scores reinforced that post-intervention differences between groups remained significant.

Suggestions

Thus, VR can be recommended as an additional training method to improve shooting skills that are more representative of futsal match situations.

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