Original Paper

Effects of BlazePod Visual Stimulus Training on Reaction Time, Agility, and Shooting in Youth Basketball Players: Randomized Controlled Trial

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Abstract

Background: Rapid visuomotor coordination, decision-making, and visual processing are key components of basketball performance.

Objective: This study aimed to evaluate the effects of a 10-week visual stimulus training program delivered with BlazePod on task-specific behavioral outcome measures of bilateral visuomotor reaction time (RT), reactive agility (dribbling), shooting execution speed, and shooting execution accuracy in youth male basketball players.

Methods: A single-blind, randomized controlled trial was carried out in a private sports club in Al-Ahsa, Saudi Arabia. Twenty-eight male recreational basketball players (mean age 16.22, SD 0.78 years) who had at least 2 years of structured training, normal visual acuity, and no prior experience with reactive lights were recruited. The participants were randomly assigned (1:1; computer-generated block randomization, block size=4) to an experimental group (EG; n=14) and a control group (CG; n=14). Allocation was masked from outcome assessors, but it was not possible to blind participants. The EG was given a progressive BlazePod visual-cognitive training program that was implemented in conjunction with standard basketball training (25-35 minutes per session, 3 times per week for 10 weeks), emphasizing reactive agility and shooting under dynamic conditions. The program was delivered under the supervision of a certified coach. Standard basketball training was conducted without reactive technology by the CG. Pretesting and posttesting consisted of bilateral simple visual RT (Lafayette apparatus), reactive agility (Modified T-Test and Y-Test taking dribbling into account, using BlazePod timing), and shooting ability (execution time and accuracy).

Results: All 28 randomized subjects were analyzed. Significant group×time interactions were found for all outcome variables after Bonferroni corrections for 6 variables (partial η^2 range 0.27-0.43; all $P<.005$). The EG demonstrated large pre-to-post improvements across all measures (Cohen *d* range 1.34-1.77; all $P<.001$), including faster bilateral RTs (right hand: $\Delta=-0.039$ s, 95% CI −0.052 to −0.026; left hand: $\Delta=-0.041$ s, 95% CI −0.053 to −0.029), improved reactive agility (Y-Test: $\Delta=-0.62$ s, 95% CI −0.78 to −0.46), and enhanced shooting performance (accuracy: $\Delta=+4.29$ points, 95% CI 3.21-5.37; execution time: $\Delta=-5.14$ s, 95% CI −6.50 to −3.78). The results of the between-group posttest comparisons showed significantly better results for the EG in all outcomes (Cohen *d* range 0.84-1.25; all $P\leq.036$). Smaller but less consistent improvements were observed for the CG, with no significant difference seen for T-Test with dribbling ($P=.05$) or shooting execution time ($P=.11$).

Conclusions: The study shows that BlazePod training is highly effective in improving visuomotor skills and shooting accuracy among youth basketball players, filling a gap in the literature of the region. Larger samples and objective match metrics should be used in future studies to validate competitive transfer and to further examine the neurocognitive mechanisms.

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KEYWORDS

reactive agility; visual reaction time; shooting performance; BlazePod training; youth basketball players; PMS skills; randomized controlled trial

Introduction

Basketball is an intermittent, high-speed team game that places considerable perceptual-cognitive challenges on players during the game. During a game, athletes are constantly required to receive, process, and respond to complex and dynamic visual information (such as the location and movement pattern of their own teammates, opponents, and the ball) to make the right decision in time. [1,2] The cognitive loads include selective attention, anticipation, spatial awareness, pattern recognition, and quick decision-making under time pressure, which are set as "expert performance" factors in invasion sports [3]. Perceptual-cognitive functions, not just a simple visual acuity test, have been shown consistently by meta-analytic evidence to differentiate athletes of differing skill levels in a variety of sports across the different domains of perceptual tasks, and to be more effective in the laboratory and sports-specific perceptual tasks for expert athletes as compared to novices [4]. In basketball, the capacity to quickly recognize relevant environmental cues, anticipate the opponent's moves, and choose an optimal motor response is essential for successful offensive play (shooting, passing, etc) and defensive play (stealing, blocking, intercepting, etc) [5,6].

An important perceptual-cognitive requirement is the ability to convert the processing of visual information into a coordinated movement plan and its execution (visuomotor coordination). It is reflected in almost all basketball actions, such as tracking a ball pass, which involves continuously updating hand position with respect to perceived distance and angle, and when carrying out a fast break, simultaneous scanning of the field and identifying open teammates requires an update of the ball position with respect to both distance and angle [7,8]. Eye-hand coordination is a skill that is essential for controlling passes, dribbles, and shots, plus keeping track of the unpredictable nature of games [9]. The direct connection between quality of visual processing and motor outcome is supported by research conducted on visual fixation, which has shown that the tendency of an elite basketball player to fixate on a target for a prolonged period of time before shooting is a strong predictor of shooting accuracy (ie, the "quiet eye" phenomenon) [10,11]. However, it is important to note that the visuomotor processing speed and learning rates are better in elite athletes as compared to novices, as seen with longitudinal and cross-sectional studies, indicating that these skills can be learned by systematic intervention rather than being innate [4,7]. Notably, such perceptual-cognitive development does not occur uniquely in basketball; recent studies in youth soccer have shown that the use of structured possession games (eg, rondo drills) effectively impacted problem-solving and creative thinking abilities of U-13 soccer players, indicating that the implications of using ecologically valid training paradigms for the development of problem-solving and cognitive flexibility in young team-sport athletes are applicable across several sports [12].

Given the well-established role of visuomotor skills in sports performance, numerous training techniques have been developed to enhance visual and perceptual-cognitive skills in athletes. Sports vision training (SVT) refers to depth perception training, peripheral training, dynamic acuity training, and/or visual tracking training designed to produce on-field benefits as a direct result of training the eye [13,14]. In recent years, several researchers have been interested in the effects of SVT on sport-specific visual and visuomotor skills, as well as how these skills transfer to competitive match performance [13]. Lochhead et al [13] found that although there is evidence that SVT can induce measurable changes in visual and visuomotor skills, there is a need for more rigorous studies to investigate transfer to competitive match performance. At the same time, perceptual-cognitive training paradigms using video and virtual reality are promising for enhancing anticipation and pattern recognition in team sports [15,16]. The cognitive-motor dual task approach, in which motor tasks are performed while simultaneously performing cognitive tasks under sport-specific conditions, has been shown to improve physical performance indicators (such as sprint speed and agility) and decision-making quality in basketball environments [17]. Recently, technology-based reactive training devices, which deliver unpredictable visual stimuli during sport-specific movements, have become available and have been identified as ecologically valid tools to integrate visual-cognitive challenges into training processes [18,19].

The BlazePod system is one of the most prominent technology-based reactive training tools emerging in sport science for the purposes of developing reactive skills in sport-specific environments. The wireless, light-emitting pod network can be programmed through a mobile application to light up in random sequences of colors at different time intervals, forcing athletes to touch the active pods as fast and accurately as possible. This stimulus-response paradigm allows for the measurement and the training of reaction time (RT), decision-making time, and reactive agility in ecologically valid movement environments [20,21]. A number of studies have reported beneficial outcomes in agility, visual RT, and movement speed in young athletes after dealing with reactive light training in various sports. For example, Theofilou et al [21] have reported that a visual stimuli program was effective in improving RT, cognition, and physical fitness in U-14 youth soccer players, and Zekailiche et al [20] found that BlazePod was effective at enhancing agility and visual RT in U-19 volleyball athletes. For basketball, Hassan et al [18] showed that the visual RT, speed, and the dribbling proficiency of players improved significantly with the use of reactive agility protocols performed with FitLight. Steff et al [22] showed improvement in the upper part of the body with the use of

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similar protocols on FitLight. Moreover, Silvestri et al [23] found acute cognitive-motor adaptations in youth basketball players after FitLight training, and Hadžović et al [24] validated new measures of reactive agility for female basketball players. Together, this evidence indicates that reactive light training is a valid method to improve the visuomotor and reactive ability of athletes.

Although the body of evidence concerning the effectiveness of visual training through technology continues to grow, there are a number of gaps in the literature. In addition, most of the studies on reactive light devices have not been conducted in the context of the sport itself (eg, soccer, volleyball, as opposed to basketball), and previous basketball research has largely examined perceptual-cognitive and motor aspects of the sport separately (eg, upper-limb coordination and simple RT) rather than concurrently (eg, reactive agility, dribbling, or shooting accuracy under visual-cognitive load) [22,23]. Second, there is a lack of rigorously controlled experimental studies that use a standardized progression protocol and well-characterized samples to investigate multiweek effects of BlazePod interventions on composite measures of full basketball performance. Third, the literature available has focused on adult or college athletes, with little research on the developmental maturation of perceptual-cognitive and visuomotor systems of youth athletes that could also be sensitive to specific training [25,26]. Fourth, there is a noticeable lack of research done in the Middle East and Gulf region that explores contexts different from those in the West, where environmental factors, youth sports training cultures, and organizational frameworks may vary significantly, which is important [27]. Therefore, there is a great need to conduct evidence-based intervention research examining the effects of using visual stimulus training on RT, reactive agility, and the execution of sport-specific skills in underserved youth basketball players using the BlazePod.

Thus, this trial aimed to determine the impact of a 10-week training program using BlazePod visual stimuli compared to regular basketball training on behavioral performance measures in youth male basketball players. In particular, it was hypothesized that in the following areas the experimental group (EG) would show significantly greater gains than the control group (CG): (hypothesis 1) bilateral visuomotor reaction time (VMRT); (hypothesis 2) dribbling agility (ie, Modified T-Test and Y-Test); and (hypothesis 3) shooting performance (ie, execution time and accuracy score). This study explicitly evaluates the performance measured by behavior in a controlled testing environment.

Methods

Trial Design

In this study, a prospective, single-blind, randomized controlled trial (RCT) was used to assess the effectiveness of a 10-week visual stimulus training program on the ability to react and move quickly through movement (VM) in male youth basketball players, reactive agility with dribbling (RAD), and shooting accuracy. The design consisted of 2 parallel sets: an EG with integrated BlazePod training, and a CG with just regular basketball training. A pretest (baseline) assessment was administered as well as a posttest (after the intervention). To reduce detection bias, outcome assessors were blinded to group allocation during data collection, but as the intervention technology was clearly visible, participant blinding was not possible. This RCT study was designed, conducted, and reported following the guidelines of the CONSORT (Consolidated Standards of Reporting Trials) 2025 statement [28] and the CONSORT-eHEALTH (Consolidated Standards of Reporting Trials of Electronic and Mobile Health Applications and online Telehealth) checklist for digital health interventions [29] to ensure that the study design, methodology, and results were well reported.

Setting and Eligibility Criteria

Trial Setting

The research was carried out in a private sports club in Al-Ahsa, Eastern Province, Saudi Arabia. Recruitment was conducted from January 15 to February 28, 2025. The baseline assessments took place in the first week of March 2025, the 10-week intervention period was conducted from March to May 2025, and the postintervention assessment was completed in the first week of June 2025. To control for circadian rhythm effects on neuromuscular performance, all testing and training took place indoors at a standardized temperature (22-24 °C) and humidity (40%-50%) between 16:00 and 19:00 local time.

Eligibility Criteria

Participants included only male individuals with a minimum of 2 years of structured out-of-school basketball training experience, who had no musculoskeletal injuries or neurological disorders in the 3-month window before the study; had normal or corrected-to-normal visual acuity (using a Snellen chart); and had no prior exposure to reactive light-based training devices. Those who participated in less than 2 training sessions during the intervention period and/or who withdrew from the treatment were considered as exclusion criteria. Biological maturation was acknowledged as a potential confounder for neuromuscular coordination and neurocognitive processing speed that may affect the sample used [12], given the age span (15-18 years) on which this study originated. The small chronological age span and homogeneous training history (≥2 years) were designed to reduce maturational variance, although maturity offset was not evaluated in this study logistically in the community club environment.

Randomization and Allocation

Sequence Generation

The random allocation sequence was prepared by an independent statistician who had nothing to do with recruitment of participants or assessing outcomes. The groups were evenly sized over the duration of the enrolment period, with a fixed block size of 4, using the block randomization method created on the computer.

Allocation Concealment Mechanism

Allocation concealment was ensured by sequentially numbered, opaque, and sealed envelopes. The envelopes were prepared by an independent statistician and kept in a strong envelope until

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they were assigned. Envelopes were opened only after baseline assessments and eligibility determination, to avoid the risk of selection bias.

Implementation

Thirty-five players were screened for eligibility, and 28 were found to be eligible and gave written informed consent (parent/guardian consent for players under age 18 years). Leaders began to enroll and assign participants to interventions immediately after baseline assessment. Leaders began enrolling and assigning participants to interventions after baseline assessment. No one who recruited participants was given the sequence in which the participants were randomly assigned. Each group (28 randomized: EG=14; CG=14) was 100% compliant with intervention attendance and had no dropouts. Demographic and anthropometric data are also shown in Table 1 as a measure of baseline equivalence between the groups.

Table 1. Demographic and anthropometric baseline data of participants in a prospective, single-blind, parallel-group RCT[a] with BlazePod visual stimulus training and standard basketball practice for youth male basketball players.

Variable	EG[b] (n=14), mean (SD)	CG[c] (n=14), mean (SD)	*t* test[d] (*df*)	*P* value
Age (years)	16.29 (0.74)	16.14 (0.81)	0.51 (26)	.61
Height (cm)	169.14 (5.37)	168.79 (5.12)	0.18 (26)	.86
Body mass (kg)	62.43 (6.18)	61.86 (5.93)	0.25 (26)	.80
BMI (kg/m²)	21.82 (1.54)	21.69 (1.41)	0.23 (26)	.82
Training experience (years)	3.57 (0.82)	3.64 (0.79)	–0.23 (26)	.82

[a]RCT: randomized controlled trial.

[b]EG: experimental group.

[c]CG: control group.

[d]Independent-samples *t* tests indicate no significant differences between groups at baseline (all *P*>.05).

Assessments and Data Sources

Primary Outcomes

All dependent variables were assessed with laboratory equipment and sport-specific assessments, which were standardized for use in youth basketball (Multimedia Appendix 1).

Visual RT (right/left hand): Visual RT was measured using a Lafayette visual RT apparatus (Model 63014A; Lafayette Instrument Company; Figure 1). Participants were seated in a standard position with their hands on the response button. The participants pressed the button as quickly as they could when they were shown a red visual signal. The total number of trials per hand was 10 (plus 3 familiarization trials), and the interstimulus intervals (ISIs) were randomly varied between 2 and 5 seconds to prevent anticipation. The mean RT of 8 valid trials (excluding the fastest and slowest) in seconds (s) was the outcome measure. The larger the number, the longer it takes the reaction to happen. The test is valid and reliable for athletic populations [22,27].

Multidirectional change-of-direction speed with ball control (reactive agility): Multidirectional change of direction speed using ball control (Figure 2). The course consisted of points A (start), B (10 m ahead), and C/D (5 m to the left or right). Biomechanical Standardization: For the purpose of eliminating the contribution of dribbling proficiency, the participants were asked to: Dribble the ball at or below knee height throughout the trial; Use alternating hands when shuffling laterally (right hand right shuffle, left hand left shuffle); Decelerate the ball with the 2 feet plant at each decision point before touching the pod. Timing was automated using BlazePod application (+/–0.01 s). A statistical analysis of the best of 3 trials (≥90 s rest) was performed. The shorter the time, the better the performance [18,22,24].

Y-Test with dribbling (reactive agility): Evaluated multidirectional perceptual-motor integration (Figure 3). The starting gate (Point A) was set 5 m away from a central point for 3 target gates set at 45° (2.5 m outwards). Visual Angle Standardization: BlazePods were placed at eye level (1.5 m above ground) at an angle of 30° inward from the expected line of sight for the athlete during the approach (independent of trajectory), so that the stimuli always fell between the central-to-peripheral visual field boundary. Participants walked to the decision point and answered a single pod that was right under them and was lit up randomly. Best of 3 trials (≥90 s rest) was analyzed. Test-retest reliability: intraclass correlation coefficient (ICC) 0.85 (95% CI 0.70-0.93) [30]. The lower the times, the better the performance.

Shooting test (speed and accuracy score): The shooting test assessed shooting accuracy and rapidity of decision-making under a reactive visual-cognitive load (Figure 4). Five BlazePods were set at specific locations to shoot at (two 3-point wings, 2 mid-range elbows, and one free-throw line). Both trials involved 5 sequences of shooting: One randomly lit pod forced the movement to that location before a jump shot within an 8-second time-out. Points were weighted (3 points=3-pointer, 2 points=mid-range, 1 point=FT, 0 points=miss). The tests were repeated 5 times each for 2 runs. Outcomes: cumulative accuracy score (points) and cumulative execution time (total elapsed time from first illumination to final release, in seconds). Protocol based on proven shooting evaluations [31,32]. Pilot reliability was demonstrated by an ICC of 0.82 (95% CI 0.65-0.91). A higher score and a shorter time mean better performance.

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Figure 1. Lafayette visual reaction time apparatus (model 63014A; Lafayette Instrument Company) used to assess bilateral simple visual reaction time in youth male basketball players during a prospective, single-blind, randomized controlled trial conducted. It measures the time (seconds) between the presentation of a red visual stimulus and the participant's manual response by pressing a response button, which is one of the most basic outcome measures of visuomotor processing speed when carried out under controlled testing conditions.



Figure 2. Study to evaluate the effects of modified T-Test with dribbling on youth male basketball players during a prospective, single-blind, randomized controlled trial, using a schematic diagram.

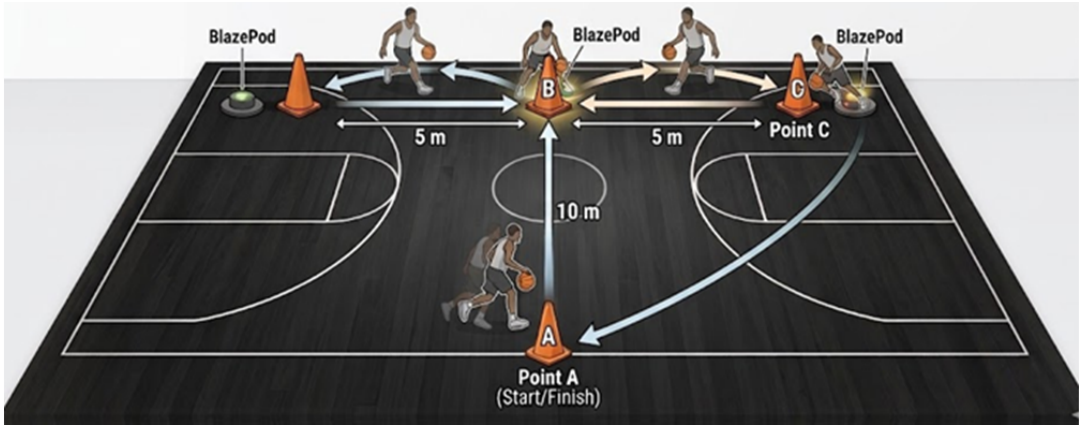
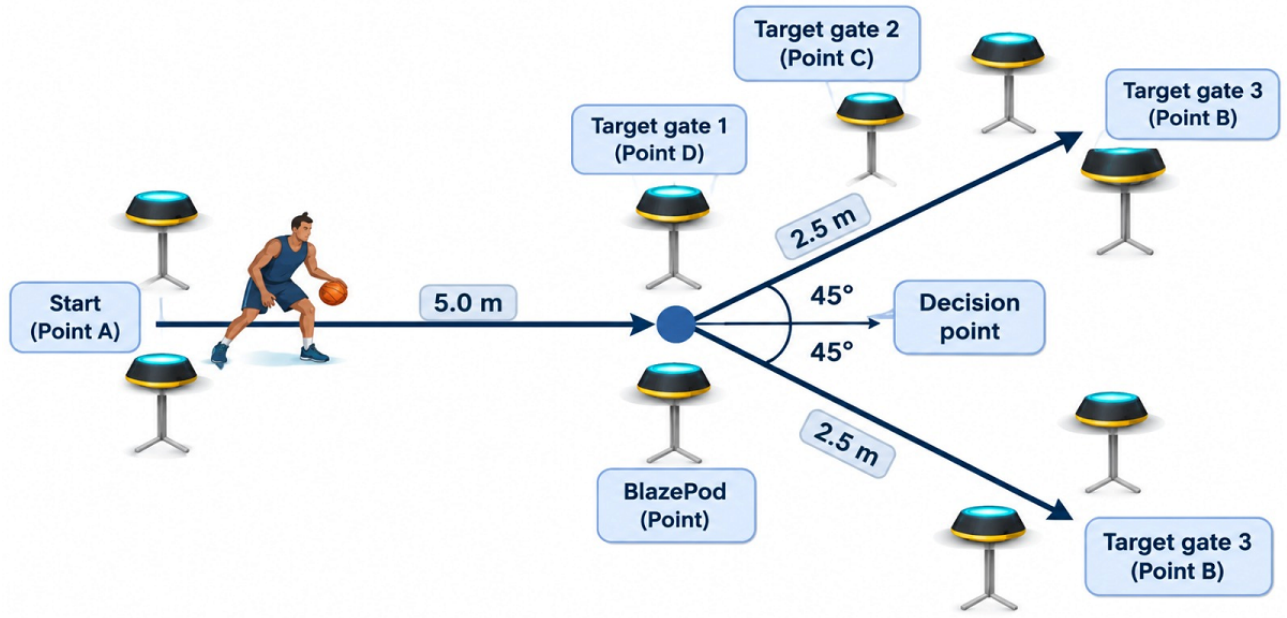


Figure 3. The modified Y-Test with dribbling (MYT-D) was used to evaluate multidirectional reactive agility and perceptual-motor integration in youth male basketball players in a prospective, single-blind study using a schematic diagram.



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Figure 4. A prospective, single blind, randomized controlled trial measuring reactive shooting accuracy and speed in youth male basketball players'visuomotor decision-making under cognitive load during a basketball game is displayed in schematic form as a test.



Anthropometrics and Equipment Standardization

Standing height was measured with a Seca 213 stadiometer (precision ±1 mm), and body mass was measured with a Seca 803 digital scale with a precision of ±0.1 kg. Weight (kg) divided by height squared (m^2) was used to determine BMI. To ensure uniformity among the participants, all the sport-specific skill test balls were Molten size 6 basketballs, as approved by Fédération Internationale de Basketball (FIBA). With respect to sensor technology, no common validation protocol exists for commercial reactive light systems [33], but the ICC for test-retest reliability for the BlazePod system was acceptable for this study population (range 0.82-0.88).

Psychometric Properties of Outcome Measures

A pilot study with 12 youth basketball players from the same club (not part of the main trial) was performed 2 weeks before data collection to establish the psychometric properties. The Cronbach α values, which were good and ranged from 0.91, for the 3 sport-specific tests embedded in BlazePod, indicated good internal consistency. Test-retest reliability over 7 days was good to excellent: Modified T-Test (ICC 0.88, 95% CI 0.75-0.94), Modified Y-Test (ICC 0.85, 95% CI 0.70-0.93), and Shooting Accuracy (ICC 0.82, 95% CI 0.65-0.91) [34]. Significant positive correlations between completion times on the T-Test and the Y-Test (r=.76; *P*=.001) and between completion time on the T-Test and choice visual RT (Lafayette 63014A; r=.71; *P*=.001) were obtained for convergent validity. Content validity was established using 3 experts on the subject: a sports scientist, certified basketball coach (with >10 years of experience), and a motor learning expert (0.92 content validity index).

Sample Size

Sample Size Determination

An a priori power analysis was performed with the program G*Power (v.3.1.9.7; Heinrich-Heine-Universität Düsseldorf) for a 2-way mixed model ANOVA (group×time interaction). The parameters used were large effect size (Cohen *f* =0.40), a significance level (α)=0.05, a statistical power (1−β)=0.80, 2 groups and 2 measurements, and a correlation among repeated measures (r=0.50). A minimum of N≥24 was required. Based on the 15% prospective dropout [35], 17 participants were recruited per group, and 35 participants were included. Post-hoc sensitivity analysis showed that the obtained final sample (n=14/group) had >95% power for the large effects observed (Cohen *d* ≥1.34), but the power was lower for smaller effects.

Interim Analyses, Stopping Guidelines

This trial was not designed to have interim analyses or prespecified stopping guidelines. The recruitment and data collection were started as originally planned and run until the desired sample size and the intervention period were met.

Protocol Intervention Delivery and Fidelity

Consistency in coaching style and session delivery was maintained by both groups, as they both trained in the same indoor facility and under the supervision of one certified basketball coach with 12 years of experience. The intervention took place over 10 weeks, consisting of 30 sessions overall (3 sessions per week, 85 to 95 minutes per session). The outcome assessors were blinded to all the testing procedures.

The EG's incorporation of the BlazePod component into regular basketball practice was done in a consistent fashion: 10 to 15 minutes warm-up, 25 to 35 minutes visual-cognitive training with the BlazePod, 30 to 40 minutes of technical-tactical/scrimmage, and 10 minutes of cool-down. Three phases of progressive overload were used: (1) increase in the number of pods; (2) narrow the response windows; (3) introduce multicolor/distractor stimuli that demand cognitive inhibition; (4) sequence multiple tasks; and (5) progressively shorten rest periods between sets. Detailed phase-specific configurations are provided in Table 2 and Multimedia Appendix 2. Participant adherence was monitored via daily attendance logs, confirming zero absences and 100% protocol compliance throughout the intervention period.

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Table 2. Progressive BlazePod visual-cognitive training protocol. The protocol outlines the systematic progression of cognitive-motor demands, BlazePod sensor configuration, and overload elements over 10 weeks (3 sessions per week, 25 to 35 minutes per session) to improve reactive agility and shooting performance under ecologically valid conditions.

Phase	Duration	Cognitive-motor focus	BlazePod configuration	Progressive overload elements
1. Foundation	Weeks 1-3	Simple stimulus-response coupling	3-4 pods; single-color cues; 4-5 s response window	Stationary reaction drills: basic dribble-react sequences
2. Development	Weeks 4-7	Multidirectional reactive agility with inhibitory control	4-6 pods; multicolor cues (color-specific responses); 3-4 s window	Reactive T/Y-test variations; 2v1 decision-making with light cues
3. Integration	Weeks 8-10	Complex game-simulated scenarios under time pressure	5-6 pods; distractor stimuli requiring selective attention; 2-3 s window	Full-court dribble-shoot sequences; fast-break simulations with decision points

Comparator Description

The CG was trained on standard basketball training, with a structure, duration, frequency, and coaching staff the same as the EG, but with no BlazePod or reactive lighting. This "usual care" comparator was created to allow for the specific effects of the visual-cognitive stimulus to emerge, while holding other factors of general training volume, coaching quality, and social interaction constant [18,35]. No additional formal training was allowed other than as prescribed, and adherence was checked by weekly self-report logs and club member checks.

Concomitant Care

All participants in both groups adhered to their normal training hours and activities outside of training hours. No other concurrent treatments (additional, psychological counseling, and nutritional supplementation) were given or restricted throughout the trial. Participants were asked to carry on with their normal lifestyle and avoid any structured physical activity for 24 hours before each assessment to reduce the confounding effects of fatigue.

Assessment Protocol Standardization

Assessments were made with the same indoor facility, time window (16:00-19:00, local time), and blinded assessors, pre- and postintervention. The sequence for the test was set as: warm-up (baseline), resting time (3 minutes), (1) Bilateral visual RT, (2) modified T Test and Y Test with dribbling, (3) Shooting performance (execution time & accuracy). The environmental conditions (22-24 °C and 40%-50% humidity) were regulated to reduce the influence of circadian and thermal conditions on neuromuscular performance.

Statistical Analysis

IBM SPSS Statistics (version 26.0) was used for data analysis. Descriptive statistics (mean, SD, minimum/maximum, skewness, and coefficient of variation) were calculated, and a coefficient of variation (CV) <30% was considered acceptable within-group homogeneity. Shapiro-Wilk tests (P>.05) and skewness range (–2.0 to +2.0) were used to confirm normality assumptions. Levene test was used to test the homogeneity of variances and Box M test was used to test the equality of covariance matrices. Two (group)×2 (time) mixed-model ANOVAs were used for the primary analyses, with group×time interaction as the effect of interest; Greenhouse-Geisser corrections were applied in cases where the assumptions of the ANOVAs were not met. Planned simple effects (paired-samples t tests for within-group pre-post comparisons and independent-samples 2-tailed t tests for between-group posttest comparisons) were used for significant interactions. To prevent family-wise error, Bonferroni-adjusted alpha (P<.008) was used for omnibus interaction tests, and hypothesis-driven (P<.05) was used for follow-up comparisons for 6 dependent variables. Partial eta squared (ηp^2) was reported for all the ANOVA tests (small ≥0.01, medium ≥0.06, and large ≥0.14); Cohen d was reported for all the pairwise comparisons (small 0.20-0.49, medium 0.50-0.79, and large ≥0.80) with 95% CIs for all point estimates. Reported P values were appropriate (P<.001 noted for P values below this limit). There were a few missing data (<2%), and Little missing completely at random (MCAR) test confirmed the data were missing completely at random (χ^2_{18}=12.4; P=.83), and listwise deletion was used.

Ethical Considerations

This study was conducted in accordance with the Declaration of Helsinki and formally approved by the Research Ethics Committee at King Faisal University, Al-Ahsa, Saudi Arabia (approval number KFU-REC-2024NOV-ETHICS2801; Multimedia Appendix 3). All participants and parents/legal guardians received a detailed Arabic information sheet explaining the purpose, procedures, risks/benefits, confidentiality procedures, and voluntary participation, and participants were explicitly told that they can withdraw at any time without penalty or loss of club status. All data were anonymized by using coded identifiers at the time of collection and placed on password-protected computers, with only principal investigators having access to the data, which was not included in any of the manuscript text, tables, figures, or supplemental data. No monetary compensation or financial incentives were offered to participants—participation was voluntary and not an added burden to the regular training programs. Also, this manuscript does not contain any photographs, videos, or images with identifiable people; only schematic diagrams, equipment setups, and anonymous data representations. As far as trial registration is concerned, this study was deemed by the ethics committee to fall outside the mandatory standards for prospective drug/device trials.

Patient and Public Involvement

This research was not designed, conducted, reported, or planned with the participation of patients or the public. No patient advocacy groups, caregivers, or members of the public were involved in outcome definitions, interpretation of results, or

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development of the intervention protocol; the study population consisted exclusively of youth basketball players recruited through a private sports club. This was determined based on the nature of the study, which was a performance-based athletic training intervention rather than a clinical health trial.

Harms and Adverse Events

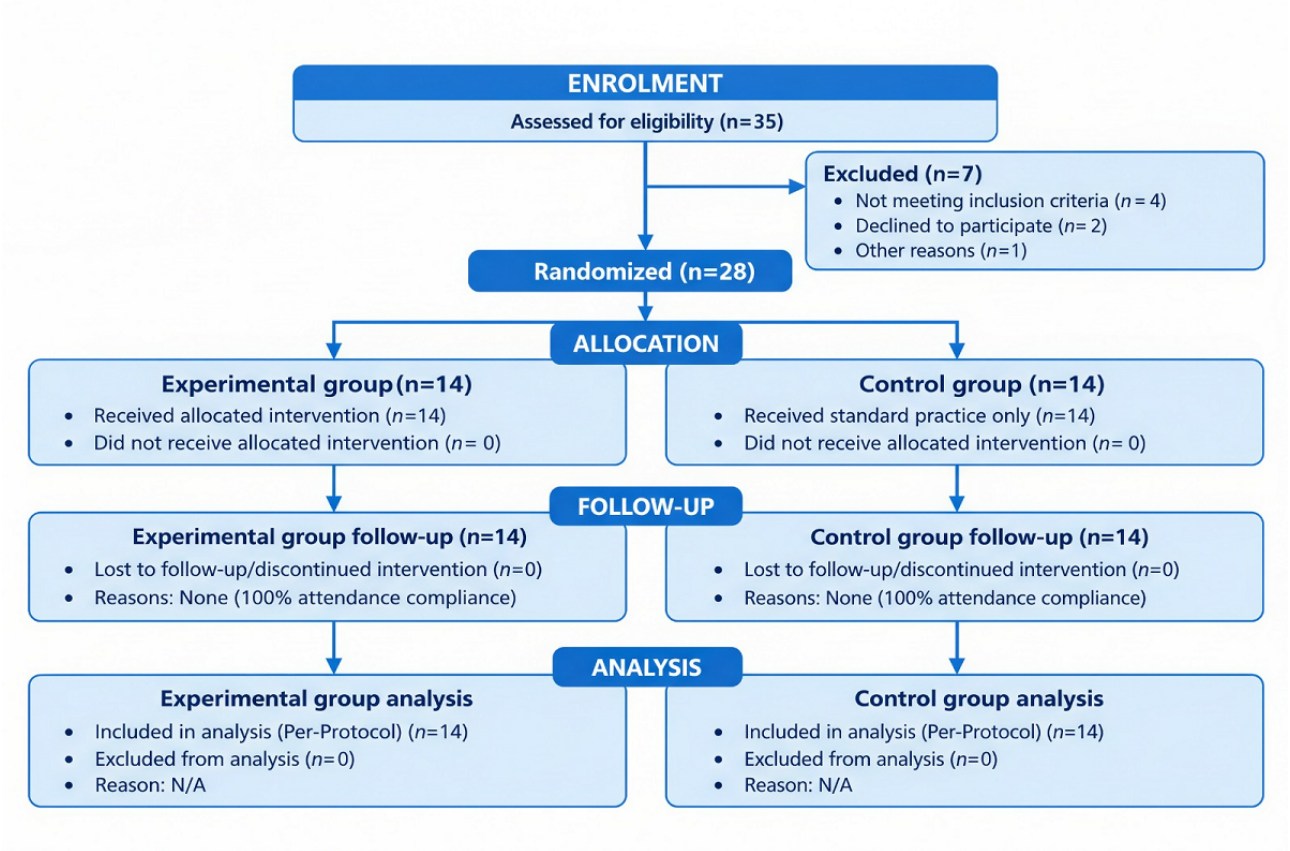
Nonsystematic passive surveillance was used to assess harms and unintended events during the 10-week intervention period. Coaches and researchers documented any injuries, discomfort, or negative events associated with the BlazePod training and normal basketball practice. Due to the low-risk nature of the visual-cognitive training intervention, no systematic harm assessment tools, validated questionnaires, or active targeted surveillance protocols were used. There were no adverse events, injuries, or withdrawals due to harm reported or observed in either the experimental or CG during the trial.

Results

Analysis Population and Missing Data Handling

The primary analysis was performed on an intention-to-treat (ITT) basis, and all randomized participants were included in the analysis according to their original group classification, irrespective of compliance. The per-protocol analysis gave similar results to the ITT analysis, and only the ITT results are reported below, as there was 100% retention and compliance with the protocol in both groups. There were very few missing data (<2%), and the Little MCAR test indicated that data were MCAR (χ^2_{18}=12.4; *P*=.83); listwise deletion was used (Figure 5).

Figure 5. CONSORT (Consolidated Standards of Reporting Trials) flow diagram for participant recruitment, allocation, follow-up, and analysis in a prospective study. It is important to note that these procedures resulted in the screening of 35 eligible patients, the randomization of 28 patients (14 in the experimental group [EG] and 14 in the control group [CG]) with 100% retention and adherence rates, and 100% of the randomized patients in the per-protocol analysis as well as in the intention-to-treat analysis. CG: control group; EG: experiment group.



Descriptive Statistics, Including Preliminary Analyses and Missing Data

Assumptions were tested before the inferential analyses for parametric testing. For the most part, Shapiro-Wilk tests showed no significant deviation from normalcy for most variables (all W>.91, all *P*>.08), and the skewness ranged from –0.52 to +0.58, which are within acceptable parameters [12]. All of Levene test for tests of homogeneity variances were less than 1.84, and all were greater than .18 at baseline, and Box M test for equality of covariance matrices indicated equality for all tests (all *P*>.12).

Descriptive Statistics and Baseline Equivalence

Descriptive statistics for all outcome measures are shown in Table 3. Independent-samples *t* tests showed no significant differences between groups at baseline on any measures (all *P*>.61) suggesting successful randomization. 95% CIs were calculated for baseline means to correct for the possible imprecision within small samples. The substantial overlap observed across all CIs provides robust evidence of baseline

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comparability despite limited statistical power: RT right hand (EG mean 0.432, 95% CI 0.414-0.450; CG mean 0.429, 95% CI 0.412-0.446), RT left hand (EG mean 0.453, 95% CI 0.436-0.470; CG mean 0.450, 95% CI 0.434-0.466), T-Test with dribbling (EG mean 13.42, 95% CI 13.07-13.77; CG mean 13.36, 95% CI 13-13.72), Y-Test with dribbling (EG mean 4.83, 95% CI 4.61-5.05; CG mean 4.79, 95% CI 4.58-5), shooting execution time (EG mean 34.56, 95 % CI 32. 73-36.39; CG mean 34.21, 95% CI 32.34-36.08), and shooting accuracy score (EG mean 10.14, 8.71-11.57; CG mean 10.36, 95% CI 8.96-11.76). There was variance within groups which was in line with youth athlete norms [26] (RT and agility ranged from 4.29% to 7.87% CV; shooting ranged from 16.29% to 24.46% CV). There was greater mean improvement in the EG than the CG in all 6 outcomes after the intervention, and there was no increase or reduction of variability pre or postintervention, supporting the hypothesis that the BlazePod intervention did not add to extraneous response variability.

Table 3. Descriptive statistics and baseline equivalence for all primary outcome measures of youth male basketball players (N=28)[a].

Variables and time	EG[b] (n=14)			CG[c] (n=14)		
	Mean (SD)	Skew[d]	CV%[e]	Mean (SD)	Skew	CV%
RT[f] right hand (seconds)						
Pre	0.432 (0.031)	0.15	7.18	0.429 (0.029)	0.42	6.76
Post	0.393 (0.027)	0.21	6.87	0.416 (0.028)	0.33	6.73
RT left hand (seconds)						
Pre	0.453 (0.029)	0.08	6.40	0.450 (0.027)	0.19	6.00
Post	0.412 (0.025)	0.12	6.07	0.437 (0.026)	0.28	5.95
T-Test with dribbling (seconds)						
Pre	13.42 (0.61)	–0.14	4.55	13.36 (0.63)	0.11	4.72
Post	12.58 (0.54)	0.09	4.29	13.08 (0.57)	–0.06	4.36
Y-Test with dribbling (seconds)						
Pre	4.83 (0.38)	0.22	7.87	4.79 (0.36)	0.16	7.52
Post	4.21 (0.33)	–0.08	7.84	4.59 (0.35)	0.25	7.63
Shooting execution time (seconds)						
Pre	34.56 (3.18)	0.31	9.20	34.21 (3.25)	0.22	9.50
Post	29.42 (2.85)	0.18	9.69	33.08 (3.02)	0.14	9.13
Shooting accuracy (points)						
Pre	10.14 (2.48)	–0.12	24.46	10.36 (2.42)	0.35	23.36
Post	14.43 (2.35)	0.24	16.29	11.50 (2.52)	0.15	21.91

[a]Smaller numbers represent greater performance for the timed variables, and larger numbers represent greater performance for the shooting accuracy.

[b]EG: experimental group.

[c]CG: control group.

[d]Skew: skewness.

[e]CV: coefficient of variation.

[f]RT: reaction time.

Mixed-Model ANOVA: Group×Time Interaction

Six separate 2×2 mixed-model ANOVAs revealed statistically significant group × time interactions for all 6 outcome variables after Bonferroni correction (α=.008; Table 4). These interaction effects suggest that the Blaze Pod intervention explains much of the variance in performance changes, with effect sizes ranging from large (ηp^2=.27 for RT of the right hand) to very large (ηp^2=.43 for shooting execution time). More specifically, the intervention explained 40%-43% of the variance in shooting execution time and accuracy and 37% of the variance in Y-Test reactive agility, both of which are complex motor-cognitive skills, indicating the visual stimulus training's high sensitivity on these tasks. There were also moderate to large interaction effects for bilateral RTs (ηp^2=.27-.33) and T-Test with dribbling (ηp^2=.29), which suggest similar adaptive trajectories across simpler and more complex visuomotor domains. The overall learning or maturation effects are reflected in all main effects for time being significant (all F>8.42; all *P*<.007), with nonsignificant main effects for group (all F<2.18; all *P*>.15), further confirming that preintervention differences among groups were not the reason for the differences at postintervention (Figure 6).

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Table 4. The results of the 2×2 mixed-model ANOVA examining the group, time, and group×time interaction on visuo-motor performance of youth male basketball players (N=28). The study presents the analysis of the difference between the EG[a] (BlazePod training) and the CG[b] (standard practice) for six main outcomes.

Variables and effects	F	*P* value	ηp^2[c]	Interpretation
RT[d] right hand (seconds)				
Group	0.74	.40	.03	—
Time	42.18	<.001	.62	Large
Group×time	9.40	.005[e]	.27	Large
RT left hand (seconds)				
Group	1.82	.19	.07	—
Time	51.36	<.001	.66	Large
Group×time	12.55	.002[d]	.33	Large
T-Test with dribbling (seconds)				
Group	1.24	.28	.05	—
Time	38.72	<.001	.60	Large
Group×time	10.37	.003[e]	.29	Large
Y-Test with dribbling (seconds)				
Group	2.18	.15	.08	—
Time	56.84	<.001	.69	Large
Group×time	15.32	<.001[e]	.37	Large
Shooting execution time (seconds)				
Group	1.96	.17	.07	—
Time	44.27	<.001	.63	Large
Group×time	19.58	<.001[e]	.43	Large
Shooting accuracy (points)				
Group	1.53	.22	.06	—
Time	52.94	<.001	.67	Large
Group×time	17.62	<.001[e]	.40	Large

[a]EG: experimental group.

[b]CG: control group.

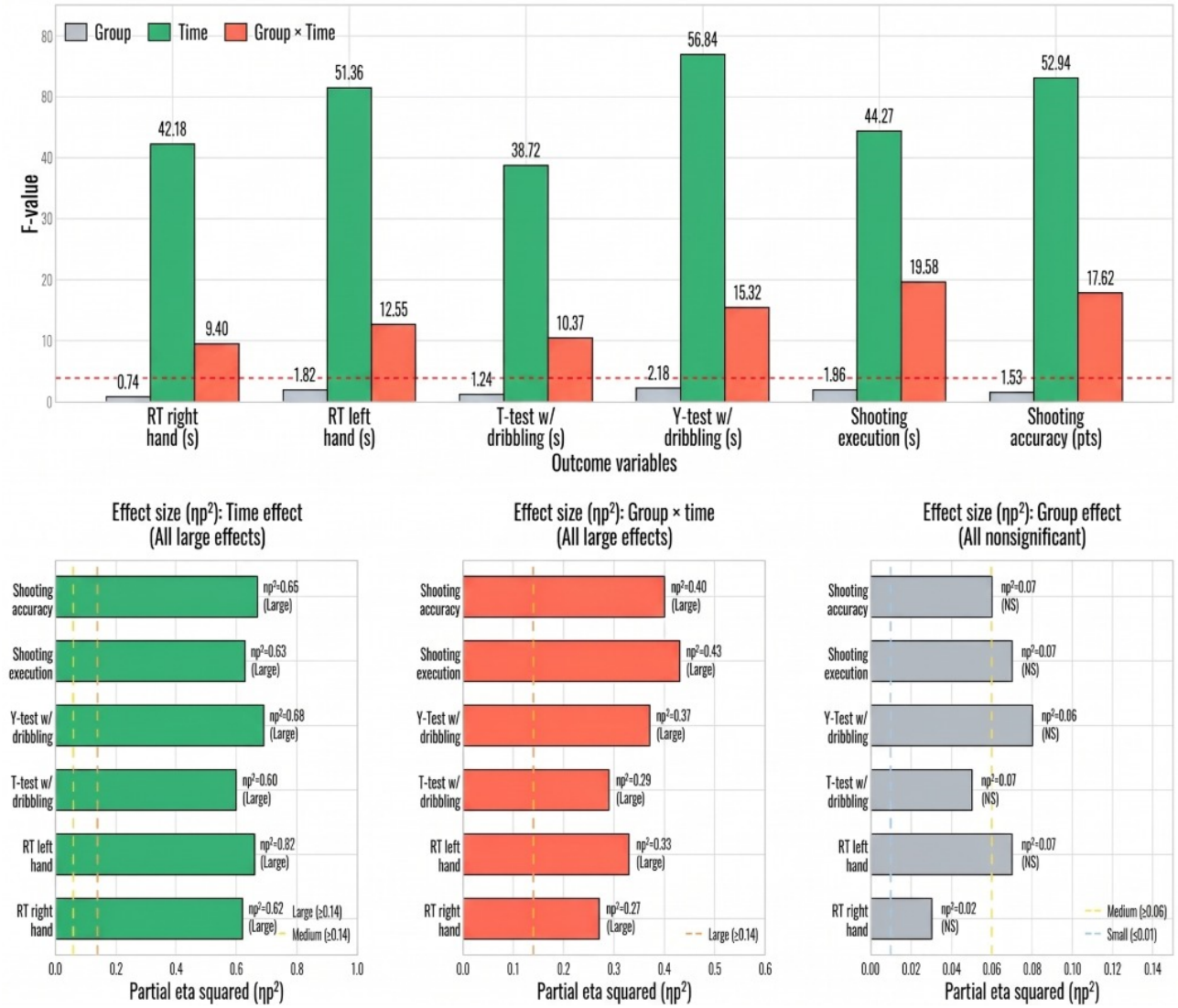
[c]ηp^2=partial eta squared. Interpretation levels: small (or greater, 0.1 or more), medium (or greater, 0.14 or more), large (or greater, 0.14 or more), large (or greater, 0.14 or more).

[d]RT: reaction time.

[e]Denotes significance with Bonferroni correction (adjusted 2=.008).

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Figure 6. A graphical display of the 2×2 mixed model ANOVA results showing the effect of group, time, and interaction between group and time on visuomotor performance in young male basketball players in a prospective, single-blind, randomized controlled trial was conducted. The upper panel shows F values for all outcome measures: reaction time right hand, T-Test/Y-Test with dribbling, shooting execution/accuracy, and the red dashed line represents the significant threshold (P<.008) following Bonferroni correction. In the lower panels, partial eta squared (ηp^2) effect sizes for Time were all large, for group×time were all large and significant, and for group were all nonsignificant, respectively, indicating baseline equivalence and differential change trajectories instead of preexisting group differences between experimental and control groups. RT: reaction time.



Follow-Up Analyses (Pretest to Posttest): Within-Group Changes

Paired-samples t tests conducted for significant group×time interactions revealed large and statistically significant improvements in the EG across all 6 outcome variables (Cohen d=1.34-1.77; all P<.001). Most importantly, the precision of these estimates is provided by the narrow 95% CIs that do not include zero, suggesting that the effects observed are likely to be reliable, even in this relatively small sample size. The greatest gains were observed in shooting accuracy (Δ=+4.29 points, 95% CI 3.21-5.37, Cohen d=1.77), Y-Test with dribbling (Δ=−0.62 s, 95% CI −0.78 to −0.46, Cohen d=1.74), and hooting execution time (Δ=−5.14 s, 95% CI −6.50 to −3.78, Cohen d=1.70). Bilateral RT also improved significantly, with precise estimates for both right hand (Δ=−0.039 s, 95% CI −0.052 to −0.026, Cohen d=1.34) and left hand (Δ=−0.041 s, 95% CI −0.053 to −0.029, Cohen d=1.51).

The effect sizes of the improvements in the CG) were smaller and less consistent (Cohen d= 0.36–0.56). Statistically significant changes were detected in 4 of 6 outcomes: right RT (Cohen d= 0.46; P=.04), left RT (Cohen d=0.49; P=.04), Y-Test (Cohen d= 0.56; P=.02), and shooting accuracy (Cohen d=0.46; P=.044). The results of the T-Test with dribbling (Cohen d=0.45; P=.05) and shooting execution time (Cohen d=0.36; P=.11) showed no significant differences, and in the latter case the 95% CI included zero (−2.54 to 0.28), indicating high uncertainty and suggesting low change in this domain at the present sample size. The data are shown in detail in Table 5 and Figure 7.

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Table 5. Within-group pretest to posttest change scores (with 95% CIs) for youth male basketball players (N=28). The table shows mean change scores (Δ)[a], SD of change (SD_Δ), 95% CIs, t-value, *P* value, and Cohen d effect size for both the EG[b] (n=14) and CG[c] (n=14).

Variables and groups	Change scores (Δ), mean (SD)	95% CI of Δ	*t* test (*df*)	*P* value	Cohen *d*
RT[d] right hand (seconds)					
EG	−0.039 (0.023)	(−0.052 to −0.026)	6.34 (13)	<.001	1.34
CG	−0.013 (0.021)	(−0.025 to −0.001)	2.32 (13)	.04	0.46
RT left hand (seconds)					
EG	−0.041 (0.021)	(−0.053 to −0.029)	7.31 (13)	<.001	1.51
CG	−0.013 (0.021)	(−0.025 to −0.001)	2.32 (13)	.04	0.49
T-Test with dribbling (seconds)					
EG	−0.84 (0.45)	(−1.10 to −0.58)	6.99 (13)	<.001	1.46
CG	−0.28 (0.47)	(−0.55 to −0.01)	2.23 (13)	.04	0.46
Y-Test with dribbling (seconds)					
EG	−0.62 (0.28)	(−0.78 to −0.46)	8.29 (13)	<.001	1.74
CG	−0.20 (0.28)	(−0.36 to −0.04)	2.67 (13)	.02	0.56
Shooting execution time (seconds)					
EG	−5.14 (2.36)	(−6.50 to −3.78)	8.15 (13)	<.001	1.70
CG	−1.13 (2.44)	(−2.54 to 0.28)	1.73 (13)	.11	0.36
Shooting accuracy (points)					
EG	4.29 (1.88)	(3.21 to 5.37)	8.54 (13)	<.001	1.77
CG	1.14 (1.92)	(0.03 to 2.25)	2.22 (13)	.04	0.46

[a]Δ=mean change (post-pre); negative change is improvement for timed variables, positive change is improvement for accuracy. Cohen *d* using pooled SDs.

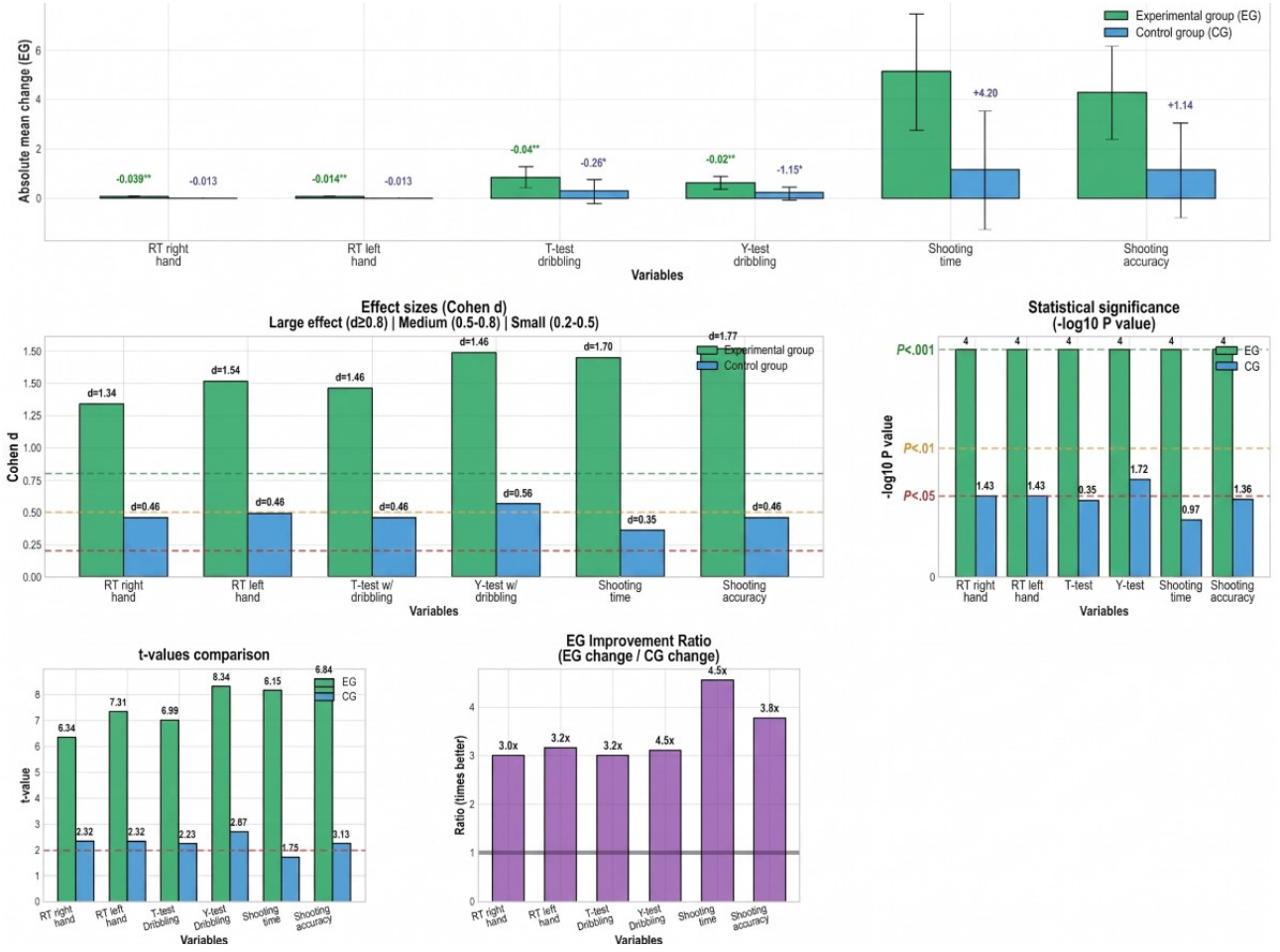
[b]EG: experimental group.

[c]CG: control group.

[d]RT: reaction time.

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Figure 7. Comprehensive graphical comparison of pre-to-post intervention changes between the experimental group and control group in youth male basketball players. The upper panel shows the absolute mean change scores, with the error bars representing 95% CIs, and minimal changes in control group. Cohen d (effect size) is shown in the middle-left panel. The middle-right panel shows statistical significance in terms of –log10 *P* values. The t-value comparisons and experimental group improvement ratios are illustrated in the lower panels. CG: control group; EG: experiment group; RT: reaction time.



Between-Group Posttest Comparisons

Posttest scores for the EG were compared with the CG using independent-samples *t* tests, which found significantly higher scores for EG in all 6 posttest scores, ranging from large to very large (Cohen *d*=0.84–1.25; Table 6). The precision of these between-group differences is indicated by the narrow 95% CIs, which do not include zero; this further underpins the robustness and reliability of the magnitude of the intervention despite the relatively small sample size. The greatest advantages were observed in shooting execution time (mean difference −3.66 s, 95% CI −5.94 to −1.38, Cohen *d*=1.25; *P*=.003) and shooting accuracy (mean difference +2.93 points, 95% CI 1.04 to 4.82, Cohen *d*=1.20; *P*=.004), indicating high sensitivity of complex motor-cognitive tasks to visual stimulus training. Large-to-moderate benefits were also found for Y-Test with dribbling (mean difference −0.38 s, 95% CI −0.64 to −0.12, *d*=1.12; *P*=.007) and T-Test with dribbling (mean difference −0.50 s, 95% CI −0.93 to −0.07, Cohen *d*=0.90; *P*=.02). Differences in RT were statistically significant, with narrower CIs and smaller absolute changes, but in the same direction for the right side (right: mean difference −0.023 s, 95% CI −0.044 to −0.002, Cohen *d*=0.84) and the left side (left: mean diff=−0.025 s, 95% CI −0.045 to −0.005, Cohen *d*=0.98). All differences in variance were not significant (all F<1.42, all *P*>.24; Figure 8).

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Table 6. Follow-up independent-samples *t* tests: between-group posttest comparisons (with 95% CIs) for youth male basketball players (N=28). The table shows postintervention means (SD) and mean difference (EG[a]-CG[b]), SE_Diff, 95% CIs, *t*-value, *P* value, and Cohen d effect sizec.

Variables	EG post, mean (SD)	CG post, mean (SD)	Mean diff	SE_Diff	95% CI of Diff	*t* test (*df*)	*P* value	Cohen *d*
RT[d] right hand (seconds)	0.393 (0.027)	0.416 (0.028)	−0.023	0.010	(−0.044 to −0.002)	−2.21 (26)	.04	0.84
RT left hand (seconds)	0.412 (0.025)	0.437 (0.026)	−0.025	0.010	(−0.045 to −0.005)	−2.59 (26)	.02	0.98
T-Test with dribbling (seconds)	12.58 (0.54)	13.08 (0.57)	−0.50	0.210	(−0.93 to −0.07)	−2.38 (26)	.02	0.90
Y-Test with dribbling (seconds)	4.21 (0.33)	4.59 (0.35)	−0.38	0.129	(−0.64 to −0.12)	−2.95 (26)	.007	1.12
Shooting execution time (seconds)	29.42 (2.85)	33.08 (3.02)	−3.66	1.110	(−5.94 to −1.38)	−3.30 (26)	.003	1.25
Shooting accuracy (points)	14.43 (2.35)	11.50 (2.52)	2.93	0.922	(1.04 to 4.82)	3.18 (26)	.004	1.20

[a]EG: experimental group.

[b]CG: control group.

[c]Mean difference=EG-CG (Negative values mean EG faster for timed variables; positive values mean EG scored higher for accuracy). SE_Diff: standard error of mean difference, Cohen *d*. Equality of variances was confirmed for all comparisons (all F<1.42; all *P*>.24).

[d]RT: reaction time.

Figure 8. Graphic comparisons of postintervention results for youth male basketball players for both the experimental group and control group. The mean (SD) error bars for all variables are shown in the top panel. The middle-left panel shows absolute mean differences (experimental group–control group) with 95% CIs. The middle-right panel shows effect sizes (Cohen d). Absolute t-values (all >2.0) and statistical significance as –log10 (*P* values) are shown in the lower panels. CG: control group; EG: experiment group; RT: reaction time.



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Discussion

Principal Findings

The purpose of this RCT was to evaluate the effects of a 10-week visual stimulus training program (BlazePod) in male youth basketball players compared to standard training. As predicted, the EG showed significantly larger gains for all major variables: bilateral visuomotor RT, dribbling reactive agility, and shooting execution speed and accuracy compared to the controls. The results are strengthened by the fact that increasing the difficulty of the visual stimuli in the motor task used in the drills is an effective add-on intervention for improving task-specific performance in a controlled testing environment in this population. However, these results are only applicable to the measured behavioral outcomes and are not necessarily a sign of direct adaptation in the brain or automatic transfer to competitive match performance, without supporting objective evidence.

RT and Perceptual-Cognitive Adaptations

This marked bilateral decrease in visual RT was consistent with perceptual-cognitive theories that propose that repeated exposure to unpredictable stimuli leads to improved allocation of attention and motor preparation [7,36]. Absolute gains were relatively small (~40 ms), but these are truly relevant in elite basketball, where milliseconds can make the difference and changes in position [1,5,37]. Our findings further support that light-based cues enhance response initiation latency in young athletes in several sports, as has been seen in previous studies [18,21,38]. Importantly, the bilateral gains help to validate the randomized protocol design that includes both hands. Unlike previous studies that used neurophysiological markers [14], this study used only behavioral measures, so the observations made here should not be interpreted as a confirmation of increased sensorimotor processing efficiency or as a measure of increased cortical plasticity [36]. Further studies should use electroencephalography (EEG) or electromyography (EMG) to confirm underlying mechanisms [39].

Reactive Agility and Ecological Learning Design

Larger effect sizes were found for complex reactive agility tasks (Y-Test) versus binary-choice tasks (T-Test); this is in line with literature, where larger effect sizes have been recorded relative to the higher perceptual demands of decision-making during the Y-Test [30]. The improvement seen in this study (6.3% for the T-Test and 12.8% for the Y-Test) is at the upper end of the range of improvements reported for reactive agility training, but is not significantly better than what has been reported for traditional plyometric and strength power programs [37]. This implies that cognitive-reactive training yields complementary, but not better, physical adaptations as compared to load-bearing modalities. Our protocol, in which ball-handling skills were integrated into reactive stimuli, followed the representative learning design principles that focus on perception-action coupling rather than isolated ball-handling skills [40]. However, because the general motor practice effect cannot be ruled out definitively when comparing the active physical CG with an identical group of subjects that practices the same ball-handling drills but without visual stimuli [35], the presence of a motor practice effect cannot be ruled out. Such active controls should be used in future RCTs to isolate the specific visual-cognitive contributions from the generic motor learning [41].

Shooting Performance Enhancements

The largest effect sizes related to BlazePod training were found for shooting execution time and shooting accuracy, which suggests that it most positively affected tasks involving visual scanning, locomotion, decision-making, and fine motor control. There is no speed-accuracy trade-off, indicating that the participants are not being strategically compensated for reacting quickly enough, but that they are more efficient in other visuomotor aspects of the task. It is important to note, however, that the shooting environment in our study was standardized, with prearranged shooting positions and preestablished stimulus-response sets, which are quite different from the dynamic and socially complex decision-making scenario that occurs in competitive basketball [13,31,32]. Therefore, there is a strong correlation with shooting in a controlled environment, but no correlation with shooting percentages in matches or shooting quality of tactics, without objective data from the game. This restriction highlights the disparity between perceptual-cognitive training in the lab and ecologically relevant competitive transfer [42].

CG Changes and Methodological Considerations

Small-to-moderate improvements were found in 4 of 6 outcomes for the CG, which was probably due to test familiarization, frequent exposure to basketball, and maturation [24]. The interaction effects in the EG (ηp^2=.27-.43) suggest that BlazePod training offered an additional adaptive stimulus to the regular training. However, caution must be used when interpreting these large effect sizes because of the small sample size (n=14/group), which leads to increased uncertainty of the point estimates and risk of overestimation [43]. Moreover, the lack of blinding leads to potential expectancy (Hawthorne) effects, in which the novelty of the technology could have had a positive motivational influence on itself, regardless of visual-cognitive content [44]. Future studies will require active control conditions with either sham technology or other cognitive tasks to help distinguish specific training effects from nonspecific motivational artifacts [39,44].

Limitations

There are a few factors that limit the interpretation and generalizability of these findings. First of all, the small sample size and narrow age range of the adults (male), and the single amateur club, restrict the external validity and precision of effect size estimates [43]. Second, the absence of double blinding and an active control makes it impossible to completely separate expectancy and novelty effects from visual-cognitive training [44]. In the third place, using only behavioral measures does not allow one to identify underlying neural and/or psychological mechanisms; future studies should integrate validated psychological measures like self-efficacy, motivation, etc [39] and neurophysiological measures such as EEG, eye-tracking, etc [14]. Fourth, there are no objective match statistics (shooting %, turnover rate, and defensive efficiency) [13] that provide evidence of the transfer of real-game performance. Fifth,

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BlazePod stimuli are less ecological than dynamic, socially rich competitive environments [40]. Most importantly, there is no longitudinal follow-up, and thus no way to evaluate the retention of skills or to determine dose-response relationships [41].

Practical Implications and Future Directions

This study is innovative in using a standardized, progressive BlazePod protocol in an ecological team sport context, whereas previous work has largely been conducted using isolated cognitive drills or with no structured progression [18,21]. The youth basketball players in this trial were directly linked with unpredictable visual stimuli, coupled with the execution of complex movements, highlighting a vital gap in the literature regarding perceptual-motor development in youth athletes from the Middle East and placing reactive technology as an effective adjunctive, instead of independent, tool for perceptual-motor development [35,38]. Such protocols should be used as an additional component of the overall athlete development framework (with prescribed times of 25 to 35 minutes per session), and implement the key principles of athlete development—unpredictability, complexity, and perception-action coupling—which can also be replicated with a low-cost alternative (colored cones or hand signals) to guarantee accessibility in resource-limited environments [35,40]. However, given the small sample sizes and absence of active control, larger, more diverse populations, sham-technology comparators, and longitudinal follow-ups with objective match-performance measures are needed for future research to confirm competitive transfer and to examine underlying neurocognitive mechanisms beyond behavioral adaptations [37,39]. Overall, further research in this area must go beyond behavioral metrics to account for all the neural, psychological, and ecological components of athletic development and determine whether reactive technologies are truly “revolutionary tools” for athletic development or just context-dependent performance enhancers [41,42].

Conclusions

This statistically and practically significant integration of the visual stimulus training of BlazePod into regular basketball practice is an innovative, ecologically valid adjunct to the standard conditioning practice, and remains a significant gap in the literature within the Middle Eastern context of youth players, as it uses unpredictable visual stimuli combined with complex motor execution rather than isolated cognitive drills. The present results support the use of reactive technology as a valid complementary intervention for perceptual-motor development, but it must be used in conjunction with sport-specific skills, rather than being used as an independent intervention, especially within restricted resources, and should be based on the principles of this technology, but adapted using more easily accessible alternatives. Active-control designs, larger and more diverse samples, longer follow-up studies, and multimodal assessments based on objective match statistics and neurophysiological measures are needed for future research to establish competitive transfer and help clarify the adaptive mechanisms that underpin this enhancement. These comprehensive assessments are crucial if we are to progress beyond the laboratory setting of behavioral gains and determine if there are real-world competitive benefits for using reactive light training and if it is a groundbreaking development in athletic training or something that fits into a broader athletic coaching model.

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Data Availability

As the data were collected at a private level and there are ethical concerns with exposing the privacy of minor participants, raw data for individuals cannot be made public. Deidentified aggregated datasets that support the conclusions of this study are available from the corresponding author upon reasonable request and approval by the institutions.

Generative AI Use

The authors declare the use of generative AI in the research and writing process. According to the GAIDeT (Generative AI Delegation taxonomy; 2026), the following tasks were delegated to GenAI tools under full human supervision: translation, image formatting (Figures), and enhancing the resolution. The GenAI tool used was ChatGPT (Anthropic OpenAI). Responsibility for this final paper lies entirely with the authors.

Authors' Contributions

Conceptualization: AKH

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Data curation: MSA
Formal analysis: AKH
Funding acquisition: AKH
Investigation: HKK
Methodology: AKH, MKA
Project administration: AN
Resources: HKK
Software: MKA
Supervision: AN
Validation: AN
Visualization: MKA
Writing – original draft: AKH, MSA
Writing – review & editing: MSA, HKK, AKH, AN, MKA

Conflicts of Interest

None declared.

Multimedia Appendix 1

The physical and skill-related variables for the study, which include the Lafayette Instrument Visual Reaction Time test, the T-test with dribbling, the Y-test with dribbling (reactive agility), and the shooting accuracy and speed test.
[DOCX File , 1602 KB-Multimedia Appendix 1]

Multimedia Appendix 2

Progressive BlazePod Training Protocol Across Three Phases.
[DOCX File , 40 KB-Multimedia Appendix 2]

Multimedia Appendix 3

Ethics Committee.
[DOCX File , 404 KB-Multimedia Appendix 3]

Multimedia Appendix 4

CONSORT eHEALTH checklist (V 1.6.1).
[PDF File (Adobe PDF File), 2798 KB-Multimedia Appendix 4]

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Abbreviations

CG: control group
CONSORT: Consolidated Standards of Reporting Trials
CONSORT-eHEALTH: Consolidated Standards of Reporting Trials of Electronic and Mobile Health Applications and online Telehealth
CV: coefficient of variation
EG: experimental group
EEG: electroencephalography
EMG: electromyography
FIBA: Fédération Internationale de Basketball
ICC: intraclass correlation coefficient
ISI: interstimulus interval
ITT: intention-to-treat
MCAR: missing completely at random
RAD: reactive agility with dribbling
RCT: randomized controlled trial
RT: reaction time
SVT: sports vision training

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