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THE IMPACT OF A SHORT-TERM PERCEPTUAL TRAINING PROGRAM ON PERFORMANCE KINEMATICS AND DYNAMIC THREE-POINT SHOOTING ACCURACY IN BASKETBALL PLAYERS

Mariam A. Abu-Alim[A, B, D]

Sport Science Department, Yarmouk University, Irbid, Jordan
ORCID:0000-0001-8692-6688

Fadi A. Fayad[C, D]

Sport Department, Faculty of Education, Lebanese University, Beirut, Lebanon
ORCID: 0000-0003-4516-3156
E-mail: fadiify1977@gmail.com

[A]Study Design; [B]Data Collection; [C]Statistical Analysis; [D]Manuscript Preparation

Abstract Purpose: This study investigated the impact of a short-term perceptual training program using the Dynavision-D2 device on dynamic three-point shooting accuracy and performance kinematics in semi-professional basketball players. Methods: Fifteen Semi-professional Basketball Players completed a three-week training program (three 30-minute sessions per week) alongside their regular practice. Pre- and post-training assessments measured shooting accuracy using the "90s dynamic three-point shooting" test and analyzed kinematic variables (e.g., wrist extension and ball release angles) using Dartfish software. Results: Results revealed a significant improvement in the three-point shooting accuracy ($p<.001$, Cohen's $d=1.70$), with post-training accuracy increasing from 15.7% to 18.2%. Regression analysis indicated significant differences in kinematic variables: Wrist Extension Angle: $p=0.004$, $R^2=0.388$, and Ball Release Angle: $p=0.05$, $R^2=0.161$. However, no statistically significant effects were observed for knee flexion ($p=0.710$), hip flexion ($p=0.418$), shoulder flexion ($p=0.629$), elbow flexion ($p=0.294$), and wrist flexion ($p=0.399$). Conclusion: The Short-Term Dynavision-D2 Training Program significantly improved three-point shooting accuracy and key kinematic variables in basketball players. The findings support the integration of cognitive-motor training into sports routines, highlighting its potential to enhance athletic performance.

Key words: cognitive training, motor skills, athletic performance, visual perception, neuromuscular coordination, movement analysis

Introduction

Optimal athletic performance is contingent upon the seamless integration of perceptual, cognitive, and motor skills, often triggered by rapidly changing visual cues during gameplay. According to Mann et al. (2007), perceptual-cognitive skills involve identifying and processing cues to make quick, informed decisions under pressure. Clutch performance- ability to maintain accuracy under pressure is a distinguishing trait of skilled players (Klostermann et al., 2020). Effective team decision-making, grounded in coordination and communication, also contributes to scoring by enabling players to anticipate actions and respond accordingly (Moeinirad et al., 2022; Sirnik et al., 2022; Huang & Liu, 2022). The integration of perception and motor action, especially maintaining visual focus on the basket, supports precise execution in dynamic environments (Klostermann et al., 2020). For example, the visual skill "quiet eye," characterized by a final fixation on the target within a 3° visual angle for at least 100 milliseconds, has been shown to enhance shooting accuracy significantly (Vickers, 2007; Basevitch et al., 2020; Zhao & Zhao, 2023).

Previous literature lays emphasis on visual–perceptual abilities as equally important as biomechanical skills in dynamic sport environments. Basketball is a sport that demands rapid decision-making and strategic coordination game and, shooting stands out as one of the most complex and vital skill (Zhao & Zhao, 2023); As players must execute accurate shots in a forceful and often unpredictable environment, with the three-point shot being a common and strategic scoring method, typically performed after coordinated team efforts (Jin & Fan, 2023). Also, biomechanical research has linked several physical and technical factors, such as release angle, velocity, height, player fatigue, and positioning, to shooting performance (Sirnik et al.,2022); However, these do not fully account for shooting success, requiring the coordination with visual and perceptual skills for the shooting accuracy in basketball. Recent studies address the crucial role of visual skills in enhancing shooting accuracy, underlining their importance in interpreting visual cues and adjusting motor responses accordingly (Moeinirad et al., 2022; Sirnik et al., 2022; Huang & Liu, 2022). Moreover, encompassing various components that support decision-making and execution, dynamic visual acuity enables players to maintain clear vision while in motion, allowing for precise motor responses. In addition, visual search behaviors and processing speed are equally essential, as players must rapidly interpret game cues—such as the positions and movements of teammates and opponents—to make timely decisions (Jin & Fan, 2023). Basevitch et al. (2020) have also confirmed that gaze behavior during shooting is particularly influential; focusing on a specific target improves scoring precision (Basevitch et al., 2020).

Coaches and researchers have integrated sports vision training programs, which have been shown to enhance athletes' performance by improving eye–brain coordination, perception, and visual processing. In recent decades, advancements in vision training have introduced perceptual learning-based programs that target sport-specific visual skills, grounded in the understanding of the visual system's structure and function (Appelbaum & Erickson, 2018; Sirnik et al., 2022). One widely used tool in this field is the Dynavision D2, which has been validated as an effective device for training and assessing reaction time, visual awareness, and hand-eye coordination (Ong, 2020; Vater & Strasburger, 2021; Wells et al., 2014). Research by Vickers et al. (2019) reported that basketball players who maintained visual fixation on the ball during shooting despite defensive pressure achieved greater three-point shooting accuracy. Similarly, Mangine et al. (2014) found that visual tracking speed measured by the Dynavision D2 positively correlated with key performance metrics in professional players: steals ($r=0.77$, $p=.003$), assists ($r=0.78$, $p=.003$), and assist-to-turnover ratio ($r=0.78$, $p=.003$). However, general reaction time did not show a significant correlation with performance, suggesting visual tracking is a more critical factor.

Most previous research studies have tested the effect of sports vision training on shooting accuracy in sedentary shooting environments and its correlation with overall player performance. The current study aimed to address this gap by examining the effects of an early-season sports vision training program on college basketball players, focusing on its impact on dynamic three-point shooting accuracy and performance kinematics. Specifically, the study investigated whether a short-term perceptual training program using the Dynavision D2 would improve dynamic three-point shooting accuracy and associated kinematic variables. It was hypothesized that the short-term training program would significantly enhance players' dynamic shooting accuracy.

Methods

Participants

Fifteen semi-professional basketball players from two local clubs were purposively selected for this study, based on coaches' recommendations. All participants were university students competing in regional championships. Ethical approval was granted by Yarmouk University's Institutional Review Board (IRB/2023/311), and the study complied with the Declaration of Helsinki (World Medical Association, 2013), ensuring participants' rights, dignity, and well-being. Informed consent was obtained, with participants assured of confidentiality and the right to withdraw at any time. The study procedures were clearly explained, and all questions were addressed. Inclusion criteria required participants to be healthy, injury-free for at least six months, and without vision problems. Exclusion criteria included wearing glasses or lenses, having vision impairments, or experiencing sickness that could affect balance or visual focus. Additionally, participants were instructed to abstain from caffeine for at least five hours before testing, and this was confirmed verbally prior to the test sessions.

Experimental Design

Participants took part in three weeks (3 sessions (30 minutes each)/week). Dynavision-D2 suggested a training program alongside their regular team practice schedule but on different weekdays. The Dynavision-D2 suggested intervention was conducted using Dynavision™ D2 Visuomotor Assessment Device (D2; Dynavision International LLC, West Chester, OH). The Dynavision-D2 training program was developed using pre-programmed training and assessment of the Dynavision-D2 software and specific tests that included the T-scope, reaction time, Endurance, Proactive mode A, and the Reactive mode B, with a total training time of 30 minutes for each session. The proposed training program was built through researchers' expertise recommendations and revision of previous literature and the basketball coach as presented in Table 1.

Table 1. Description of Dynavision-D2's Suggested Training Program Used

Task #	Training Model (Task)	Training Duration (Minutes/Session)
1	T-scope - L hand	3
2	T-scope - R hand	3
3	Reaction @ 30% green	2
4	Reaction: Training Upper	2
5	Reaction time	1
6	Endurance	5
7	Proactive mode A	2
8	Reactive mode B	2
Total training time for each session	20 minutes	+ 2 minutes warm-up + 1-minute break between tasks

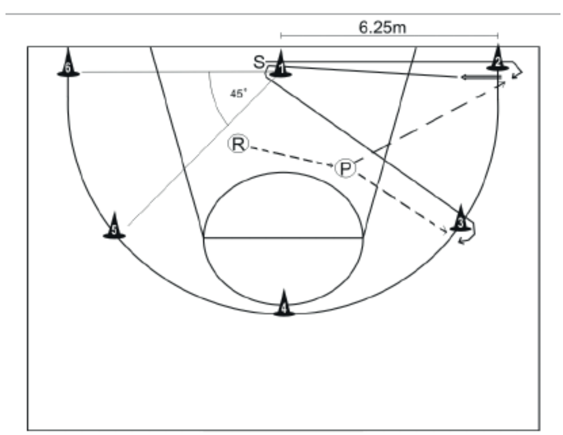
Procedures

The study intervention took place at the Peak Performance Center (PPC), which is located in the sports sciences department of Yarmouk University. The Dynavision-D2 suggested intervention took place during the general conditioning training session of the university basketball training and had no focus on game skills training. All sessions were scheduled in the morning (10 am–12 pm).

At the initial training session, researchers gave the participants a standardized script and verbal instructions on the training protocol; all training task protocols followed the instructions and recommendations of the manufacturer protocols of Dynavision™ D2 Visuomotor Assessment Device (D2; Dynavision International LLC, West Chester, OH). Researchers then addressed all their questions to familiarize them with the Dynavision D2 device. Then, the participants were asked to stand comfortably with an upright posture and balance (flexed knees, lowering center of gravity) in front of the Dynavision D2 board. The board was adjusted to the participant's height as instructed, the LCD screen was set approximately at the participant's eye level, and the outer-most target buttons were within hand reach. To ensure the board position, participants completed a practice trial along with verbal instruction. Training room conditions were standardized as temperatures were kept between 24-26 degrees and monitored by air conditioners and thermostats. Testing room lighting was also standardized for all participants across all sessions. The description of Dynavision-D2's suggested training program used is presented in Table 1, and practices were randomized.

Dynamic Three-Point Shoot Assessment

The accuracy of the dynamic three-point shoot was assessed using the widely used "90s dynamic three-point shooting" (Figure 1) assessment test protocol, which can be referred to (Zhang et al., 2023). In this assessment, participants are to shoot the 3-point shot from five marked positions around the three-point line as Pos1: Left Corner, Pos2: Left Wing, Pos3: Top of the Key, Pos4: Right Wing, Pos5: Right Corner. This setting is a real game scenario where players must reposition quickly to open shooting spots. The assessment is performed within 90 seconds. Furthermore, players have to stay dynamic between positions. Shooting accuracy is represented by calculating the percentage of shots made and the total points scored from all positions.



Note. The dynamic 90-second three-point shooting test (S3P60). R=rebounder; P=passer; S=shooter.

Figure 1. Dynamic 90-second three-point shooting test accuracy

Kinematic Analysis

The selected kinematic variables of the three-point basketball shot were analyzed using Dartfish software (Dartfish v5.0.1.0; Dartfish, 2020). The measurement procedures followed previously established basketball shooting kinematic protocols (Alexander & Hayward-Ellis, 2016; Ammar et al., 2016; Cabarkapa et al., 2022; Kambič et al., 2022; Majed et al., 2012) and were conducted in accordance with the operational guidelines described in the Dartfish User Guide (Dartfish, 2020).

Prior to data collection, a two-dimensional (2D) direct linear transformation (DLT) calibration was performed for the video camera to ensure spatial accuracy in angle measurement. A calibration frame with known vertical and horizontal dimensions was positioned within the shooting area and recorded before each session to establish scaling and minimize parallax error. For the kinematic analysis, the performance of the 3-point shot from position (3) (Top of the Key) was selected for analysis due to the convenience of video recording, and the average of two shots was statistically analyzed as most of the players were able to achieve at least two successful 3-point shots. Otherwise, the successful 3-point shot was kinematically analyzed. The researcher ensured the player performed the shot naturally to capture realistic kinematic data. The recorded performance videos were then imported into the Dartfish software. Dartfish's tracking and analysis tools were used following the software protocol to mark and analyze the key points. To calculate the selected Kinematic Variables of the 3-point basketball shoot, the following angles were defined as described in Table 2.

Table 2. Definitions of Kinematic Variables for the 3-Point Basketball Shot

Variable	Definition
Shoulder Flexion Angle	Angle between the trunk (torso) and the upper arm (humerus).
Elbow Flexion Angle	Angle between the upper arm (humerus) and the forearm (radius/ulna)
Wrist Flexion/Extension Angle	Angle between the forearm and the hand (metacarpals)
Hip Flexion Angle	Angle between the trunk (torso) and the thigh (femur)
Knee Flexion Angle	Angle between the thigh (femur) and the lower leg (tibia/fibula)
Wrist Extension Angle	Angle of wrist extension during the shot
Ball Release Angle	Angle of the ball's trajectory relative to the horizontal at the moment of release

The performance phases were defined in constant with previous literature as follows: Preparation Stage: This stage involves the setup and body positioning before the initiation of the shooting motion. During this phase, key kinematics include: Knee Flexion Angle, Hip Flexion Angle, Shoulder Flexion Angle, and Elbow Flexion Angle. Execution Stage; is the dynamic phase when the shooter initiates and completes the upward movement of the shot. In this stage, variables include: Knee Flexion Angle, Hip Flexion Angle, Shoulder Flexion Angle, Elbow Flexion Angle, and Wrist Extension Angle. Follow-Through Stage After the ball is released, continue the motion and help stabilize the shot. The primary kinematics are: Wrist Flexion Angle and Ball Release Angle.

Statistical Analysis

Statistical analyses included descriptive statistics (means and standard deviations) and paired-samples t-tests to evaluate pre–post differences in dynamic three-point shooting accuracy following the short-term Dynavision D2 training program. Effect sizes for within-subjects comparisons were calculated as Cohen's d_x using the formula $d_x = t/\sqrt{n}$. Simple linear regression analyses were conducted to examine the association between changes in kinematic variables (predictors: knee, hip, shoulder, elbow, and wrist joint angles, and ball-release angle) and changes in shooting accuracy (outcome variable). The regression analyses served to elucidate which kinematic modifications most effectively accounted for enhancements in performance. Coefficients of determination (R^2) were interpreted as the proportion of variance in shooting accuracy explained by each kinematic variable. All statistical analyses were executed utilizing IBM SPSS Statistics for Windows, Version 20.0 (IBM Corp., Armonk, NY), with a level of statistical significance established at $\alpha=0.05$.

Results

The study employed a paired samples t-test and regression analysis to evaluate the effectiveness of the Short-Term Dynavision-D2 Training Program on basketball players' three-point dynamic shooting accuracy and kinematic variables.

Shooting Accuracy Improvement:

A paired samples t-test revealed a statistically overall significant improvement in three-point shooting accuracy from pre-training to post-training with a large calculated effect size (d=1.61), indicating that the training program had a substantial impact on shooting accuracy. These results are shown in Table 3.

Table 3. Paired Samples t-Test Results for Pre-Training and Post-Training Accuracy

Variable	M (Pre)	SD (Pre)	M (Post)	SD (Post)	t	df	p	Cohen's d
Accuracy (%)	15.7	2.16	18.2	2.10	6.23	14	<.001	1.61

Kinematic Performance Analysis:

Simple linear regressions were performed to define which kinematic variables best predicted improvements in shooting accuracy following the Dynavision-D2 intervention, key variables: Wrist Extension Angle, and Ball Release Angle. However, no statistically significant effects were observed for other kinematic assessed variables, results shown in Table 4.

Table 4. Regression Analysis of Kinematic Variables of 3-point Basketball Shooting Performance Pre and Post Training on the Short-Term Dynavision-D2 Training Program

Variable	t	β	R^2	F	p
Knee Flexion Angle	-0.374	0.078	0.008	0.138	.710
Hip Flexion Angle	-0.858	0.188	0.038	0.729	.418
Shoulder Flexion Angle	0.465	0.126	0.019	0.249	.629
Elbow Flexion Angle	1.08	0.247	0.066	1.157	.294
Wrist Extension Angle	-3.353	0.626	0.388	10.946	.004*
Wrist Flexion Angle	0.863	0.199	0.040	0.746	.399
Ball Release Angle	-2.856	0.401	0.161	8.158	.050*

Note. N=15. Significant p-values are indicated with an asterisk (*p<0.05).

Moreover, the results revealed that the Wrist Extension Angle accounted for 38.8% of the variance in performance improvements with a large effect size ($f^2=0.634$). Ball Release Angle accounted for 16.1% of the variance with a medium effect size ($f^2=0.192$). The current results could highlight the role of athlete-specific kinematic adjustments during visual–perceptual training, suggesting that players who exhibited greater refinements in wrist extension and release mechanics achieved higher gains in shooting accuracy (see table 5 and figure 3).

Table 5. Kinematic Variables of the 3-Point Shooting Basketball Performance Before and After Training on the Short-Term Dynavision-D2 Training Program

Stage of Performance	Condition	Variable	Min	Max	Mean	SD
Preparation	Post-Training	Knee Flexion Angle	109.3°	116.2°	112.75°	1.99°
		Hip Flexion Angle	161.1°	166.6°	163.85°	1.59°
		Shoulder Flexion Angle	68.4°	77.1°	72.75°	2.51°
		Elbow Flexion Angle	65.6°	75.4°	70.50°	2.83°
	Pre-Training	Knee Flexion Angle	91.5°	125°	108.25°	9.67°
		Hip Flexion Angle	134.8°	140.2°	137.50°	1.56°
		Shoulder Flexion Angle	56.23°	67.2°	61.72°	3.17°
		Elbow Flexion Angle	42.9°	69.8°	56.35°	7.76°
Execution	Post-Training	Knee Flexion Angle	143.4°	162.6°	153.00°	5.54°
		Hip Flexion Angle	175.2°	185.97°	180.59°	3.11°
		Shoulder Flexion Angle	118.2°	120.8°	119.50°	0.75°
		Elbow Flexion Angle	144.4°	161.83°	153.12°	5.03°
		Wrist Extension Angle	133.6°	142.7°	138.15°	2.63°
	Pre-Training	Knee Flexion Angle	134.60°	152.85°	143.73°	5.27°
		Hip Flexion Angle	175.70°	179.45°	177.58°	1.08°
		Shoulder Flexion Angle	94.17°	115.80°	104.99°	6.25°
		Elbow Flexion Angle	145.60°	154.23°	149.92°	2.49°
		Wrist Extension Angle	135.77°	157.37°	146.57°	6.24°
Follow-Through	Post-Training	Wrist Flexion Angle	132.7°	148.5°	140.60°	4.56°
		Ball Release Angle	52°	58.6°	55.30°	1.91°
	Pre-Training	Wrist Flexion Angle	126°	135.5°	130.75°	2.74°
		Ball Release Angle	40.40°	53.40°	46.90°	3.75°

Note. Min=Minimum value; Max=Maximum value; SD=Standard Deviation. All data are representative as angles in degrees (°).

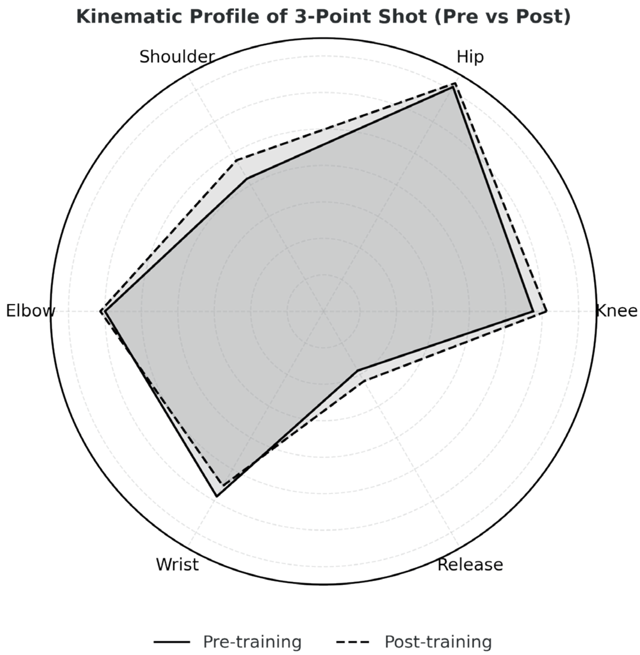


Figure 3. Kinematic profile of joint angles during the shooting sequence pre- and post-training. Solid line represents pre-training, dashed line represents post-training. Shaded areas indicate SD range.

Discussion

This study examined the effect of a short-term perceptual training program using the Dynavision D2 on dynamic three-point shooting accuracy and related motor performance variables in semi-professional basketball players. The results confirm that short-term training with the Dynavision D2 enhanced dynamic shooting accuracy, which may be related to post-training modifications in key kinematic parameters such as release angle and wrist extension—that reflect improved coordination rather than static or universally optimal movement patterns. Literature has emphasized that task related kinematic adaptations are player-specific and may not follow the optimal model. The most effective shooting performance kinematics, such as ball release angle or wrist angles, depend on an athlete's anthropometric characteristics, underlying technique, and situational context. Which highlights that improvement is better defined by consistency and adaptability rather than fixed numerical values (Cowin et al., 2022; Ammar et al., 2025).

The current study results support the integration of cognitive-motor training tools like Dynavision-D2 into basketball routines to boost performance, aligning with prior research emphasizing the benefits of such training on athletic capabilities (Jin et al., 2020; Lu et al., 2020; Sirnik et al., 2022; Zhao et al., 2024). It is worth noting that researchers focused on a within-subjects design in integrating the Dynavision D2 assessments, allowing players to track their individual progress. However, the absence of a control group might limit the generalizability of the current study results.

A comparable study by Lucia et al. (2023) found that fifty-two semi-professional players who completed cognitive-motor training showed a 13% greater performance improvement than those undergoing standard training, particularly in decision-making and response execution. Similarly, this study observed a statistically significant improvement ($p<0.05$) in shooting accuracy after the Dynavision-D2 intervention. These findings suggest that the program enhanced key skills such as coordination, visuomotor integration, and decision-making under dynamic conditions. The training included modules focused on reaction time, endurance, and proactive/reactive responses, all of which likely contributed to the observed performance improvements, supporting the study's hypothesis. By improving visual fixation, players can better plan and adjust motor actions in real-time, which is crucial during high-pressure situations in basketball (Blackwell et al., 2020; Wells et al., 2014). These findings align with Feldhacker et al. (2019), who demonstrated that Dynavision-D2 offers more effective proactive training than non-technological methods for collegiate softball athletes. Similarly, Aitcheson-Huehn et al. (2024) found that visual fixation before initiating motor actions significantly improved basketball shot accuracy. Their machine learning-based study, involving 12 players and 200 shots from six court locations, reported that fixation durations beyond 18% could enhance shooting success.

This study also supports earlier research linking superior shooting performance to strong perceptual and visual skills (Vickers et al., 2019; Ji, 2020; Uludağ et al., 2021; Huang & Liu, 2022). Enhanced visual perception contributes to improved shooting mechanics, including joint angles, smoother movements, and better upper-lower body coordination (Appelbaum & Erickson, 2018; Laby & Appelbaum, 2021; Lochhead et al., 2024). Current study linear-regression analysis revealed significant improvements in some shooting kinematics after the Dynavision-D2 intervention: wrist extension angle ($T=-3.353$, $p=0.004$, $R^2=0.388$) and ball release-angle ($T=-2.856$, $p=0.05$, $R^2=0.161$), These regression findings indicate that players who developed more coordinated wrist and release mechanics achieved greater improvements in accuracy, suggesting that perceptual–motor training with the Dynavision D2 can be effectively integrated into coaching practice. It could also be important to interpret these biomechanical adaptations as distinctive performance adjustments rather than as references to an optimal fixed model. Merging from individual constraints, experience, and coordination tendencies.

Comparable results were found by Lucia et al. (2024), who integrated cognitive training into physical sessions for professional and semi-professional basketball players, reporting improvements in sprint agility and motor preparation after just five weeks. Additionally, previous studies have shown that top scorers in free throws demonstrated superior proprioception, with strong correlations between wrist and elbow joint positions and shooting success (Oks et al., 2019; Sevrez & Bourdin, 2015). Zhen et al. (2015) also noted that during one-handed shooting, the ball is released when the legs are fully extended, and guidance is primarily controlled by the index finger, further confirming the importance of precise biomechanics. Similarly, França et al. (2022) used Dartfish-based kinematic analysis to emphasize the importance of shooting arm positioning, supporting the current study's conclusions. In summary, the success of this short-term intervention can be attributed to the Dynavision-D2's cognitive-motor skills (proactive/reactive) training. With its user-friendly interface and practical design, the Dynavision-D2 proves to be a valuable tool for basketball coaches aiming to improve player accuracy and reaction speed.

Conclusion

In conclusion, the Short-Term Dynavision-D2 Training Program significantly enhances three-point shooting accuracy and some kinematic variables in basketball players. These findings provide compelling evidence for the integration of cognitive-motor training tools into basketball practice, paving the way for further research and practical applications in sports performance enhancement.

This study contributes to the literature on sports skill training by exploring the effect of electronic training devices on shooting accuracy in basketball. It advances understanding of the role of coordination, visuomotor skills, and decision-making in shooting performance, highlighting the potential of Dynavision-D2 as a tool to improve these abilities. The study also contributes to the field of physical education and sports coaching by demonstrating the effectiveness of this type of program in improving shooting accuracy and overall fitness levels. Practically, the current study provides evidence-based support for the use of Dynavision-D2 in basketball training programs. Basketball coaches and trainers can address these findings to incorporate this device into their off-season training regimens to enhance three point shooting accuracy. The simple setup and user-friendly interface of Dynavision-D2 make it easily applicable in training environments, making it practical for a wide range of athletes. Despite its benefits, there are limitations of this study that should be acknowledged. The primary limitation is the relatively small sample size of 15 male basketball players and the absence of a separate control group, which may limit the generalizability of the results to a broader population. Additionally, the study was conducted over a relatively short time frame, spanning three weeks, which may not fully capture the long-term effects of the Dynavision-D2 program on player performance. Future research should examine the sustainability of these improvements over extended periods and across diverse athletic groups.

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