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Section: Original Investigation

Article Title: Effects of Ball-Drills and Repeated Sprint Ability Training in Basketball Players

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Abstract

Purpose. The aim of the study was to investigate the effects of ball-drills and repeated sprint ability training during the regular season in basketball players. **Methods**. Thirty players were randomized into 3 groups: ball-drills training (BDT, n=12; 4x4min, 3 vs 3 with 3min passive recovery), repeated sprint ability training (RSAT, n=9, 3x6x20m shuttle running with 20-sec and 4-min recovery) and general basketball training (GBT, n=9, basketball technical/tactical exercises), as control group. Players were tested, before and after 8 weeks of training using the following tests: $\dot{V}O_{2max}$, Squat Jump (SJ), Counter Movement Jump (CMJ), Yo-Yo Intermittent Recovery Test level 1 (Yo-Yo IR1), Agility T-test, line drill test, 5/10/20 m sprints, and blood lactate concentration (BLC). A custom-developed survey was used to analyze players' technical skills. **Results**. After training significant improvements were seen in Yo-Yo IR1 (BDT: p=0.014, ES±90%CI=0.8±0.3; RSAT: p=0.022, ES±90%CI=0.7±0.3), the agility T-test (BDT: p=0.018, ES±90%CI=0.7±0.5; RSAT: p=0.037, ES±90%CI=0.7±0.5), and the line drill test (BDT: p=0.010, ES±90%CI=0.3±0.1; RSAT: p<0.0001, ES±90%CI=0.4±0.1). In the RSAT group only 10-m sprint speeds (p=0.039, ES±90%CI=0.3±0.2) and BLC (p=0.004, ES±90%CI=0.8±1.1) were improved. Finally, technical skills were increased in BDT regarding dribbling (p=0.038, ES±90%CI=0.8±0.6), shooting (p=0.036, ES±90%CI=0.8±0.8), passing (p=0.034, ES±90%CI=0.9±0.3), rebounding (p=0.023, ES±90%CI=1.1±0.3), defense (p=0.042, ES±90%CI=0.5±0.5), and offense (p=0.044, ES±90%CI=0.4±0.4) skills. **Conclusions**. BDT and RSAT are both effective in improving the physical performance of basketball players. BDT had also a positive impact on technical skills. Basketball strength and conditioning professionals should include BDT as a routine tool to improve technical skills and physical performance simultaneously throughout the regular training season.

Key-words. Physical fitness, technical skills, regular season, testing, conditioning.

INTRODUCTION

Basketball is considered an intermittent high intensity sport that heavily stresses both aerobic and anaerobic metabolic systems[1]. Although basketball is thought to be mainly dependent on players' anaerobic capacity, high aerobic fitness is also crucial to performance[2]. Since physical demands in basketball are so diverse, coaches aim to simultaneously optimize physical fitness[3] and neuromuscular strength[4,5]. Hence, according to Hoffman et al.[6], this provides a complex range of variables to be considered when developing training programs and can often lead to confusion and misuse of training modalities, particularly in the development of aerobic, anaerobic**,** and technical conditioning[6]. However, the design of such training sessions requires precise knowledge of the physiological qualities associated with different training stimuli. For these reasons, coaches need to design training protocols properly with strong evidence-based support.

Ball-drills and repeated sprint ability training have begun to be widely used by coaches to improve physical fitness[7]. Ball-drills training consists of a series of short duration matches with a small number of player**s** and which replicate match-like technical/tactical and physiological demand**s**, fostering time efficiency and players**'** motivation[7]. A number of studies specifically investigated the physiological demand changes during ball-drills training in basketball[7-12]. In particular, it was observed that maturation status[11], limitation of the number of dribbles[12], training regimens[12], the number of players[8, 11]**,** and the playing position[10] of involved the players represent the key factor**s** in to determin**ing** training intensity in ball-drills. Moreover, it has been suggested that this type of training improve specific technical skills in all playing position**s** [10,13]. Repeated sprint ability training consists of the reiteration of maximal sprints with incomplete recovery in order to improve sprint performance in general, as well as to efficiently recover and reproduce performance in subsequent sprints[14]. Several studies investigated the use of repeated sprint ability training in basketball practice[15-17]. In particular, it was observed that this type of training was correlated with maximal jump performance[15] and with a potential role in the development of repeated sprint ability[16]. Moreover, it was observed that different repeated sprint ability training modalities were effective in improving jump performance and aerobic fitness among basketball players[17]. While ball-drills and repeated sprint ability training have been considered valuable training methodologies in basketball, no previous studies have compared their effects on physical, physiological, and technical demands, thus calling for further investigation in this area. Therefore, the aim of this randomized controlled trial was to compare both ball-drills and repeated sprint ability training with respect to the normal training routine practice during a regular basketball regular season. Our rationale for selecting these training methodologies was because basketball coaches use these two practices drills the most for the improvement of physical, physiological and technical performance.

METHODS

Participants

Participants were recruited from 2 basketball teams that played at a semi-professional collegiate level. Inclusion criteria were age ≥18 years and practicing 3 times a week for ≥2 hours. The exclusion criterion was a history of lower extremity injury or surgery in the 6 months before the experiment. An exercise physician screened participants for eligibility. Thirty-six players (age: 19±1 year; height: 1.82±0.07 m, body mass: 74±10 kg; basketball training experience: 10±2 years; weekly training volume 6±2 hours) were screened and deemed eligible for participating in the study. A computerized random group allocation was performed to generate three groups: Ball-drills Training (BDT), Repeated Sprint Ability Training (RSAT), and General Basketball Training (GBT), which served as control group. All players were blinded to the aim of the study. Twelve players were allocated to BDT, 12 to RSAT, and 12 to GBT. The players of the two teams were allocated in an equal number to each training intervention group. Moreover, they were matched according to age, height, and body mass. Thirty players completed the study and 6 were not included in data analysis. Reasons for this exclusion were a training attendance of less than 90% (RSAT, n=2; GBT, n=2) and medical problems unrelated to the study (RSAT, n=1; GBT, n=1) (Figure 1). Before taking part in the experimental sessions, participants were fully informed about the procedures: a filled-out informed consent form outlining the study protocol benefits and risks of participating was obtained from each participant. The study protocol was approved by the Institutional Ethics Review Committee of the Università degli Studi di Milano in accordance with current national and international laws and regulations governing the use of human subjects

(Declaration of Helsinki II). All participants were aware that they could withdraw from the study at any time without penalty. Participants were requested to avoid physical activity other than their normal routine, as well as to maintain their usual diets for the duration of the study.

Study Design

This was a 3-arm parallel group randomized controlled trial. The study procedure was performed during the regular season which lasts October to December. Participants were tested before (PRE) and after (POST) 8-weeks of training in terms of anthropometrics, maximal aerobic power assessment ($\dot{V}O_{2max}$), Squat Jump (SJ), Counter Movement Jump (CMJ), Yo-Yo intermittent recovery test Level 1 (Yo-Yo IR1), agility T-test, line drill test, 5/10/20 m sprint, 20 m shuttle run, and technical assessment.

Methodology

Anthropometric assessment

Height was measured to the nearest 0.1 cm and body mass to the nearest 0.1 kg (Seca 217, Vogel & Halke, Hamburg, Germany). Thigh circumference was measured using an ergonomic measuring tape at the midpoint between the inguinal crease and the proximal margin of the patella (Seca 203, Vogel & Halke, Hamburg, Germany). Pectoral, abdominal, and thigh skinfolds were taken using a caliper (Holtain Ltd, Crymych UK) and recorded to the nearest 0.1 mm, for 3 times at each anatomic point. The average was used for data analysis. Jackson and Pollock's equation[18] was used to calculate body density, and Siri's two-compartment formula[19] was used to calculate the percentage of body fat from body density.

Maximal aerobic power assessment

Oxygen consumption ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$), and pulmonary ventilation ($\dot{V}E$) were measured on a breath-by-breath basis (Quarkb2 Cosmed, Rome, Italy) during a graded ramp treadmill test (Mod. 770S, RAM Medical and Industrial Instruments & Supplies, Germany), set a 1% gradient. The protocol consisted of 5 min at 8 km·h^{-1} followed by a constant speed increment of 1 km·h^{-1} per minute until exhaustion. Achievement of $\dot{V}O_{2max}$ was considered as the attainment of at least two of the following criteria: i) a plateau of $\dot{V}O_2$ despite increasing speed; ii) a respiratory exchange ratio above 1.1; and iii) a HR of ±10 bpm of age-predicted maximal HR (220-age). Treadmill speed at exhaustion was considered as the maximal speed. HR was recorded during the entire test by a HR monitor (Polar RS800, Polar Electro 2011, Kempele, Finland). Maximal HR at exhaustion was considered as HR_{max}. Ventilatory threshold (VT) was calculated according to a combined method described by Gaskill et al.[20] and expressed as a percentage of the $\dot{V}O_{2max}$ (%$\dot{V}O_{2max}$). Blood Lactate Concentration (BLC) (Lactate Pro® LT 1710 Arkray Factory Inc., Shinga, Japan), was obtained by small earlobe sampling two minutes after exhaustion.

Vertical jump assessment

Series of 3 SJs and 3 CMJs were performed on a force platform (model Quattro Jump, Kistler, Winterthur, Switzerland). Before testing, participants performed 15 minutes of standardized warm-up, consisting of 10 minutes of running on a treadmill at 8-10 $km \cdot h^{-1}$ with several submaximal jumps to familiarize with the jump technique. Each participant then performed 3 trials for each jump; 90 seconds and 3 minutes of passive recovery between each repetition and series, respectively, was provided. Take-off was strictly monitored by allowing no preliminary steps or movements. SJs and CMJs not meeting these criteria were repeated. The force platform accurately recorded take-off and landing time and this allowed for the assessment the duration of the flight phase and hence the calculation of CMJ and SJ height using the equation proposed by Bosco et al.[21]. The best jump from each series was used for analysis.

Yo-Yo intermittent recovery test level 1

The Yo-Yo IR1 was administered according to the guidelines proposed by Bangsbo et al.[22] and consisted of repeated 2×20m shuttle runs followed by a 10sec active recovery (2×5m of jogging) at a progressively increased speed controlled by an audio signal from a tape recorder until exhaustion. When a participant failed to reach the finishing line on time twice, the total covered distance was considered as the test score.

Agility T-test

The agility T-test was administered according to the guidelines proposed by Semenik[23]. All times were recorded using an electronic twin beam photocell system (Microgate, Bolzano, Italy). Participants performed 3 trials with a 3min recovery between each trial. The best trial was used for analysis.

Line drill test

The line drill test was administered according to the guidelines proposed by Semenik[24]. All times were recorded using an electronic twin beam photocell system (Microgate, Bolzano, Italy). Participants performed 3 trials with a 3min recovery between each trial. The best trial was used for analysis.

5m, 10m and 20m sprint

Participants performed 3 trials for each 5m, 10m and 20 m sprint with 20 seconds of recovery between sprints and 3min between each trial[25]. All times were recorded using an electronic twin beam photocell system (Microgate, Bolzano, Italy). The best sprint was used for analysis.

20m shuttle run

The 20m (10+10m) shuttle run test consisted of maximal speed linear runs with a 180° change in direction at the 10m mark from the starting line. Participants were required to start from a specific line, sprint for 10m to reach and touch a 10m line with a foot and to turn and come back to the starting line as fast as possible. After 20sec of passive recovery, participants repeated the run. Participants performed 3 trials with a 3min recovery between each trial. The best trial was used for analysis.

Technical assessment

The technical assessment was developed by members of the Italian Basketball Federation Coaches Committee who have more than 10 years of experience. Based on their coaching experience, they assumed that specific technical skills would have to be evaluated during a standard 5 vs 5 basketball competition. Therefore, they divided players' technical skills during a match into 6 individual technical items: dribbling, shooting, passing, rebounding, defense, and offence skills (i.e. the ability to sustain and effectively contribute to the team's offence tactic). Moreover, they further divided the players' technical skills into six different technical abilities. At each feature they gave a score: 1) weakness; 2) progressing; 3) satisfactory; 4) strength; 5) exemplary. The total score for each item was 30. Using this survey tool, players' technical skills before and after the 8-week training intervention were evaluated. Four basketball coaches that were blinded to the study's aims, participants, allocations, and protocol had to fill out the survey tool by assigning a performance score **to** each individual. In particular, each coach had to focus for at least 10min on a specific player and fill out the survey evaluating the players separately and independently from the others. For each single item a final score was given using the average score from the 4 coaches. In order to assess test-retest reliability of the survey tool, 2 standard 5 vs 5 matches between players allocated to the different training intervention were performed 1 week apart. For each player the average scores were compared using the interclass correlation coefficients (ICCs).

Training

Participants trained 3 times a week from 6:00 to 8:00 pm. Each training session consisted of these main sections: i) briefing with coaches and organization of the training session (10 min); ii) warm-up (20 min); iii) the training intervention (i.e. BDT, RSAT, GBT) (20 min); iv) technical/tactical exercises for the preparation for the weekend match (30 min); vi) cool-down (10 min). Moreover, players had 15 min before and after the training session to change and take a shower. Training interventions consisted of:

I. BDT: 3 vs 3 half-court match consisting of three 4-minute bouts separated by 1-min **recovery** periods.
II. RSAT: 3 series of 6 repetitions of 40m (20+20m) shuttle run at a maximal intensity with 20sec of passive recovery between the repetitions and 3min the between series.
III. The GBT group carried out the standard training routine consisting of i) basic basketball movements **(**offensive, ready stance, running, changing direction/speed, stopping, pivoting**,** and jumping**)**; ii) specific basketball movements (triple threat position, pivot, face up or one- and

two-phase stop); iii) basketball technique fundamentals (dribbling, passing, and shooting); iv) basic defensive movements (defensive stance, defensive slide, denial defense, and box-out).

Training was matched between the 3 conditions and the Borg CR-10 category-ratio scale was selected to rate the perceived intensity of exertion[26]. Blood Lactate Concentration (BLC) was assessed 2min after training sessions at PRE and POST 8 weeks of training.

Statistical analysis

Descriptive statistics [mean±standard deviation (SD)] for the outcome measures were calculated. The normality of the distribution of the participants' characteristics at baseline was checked using the Kolmogorov-Smirnov test. PRE and POST intervention intra- and inter-group differences between BDT, RSAT, and GBT for all variables considered were checked using two-way analysis of variance with the Bonferroni post-hoc test. The ICCs were used to establish intersession repeatability of the single items of the technical assessment form, where $r < .50$ was classified as weak, 0.50 to 0.79 as moderate, and ≥0.80 as strong. The level of statistical significance was set at $p < 0.05$. Statistical analyses were performed using commercially available statistical software (SigmaStat, vers. 3.11, Systat Software Inc., USA). The magnitude of change after the training (i.e. the difference between groups**)**, was analyzed by means of a modified statistical spreadsheet[27]. This spreadsheet calculated the standardized differences or effect sizes (ES) with precision of estimated by the 90% confidence intervals (90%CI) using the pooled pre-training SDs. Threshold values for ES statistics were: ≤0.2, trivial; >0.2, small; >0.6, moderate; >1.2, large; ≥ 2.0, very large[28].

Results

There was no difference between the 3 training groups in terms of demographic, anthropometric, and performance/technical assessment at PRE. Mean overall adherence of players that completed the study was 94%. No significant differences in the means of the session-RPE between the 3 training interventions was noted (BDT: 5.5 ± 1.3; RSAT 6.1 ± 2.7; GBT: 4.7 ± 1.1). At the end of the training program thigh muscle area significantly increased (interaction: p=0.034; time: p=0.040; group: p=0.026) and HR_{max} was reduced (interaction: p=0.046; time: p=0.046; group: p=0.003) only in the

BDT group, whereas no significant PRE to POST differences were seen in the RSAT and GBT groups (Table 1).

Table 2 shows the PRE and POST performance and the statistical significance and effect sizes of the Yo-Yo IR1, agility T-test, line drill test, 5-10-20m sprints, and the 20m shuttle run for the BDT, RSAT and GBT groups. At the end of the training protocol in both BDT and RSAT groups, significant improvements in the Yo-Yo IR1 (BDT: interaction, p=0.003; time, p=0.038; group, p<0.001; RSAT: interaction, p=0.0009; time, p<0.0001; group, p=0.047), agility T-test (BDT: interaction, p=0.045; time, p=0.006; group, p=0.029; RSAT: interaction, p=0.024; time, p=0.007; group, p=0.45), and line drill test (BDT: interaction, p=0.043; time, p=0.014; group, p=0.006; RSAT: interaction, p=0.006; time, p=0.001; group, p=0.004) were retrieved. Moreover, in only the RSAT group, 10m sprint velocity significantly increased (interaction: p=0.037; time: p=0.024; group: p=0.015). No PRE to POST differences were found in GBT group. Table 2 shows that the BDT group increased the distance covered during in Yo-Yo IR1, with respect to both GBT and RSAT. No significant post-hoc inter-group comparisons regarding the agility T-test, line drill test, 5-10-20m sprints, and 20m shuttle run were found in the BDT, RSAT and GBT.

Data of BLC measured 2min after BDT, RSAT, and GBT-specific training are reported in Figure 2. Two-way analysis of variance results showed no significant interactions, time and group results for both BDT and GBT. However, two-way analysis of variance of RSA was significant (interaction: p=0.008; time: p=0.006; group: p<0.0001). Post-hoc inter-group comparisons with Bonferroni’s multiple comparisons test showed significantly lower BLC values in BDT with respect RSAT, as well as with respect to GBT at PRE. At POST conditions for the BDT group, BLC reduced from 5.04 $mmol \cdot l^{-1}$ to 4.03 $mmol \cdot l^{-1}$ (-20.1%, p=0.045, ES±90%CI=0.5±0.3, small), and for the RSAT group, BLC improved from 8.80 $mmol \cdot l^{-1}$ to 11.13 $mmol \cdot l^{-1}$ (+26.4%, p = 0.024, ES±90%CI = 0.8±1.1, moderate). No differences for GBT between PRE and POST were noted. Comparisons between BDT and RSAT (p<0.0001, +36.2, ES±90%CI= ≥2.0±0.5, very large), and between RSAT and GBT (p<0.0001, +33.5, ES±90%CI= ≥2.0±0.5, very large) were noted. No post-hoc intergroup differences between BDT and GBT were found.

The ICCs (1,1) of the single items of technical evaluation form were 0.91 (dribbling), 0.83 (shooting), and 0.82 passing), 0.88 (rebounding), 0.89 (defensive skills), and 0.85 (offensive skills), respectively. At the end of the training protocol two-way analysis of variance showed BDT displayed significant improvement in dribbling (interaction: $p=0.001$; time: $p=0.006$; group: $p=0.035$), shooting (interaction: $p<0.0001$; time: $p<0.0001$; group: $p=0.038$), passing (interaction: $p=0.007$; time: $p=0.0002$; group: $p=0.038$), rebounding (interaction: $p=0.011$; time: $p=0.0003$; group: $p=0.037$), defense (interaction: $p=0.004$; time: $p<0.0001$; group: $p=0.002$), and offence (interaction: $p<0.0001$; time: $p<0.0001$; group: $p=0.009$) skills, whereas no significant differences were noted in the RSAT and GBT groups. Table 3 shows the post-hoc inter-group comparisons with statistical significance and effect sizes of all the single items from the technical evaluation form.

Discussion

To the best of our knowledge, this is the first intervention study comparing the effect of BDT, RSAT and GBT on physical, physiological and technical basketball demands. Comparisons of the PRE and POST intervention scores of the Yo-Yo IR1, agility T-test, and line drill test showed significant improvements in both BDT and RSAT groups, whereas improvements of 10m sprint and BLC were found in only RSAT group. Regarding technical skills, only BDT showed improvements in all the technical skills analyzed by the survey. With regards to the GBT group, no remarkable improvements were in any of the items.

After the intervention we observed no significant improvements in $\dot{V}O_{2max}$, VT, and BLC in any of the groups during the maximal treadmill test. As the study protocol was carried out during the regular season, we could reason that athletes were maybe already conditioned and improvement margins were limited for further specific $\dot{V}O_{2max}$ improvements[29]. We could also hypothesize that this laboratory test is less sensitive to detecting training-induced improvements in aerobic performance as suggested by Bangsbo et al.[22]. Moreover, Castagna et al.[2] detected that the relationship between speed at $\dot{V}O_{2max}$ and Yo-Yo IR1 test performance was influenced by other components of aerobic performance, then solely $\dot{V}O_{2max}$. In their study, they observed the Yo-Yo IR1 test performance was also inversely related to the percentage of $\dot{V}O_{2max}$ attained at VT, partially supporting the hypothesis of a more complex influence of aerobic-components on Yo-Yo IR1 test performance[2].

In parallel to the laboratory tests, we performed a battery of field-based performance tests commonly used by basketball coaches to evaluate physical performance. The improvement in aerobic performance measured by a field test was already found by Delextrat and Kraiem[9]. For this reason, in order to assess the players' aerobic capacity, we used the Yo-Yo IR1 in our experimental protocol. After 8 weeks of training we observed an improvement in the distance covered during the Yo-Yo IR1 of 20.2% and 27.7% in BDT and RSAT, respectively. Moreover, BDT showed improvements in T-test and line drill test results, whereas RSAT showed improvements in the T-test, line drill test, and 10m sprint. Our results are consistent with the study of Balciunas et al.[30], in which BDT training and RSAT resulted in an improvement in linear sprinting, change of direction, and multidirectional movement pattern performance. For this reason, prescribing training in accordance with the competition field-based performance test is fundamental to prepare players to respond adequately to these requirements. In fact, during a competition, players will never perform high-intensity drills for more than 10-15 seconds or run more than 20m without change in direction[1].

In addition, we investigated the effects of BDT and RSAT on vertical jump performance as this is one of the most prevalent acts performed by basketball players. According to Ziv and Lidor[31], jumping is part of various defensive and offensive maneuvers performed by basketball players in matches and practices. Furthermore, in real-match situations, players are required not only to perform a high number of jumps, but also to do them in a competitive and demanding condition[31]. Therefore, improve jumping ability is one of the main goals for players, regardless of their playing position[31]. At the end of our protocol we did not find significant improvements in SJ and CMJ, but on the other hand we did not observe also deterioration of jumping ability, which means that this specific ability during the interventions period was conserved. However, finding comparisons with literature regarding vertical jump performance was difficult. In fact, the multiple testing protocols used in observational and experimental basketball research made it difficult to compare final results[31]. Therefore, we implemented the gold standard measurements for vertical jump performance. On the other hand, we admit that these tests did not mimic basketball-specific jumps and therefore possible training-induced improvements might be not have been detected. Moreover, we did not include any specific training to improve jumping or lower limb strength training in our intervention. In fact, the review of Ziv and Lidor[31], reported the key role of short plyometric training sessions as part of the strength and conditioning program to enhance vertical jump performances in basketball players.

Blood lactate concentration has been frequently measured as a physiological response in basketball players during a match[32]. However, there is a lack of information on the stress imposed on basketball players during different types of training. The BLCs recorded during the BDT in the present study were comparable to those reported during actual matches in previous studies[14]. Moreover, they are similar to those found by Castagna et al.[7] in a previous study, analyzing 3 vs 3 ball-drills (i.e. 6.2±2.3 $mmol \cdot l^{-1}$). This indicates that the BDT implemented in our study stresses both the aerobic and the anaerobic capacity during exercise, enhancing players' lactate clearance during low intensity match phases. On the contrary, RSAT induced a greater accumulation of BLC, indicating that this type of training stresses only the rapid glycolytic energy pathway.

As mentioned above, the novelty of this study relies on assessing specifically whether BDT and RSAT simultaneously improved technical skills directly evaluated during short custom-designed matches. Our results showed a significant improvement in technical skills in the BDT group rather than the RSAT and GBT groups, due to the highly increased basketball-specific activity (i.e. involvement with the ball) during match simulation. In fact, there are several factors that could influence the physiological and technical demands of BDT and thus the desired training stimulus from match-based conditioning. According to this, Klusemann et al.[11] studied the combination of player number, the court size, and the work-to-rest ratio in their controlled experimental trial[11]. The number of players had the largest effect on all technical demands, with the total number of technical elements per player substantially higher in 2 vs 2 matches compared to 4 vs 4 matches. The court size was less influential on the technical demands, with the half-court matches eliciting 20% more total technical elements and passing than full court matches. The work-to-rest ratio had a small effect on overall technical demands with more technical elements in 4×2.5min type matches. However, to our knowledge, only one study examined the effects of BDT on technical demands. Delextrat and Martinez[10] studied the effects of match-based conditioning in technical parameters in their randomized parallel matched-group experiment. They found an effect of time on defensive agility (+4.5%) and shooting skills (+7.4%) with significantly better performances achieved in the post- compared to pre-test[10]. However, this study analyzed a limited number of technical actions and did not assess them during a competition. For this reason, in order to further investigate these aspects, we created an assessment scale that was developed to analyze players' technical skills during a simulated a 5 vs 5 match finding an improvement in dribbling, shooting, passing, rebounding, defensive, and offensive skills. According to the authors' knowledge, a specific validated scale to assess basketball technical skills is still not available in the scientific literature. Therefore, in order to evaluate players' technical skills, we built our own technical evaluation form. We are aware that this is a limitation of the study because our evaluation is subjective. On the other hand, we tried to improve the reliability of our assessment tool by hosting 2 matches 1 week apart and comparing the scores using ICCs. Moreover, we fixed specific items and chose external qualified observers and applied the same method as the Likert scale. Therefore, further studies involving a similar approach are need. It would be possible in the future to retrieve more information about players' technical skills through coaches rating videos of the same session multiple times. In addition, it would be possible to compare the technical skills performance with some game statistics.

Conclusions

The finding of this study provides evidence that BDT and RSAT were both effective in improving the specific physical performances of basketball players. However, BDT training had a positive impact on improving technical skills. Therefore, using BDT during the season would appear more beneficial for basketball players because in addition to similar improvement in physical performance with regard to RSAT**.** BDT increased basketball-specific skills. On the other hand, if RSAT is administered, more intense sessions should be undertaken.

Practical applications

Practical application of this study suggests to use both BDT and RSAT to provide specific physical and physiological conditioning during the season. Moreover, since BDT resembles real-life basketball play it could be used to achieve a parallel improvement in the technical and tactical skills of the players.

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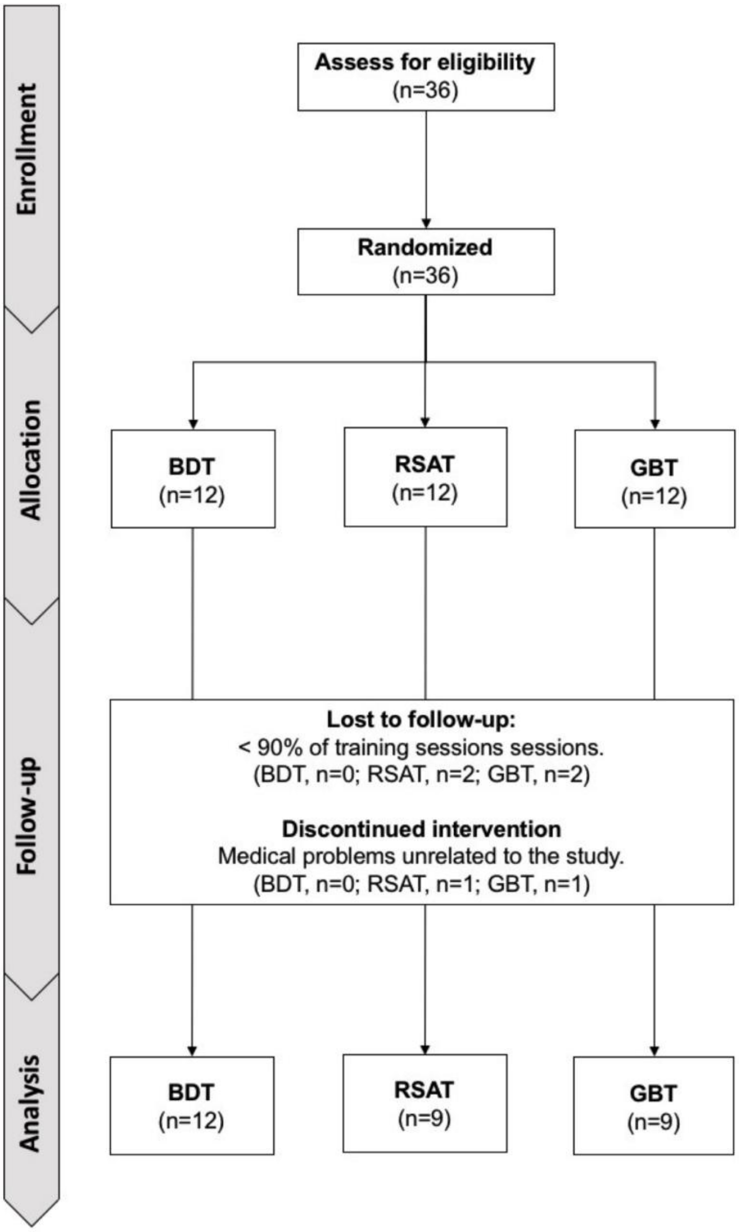

Figure 1. Study flow diagram.

Legend. BDT: ball-drills training; RSAT: repeated sprint ability training; GBT: general basketball training

Player Tecnical Assessment

Player Information

First Name	Last Name
Date of birth	Role
Height	Weight

Dribbling	Shooting	Passing
...... Maintains control	...... Lay-up	...... Timing
......Sees the court	...... 2-point range	......Catching
...... Goes both ways	...... 3 point-range	...... Avoids turnover
...... Handles pressure	...... Catch and shoot	...... 2 handed
...... Speed	...... Shoot off dribble	...... 1 handed
...... Dribbles with purpose	...... Use of weak hand	...... Bounce pass

Rebounding	Defense	Offense
...... Positioning	...... Position	...... Position
...... Anticipates	...... Transition	...... Transition
...... Goes for the ball	...... On ball	...... On ball
......Boxes out	...... Off ball	...... Off ball
...... Find the right spot	...... Closes out	...... Back cut
...... Protect/chins the ball	...... Help	...... Help

(1): Exemplary (2): Strength (3): Satisfactory (4): Progressing (5): Weakness

Overall Strengths

...... Dribbling, ... Shooting; ...... Passing; ...... Rebounding; ...... Defense; ...... Offense

Figure 2. Technical evaluation form.

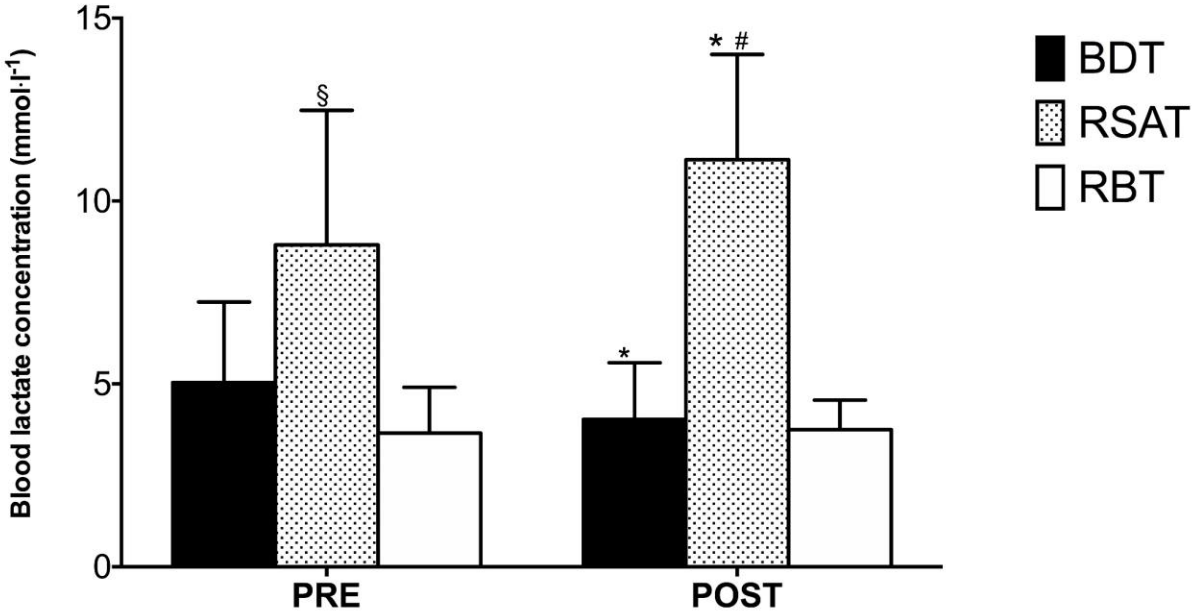

Figure 3. Blood lactate concentration after 2 min recorded during the first and last training session.

Legend. BDT: ball-drills training; RSAT: repeated sprint ability training; GBT: general basketball training; §: significant differences between the groups at PRE; *: PRE to POST significant differences; #: significant differences between the groups at POST.

“Effects of Ball-Drills and Repeated Sprint Ability Training in Basketball Players” by Maggioni MA et al.
International Journal of Sports Physiology and Performance

Table 1. Anthropometric characteristics and treadmill incremental test results.

	Ball Drill Training			Repeated Sprint Ability Training			Regular Basketball Training		
Parameter	**PRE**	**POST**	**ES±90%CI**	**PRE**	**POST**	**ES±90%CI**	**PRE**	**POST**	**ES±90%CI**
BMI ($kg \cdot m^{-2}$)	21.8±2.0	21.9±1.7	0.1±0.6	24.0±3.5	23.1±2.5	0.3±0.5	21.9±2.4	22.4±2.4	0.2±0.7
Fat mass (%)	9.8±2.2	9.6±1.7	0.1±0.8	11.3±5.6	10.5±5.8	0.1±0.6	8.9±3.9	8.7±4.1	0.1±0.5
Thigh muscle area (cm^2)	188±16	194±18*	0.4±0.3	197±19	198±20	0.1±0.7	197±27	201±27	0.1±0.7
HR_{max} (bpm)	196±7	192±8*	0.6±0.3	196±9	194±10	0.2±1.5	193±7	187±10	0.8±1.1
Speed max ($km \cdot h^{-1}$)	16.2±1.6	16.9±1.5	0.4±0.5	16.1±2.6	17.1±1.9	0.4±1.0	16.5±1.2	16.1±1.9	0.3±0.9
$\dot{V}O_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	57.4±6.7	60.2±9.4	0.1±0.4	55.7±7.2	57.5±5.8	0.3±0.5	56.7±2.8	54.2±4.1	0.8±0.5
Blood Lactate ($mmol \cdot l^{-1}$)	7.1±2.1	7.4±1.8	0.1±0.7	7.8±2.3	8.1±1.3	0.1±1.0	7.2±0.8	6.5±2.7	0.2±1.0
VT (%$\dot{V}O_{2max}$)	69.8±8.0	69.6±11.5	0.4±0.7	73.3±6.5	75.3±7.6	0.3±0.5	69.1±6.9	63.5±3.5	0.6±0.8
SJ (cm)	28.0±4.8	28.5±4.2	0.1±0.3	24.7±5.6	24.9±5.2	0.1±0.3	26.5±3.8	26.2±4.6	0.1±0.4
CMJ (cm)	36.1±4.8	35.9±3.5	0.1±0.4	31.1±5.3	31.1±5.9	0.1±0.3	33.5±3.7	32.0±4.9	0.4±0.3

Legend. BMI: body mass index; HR: heart rate; $\dot{V}O_{2max}$: maximal oxygen consumption; VT: ventilatory threshold: SJ: squat jump; CMJ: counter movement jump; *: PRE to POST significant differences.

"Effects of Ball-Drills and Repeated Sprint Ability Training in Basketball Players" by Maggioni MA et al.
International Journal of Sports Physiology and Performance

Table 2. Agility T-test, line drill test, sprints and 20 m shuttle test results.

	Ball Drill Training			**Repeated Sprint Ability Training**			**Regular Basketball Training**		
Parameter	**PRE**	**POST**	**ES±90%CI**	**PRE**	**POST**	**ES±90%CI**	**PRE**	**POST**	**ES±90%CI**
Yo-Yo IR1 (m)	1470±309	1767±349 * #	0.8±0.3	1350±450	1725±479 *	0.7±0.3	1445±420	1505±486	0.1±0.1
Agility T- test (sec)	10.0±0.3	9.7±0.6 *	0.7±0.5	10.0±0.5	9.5±0.7 *	0.7±0.5	9.8±0.2	9.6±0.3	0.7±0.7
Line drill test (sec)	27.9±1.1	27.5±1.1 *	0.3±0.2	28.2±1.4	27.6±1.3 *	0.4±0.4	27.8±0.8	27.6±0.7	0.2±0.4
5 m sprint (sec)	1.06±0.05	1.05±0.05	0.2±0.3	1.08±0.06	1.08±0.06	0.1±0.3	1.04±0.05	1.04±0.50	0.1±0.4
10 m sprint (sec)	1.80±0.07	1.81±0.06	0.2±0.5	1.87±0.10	1.82±0.14 *	0.3±0.2	1.77±0.04	1.78±0.40	0.3±0.6
20 m sprint (sec)	3.15±0.09	3.19±0.13	0.4±0.4	3.20±0.25	3.22±0.22	0.8±0.3	3.10±0.12	3.12±0.30	0.1±0.3
20 m shuttle run (sec)	4.54±0.10	4.23±1.30	0.3±0.7	4.54±0.20	4.58±0.20	0.10±0.2	4.43±0.1	4.43±0.10	0.1±0.3

Legend. *: PRE to POST significant differences; #: significant differences between the groups at POST.

Table 23 Technical assessment results.

	Ball-drills Training			Repeated Sprint Ability Training			General Basketball Training		
Parameter	**PRE**	**POST**	**ES±90%CI**	**PRE**	**POST**	**ES±90%CI**	**PRE**	**POST**	**ES±90%CI**
Dribbling	18.6±4.0	21.9±3.8*#	0.8±0.6	17.0±3.8	17.4±4.1	0.1±0.5	19.0±3.7	19.2±2.4	0.1±0.7
Shooting	19.9±3.4	22.6±3.3*#	0.8±0.8	19.0±2.6	19.5±5.8	0.2±0.6	19.4±3.9	20.1±3.3	0.1±0.5
Passing	12.8±1.8	14.5±1.8*#	0.9±0.3	12.3±2.1	12.6±2.0	0.1±0.7	13.3±1.9	13.4±2.1	0.1±0.7
Rebounding	18.2±3.7	22.3±3.6*#	1.1±0.3	18.1±4.0	18.9±3.8	0.2±1.5	18.3±3.9	18.4±3.6	0.1±1.1
Defence skill	24.5±4.5	26.9±3.9*#	0.5±0.5	23.6±4.1	24.2±4.2	0.1±1.0	23.7±3.2	23.5±3.6	0.1±0.9
Offense skill	19.4±4.0	21.3±9.4*#	0.4±0.4	18.8±7.2	17.2±3.9	0.2±0.5	19.6±3.5	19.7±3.5	0.1±0.5

Legend. *: PRE to POST significant differences; #: significant differences between the groups at POST.