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Research article

Does The Timing of High-Intensity Interval Training Affect Technical Accuracy Under Fatigue? An Experimental Study in Basketball Players

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Abstract
The scheduling (i.e., timing) of high-intensity interval training (HIIT) during basketball sessions may influence physical development and technical-tactical execution under fatigue, yet limited evidence exists to guide practice. This study compared the effects of early-session HIIT (HIITearly) versus post-session HIIT (HIITpost) on aerobic fitness and technical performance under fatigue in youth basketball players. Thirty-six male athletes (16.5 ± 0.7 years) were stratified and randomly assigned to HIITearly, HIITpost, or control groups in a six-week intervention (2 sessions/week). All groups followed the same HIIT protocol; only timing varied. Physical fitness was assessed via the 30-15 Intermittent Fitness Test (VIFT), and technical accuracy for passes, dribles and shots was assessed during a 3v3 game conducted immediately after the 30-15 test. Results showed a significant improvement in VIFT for both HIIT groups (HIITearly: $p < 0.001$; HIITpost: $p < 0.001$), with no change in the control group ($p = 0.705$). HIITearly led to greater improvements than control in passes accuracy ($p < 0.001$), shot accuracy ($p < 0.001$), and dribble accuracy ($p < 0.001$). HIITpost showed smaller, yet significant, improvements in passes ($p < 0.001$), shots ($p < 0.001$), and dribbles ($p < 0.001$), while the control group exhibited only minor changes. Statistical interactions for all technical variables were significant, with particularly large effects for passes ($\eta p^2 = 0.678$), dribbles ($\eta p^2 = 0.600$), and shots ($\eta p^2 = 0.610$). These findings suggest that both HIIT modalities improve physical and technical capacities under fatigue, with early-session HIIT potentially offering benefits for technical accuracy. However, definitive conclusions should be avoided due to the highly contextual nature of the results. Coaches may consider scheduling HIIT prior to skill-focused activities to maximize performance under fatigue conditions in youth basketball.

Key words: Interval training; sports training; skill development; technical performance; fatigue.

Introduction

High-intensity interval training (HIIT) has been shown to be an effective method for improving physical fitness and performance in basketball players. Multiple studies have shown that HIIT significantly enhances cardiorespiratory fitness, with increases in VO_2 max ranging from 3.2% to 13.3% in interventions lasting 6 to 8 weeks across different competitive levels (Shamim, 2021; Kumari et al., 2023). HIIT also improves anaerobic performance, including sprint performance, jump performance, and local muscle endurance to repeated contractions (Shamim, 2021). A systematic review and meta-analysis revealed very large effects on the Yo-Yo intermittent recovery test and moderate effects on VO_2 max, agility, and countermovement jump height (Cao, 2024). Additionally, HIIT has been found to improve not only physical fitness but also basketball-specific skills such as dribbling, passing, and shooting in a controlled study (Kumari et al., 2023). The time efficiency of HIIT, relative to conventional continuous, longer-duration, and lower-intensity training methods, makes it an appealing choice for coaches (Hita and Pambayu, 2024).

Although HIIT has been extensively studied in relation to physical fitness adaptations, the impact of its timing within a training session remains largely unexplored in the literature. The question of when HIIT should be implemented—at the beginning or end of a session—may be particularly relevant in basketball, where training sessions typically include other components such as technical and tactical work. Understanding the optimal timing of HIIT could therefore have important implications for maximizing overall training effectiveness. For instance, research suggests that acute fatigue can significantly influence tactical decision-making and performance in sports. Fatigue may affect tactical behaviors by decreasing actions near the ball and increasing errors in defensive movements, but it can also improve some offensive tactical actions (Teoldo et al., 2024). However, players with high decision-making skills maintain tactical efficiency under fatigue, while those with lower skills show reduced efficiency (Dambroz and Teoldo, 2023). Also, acute physical effort, especially during high-intensity or short-regime drills, increases perceived exertion and mental effort, which correlates with increased mental fatigue and can influence tactical performance (Sansone et al., 2020). On the other hand, a previous study found physical effort increased sympathetic modulation-related indices, and correlations between heart rate variability and cognitive performance were stronger post-exercise (Luft et al., 2009).

The medium-term impact of exposure to high physical intensity and subsequent technical execution is an important area for understanding performance development, but current research on this topic is limited. For instance, high-intensity resistance circuit training immediately before practice or games can lead to acute performance decrements, while lower-intensity power circuit training does not negatively affect performance (Freitas et al., 2016). While some pedagogical approaches suggest that technical and tactical skills should be developed in the absence of fatigue or intense physical effort, a previous study (Ramos et al., 2015) indicate that coaches and strength and conditioning professionals in basketball should consider incorporating moderate—and especially high—intensity

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exercise into skill-based training sessions. This type of integrated training may help players at all levels better adapt to the physical demands of the game and sustain a higher level of performance during competition (Ramos et al., 2015). This aligns with a study which suggests that performing high-intensity exercise before technical-tactical drills does not significantly reduce overall technical-tactical performance, but it does negatively affect the quality of specific actions such as shooting accuracy, assists, turnovers, field goal percentage, successful fast breaks, and defensive rebounds during subsequent play (Jesus et al., 2018).

Although the schedule (i.e., timing) of HIIT—whether implemented before or after the main training session— may influence technical and tactical development in youth basketball; however, current evidence is insufficient to determine its long-term effects. This study positions itself within the ongoing pedagogical debate regarding whether high-intensity efforts should precede or follow technical-tactical training to maximize skill acquisition and performance under fatigue. To provide coaches with more robust, evidence-based guidance on the optimal timing of high-intensity efforts such as HIIT within a training session, this study aimed to compare the effects of early-session HIIT (HIITearly) versus post-session HIIT (HIITpost). Specifically, the study examined how the timing of HIIT influences both physical development and technical-tactical performance under fatigue conditions.

Methods

Experimental approach to the problem

This study employed a randomized parallel design, in which participants were randomly assigned to one of three groups: HIITearly, HIITpost, or control (which did not receive any HIIT intervention). Over a period of six weeks, players in the intervention groups participated in HIIT sessions twice per week, following the same modality and training regimen. The only difference between the groups was the timing of the HIIT sessions. Randomization was conducted using stratified randomization based on playing positions, to ensure balanced group allocation. The randomization sequence was computer-generated (Research Randomizer) with block sizes of six to maintain equal group sizes. A convenience sampling method was used, including players from local-level teams. The study took place during the first quarter of the season, with assessments conducted in the week prior to and the week following the six-week intervention period.

Players

Thirty-six male youth basketball players (age: 16.5 ± 0.7 years; weight: 65.9 ± 6.3 kg; height: 175.3 ± 6.2 cm; body mass index: 21.4 ± 1.5 kg/m²; training experience: 4.2 ± 1.3 years) participated in this study. The sample included 12 guards, 14 forwards, and 10 centers. All players were members of three local-level basketball teams. The eligibility criteria for participation were as follows: (i) a minimum of 2 years of basketball training experience; (ii) full participation in all intervention sessions; (iii) attendance at all assessment time points; and (iv) being in good health and free from injury during the study and in the month prior to its start.

The participants included in the study were volunteers selected from an initial pool of 39 players. However, three players were excluded prior to allocation due to injuries—two with lower limb injuries and one with an upper limb injury—which made them unfit to begin the intervention (Figure 1).

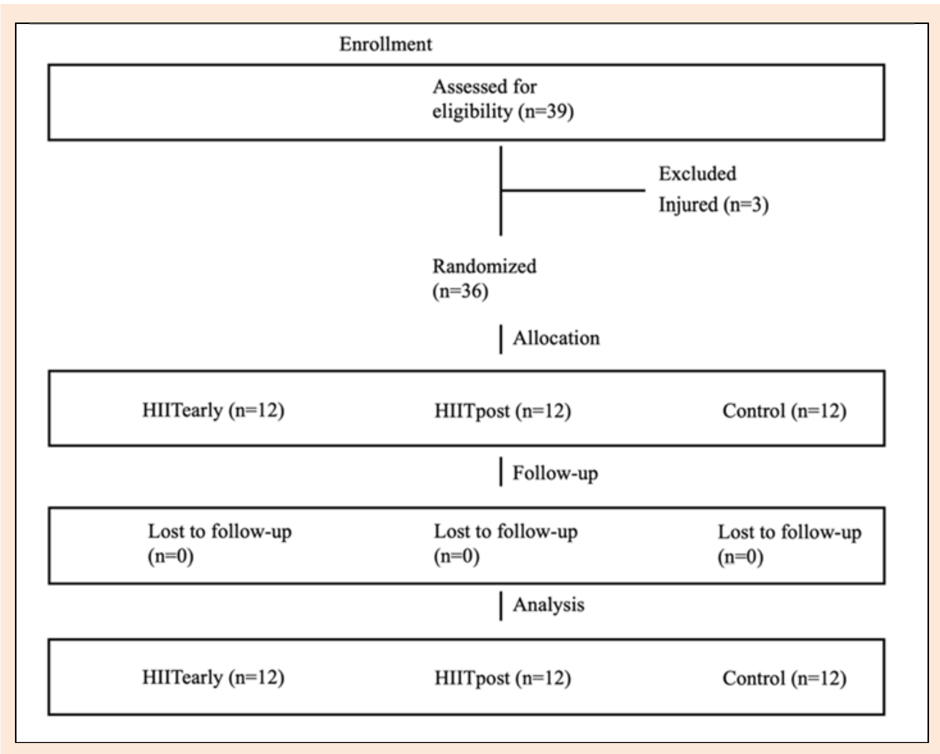

Figure 1. Allocation and follow-up of players.

The players trained three times per week and participated in one competitive game each weekend. Training sessions lasted between 100 and 120 minutes and focused primarily on strength and conditioning, followed by technical and tactical drills aimed at developing basketball-specific skills and game strategies.

The study was approved by the Ethics Committee of Chengdu Sport University with the code number (2025/114), prior to the start of the intervention. The participants and their legal guardians received both verbal and written information about the study's design and implications. Legal guardians provided written informed consent for voluntary participation.

Training intervention

Training interventions were conducted at three local clubs, with players at each club randomly assigned to one of three groups (experimental or control), ensuring that team affiliation did not introduce bias into the results. Training sessions were held twice per week: the first session occurred approximately 48 hours after the most recent match, and the second session took place during the third training session of the week, roughly 72 hours after the first. The implementation of the HIIT interventions was carried out by members of the research team, in constant coordination with the club's staff.

Both experimental groups (HIITearly and HIIT-post) started their sessions at 5 pm on an indoor basketball court. The warm-up began with progressive running around the court to gradually increase heart rate, followed by dynamic stretching targeting the upper and lower limbs to enhance mobility and prepare muscles. The warm-up concluded with basketball-specific technical drills, including ball handling, dribbling, and shooting exercises.

After the warm-up, the HIITearly group immediately began the HIIT intervention, followed by the regular technical and tactical training routines. In contrast, the HIITpost group performed the technical and tactical routines first, and completed the HIIT intervention at the end of the session. The HIIT volume per session started at 9 minutes, progressively increasing up to 20 minutes by Week 6, focusing on intensities between 85 and 95% VIFT. Intensity was ensured by maintaining the pace established according to the individualized training approach based on the VIFT (Table 1).

The technical training was conducted by the coaching staff, with the regular technical and tactical routine typically beginning with individual skill development drills focusing on dribbling, passing, and shooting (15 to 20 minutes). This was regularly followed by team-oriented tactical work, including offensive and defensive set plays, positioning, and movement without the ball (30 to 40 minutes). Coaches often incorporated small-sided games, such as 3v3 or 4v4 formats (15 to 25 min), as well as situational scrimmages to emphasize decision-making.

Measurement procedures

Measurements were conducted in the afternoon, 48 hours after the last match and following a rest period. All procedures took place in the teams' indoor facility, maintained at a controlled temperature between 21°C and 23°C. After a standardized warm-up—identical to the one used during the HIIT interventions—the players underwent a sequence of tests. First, they completed the 30-15 Intermittent Fitness Test, followed by a 3v3 game format to assess technical accuracy during the drill. All assessments were consistently conducted by the same group of researchers. Importantly, those involved in the evaluations did not participate in the HIIT interventions, in order to minimize potential bias.

The 30-15 Intermittent Fitness Test (30-15 IFT)

The 30-15 Intermittent Fitness Test (30-15 IFT) was implemented to assess the aerobic capacity and intermittent fitness of the players. Its primary aim was to evaluate the athletes' ability to repeatedly perform high-intensity intermittent exercise, reflecting the specific demands of basketball. The test protocol involved players running back and forth over a 40-meter shuttle distance for 30 seconds, followed by a 15-second passive recovery period. The test started at a running speed of 8 km/h and increased by 0.5 km/h at the beginning of each subsequent 30-second stage, requiring players to adapt their rhythm progressively as the intensity rose. The test continued until the athlete could no longer maintain the required pace, identified by failing to reach the line on time for two consecutive stages despite verbal encouragement. The main outcome of the 30-15 IFT was the maximal running speed (km/h) achieved during the last fully completed stage (VIFT), which served as an indicator of aerobic fitness and was used to individualize training intensity.

Table 1. Six-week high-intensity interval training (HIIT) intervention.

Week	Session	Sets	Time (min)	Rest (min)	Intensity work	Intensity rest
1	1	3	3	2	85% VIFT	55% VIFT
1	2	3	3	2	85% VIFT	55% VIFT
2	3	3	4	2	85% VIFT	55% VIFT
2	4	3	4	2	85% VIFT	55% VIFT
3	5	4	3	2	90% VIFT	55% VIFT
3	6	4	3	2	90% VIFT	55% VIFT
4	7	4	4	2	90% VIFT	55% VIFT
4	8	4	4	2	90% VIFT	55% VIFT
5	9	5	3	2	95% VIFT	55% VIFT
5	10	5	3	2	95% VIFT	55% VIFT
6	11	5	4	2	95% VIFT	55% VIFT
6	12	5	4	2	95% VIFT	55% VIFT

VIFT: final velocity at 30-15 Intermittent Fitness Test

Table 2. Categories of technical observation.

Technical action	Successful	Unsuccessful	Accuracy (%)
Pass	Ball deliberately sent to a teammate and possession is maintained	Intercepted, misdirected, or results in loss of possession	Represents the proportion of successful passes relative to the total number of passes (successful plus unsuccessful).
Dribble	Player beats opponent or retains possession under pressure	Turnover caused by failed control or dispossession	Represents the proportion of successful dribble relative to the total number of dribbles (successful plus unsuccessful).
Shot	Attempted shot goes through the hoop and scores	Shot is saved, blocked, or misses the basket	Represents the proportion of successful shots relative to the total number of shots (successful plus unsuccessful).

Simulated 3vs3 match

To induce a state of fatigue, immediately following the 30-15 IFT, two teams participated in a simulated 3v3 basketball match lasting 10 minutes. The game was played at half-court with one basket, and no substitutions were allowed. The 3v3 format has been shown to cause fatigue and neuromuscular impairment in players (Sansone et al., 2025). Moreover, the Hooper Scale fatigue questionnaire was administered immediately after the game to assess the players' fatigue levels.

Technical analysis

Technical accuracy during the 3v3 format was analyzed using a custom-designed observational tool developed specifically for this study. Each variable was operationally defined to maintain consistency in coding and interpretation (Table 2). The accuracy percentages for passes, dribbles, and shots were collected for further comparison.

To validate the observational tool, a pilot study was conducted involving expert basketball researchers independent of the study to assess its content validity, relevance, and clarity. The experts reviewed the instrument, provided suggestions for modifications, and the research team subsequently incorporated these changes into the final version, which was then tested in a pilot trial. To evaluate the reliability of the observation process, intra-observer agreement was measured. The primary evaluator recoded 15% of the recorded game segments after a two-week interval to reduce recall bias. Cohen's Kappa (κ) values ranged from 0.09 to 0.95 across all coded categories, reflecting a high degree of reliability. All SSG bouts were filmed using a Osomo Action 4 (4K at 20 fps, DJI China), positioned on a tripod at an elevated point along the center of the sideline to ensure optimal view and full court coverage.

Statistical analysis

An *a priori* power analysis was conducted using G*Power 3.1.9.7 to determine the necessary sample size for detecting a significant interaction effect in the mixed ANOVA. Given a desired power of 0.80, an alpha level of 0.05, two time points (pre- and post-), and three groups, and assuming a medium effect size of $\eta p^2 = 0.06$ (corresponding to Cohen's $f = 0.25$), a total sample size of approximately 30 participants was required. This translated to 10 participants per group, providing adequate statistical power to detect a meaningful effect if one existed.

A mixed analysis of variance (ANOVA) was conducted to examine the effect of time (pre vs. post) and group (three levels) on the dependent variable. No missing data was observed. Assumptions of normality were assessed using the Shapiro-Wilk test. Mauchly's test of sphericity was also examined, and where violated, Greenhouse-Geisser corrections were applied. Post-hoc comparisons were conducted using Bonferroni correction. The magnitude of effects was reported using partial eta squared (ηp^2), with values of 0.01, 0.06, and 0.14 representing small, medium, and large effect sizes, respectively. All statistical analyses were performed using SPSS statistical software (version 27, SPSS, USA). A significance level was set at $p < 0.05$.

Results

Prior to showing the inferential analyses, descriptive statistics were calculated to summarize the performance of each group (HIITearly, HIITpost, and Control) on all dependent variables (passes accuracy, dribble accuracy, shot accuracy, and VIFT) at both pre- and post-intervention time points. These mean scores and standard deviations are presented in Table 3.

Table 3. Descriptive statistics for the variables. Data are means ± SD.

Variable	Group	Pre	Post
VIFT (km/h)	**HIITearly**	16.208 ± 0.542	17.542 ± 0.722 *
	HIITpost	16.542 ± 0.498	17.792 ± 0.690 *
	Control	16.417 ± 0.597	16.500 ± 0.603
Passes Accuracy (%)	**HIITearly**	66.242 ± 6.325	72.992 ± 4.788 *
	HIITpost	66.858 ± 7.541	69.592 ± 7.225 *
	Control	65.800 ± 4.729	66.717 ± 4.528
Dribble Accuracy (%)	**HIITearly**	76.592 ± 4.459	78.092 ± 4.339 *
	HIITpost	78.500 ± 4.835	79.342 ± 4.796 *
	Control	76.717 ± 4.719	77.208 ± 4.777 *
Shot Accuracy (%)	**HIITearly**	37.625 ± 5.727	41.683 ± 4.797 *
	HIITpost	37.342 ± 4.403	38.842 ± 4.368 *
	Control	35.725 ± 5.144	36.625 ± 4.522 *

VIFT: final speed at 30-15 intermittent fitness test; HIITearly: high-intensitry interval training conducted at the beginning of the session; HIITpost: high-intensity interval training conducted at the end of the session; * significant different ($p < 0.001$) intra-group (pre vs post).

Final speed at 30-15 Intermittent Fitness Test

The analysis revealed a statistically significant main effect of time on VIFT, $F_{(1,33)} = 49.841$, $p < 0.001$, partial $\eta^2 = 0.602$. A significant interaction effect was observed between time and group, $F_{(2,33)} = 10.270$, $p < 0.001$, partial $\eta^2 = 0.384$.

At Time 1, there was no statistically significant difference in VIFT among the HIIEarly, HIITpost, and Control groups, $F_{(2,33)} = 1.137$, $p = 0.333$, partial $\eta2 = 0.064$. Pairwise comparisons confirmed no significant differences between any group pairs at Time 1 (HIIEarly vs. HIITpost: Mdiff (mean difference) = −0.333, p = 0.435; HIIEarly vs. Control: Mdiff = −0.208, p > 0.999; HIITpost vs. Control: Mdiff = 0.125, p > 0.999).

At Time 2, a statistically significant difference was observed among the groups, $F_{(2,33)} = 12.425$, $p < 0.001$, partial $\eta^2 = 0.430$. Bonferroni-adjusted pairwise comparisons at Time 2 revealed the following: The HIIEarly group had significantly higher VIFT scores compared to the Control group (Mdiff = 1.042, p = 0.002). The HIITpost group also had significantly higher VIFT scores compared to the Control group (Mdiff = 1.292, p < 0.001). There was no significant difference in VIFT between the HIIEarly and HIITpost groups at Time 2 (Mdiff = −0.250, p > 0.999). As depicted in Figure 2, the change in VIFT (delta VIFt) over the intervention period differed across the groups. Both the HIITearly and HIITpost groups showed a positive median change in VIFT, suggesting an overall increase in VIFT performance.

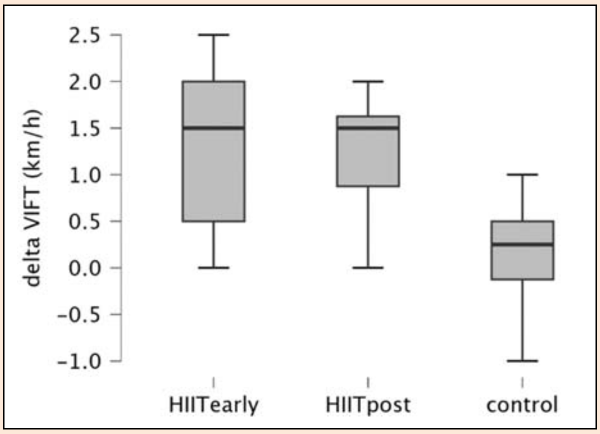

Figure 2. Box plot of delta VIFT (km/h) by group. VIFT: final speed at 30-15 intermittent fitness test; HIITearly: high-intensity interval training conducted at the beginning of the session; HIITpost: high-intensity interval training conducted at the end of the session.

Passes accuracy

There was a statistically significant main effect of time on passes accuracy, $F_{(1,33)} = 140.754$, $p < 0.001$, with a very large effect size, $\eta p^2 = 0.810$. A statistically significant interaction effect was found between time and group on passes accuracy, $F_{(2,33)} = 34.786$, $p < 0.001$, with a large effect size, $\eta p^2 = 0.678$.

At Time 1, there were no statistically significant differences in passes accuracy between the groups, $F_{(2,33)} = 0.085$, $p = 0.918$, $\eta p^2 = 0.005$. Pairwise comparisons confirmed no significant differences: HIITearly vs. HIITpost (Mdiff = −0.617, p > 0.999), HIITearly vs. Control (Mdiff = 0.442, p > 0.999), and HIITpost vs. Control (Mdiff = 1.058, p > 0.999).

At Time 2, there were statistically significant differences in passes accuracy between the groups, $F_{(2,33)} = 3.715$, $p = 0.035$, $\eta p^2 = 0.184$. Post-hoc pairwise comparisons revealed that the HIITearly group exhibited significantly higher passes accuracy compared to the Control group, Mdiff = 6.275, p = 0.031. No other significant pairwise differences were found at Time 2: HIITearly vs. HIITpost (Mdiff = −3.400, p = 0.449) and HIITpost vs. Control (Mdiff = 2.875, p = 0.663). As illustrated in Figure 3, the change in passes accuracy (delta passes accuracy) over the intervention period varied across the groups.

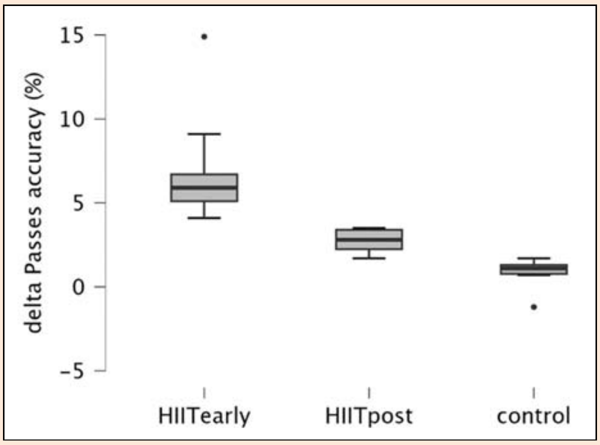

Figure 3. Box plot of delta passes accuracy (%) by group. HIITearly: high-intensity interval training conducted at the beginning of the session; HIITpost: high-intensity interval training conducted at the end of the session.

Dribble accuracy

There was a statistically significant main effect of time on dribble accuracy, $F_{(1,33)} = 252.402$, $p < 0.001$, with a very large effect size, $\eta p^2 = 0.884$. A statistically significant interaction effect was found between time and group on dribble accuracy, $F_{(2,33)} = 24.723$, $p < 0.001$, with a large effect size, $\eta p^2 = 0.600$.

At Time 1 (pre-intervention), there were no statistically significant differences in dribble accuracy between the groups, $F_{(2,33)} = 0.626$, $p = 0.541$, $\eta p^2 = 0.037$. Pairwise comparisons confirmed no significant differences: HIITearly vs. HIITpost (Mdiff = −1.908, p = 0.973), HIITearly vs. Control (Mdiff = −0.125, p > 0.999), and HIITpost vs. Control (Mdiff = 1.783, p > 0.999). At Time 2 (post-intervention), there were no statistically significant differences in dribble accuracy between the groups, $F_{(2,33)} = 0.640$, $p = 0.534$, $\eta p^2 = 0.037$. Pairwise comparisons confirmed no significant differences: HIITearly vs. HIITpost (Mdiff = −1.250, p > 0.999), HIITearly vs. Control (Mdiff = 0.883, p > 0.999), and HIITpost vs. Control (Mdiff = 2.133, p = 0.805). As depicted in Figure 4, the change in dribbles accuracy (delta dribbles accuracy) over the intervention period varied across the groups.

Shot accuracy

There was a statistically significant main effect of time on shot accuracy, $F_{(1,33)} = 127.420$, $p < 0.001$, with a very large effect size, $\eta p^2 = 0.794$. A statistically significant interacttion effect was found between time and group on shot accuracy, $F_{(2,33)} = 25.784$, $p < 0.001$, with a large effect size, $\eta p^2 = 0.610$.

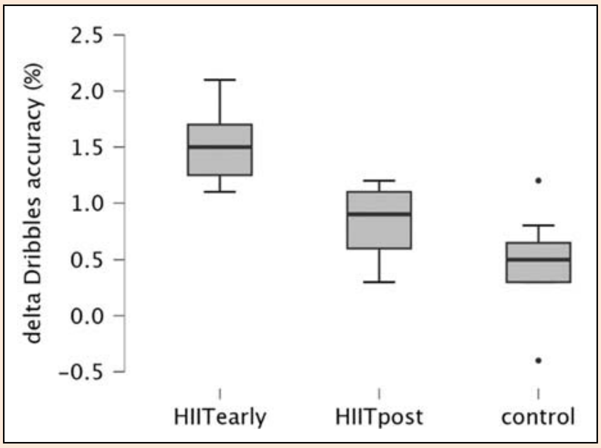

Figure 4. Box plot of delta dribbles accuracy (%) by group. HIITearly: high-intensitry interval training conducted at the beginning of the session; HIITpost: high-intensity interval training conducted at the end of the session.

At Time 1 (pre-intervention), there were no statistically significant differences in shot accuracy between the groups, $F_{(2,33)} = 0.481$, $p = 0.622$, $\eta p^2 = 0.028$. Pairwise comparisons confirmed no significant differences: HIITearly vs. HIITpost (Mdiff = 0.283, $p > 0.999$), HIITearly vs. Control (Mdiff = 1.900, $p > 0.999$), and HIITpost vs. Control (Mdiff = 1.617, $p > 0.999$).

At Time 2 (post-intervention), there were statistically significant differences in shot accuracy between the groups, $F_{(2,33)} = 3.701$, $p = 0.035$, $\eta p^2 = 0.183$. Post-hoc pairwise comparisons revealed that the HIITearly group (M = 41.68, SD = 4.80) exhibited significantly higher shot accuracy compared to the Control group (M = 36.63, SD = 4.52), Mdiff = 5.058, $p = 0.031$. No other significant pairwise differences were found at Time 2: HIITearly vs. HIITpost (Mdiff = 2.842, $p = 0.411$) and HIITpost vs. Control (Mdiff = 2.217, $p = 0.729$). As shown in Figure 5, the change in shots accuracy (delta shots accuracy) over the intervention period varied across the groups.

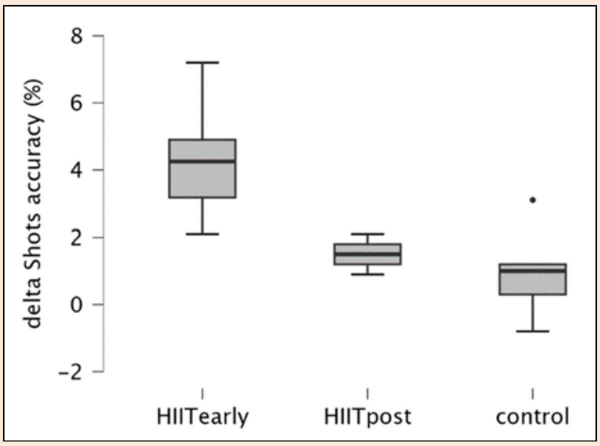

Figure 5. Box plot of delta shots accuracy (%) by group. HIITearly: high-intensitry interval training conducted at the beginning of the session; HIITpost: high-intensity interval training conducted at the end of the session

Discussion

This study investigated the effects of HIIT timing—either before (HIITearly) or after (HIITpost) technical training—on physical and technical performance over a six-week period. The results showed significant improvements in the VIFT for both HIIT groups compared to the control, with no significant difference between HIITearly and HIITpost, indicating that HIIT, regardless of timing, effectively enhanced aerobic fitness. For technical skills, HIITearly produced superior improvements in passing and shooting accuracy compared to the control group, while HIITpost showed more modest, though still significant, improvements. Dribbling accuracy improved across all groups, including control, though improvements were slightly higher in the HIIT conditions.

Our results revealed that both HIITearly and HIITpost significantly enhanced aerobic capacity measured by means of 30-15IFT. These findings are consistent with previous studies showing that HIIT improves 30-15 IFT performance in youth basketball players (Delextrat et al., 2018; Arslan et al., 2022; Rodríguez-Fernández et al., 2022). The intensity nature of HIIT, regardless of the timing of the sessions, likely contributed to improvements in VO_2max and cardiovascular efficiency, enhancing oxygen delivery and utilization during intense exercise and promoting faster recovery (Delextrat et al., 2018). However, these assumptions were not tested in our study; therefore, any inference of causality should be avoided. Further research is needed to explore the mechanisms underlying the adaptations. Furthermore, previous studies have also showed that HIIT contributes to improvements in anaerobic capacity and power (Arslan et al., 2022) potentially enabling athletes to sustain higher running speeds and recover more efficiently between shuttle runs by facilitating phosphocreatine resynthesis. Additionally, neuromuscular adaptations have been reported (Bendo et al., 2024), which may support athletes in coping better with rapid changes in direction and acceleration required by the 30-15 IFT.

Our results also revealed that passing accuracy and shooting accuracy were significantly improved in the HIITearly group compared to the control group. However, no significant differences were found between the HIIT groups after the intervention, nor between the HIITpost group and the control group. Although no studies have directly examined this specific design, it aligns with the recommendation for incorporating intense physical effort. A previous study (Ramos et al., 2015) suggests that basketball coaches and strength and conditioning professionals should consider integrating moderate—and particularly high—intensity exercise into skill-based training sessions.

The greater improvements in passing and shooting accuracy under fatigue condition observed in the HIITearly group may be explained by the timing of neuromuscular and cognitive stress relative to skill development (youth players from local-level contexts) (Jesus et al., 2018). Performing HIIT prior to technical-tactical training possibly increased acute neuromuscular fatigue and cognitive load, simulating high-pressure game conditions and fostering greater adaptations in skill execution under stress (Lyons et al., 2006). This possibly aligns with the contextual interference effect (Apidogo et al., 2023), where practicing skills in more challenging conditions (in this case physiologically) enhances learning transfer to fatigue scenarios. Additionally, early HIIT may have primed arousal and attentional focus during subsequent skill training (Hutchinson and Tenenbaum, 2007). In contrast, when HIIT followed skill training (HIITpost), players may have experienced residual fatigue without skill-specific adaptations under pressure, limiting adaptations, namely in passing and shooting which requires greater precision. Eventually, the training order can also affect not only physiological factors but also aspects such as sustained mental commitment, exercise performance, mental freshness for specific technical demands, and even effort regulation, thus further research is needed to understand the mechanisms of these findings.

Interestingly, no significant differences in dribbling accuracy were found between groups, although all groups—including the control—demonstrated significant improvements from Time 1 to Time 2. One possible explanation is that dribbling accuracy was already relatively high at baseline, which may have limited the potential for further substantial improvement—ceiling effect (Boddington et al., 2020). Possibly some more automatized skills like dribbling tend to plateau earlier in development and are less sensitive to variations in training interventions (Fisher, 2023). Moreover, dribbling may be less influenced by fatigue compared to more precision-dependent skills such as passing or shooting (Li et al, 2021). It is also plausible that the similar improvements observed across all groups reflect the impact of regular on-court practice, thereby reducing the likelihood that the improvements were solely attributable to the HIIT intervention.

This study presents limitations that should be acknowledged. Although the 3v3 format is highly demanding and was performed immediately after the 30-15 IFT, no specific fatigue measurements were taken to confirm the fatigue levels or performance impairments of each player. The sample consisted of youth players from local-level contexts, which may limit the generalizability of the findings to higher-level or adult athletes, namely because of possibly celling effect in higher competitive levels. These effects may be less pronounced at higher competitive levels. For this reason, it is important for future studies to understand how training status and skill level influence the tendency for adaptations. The use of convenience sampling also introduces potential limitations; however, this approach is common in sports science research due to the significant challenges in recruiting available teams. Additionally, the study duration was relatively short, which may not fully show long-term adaptations (e.g., physiological, physical, and coordinative) or potential differences in training progression between groups. Future research should explore the underlying physiological and psychological mechanisms through more testing, including cognitive load assessments, hormonal responses, and motor learning markers. Longitudinal studies with larger, more diverse samples are also needed to evaluate the sustainability and transferability of these findings across different competition levels and age groups. On the other hand, the coaching approach used during regular on-court basketball sessions can also have a concurrent effect, potentially influencing the results. However, we implemented mitigation strategies by assigning different groups to separate teams, thereby reducing bias from coaching practices. Practically, these findings suggest that the timing of HIIT can influence skill development, with early HIIT potentially offering added benefits for more precise technical skill performance under fatigue. When the goal is to improve skill execution under pressure, HIIT before technical drills may be more beneficial.

Conclusion

In conclusion, this study suggests that HIIT, whether performed before or after technical training, effectively improved aerobic fitness in youth basketball players over a six-week period. However, the timing of HIIT appeared to influence technical accuracy development, with the HIITearly group showing greater improvements in passing and shooting accuracy compared to both the control and HIITpost groups. These findings suggest that performing HIIT prior to skill training may better simulate game-like fatigue conditions, thereby enhancing accuracy execution under conditions of fatigue. While dribbling accuracy improved across all groups, the lack of significant differences may reflect a ceiling effect or the lower sensitivity of this skill to fatigue. Taken together, these findings tentatively suggest that the timing of HIIT relative to technical training might influence certain aspects of skill development, such as passing and shooting accuracy, in youth basketball players. However, further research is needed to confirm these effects, better understand the underlying mechanisms, and eventually assess the influence of skill level and training status on these findings.

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Key points

- Both early- and post-session HIIT significantly improved aerobic fitness (VIFT) compared to control.
- HIIT performed early in the session led to greater improvements in technical accuracy (passes, shots, dribbles) under fatigue than post-session HIIT.
- Early-session HIIT produced the largest effect sizes across technical variables, suggesting greater transfer to in-game skill execution.

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