©Journal of Sports Science and Medicine (2025) **24**, 341-350
http://www.jssm.org DOI: https://doi.org/10.52082/jssm.2025.341

Research article

Leveling The Playing Field in Youth Basketball: How Compensatory Training With Small-Sided Games Enhances Physical Fitness and Reduces Relative Age Effect Bias in Match Selection

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Abstract
The purpose of this study was to analyze the effects of compensatory training on later-born basketball players, who had less match time compared to their peers, focusing on their physical fitness and skill development. A prospective cohort study compared three groups of male youth basketball players (ages 12 - 14). One group consisted of later-born players with a high volume of match play in competitive scenarios (lbHPT), while the other two groups had match play below the median of the teams. Among these two groups, one received compensatory training (lbLPTcomp), and the other did not (lbLPTreg). Players were evaluated at three time points: baseline, 3 months, and 6 months. The assessments measured aerobic capacity (using the Yo-Yo intermittent recovery test), 10-meter sprint performance, 5-0-5 change of direction (COD deficit), and performance on the basketball technical test (LSPT). The compensatory training consisted of two weekly sessions in which, after regular training, the later-born players participated in 2v2 or 3v3 small-sided games lasting 15 minutes per session. The results revealed that lbLPTcomp was significantly effective in reducing the differences with lbHPT, as no significant differences were observed between the two cohorts over the 6 months for any of the outcomes ($p > 0.05$). Additionally, lbLPTcomp performed significantly better than lbLPTreg post-6 months in the LSPT ($p = 0.033$) and COD deficit ($p = 0.003$). The lbLPTreg group was also significantly worse than lbHPT in the YYIRT ($p = 0.022$), LSPT ($p = 0.036$), and COD deficit ($p = 0.005$). No significant between-group differences were found in 10-m sprint after 6 months (p = 0.241), though lbHPT and lbLPTcomp improved significantly (both p < 0.001). In conclusion, while compensatory training like twice-weekly small-sided games may help later-born youth athletes with limited playtime, further research is needed before broad implementation.

Key words: Team sports, youth athletes, compensatory training, motor skill development, physical fitness.

Introduction

The relative age effect (RAE) may significantly impact youth basketball participation, with players born earlier in the selection year overrepresented at elite levels (Campo et al., 2010; Williams, 2010). This effect is particularly pronounced during adolescence and increases with performance level (Bozděch et al., 2023). RAE influences match participation, with players born in the first quarter of the selection year receiving more playing opportunities in semi-professional and amateur settings (Vaeyens et al., 2005). Actually, maturation seems to play a role in favoring those who are more mature, allowing them more playing time at younger ages (Clemente et al., 2021a). Therefore, basketball is a sport where early maturation can confer significant competitive advantages, making it an ideal setting to investigate RAE. RAE phenomenon leads to potential talent being overlooked (Campo et al., 2010) and raises concerns about fair selection practices in youth development (Bozděch et al., 2023).

The RAE bias is particularly strong at entry-level and during puberty (Lovell et al., 2015). While early-born players tend to have anthropometric advantages, especially in height (Carling et al., 2009; Lovell et al., 2015), the relationship between RAE and physical fitness is less clear. Some studies found small advantages in sprint performance for relatively older players (Lovell et al., 2015), while others reported no significant differences in fitness measures across birth quarters (Carling et al., 2009). Maturity status influences physiological and technical characteristics, with early maturers often outperforming their peers (Meylan et al., 2010).

Research suggests that youth players who play more matches may experience greater development in physical fitness. A study found that players with more match time had significantly better aerobic capacity (Silva et al., 2022). Longitudinal studies have shown that youth players generally demonstrate better physical fitness than non-players, particularly in cardiovascular endurance and agility (Vänttinen et al., 2011). Therefore, RAE may not only introduce a bias in competition selection but also exacerbate the opportunities for developing performance in later-born athletes. This issue could be a focal point for coaches to address in order to mitigate such a gap.

One proposed approach to mitigating the effects of the RAE is the use of the average team age method, which bases eligibility on the team's average age rather than individual players' ages (Verbeek et al., 2021). However, in cases where competition structures fail to address RAE, alternative strategies must be considered. One such strategy, drawn from professional team sports, is compensatory training—a well-established practice designed to replicate match-like stimuli for players who do not regularly participate in games, thereby supporting their physical fitness and development (Clemente et al., 2024). In this context, a compensatory strategy refers to a deliberate training approach used to offset the lack of match play by providing

Received: 01 April 2025 / Accepted: 14 May 2025 / Published (online): 01 June 2025

players with alternative physical and tactical stimuli that mimic game conditions.

Based on this premise, the current study aimed to explore whether compensatory training could benefit later-born youth players, who may not participate as much as their peers in matches, by helping to mitigate the developmental consequences of limited match exposure. To our knowledge, no prior research has investigated the use of compensatory training to offset the developmental disadvantages faced by later-born youth basketball players. Therefore, the aim of this study was to compare the effects of compensatory training on the physical performance development and skill level of later-born players with limited match participation.

Methods

Study design

This study utilized a prospective cohort design to evaluate the effects of compensatory training on physical fitness and skill development in later-born basketball players. Participants were divided into three groups: one group consisting of later-born players with high-volume match play in competitive scenarios, and two groups with match play below the median of their teams. Of the latter two groups, one group received compensatory training while the other did not. The study adhered to the STROBE guidelines.

Baseline, 3-month, and 6-month evaluations were conducted to measure key outcomes, including aerobic capacity (Yo-Yo intermittent recovery test), 10-meter sprint performance, change of direction with the ball, and performance on the basketball technical test. These evaluations were performed by a trained research team blind to the groups.

Compensatory training involved two weekly sessions, each lasting 15 minutes, in which the later-born players participated in small-sided games (2v2 or 3v3) following regular team training. This design allowed for a comparison between players with varying levels of competitive match play exposure and the additional effects of structured training on performance outcomes.

Setting

The study was conducted in a naturalistic setting within a competitive basketball environment, involving youth basketball teams from three local clubs. Participants were recruited by convenience from a pool of male players aged 12 to 14 years, who were actively participating in regular training sessions and competitive matches. The study took place over a 6-month period, with all evaluations and interventions conducted at the teams' training facilities. The players were trained under the supervision of their regular coaches, ensuring that the compensatory training sessions were integrated with their existing training schedules. The study was designed to reflect real-world conditions, where training and match play occur simultaneously, with the research team having no influence on player selection or the training process.

Participants

The participants in this study were male youth basketball players aged 12 to 14 years, recruited from local clubs. Inclusion criteria required participants to be born in the 3rd or 4th quartile of the year, actively engaged in competitive basketball (with more than 2 years of experience), and regularly participating in training sessions and matches. Players were eligible if they had a minimum of 24 months of basketball experience and had not sustained an injury lasting longer than 2 weeks during the observation period. Exclusion criteria included injury that would prevent participation in testing moments, and participants with injuries longer than 2 weeks over the period. Participants who withdrew from the study before the completion of the follow-up assessments were excluded from the final analysis.

A total of 64 players were initially screened for eligibility, and after applying the inclusion and exclusion criteria, 36 players were enrolled in the study. Participants were categorized into three groups based on their match play exposure: one group of later-born players with a high volume of competitive match play (above the median) (n = 14), and two groups (n = 12 and n = 10) of players with match play below the median of their teams. These players trained three times a week, in addition to weekend competitive matches. Each training session typically consisted of a warm-up, followed by brief conditioning exercises focusing on either aerobic fitness or agility, then analytical drills to refine technical skills, and concluded with strategic drills or a formal match. On average, the sessions lasted 100 minutes.

Ethical approval was obtained from the Chengdu Sport University ethics committee (2024#161), ensuring compliance with institutional and regulatory ethical standards. Since the participants were minors, informed consent was obtained from their legal guardians, along with assent from the participants themselves. The study adhered to the ethical principles of the Declaration of Helsinki, emphasizing respect for human dignity, risk minimization, and scientific integrity.

Independent variables

Three teams were monitored over a 6-month period, with daily tracking of their attendance at training sessions and their playing time during matches. In addition to the players in the study cohort (those born in the 3rd and 4th quartiles of the year – later-born players), the remaining teammates (those born in the 1st and 2nd quartiles) were also monitored for their training attendance and match playing time. By analyzing the total match play time across all three teams, the median playing time for each team was calculated. Participants were then classified as either playing above or below the median.

At the end of the 6-month period, it was observed that out of the total sample of 36 players born in the 3rd and 4th quartiles, 14 played more than the median playing time of their teams (including all the players, even players born in the 1st and 2nd quartiles), while 22 players born in the 3rd and 4th quartiles played less than the median.

Additionally, from the start of the study, a compensatory training program was implemented for half of the players born in the 3rd and 4th quartiles. This group (in each of the teams) received small-sided game sessions lasting 15 minutes, twice a week, while the other half did not participate in these additional sessions. It is important to note that at the beginning of the study, players were randomly assigned to the different training groups using a simple randomization method. Specifically, each player was assigned a number, and these numbers were randomly drawn using a computer-generated random number sequence to ensure unbiased group allocation. Once assigned, players remained in their respective groups for the duration of the study. Furthermore, even players born later in the year who played above the median also participated in the compensatory training, as it was not possible to predict at the outset which players would have more or less playing time.

Therefore, three groups of later-born players were categorized as follows: (i) later-born players who played above the median playing time per player per team (lbHPT); (ii) later-born players who played below the median playing time per player per team and received compensatory training (lbLPTcomp); and (iii) later-born players who played below the median playing time per player per team and did not receive compensatory training (lbLPTreg).

Compensatory training

The compensatory training program was designed by the research team and discussed with the technical staff of the three teams where it was implemented. This training took place during the first and third training sessions of the week -typically 48 hours after the last match and 48 hours before the next match, respectively. The compensatory sessions were conducted after the regular team training and focused on small-sided games in 2v2 and 3v3 formats.

In the first compensatory session of the week, players participated in a 3v3 format with small baskets on a 30x20 m (100 m² per player). The game followed an intermittent regimen of 3x5-minute bouts with 2-minute rest intervals (Xu et al., 2024). In the second compensatory session, players engaged in a 2v2 format, also using small baskets, on a 23x12 m court (69 m² per player), with 5x3-minute bouts and 2-minute rest intervals.

There were no offside rules, and ball repositioning was done by foot. Additionally, corner kicks were not allowed, and players were required to shoot only from within the opponent's half of the field.

Assessments

Players were assessed three times under similar conditions: at baseline, three months after the initial evaluation, and six months after the baseline evaluation. Assessments were conducted during the first training session of the week, following a 48-hour rest period after the most recent match.

All procedures took place in the afternoon (4:00 PM), beginning with anthropometric evaluations, followed by a standardized warm-up protocol. Next, players performed the basketball shooting test. After completing this test, they rested for two minutes before proceeding to the 5-0-5 change of direction (COD) test. Another two-minute rest period was given before assessing maximal sprint performance in the 10-meter sprint test. Finally, players were evaluated for aerobic capacity using the Yo-Yo Intermittent Recovery test. The sequence of tests was the same for all participants and was conducted in a specific order to minimize the effects of central fatigue from the Yo-Yo Intermittent Recovery Test, which was therefore scheduled at the end.

Anthropometric evaluations

Height was measured to the nearest 0.1 cm using a calibrated stadiometer (model 213, SECA), and body mass was assessed to the nearest 0.1 kg using a digital scale (model 803, SECA). All measurements were taken following standardized procedures, with participants standing erect, barefoot, and looking straight ahead. To estimate peak height velocity (PHV), a key indicator of adolescent growth spurts, longitudinal height data was collected.

Height measurements were collected at each assessment moment. PHV was subsequently estimated using the Mirwald et al. (2002) prediction equation (-(9.236 + 0.0002708 × leg length and sitting height interaction) - (0.001663 × age and leg length interaction) + (0.007216 × age and sitting height interaction) + (0.02292 × weight by height ratio). This method incorporates sex, chronological age, height, leg length, and sitting height to predict the maturity offset, which is then used to determine the age at PHV. Leg length and sitting height were measured using the SECA model 213. The primary outcome of this procedure was the maturity offset, which represents the number of years before or after PHV.

Basketball technical test

Technical ability was assessed using a modified version of the Loughborough Soccer Passing Test (LSPT), a validated measure of technical accuracy and technique. We updated the setup by replacing the pass zones with baskets where the player could score. Additionally, we required the ball to be received from researchers positioned on each side. The test was conducted on the basketball court. The adjusted LSPT involved participants performing a series of basketball shooting to baskets positioned at varying distances and angles. Specifically, participants were required to shoot the basketball from a designated starting point to 4 targets, similar to the described in the original validation article (Le Moal et al., 2014). The test completion time and penalty time for errors were recorded according to the guidelines from a previously validated study (Le Moal et al., 2014). Participants were instructed to shooting the ball using only their dominant hand. Each participant completed two trials, with the primary outcome measure being the best overall performance, measured in seconds.

5-0-5 change of direction (COD) test

Change of direction (COD) performance was assessed using the 5-0-5 test, which was conducted on basketball court. Participants started by standing 10 meters behind the starting line. Upon the 'go' signal, they sprinted forward 10 meters, then 5 meters further to the COD line, where they performed a 180-degree turn using their preferred foot, and sprinted back through the starting line. The direction of the turn remained consistent across trials.

Participants completed two trials, with a 2-minute rest between trials to minimize fatigue. The best performance from the two trials was used for analysis. Photocells, positioned at the hip level of the players, were activated when the participant crossed the COD starting line and stopped when they crossed the same line after completing the return sprint. Time was recorded to the nearest 0.01 seconds using the Witty timing gates. The primary outcome measure was the COD deficit (Nimphius et al., 2016), which was calculated as the COD time minus the 10-meter linear sprint time.

10-meter sprint test

Linear sprint speed was assessed using the 10-meter sprint test, conducted on basketball court. Participants began by standing with their front foot positioned 0.2 meters behind the starting line, adopting a standing split start with their preferred foot in front.

Upon the 'go' signal, participants sprinted maximally over a 10-meter distance. Timing was initiated when the participant's first movement triggered the timing device and terminated when they crossed the 10-meter finish line. Time was recorded to the nearest 0.01 seconds using Witty timing gates.

Participants performed 2 trials, with a rest period of 2 minutes between trials to minimize fatigue. The primary outcome measure was the time taken to complete the 10-meter sprint, representing linear sprint performance.

Yo-Yo Intermittent Recovery test – level 1

Aerobic capacity was assessed using the Yo-Yo Intermittent Recovery Test Level 1 (YYIR1), a validated measure of an individual's ability to perform repeated high-intensity exercise with short recovery periods (Deprez et al., 2014). The test was conducted on basketball court. Participants began at the starting line and ran a 20-meter shuttle, paced by audio beeps from a pre-recorded CD or digital file. Upon hearing the beep, participants ran to the 20-meter line and back to the starting line before the next beep. Following each 2 x 20-meter shuttle, participants had a 10-second active recovery period, during which they jogged to the recovery zone (5 meters away) and back to the starting line. The speed of the shuttles progressively increased throughout the test, as dictated by the audio beeps. The test continued until the participant failed to reach the 20-meter line in time with the audio beeps on two consecutive occasions. The primary outcome measure was the total distance covered (meters) before failure.

Sample size

Sample size was estimated a priori using G*Power 3.1. The sample size calculation was based on the aerobic capacity. We aimed to detect a 0.3 effect size with a power of 0.80 and an alpha level of 0.05, using a mixed repeated measures ANOVA. Given the three groups in our prospective cohort study, and three evaluation, the required sample size was calculated to be 27 participants.

Statistical procedures

Statistical analyses were conducted IBM SPSS (version 27). The alpha level for all statistical tests was set at $p < 0.05$. A mixed-design analysis of variance (ANOVA) was employed to examine the effects of group (three groups and three evaluation moments) on the dependent variables. The mixed ANOVA model included group as a between-subjects factor and time as a within-subjects factor.

Prior to conducting the mixed ANOVA, the assumptions of normality, homogeneity of variance, and sphericity were assessed. Normality was assessed using Shapiro-Wilk test for each group at each time point. Homogeneity of variance was assessed using Levene's test. Sphericity was assessed using Mauchly's test. In cases where Mauchly's test indicated a violation of sphericity, Greenhouse-Geisser corrections were applied to the degrees of freedom.

Significant main effects of group or time, or significant interaction effects between group and time, were followed up with post-hoc analyses. For between-group and within-group comparisons, Bnferroni post-hoc tests were used.

Effect sizes were calculated to quantify the magnitude of observed effects. For main effects and interaction effects in the mixed ANOVA, partial eta-squared (ηp^2) was reported. For post-hoc t-tests, Cohen's d was reported. Partial eta-squared was interpreted as follows: small ($\eta p^2 = 0.01$), medium ($\eta p^2 = 0.06$), and large ($\eta p^2 = 0.14$). Cohen's d was interpreted as follows: small ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$).

Results

Table 1 provides a statistical summary of the players' data over the six months of evaluation. Additionally, Figure 1 illustrates the total minutes of play for each cohort during the six-month observation period. It is observed that players in the lbHPT cohort had an average of 976.9 ± 189.5 minutes of play, while those in the lbLPTcomp and lbLPTreg cohorts had averages of 477.8 ± 255.0 and 517.8 ± 192.1 minutes, respectively.

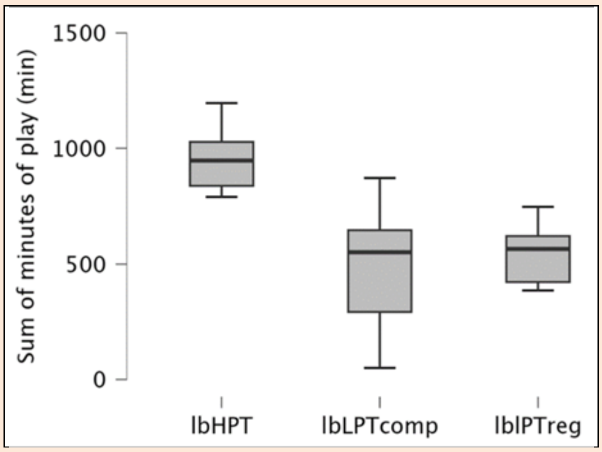

Figure 1. Accumulated playtime in minutes over the 6-month period for each cohort. lbHPT: later-born players who played above the median playing time per player per team; lbLPTcomp: later-born players who played below the median playing time per player per team and received compensatory training; lbLPTreg: later-born players who played below the median playing time per player per team and did not receive compensatory training.

Table 1. Anthropometric statistics of the cohorts at each assessment timepoint.

		lbHPT (n = 14)	lbLPTcomp (n = 12)	lbLPTreg (n = 10)
Age (y)	**Baseline**	12.8 ± 0.5	12.3 ± 0.5	13.5 ± 0.4
	Post 3-months	13.1 ± 0.5	12.6 ± 0.5	13.8 ± 0.4
	Post 6-months	13.4 ± 0.5	12.9 ± 0.5	14.1 ± 0.4
Height (cm)	**Baseline**	153.7 ± 7.7	147.6 ± 8.9	161.0 ± 3.3
	Post 3-months	154.5 ± 7.6	148.2 ± 8.8	161.5 ± 3.3
	Post 6-months	155.3 ± 7.4	148.9 ± 8.7	162.0 ± 3.3
Body mass (kg)	**Baseline**	44.3 ± 7.0	41.1 ± 7.6	51.5 ± 4.2
	Post 3-months	45.3 ± 6.9	42.2 ± 7.3	52.5 ± 4.5
	Post 6-months	46.4 ± 7.1	43.1 ± 7.7	53.5 ± 4.1
Body mass index (kg/m^2)	**Baseline**	18.7 ± 2.4	18.8 ± 1.8	19.9 ± 1.7
	Post 3-months	19.0 ± 2.5	19.0 ± 1.9	20.1 ± 1.6
	Post 6-months	19.2 ± 2.3	19.3 ± 1.8	20.4 ± 1.8
Maturity offset (years)	**Baseline**	–1.2 ± 0.6	–1.8 ± 0.6	–0.4 ± 0.4
	Post 3-months	–1.1 ± 0.6	–1.7 ± 0.6	–0.3 ± 0.4
	Post 6-months	–1.0 ± 0.6	–1.6 ± 0.6	–0.2 ± 0.4

lbHPT: later-born players who played above the median playing time per player per team; lbLPTcomp: later-born players who played below the median playing time per player per team and received compensatory training; lbLPTreg: later-born players who played below the median playing time per player per team and did not receive compensatory training.

Table 2 presents the descriptive statistics of the basketball performance outcomes evaluated over the six-month period. Significant interactions between the evaluation timepoints and cohorts were observed for the LSPT (p<0.001; ηp² = 0.695, large effect size), COD deficit (p<0.001; ηp² = 0.829, large effect size), 10-m sprint (p<0.001; ηp² = 0.670, large effect size), and YYIRT (p<0.001; ηp² = 0.622, large effect size).

Between-group comparisons revealed no significant differences between cohorts at baseline for LSPT (p = 0.955; ηp² = 0.003, small effect size), COD deficit (p = 0.964; ηp² = 0.002, small effect size), 10-m sprint (p = 0.932; ηp² = 0.004, small effect size), and YYIRT (p = 0.473; ηp² = 0.044, small effect size). Similarly, no significant differences were found between cohorts post 3 months for LSPT (p = 0.244; ηp² = 0.082, medium effect size), 10-m sprint (p = 0.782; ηp² = 0.015, small effect size), and YYIRT (p = 0.367; ηp² = 0.059, small effect size). However, a significant difference was observed between cohorts for the COD deficit after 3 months (p = 0.008; ηp² = 0.256, large effect size), with the lbHPT group showing a significantly smaller COD deficit compared to the lbLPTreg group (p = 0.022; d = 1.474, large effect size).

After 6 months, significant differences between cohorts were observed in the LSPT (p = 0.018; ηp² = 0.217, large effect size). Specifically, the lbLPTreg group showed significantly smaller scores compared to both the lbHPT group (p = 0.036; d = 1.175) and the lbLPTcomp group (p = 0.033; d = 1.084, large effect size). The descriptive statistics for the LSPT across cohorts over the 6-month period can be seen in Figure 2. Within-cohort comparisons revealed that the lbHPT group showed significant improvement from baseline to 3 months (p<0.001) and from 3 months to 6 months (p<0.001), with a mean difference of 8.1 s from baseline to post-6 months (p<0.001). Similarly, lbLPTcomp group showed significant improvement from baseline to 3 months (p<0.001) and from 3 months to 6 months (p<0.001), with a mean difference of 8.7 s from baseline to post-6 months (p<0.001). Finally, lbLPTreg group showed significant improvement from baseline to 3 months (p<0.001) and from baseline to post-6 months (p = 0.001), although no differences from 3 to 6 months (p = 0.241).

After 6 months, significant differences between cohorts were observed in the LSPT (p = 0.018; ηp² = 0.217, large effect size). Specifically, the lbLPTreg group showed significantly smaller scores compared to both the lbHPT group (p = 0.036; d = 1.175) and the lbLPTcomp group (p = 0.033; d = 1.084, large effect size). After 6 months, significant differences between cohorts were observed in the

Table 2. Basketball performance statistics of the cohorts at each assessment timepoint.

		lbHPT (n = 14)	lbLPTcomp (n = 12)	lbLPTreg (n = 10)
LSPT (s)	**Baseline**	62.8 ± 5.1	63.2 ± 6.7	63.6 ± 6.6
	Post 3-months	58.3 ± 5.2	58.7 ± 7.0	62.4 ± 6.4
	Post 6-months	54.8 ± 5.2	54.4 ± 6.9	61.5 ± 6.2
COD deficit (s)	**Baseline**	0.72 ± 0.09	0.71 ± 0.11	0.72 ± 0.12
	Post 3-months	0.58 ± 0.09	0.57 ± 0.11	0.70 ± 0.11
	Post 6-months	0.55 ± 0.09	0.54 ± 0.11	0.69 ± 0.10
10-m sprint (s)	**Baseline**	2.21 ± 0.09	2.22 ± 0.12	2.21 ± 0.10
	Post 3-months	2.16 ± 0.08	2.17 ± 0.12	2.19 ± 0.10
	Post 6-months	2.13 ± 0.08	2.14 ± 0.11	2.20 ± 0.10
YYIRT (m)	**Baseline**	504.3 ± 98.0	456.7 ± 99.0	478.0 ± 97.7
	Post 3-months	565.7 ± 100.0	511.7 ± 100.3	528.0 ± 93.9
	Post 6-months	620.0 ± 93.8	571.7 ± 100.3	502.0 ± 107.7

LSPT: adjusted basketball performance test; COD: change-of-direction; YYIRT: Yo-Yo intermittent recovery test level 1; lbHPT: later-born players who played above the median playing time per player per team; lbLPTcomp: later-born players who played below the median playing time per player per team and received compensatory training; lbLPTreg: later-born players who played below the median playing time per player per team and did not receive compensatory training.

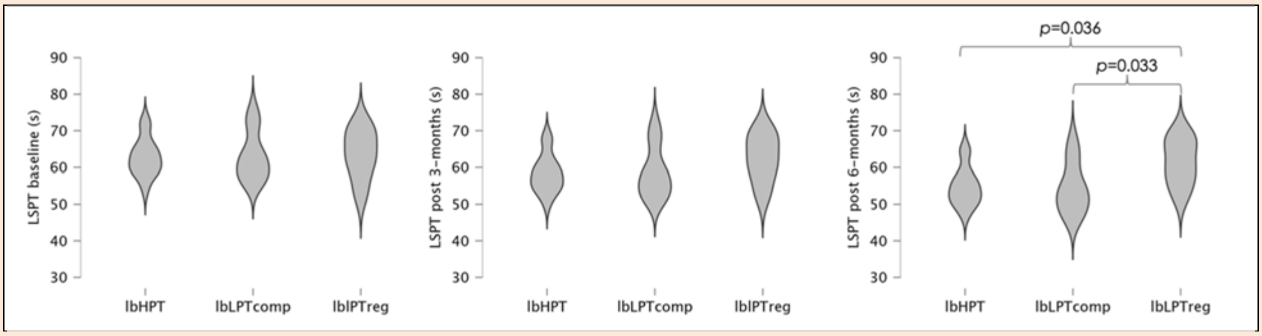

Figure 2. Violin plots of the adjusted basketball performance test (LSPT) at baseline, and at 3- and 6-month follow-ups for each cohort. lbHPT: later-born players who played above the median playing time per player per team; lbLPTcomp: later-born players who played below the median playing time per player per team and received compensatory training; lbLPTreg later-born players who played below the median playing time per player per team and did not receive compensatory training.

COD deficit ($p = 0.002$; ηp² = 0.323, large effect size). Specifically, the lbLPTreg group showed significantly worse values compared to both the lbHPT group ($p = 0.005$; $d = 1.474$, large effect size) and the lbLPTcomp group ($p = 0.003$; $d = 1.429$, large effect size). The descriptive statistics for the COD deficit across cohorts over the 6-month period can be seen in Figure 3. Within-cohort comparisons revealed that the lbHPT group showed significant improvement from baseline to 3 months ($p<0.001$) and from 3 months to 6 months ($p<0.001$), with a mean difference of 0.17 s from baseline to post-6 months ($p<0.001$). Similarly, lbLPTcomp group showed significant improvement from baseline to 3 months ($p<0.001$) and from 3 months to 6 months ($p<0.001$), with a mean difference of 0.17 s from baseline to post-6 months ($p<0.001$). Finally, lbLPTreg group showed significant improvement from baseline to 3 months ($p = 0.026$) and from 3 months to 6 months ($p = 0.003$), with a mean difference of 0.03 s from baseline to post-6 months ($p = 0.026$).

After 6 months, no significant differences between cohorts were observed in the 10-m sprint ($p = 0.241$; ηp² = 0.083, medium effect size). The descriptive statistics for the 10-m sprint across cohorts over the 6-month period can be seen in Figure 4. Within-cohort comparisons revealed that the lbHPT group showed significant improvement from baseline to 3 months ($p<0.001$) and from 3 months to 6 months ($p<0.001$), with a mean difference of 0.08 s from baseline to post-6 months ($p<0.001$). Similarly, lbLPTcomp group showed significant improvement from baseline to 3 months ($p<0.001$) and from 3 months to 6 months ($p<0.001$), with a mean difference of 0.04 s from baseline to post-6 months ($p<0.001$). Finally, lbLPTreg group showed significant improvement from baseline to 3 months ($p<0.001$), although no significant differences from 3 to 6 months ($p>0.999$) and from baseline to post-6 months ($p = 0.226$).

After 6 months, significant differences between cohorts were observed in the YYIRT ($p = 0.026$; ηp² = 0.198, large effect size). Specifically, the lbLPTreg group showed significantly smaller values compared to both the lbHPT group ($p = 0.022$; $d = 1.171$, large effect size) (Figure 5). The descriptive statistics for the COD deficit across cohorts over the 6-month period can be seen in Figure 3. Within-cohort comparisons revealed that the lbHPT group showed significant improvement from baseline to 3 months ($p<0.001$) and from 3 months to 6 months ($p<0.001$), with a mean difference of 115.7 m from baseline to post-6 months ($p<0.001$). Similarly, lbLPTcomp group showed significant improvement from baseline to 3 months ($p<0.001$) and from 3 months to 6 months ($p<0.001$), with a mean difference of 115.0 m from baseline to post-6 months ($p<0.001$). Finally, lbLPTreg group showed significant improvement from baseline to 3 months ($p<0.001$) and from 3 months to 6 months ($p = 0.018$), with a mean difference of 24.0 m from baseline to post-6 months ($p = 0.045$).

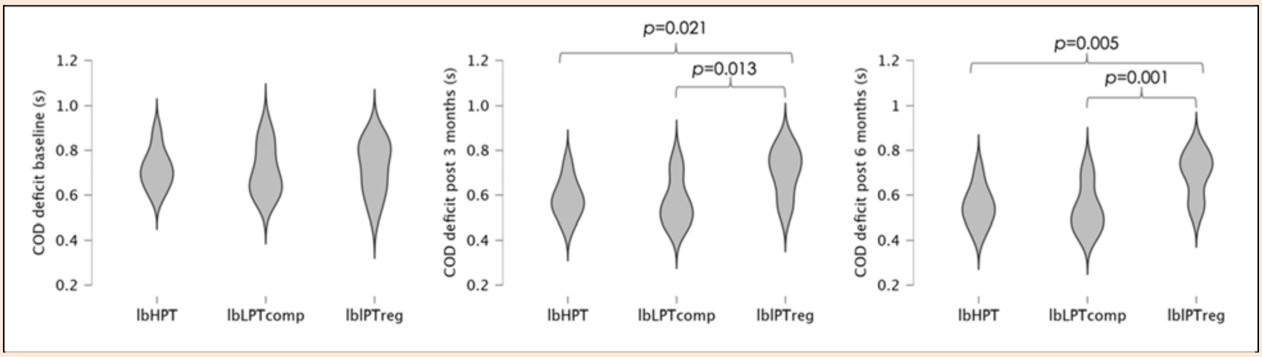

Figure 3. Violin plots of the 5-0-5 change-of-direction deficit (COD deficit) at baseline, and at 3- and 6-month follow-ups for each cohort. lbHPT: later-born players who played above the median playing time per player per team; lbLPTcomp: later-born players who played below the median playing time per player per team and received compensatory training; lbLPTreg later-born players who played below the median playing time per player per team and did not receive compensatory training.

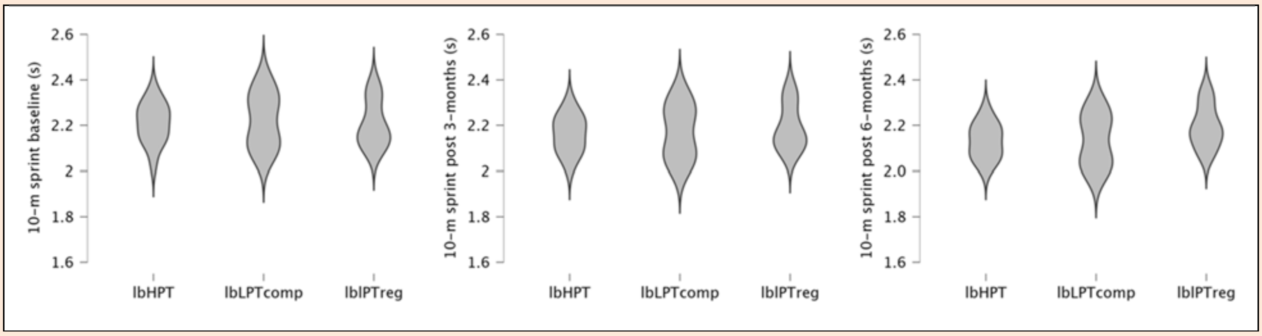

Figure 4. Violin plots of the 10-m sprint test at baseline, and at 3- and 6-month follow-ups for each cohort. lbHPT: later-born players who played above the median playing time per player per team; lbLPTcomp: later-born players who played below the median playing time per player per team and received compensatory training; lbLPTreg later-born players who played below the median playing time per player per team and did not receive compensatory training.

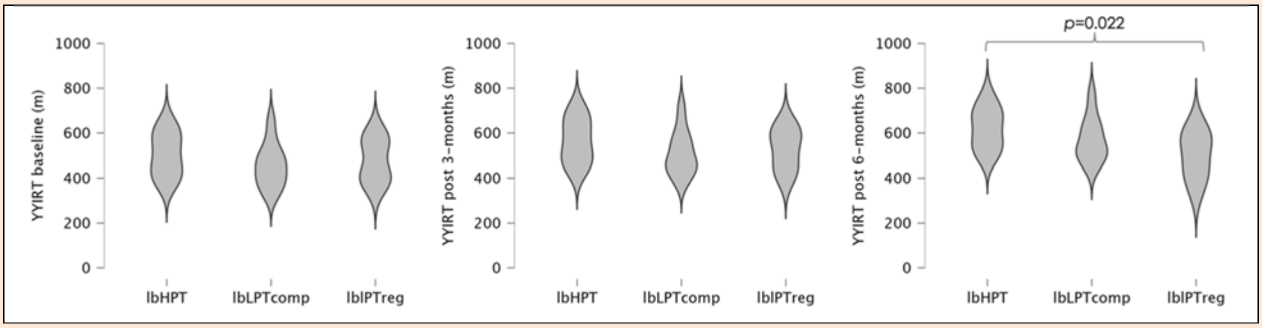

Figure 5. Violin plots of the Yo-Yo Intermittent Recovery Test – level 1 (YYIRT), at baseline, and at 3- and 6-month follow-ups for each cohort. lbHPT: later-born players who played above the median playing time per player per team; lbLPTcomp: later-born players who played below the median playing time per player per team and received compensatory training; lbLPTreg later-born players who played below the median playing time per player per team and did not receive compensatory training.

Discussion

The results of this study are noteworthy and suggest that, within the given context, implementing compensatory training for later-born players -who typically receive less playtime- may help to mitigate, to some extent, the performance gap between them and their teammates with more minutes over the course of a season. The study found that, while the group receiving compensatory training and fewer minutes did not exhibit significant differences in key basketball performance outcomes compared to their teammates with more playtime, the group without compensatory training experienced a meaningful increase in the gap over the 6-month evaluation period. Specifically, they showed significantly lower performance in technical skill tests, aerobic capacity, and COD ability after the 6 months.

There is a lack of evidence regarding the impact of match play accumulated over the season on technical development. However, a previous study suggested that training duration is unlikely to cause maladaptations in talent development programs for elite youth basketball (Brownlee et al., 2018). Despite this, considering that matches involve maximal effort and increased demands for technical application, a growing performance gap among players due to match play may impact their development potential. This was observed in the current study, where the lbLPTreg group showed progressive improvement in LSPT performance over the 6-month period. However, by the end of the 6 months, the differences between the lbLPTreg and the lbLPTcomp groups became significant, suggesting a smaller magnitude of improvement in the lbLPTreg cohort. In the specific context of only three training sessions per week, additional match participation may play a significant role in increasing exposure to various tactical and technical scenarios. For instance, a previous study suggests that more hours of play, but not practice, between ages 6-12 differentiated elite youth players who progressed to professional status (Ford et al., 2009). Additionally, accumulated practice seems to be key to developing expertise (Helsen et al., 2000). Since small-sided games played during the two additional weekly sessions totaled about 30 minutes per week of high-demand play with significant individual participation, they may serve as a potential method to improve technical skills (Clemente and Sarmento, 2020). A previous systematic review highlighted the effectiveness of smaller formats, such as 2v2 and 3v3, in enhancing technical competencies compared to other training approaches (Clemente et al., 2021b).

This study also observed that the COD deficit was another key outcome where the lbLPTreg group lagged, failing to show similar progress to the lbLPTcomp and lbHPT groups. A previous study (Nobari et al., 2020) showed that accumulated training workload parameters correlate with changes in anaerobic power and change of direction ability in elite youth players. Given the specific demands of matches, the occurrence of intense playing and tactical scenarios can increase the frequency of turns and COD, potentially contributing to skill acquisition in this area.

The evidence of compensatory training enhancing the progression of this skill, compared to players with higher play volumes, supports previous research suggesting that small-sided game drills can improve agility and COD abilities in youth players (Chaouachi et al., 2014). Specifically, in small-sided games formats like those implemented in this study (Merks et al., 2022), the frequency of turns can be higher, challenging players to improve this skill. Moreover, the cognitive component may also play a role, as small-sided games can enhance perception and reaction, which are factors known to improve COD, as observed in a previous study (Young and Rogers, 2014).

The progression of aerobic capacity, measured using the YYIRT, also showed significant differences between cohorts over the 6 months. Specifically, the lbLPTreg group showed significantly lower aerobic capacity than the lbHPT cohort after 6 months, while no differences were observed between the lbHPT and lbLPTcomp cohorts. A previous study suggested that greater accumulated match play time is associated with higher aerobic capacity in youth players (Silva et al., 2022). Another study (Nobari et al., 2021) revealed that accumulated training workload over a season is associated with changes in aerobic capacity and other physiological variables in young male players. It was observed that compensatory training based on small-sided games effectively maintained progress in aerobic capacity, aligning with the improvements seen in players with more minutes of play. Small-sided games have consistently been shown to effectively target aerobic power due to their physiological demands (Hill-Haas et al., 2011), making them particularly effective in enhancing aerobic capacity in youth players, even when compared to other analytical training methods (Clemente et al., 2023).

The progression in the 10-meter sprint time over the season was the only variable where no differences between cohorts were observed, with all groups showing positive improvement throughout the season. Given that sprinting is a highly refined skill, compensatory training may have limited impact compared to the skill itself, particularly when sprinting near maximum effort. For instance, submaximal sprinting, as typically occurs in small-sided games, may not be sufficient to improve maximal sprint speed, as suggested by previous studies indicating that sprinting at least 90% of maximal speed is necessary for such improvement (Haugen et al., 2014). As such, compensatory training based on small-sided games may not be particularly effective, as these games are played in small spaces with limited opportunities for sprinting (Castagna et al., 2017). Furthermore, the more analytical training contexts at the clubs, particularly for sprinting, may have been sufficient to ensure consistent progress across the cohorts.

Despite the interesting findings into the impact of compensatory training on player development, some limitations must be considered. The relatively small sample size, the implementation in males and the use of only three training sessions per week may limit the generalizability of the findings to broader populations and sexes or different training frequencies. Moreover, implementing this design in a real-world context also presents challenges, particularly the lack of standardization in the remaining training sessions conducted by the teams. Although these sessions were similar, they were not explicitly identical, which could potentially influence the final results. Future research could explore the impact of varying training frequencies and durations, as well as the role of match play intensity, to better understand the relationship between playtime and skill acquisition in youth basketball. Furthermore, longitudinal studies that track player development over multiple seasons would help clarify whether the benefits of compensatory training persist beyond the six-month period evaluated in this study.

The findings of this study suggest that compensatory training, particularly through small-sided games, can help mitigate the performance gap between later-born players and their teammates with more playtime. Incorporating additional training based on game scenarios, such as small-sided games, can enhance individual participation, promoting tactical development while also providing specific stimuli to support physical development. Coaches working with youth basketball teams may consider implementing additional small-sided game sessions for later-born players with fewer minutes of play to enhance technical skills, aerobic capacity, and change of direction abilities. These training sessions can be integrated within existing schedules, as they offer an efficient way to address key performance deficits without requiring significant changes to the overall training structure. However, it is also important to carefully manage this additional training to avoid exposing players to fatigue, which could ultimately affect their performance.

Conclusion

This study shows that compensatory training, particularly through small-sided games, can effectively support the development of later-born players who receive fewer minutes of play. While the compensatory training group showed improvements in technical skills, aerobic capacity, and change of direction ability, those without compensatory training experienced a significant gap in performance over time. These findings suggest that integrating small-sided games into training can help bridge the performance gap between players with varying levels of playtime, promoting more balanced development across the team. Further research is needed to explore the long-term effects and optimize training protocols for players with limited match play.

Acknowledgements

The experiments comply with the current laws of the country where they were performed. The authors have no conflict of interest to declare. The datasets generated during and/or analyzed during the current study are not publicly available but are available from the corresponding author who organized the study.

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Key points

- Compensatory Training with Small-Sided Games significantly improved physical fitness and technical skills in later-born youth basketball players with less match play.
- Later-born players in the compensatory training group performed similarly to their older peers in key physical and technical assessments after 6 months.
- Twice-weekly small-sided games helped bridge the development gap, enhancing aerobic capacity, sprint performance, and change of direction abilities.

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