Enhancing high-intensity actions during a basketball game after a strength training program with random recovery times between sets

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Conflict of Interest

There is no conflict of interest.

ABSTRACT

To examine the effects of a strength training program with random recovery times between sets in consideration of several physical parameters, high-intensity actions (HIA), and spatial exploration index during a simulated basketball game. Twenty male basketball players (age: 19.45 ± 4.36 years) were assigned randomly, either to strength training group (n = 10), or a control group (n = 10). The strength training included: parallel back squat and bench press exercises, twice a week for the duration of 10 weeks, with two blocks of 5 sets × 5 repetitions interspersed with variable passive recovery (range = 15–35 sec.) between sets, and constant passive recovery (3-min) between blocks with the load that maximized propulsive power output. The pre- and post-test assessments included jumping (bilateral and unilateral), change-of-direction, straight sprinting, and a 5-on-5 full-court situation. The external training load was assessed using the local positioning system, and the internal load was recorded with the use of individual heart rate monitors. A significant interaction effect (group x time) was observed on countermovement jump (CMJ), unilateral right hops, high-intensity accelerations and decelerations, and peak accelerations and decelerations in the 5-on-5 full-court situation. Relative improvements observed and recorded in the training group on unilateral right hops, accelerations, and decelerations were correlated. Similar results were observed on 0–25m sprints, high-intensity decelerations, peak accelerations, and decelerations. Strength training paired with random recovery times enhanced physical and game-related aspects in the observed basketball players.

Key Words: Repeated power ability, team sports, inertial movement sensors, movement demands, game analysis, high-intensity efforts.

INTRODUCTION

In basketball, players are required to repeatedly perform brief high-intensity actions (HIA) such as sprints, accelerations, decelerations, turns, changes of direction (CODs), and jumps (33). Specifically, a short sprint generally takes place every 21 to 39 seconds (33), and a HIA is repeated every 10 to 20 seconds during a game (33). Despite the fact that the ability to maintain HIA for the entire duration of a game has been identified as an important physical fitness component in basketball, (7) along with other ball sports such as soccer (15), substantial decrements in HIA, mainly in the latter stages of competition (e.g., second half), have been typically reported (33). Thus, training strategies aimed at improving the ability to perform HIA repeatedly throughout competitive games should be included within basketball practice routines and training regimes.

Despite the fact that the origin of the decrements in HIA remain to be fully elucidated, several metabolic, mechanical, and neural factors have been suggested to directly or indirectly mediate most performance decrements in HIA observed in team sports (26). As basketball involves multiple motor demands (e.g., sprinting, jumping, COD, accelerations, and decelerations), training methods are required to ensure enough specific overload of such demands. With training time at a premium, the search for training methods able to concurrently target different physical fitness factors is necessary. In this regard, high-intensity muscle power training performed with incomplete recovery periods between sets (e.g., repeated power ability [RPA]) (27) has been recently proposed as an effective training method to simultaneously improve both isolated HIA (e.g., vertical and horizontal jumps, linear sprinting, and COD) and fatigue resistance during HIA (e.g., repeated sprints and COD) (18,34). For example, a combination of repeated power ability training in the squat exercise with superimposed vibrations and repeated-sprint exercises were substantially more effective in several HIA markers than the performance of repeated-sprint exercises alone by rugby players (34). Furthermore, a strength training intervention developed through the leg-press exercise achieved beneficial effects for repeated-sprint ability and repeated-COD ability in basketball players (18). Both studies used similar strategies to increase the training load through a volume increment maintaining the recovery time between-sets. It is worth noting that HIA are required suddenly during a game setting, and that there is no constant time between these high-intensity efforts (8). However, to the best of our knowledge, there is not yet a study analyzing the effects of manipulating the recovery times between sets during an RPA training regarding physical-fitness performance.

Despite the fact that a vast majority of training interventions have a direct impact on physical fitness tests (13,17,19), their influence on HIA performed throughout a basketball game remains unknown. To our knowledge, there is no study examining how a resistance training strategy can affect both peak performance (e.g., peak acceleration, deceleration, and speed), and frequency of HIA (i.e., number of high-intensity accelerations and decelerations per minute) carried out while playing in a 5-on-5 game situation. Therefore, the main objective of this study was to examine the effect of 10-week training intervention with the load that maximized propulsive power output, and with random recovery times between sets, on physical tests and; physical performance and spatial exploration index during a simulated basketball game.

METHODS

Experimental Approach to the Problem

An experimentally controlled trial with two consecutive measurements was designed for this study. Subjects were randomly divided into the strength training group (n = 10) or control group (n = 10). The training period lasted 10 weeks and was carried out in addition to the regular training sessions. The first two weeks (sessions one to four) served as the players' familiarization with the exercises. The control group only completed regular basketball practices. Before the commencement of the study, a reliability analysis of the physical fitness tests employed in the present investigation was completed by the players (n = 20) who participated in the study. The tests were performed one and two weeks before the commencement of the training period, and one week after the intervention. Physical performance tests were performed under the same environmental conditions (training session time and indoor basketball court). Testing sessions included the following order of tests: anthropometrical measurements, jumping tests (countermovement jump [CMJ], single leg countermovement jumps [SLCMJs]), V-cut test, incremental load tests (parallel back squat and bench press), straight sprinting tests (0–10 and 0–25 m splits time), Yo-Yo intermittent recovery test—Level 1 (Yo-Yo IR1), and 5-on-5 full-court situations. All subjects had previous experience in all test procedures.

Subjects

Twenty male basketball players (from the under-18 age-group up to the amateur senior level) (age: 19.45 ± 4.36 years; height: 183.05 ± 8.58 cm; body mass: 86.36 ± 17.20 kg) volunteered to participate in this study. All players participated on an average of six hours of basketball training (three basketball sessions/week, 90 min/session), and in one to two competitive matches per week. All players had at least one year of experience in strength and power training. Only subjects who participated in at least 90% of the workouts were considered for the purpose of data analysis. Written and informed consent was obtained from all participants' parents, and player approval was obtained before the beginning of this investigation. The present study was approved by the Institutional Research Ethics Committee, and conformed to the recommendations of the Declaration of Helsinki.

Procedures

Incremental Back Squat and Bench Press. The incremental free parallel-back squat and the bench press load tests were used to determine the load that maximized propulsive power output (Loadopt) (30). The parallel-back squats were performed with plantar flexion to finish the movement, but jumping was not allowed. Subjects were instructed to squat until the top of the thighs were parallel to the ground, in a controlled manner, and to perform the concentric phase of each repetition as fast as possible. The parallel-bench press started with the bar at arm's length, and the bar was lowered until the chest was lightly touched without bounding the bar. Subjects were instructed to perform the concentric phase of each repetition as fast as possible without any pauses between the eccentric and concentric phases. The initial load was set at 20 kg for all subjects, and was progressively increased in 10 kg increments until the attained mean propulsive velocity (MPV) was lower than 0.99 $m\cdot s^{-1}$ in the parallel-back squat, and lower than 0.50 $m\cdot s^{-1}$ in the parallel-bench press (30). Thereafter, the load was adjusted with smaller increments

(2.5–5 kg) for each subject individually. For lighter loads (BS = MPV > 1.0 $m \cdot s^{-1}$; BP = MPV > 0.97 $m \cdot s^{-1}$), three attempts were executed at each load: two for the medium (BS = 0.57 $m \cdot s^{-1}$ ≤ MPV ≤ 0.99 $m \cdot s^{-1}$; BP = 0.50 $m \cdot s^{-1}$ ≤ MPV ≤ 0.97 $m \cdot s^{-1}$) and only one for the heaviest loads (BS = MPV < 0.57 $m \cdot s^{-1}$; BP = MPV < 0.50 $m \cdot s^{-1}$) (30). Passive resting pauses were 3-min for the lighter and medium loads, and 5-min for the heaviest loads (30). Only the best repetitions at each load, according to the criteria of highest mean propulsive power output (MPP), were considered for analysis (30). The test was performed using the barbell standard 20-kg (*BOXPT Equipment, Póvoa do Varzim, Portugal*), the barbell velocity was recorded with a SmartCoach Power Encoder linear transducer (*SmartCoach Europe AB, Stockholm, Sweden*), and computed using SmartCoach software into a personal computer (*ASUS, model A541U*).

Training intervention. The subjects included in the strength training group participated in two weekly training sessions prior to in-court training sessions during a 10-week period. The strength training protocol was comprised by two blocks of five sets of five repetitions with variable seconds (range = 15–35) of passive recovery between sets, and 3-min of passive recovery between blocks in the free parallel-back squat and the bench press exercises using the Loadopt. The subjects were instructed to squat until the top of the thighs were parallel to the ground in the parallel-back squat position. The concentric phase was executed as fast as possible, and the eccentric phase was performed at a slower velocity (i.e., self-selected and never exceeding 3-sec) than the concentric phase, without bouncing on the chest (parallel bench press). Three minutes of passive recovery were provided between exercises. After each set, the experimental group was verbally instructed by the certified strength and conditioning coach to perform one of the rest intervals (15, 20, 25, 30, and 35-sec) in a random order. No rest intervals were repeated more than three times. The same individual supervised all training sessions. Strong verbal encouragement was provided to each player. Control group only completed regular basketball in-court training sessions, and they were instructed to avoid strength and power training during the whole experimental period.

Bilateral and Unilateral Countermovement Jumps. CMJs were assessed according to the Bosco Protocol. Subjects performed three successful SLCMJs with each leg in the vertical and horizontal directions. Subjects began with standing on one leg, descending into a countermovement, and then extending the stance leg to jump as far as possible in the vertical and horizontal directions. The landing was performed on both feet simultaneously. A successful trial included hands remaining on the hips throughout the movement, and balance being maintained for at least 3 seconds after landing. If the trial was considered unsuccessful, a new trial was permitted. In the horizontal direction, the subjects started with the selected leg positioned just behind a starting line. The jump height was recorded using an infrared optical system (*OptoJump Next—Microgate, Bolzano, Italy*).

Unilateral Horizontal Jumps. Horizontal jump (HJ) performance (i.e., distance) was assessed as described elsewhere (18). Each test (right and left) was performed 3 times with 30 seconds of recovery between jumps, and 2-minutes between legs.

Speed tests. The average running speeds were evaluated by 10-m (0–10 m) and 25-m (0–25 m) split times.Running times were recorded with 90 cm height photoelectric cells separated by 1.5 m (*Witty, Microgate, Bolzano, Italy*). Each participant performed three trials of running abilities with 2 minutes of rest between each of the trials. Players began each trial in standing position with their feet 0.5 m behind the first timing gate.

Change-of-direction speed (V-Cut test). Players performed a 25-m sprint with 45° COD every 5 m (i.e., four CODs) by stepping between each pair of cones separated by 0.7 m (17,19). The subjects were asked to pass the line indicated on the surface with the entire foot at each turn. V-Cut test total time was recorded with 90 cm height photoelectric cells separated by 1.5 m (*Witty*, *Microgate*, *Bolzano*, *Italy*). Each participant performed three trials change-of-direction abilities with 2 minutes of rest between each of the trials. Players began each trial in standing positions with their feet 0.5 m behind the first timing gate .

Yo-yo intermittent recovery test—Level 1 (Yo-Yo IR1). Before the experimental period, the Yo-Yo intermittent recovery test was carried out to estimate maximal aerobic speed (MAS). The test consists of a series of 20-meter shuttle runs at progressive velocities, controlled by an audio beep interspersed with regular, short rest periods of 10 seconds (1). The test was completed when a subject failed to keep up with the audio beep in reaching the finish line on two separate occasions. The final distance covered was recorded as estimated MAS using the following formula (23): MAS = speed at the last uncompleted stage ($km \cdot h^{-1}$) + 0.5 × (*n*/8) where *n* = the number of runs completed in the last stage from 14.5 $km \cdot h^{-1}$.

Game situation. The game situation consisted of a 5-on-5 full-court situation (28 x 15 m) (1 x10 min.). In order to ensure balance between the two teams, players were classified according to the coach's subjective appraisal of their ability, and were then assigned to a given team as deemed appropriate within each training group (strength and control) (16). Teams kept the same in both pre- and posttest. In full-game situations, teams used a 4:1 offensive formation (four players on the perimeter, and one player on the inside), a 24 second shot-clock, and a mandatory man-to-man defense. Neither verbal encouragement nor technical or tactical instructions (including time-outs) were given by the research and coaching staff during the games to avoid influencing the style of play of the athletes. No substituitions were made. Movement demands were recorded using The WIMU PRO Local Positioning System (*Realtrack Systems*, *Almeria*, *Spain*), which integrates different sensors registering different sample frequencies. Sampling frequency for 3-axis accelerometer, gyroscope, and magnetometer was 100 Hz, 120 kPa for the barometer, and 18 Hz for the positioning system. The WIMU PRO® showed satisfactory accuracy (x-axis = 5.2 ± 3.1 cm; y-axis 5.8 ± 2.3 cm) and reliability (x-axis, ICC = 0.65; y-axis, ICC = 0.85) in the fixed reference lines of a basketball court at a speed of over 15 km/h (3). The same system showed better accuracy (bias: 0.57–5.85%), test-retest reliability (%TEM: 1.19), and inter-unit reliability (bias: 0.18) in determining distance covered and mean velocity (bias: 0.09; ICC: 0.979; bias: 0.01 > bias: 0.18; ICC: 0.951; bias: 0.03) than GPS technology (4).

The following variables were calculated per minute: (a) distance covered (DC; m), (b) high-intensity accelerations (HIAcc) and decelerations (HIDec), (c) the number of body impacts (> 5 g), and (d) player load. Also, average and peak speed ($km \cdot h^{-1}$), peak acceleration (PAcc; $m \cdot s^{-2}$), and deceleration (PDec; $m \cdot s^{-2}$) were calculated (1). The > 2 $m \cdot s^{-2}$ and > -2 $m \cdot s^{-2}$ were the criteria to detect high-intensity accelerations/decelerations, respectively (1). Body impacts considered the number of jumps and impacts that exceed 5G forces, measured with the inertial accelerometer in the z, x, and y axes (1). The instantaneous player load (PLn) was computed using the following formula: $PLn = \frac{\sqrt{(Xn-Xn-1)^2+(Yn-Yn-1)^2+(Zn-Zn-1)^2}}{100}$. The accumulated player load (PL) ($PL = \sum_{n=0}^{m}(PLn) \times 0{,}01$) and PL that was accumulated at locomotor velocities below 2 $m.sec^{-1}$ were computed and calculated per minute for further analysis.

Average heart rate (HR) was recorded with individual HR monitors (*Garmin, Soft Strap Premium, USA*). Also, SampEn was used to assess each players' HR regularity during the games (25). SampEn (m, r, n) is defined as the negative natural logarithm of the conditional probability that two sequences, and similar form points (length of the vector to be compared), remain similar at the next point m + 1 (25). The values used to calculate sampEn were 2 to vector length (m) and 0.2 ±SD to the tolerance (r) (25). The values of sampEn range from zero towards infinity, where values close to zero are indicative of higher regularity in HR, while the higher the sampEn, the more unpredictable the HR (25). The Spatial Exploration Index (SEI) was obtained for each player by calculating their mean court position, computing the distance from each positioning time-series to the mean position and, finally, computing the mean value from all the obtained distances (10,16). Data was analyzed using commercially available software (*WIMU SPRO Software; Realtrack Systems SL*).

Delayed onset of muscle soreness (DOMS). DOMS was determined by the visual analogue scale (0: no pain at all, 10: worst pain ever) before the players began their post-game session (24-hours after game situation). To determine the pain level, subjects were instructed to perform a 90-degree half squat and indicate the muscle pain perceived at the thigh level (31). This method has been previously used as a non-invasive form of monitoring pain perception after strenuous exercise protocols (31).

Statistical Analyses

Data are presented as mean ± SD. The lower limb Asymmetry Index (ASI) was determined by adhering to the procedures described by Bishop and colleagues (5) using the following formula: *ASI = 100/Max Value (right and left)*Min Value (right and left)*-1+100*. Within-session reliability of test measures computed using an average measures two-way random intraclass correlation coefficient (ICC) with absolute agreement, inclusive of 90% confidence intervals, and the coefficient of variation (CV). The ICC was interpreted as follows: poor (< 0.5), moderate (0.5–0.74), good (0.75–0.9), and excellent (>0.9) (22). Coefficient of variation values were considered acceptable if < 10% (9). Normality of data distribution and homoscedasticity were confirmed using the Shapiro-Wilk statistic and Levene'sTest for equality of variances, and thus, parametric analyses were used. . A parametric related-samples t-test was used to analyze within-group changes. One specific Excel spreadsheet was used to examine within-group (xPostOnlyCrossover.xls) comparisons. This method has been previously used to examine within-group differences, in basketball training programs (17–19). The threshold values for Cohen's d for effect sizes (ES) statistics were 0–0.2 trivial, >0.2–0.6 small, >0.6–1.2 moderate, >1.2–2.0 large, and >2.0 very large (21). The quantitative chances of the beneficial/better or detrimental/poorer effect were assessed qualitatively as follows: 1%, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possibly; 75–95%, likely; 95–99%, very likely; and 99%, almost certain. If the chances of having beneficial/better or detrimental/poorer performances were both >5%, the true difference was assessed as unclear. A 2x2 mixed-modelanalysis of variance (ANOVA) was performed on the absolute values of all parameters to determine the main effects between groups (experimental and control group) and time (pre- and post-test). Effect size was evaluated with partial eta squared (η^2_p) and the threshold values were no effect ($\eta^2_p <$ 0.04), minimum effect ($0.04 < \eta^2_p < 0.25$), moderate effect ($0.25 < \eta^2_p < 0.64$), and strong effect ($\eta^2_p > 0.64$) (12). This measure has been is widely cited as a measure of effect size, and predominantly provided by statistical software software (24). A Pearson productmoment correlation was used to determine the relationship between relative changes in game-related variables for which significant differences were identified between moments and physical parameters. All statistical analyses were performed using SPSS software (*version 24 for Windows; SPSS Inc., Chicago, IL, USA*).

RESULTS

Within-session reliability

All ICC values ranged from good to excellent (ICC range = 0.82-0.96) and all CV values were acceptable (CV range = 1.25-5.78%) (Table 1).

*** *Insert Table 1 Here****

Within-group changes

Relative changes and qualitative outcomes for both training groups are described in Tables 1 and 2, respectively. The strength training group showed significant improvements in accelerations (ES = 1.91, $p \leq 0.01$), decelerations (ES = 1.78, $p \leq 0.01$), high-intensity accelerations (ES = 1.87, $p \leq 0.001$), high-intensity decelerations (ES = 1.45, $p \leq 0.0001$), peak accelerations (ES = 1.51, $p \leq 0.001$), and peak decelerations (ES = 1.63, $p \leq 0.0001$) during 5-on-5 game situation (Table 1). Furthermore, they substantially improved 0–10 m sprint time (ES = 0.49, $p \leq 0.01$), V-cut test (ES = -0.90, $p \leq 0.01$), and CMJ_{ASI} (ES = -0.91, $p \leq 0.05$) (Table 1). The control group showed significant improvements in accelerations (ES = 0.69, $p \leq 0.05$), decelerations (ES = 0.66, $p \leq 0.05$), high-intensity accelerations (ES = 0.80, $p \leq 0.05$), high-intensity decelerations (ES = 0.73, $p \leq 0.05$), and peak accelerations (ES = 0.94, $p \leq 0.05$) during 5-on-5 game situation (Table 2). Furthermore, they significantly improved V-cut test (ES = -0.53, $p \leq 0.01$) (Table 2).

*** *Insert Table 2 Here****

*** *Insert Table 3 Here****

Between-group changes

The 2x2 mixed-model ANOVA indicated a significant interaction effect (group x time) on CMJ ($F(1,18) = 11.55$; $p < 0.01$; $\eta^2_p = 0.39$), HJ_R ($F(1,18) = 7.35$; $p < 0.05$; $\eta^2_p = 0.29$), high-intensity accelerations ($F(1,18) = 4.61$; $p < 0.05$; $\eta^2_p = 0.20$), high-intensity decelerations ($F(1,18) = 5.53$; $p < 0.05$; $\eta^2_p = 0.24$), peak accelerations ($F(1,18) = 5.33$; $p < 0.05$; $\eta^2_p = 0.23$), and peak deceleratios ($F(1,18) = 12.54$; $p < 0.01$; $\eta^2_p = 0.41$) (Table 3).

*** *Insert Table 4 Here****

Relationships between physical and game performance variables

In the strength group, significant relationships were found between relative changes in 0–25m, HIDec ($r = 0.63$, [90% CI 0.43; 0.92], $p \leq 0.05$), PAcc ($r = 0.67$, [90% CI 0.19; 0.92], $p \leq 0.05$), and PDec ($r = 0.65$, [90% CI 0.45; 0.89], $p \leq 0.05$). In the same group, significant relationships were found between relative changes in CMJ_R, Acc (r = 0.71 [90% CI 0.44; 0.87], $p \leq 0.05$), and Dec (r = 0.63, [90% CI 0.41; 0.82], $p \leq 0.05$). Also, significant relationships were found between relative changes in CMJ_{ASI}, and Acc (r = -0.67, [90% CI -0.91; -0.20], $p \leq 0.05$). No significant relationships were found between relative changes within the control group.

DISCUSSION

The main aim of the current study was to examine the effect of 10-week training intervention with the load that maximized propulsive power output, and with random recovery times between sets, on physical tests;and physical performance and spatial exploration index during a simulated basketball game. We found that including strength training into the athletes' training schedules was more beneficial to improve than purely facilitating 'standard' practice regimes. Improvements were observed in, 1) high-intensity activities during a simulated basketball match, particularly in consideration to the number and peak of high-intensity activities (e.g., accelerations and decelerations), and 2) horizontal and vertical jumping abilities. In addition, a significant relationship was observed between relative changes in physical fitness parameters and game-related variables.

To the best of our knowledge, this is the first study to analyze the influence of strength training on game-related variables in basketball. The results indicate that 10 weeks of strength training had a beneficial impact on the above-mentioned variables (i.e., HIAcc, HIDec, PAcc, and PDec) during a simulated basketball match, and this effect was likely better than that seen in the control group. Thus, through our research, it appears that strength training may help to perform and repeat HIAs, with observed benefits in training or higher-level competition. A previous study with elite basketball players examined the differences between half-court, half-court and transition, and full-court 5-on-5 situations on physical performance (36). In full-court situations, athletes performed more HIAcc and HIDec than in half-court situations (36). Also, man-to-man defense performed in a full-court setting promoted a higher number of total actions, transition sprints, fakes, and defensive actions than observed in half-court situations (6). Particularly, fakes (which are displacements involving CODs or rhythm with or without the ball, performed to overcome or mislead the opponent) (6) seem to match the movement demands involving HIAcc and HIDec. Both results suggest that a full-court situation could better stimulate fast-break or fast transition offense and full-court press or sprint back on defense. A greater ability to repeatedly perform HIAcc and/or HIDec may enable coaches who base their coaching (and thus playing style) on either fast-breaks or fast transition offense, and/or full-court press or sprint back on defense, to develop tactical principles and, consequently, to increase the possibilities of winning. In fact, previous findings revealed that teams which played a fast-paced game (i.e., including a higher number of ball possessions) were more likely to be able to conquer more balls from the opponents, performed effective field-goal shooting, and were most likely to be winners overall (29). Previously, players' performance was mainly defined (i.e., were the most discriminant variables in comparison to both medium and lower performers) through HIAcc, HIDec, PAcc, and DC during an international U-18 competition (35). After the experimental period, the participants in our study were able to generate greater developments in velocity per unit time of the body, expressed by PAcc, which could underpin advantages in performing more desired, and 'successful' actions during a game.

Esteves and colleagues (11) investigated how attackers attained success in basketball 1-on-1 by exploring angular relations with immediate opponents and the basket itself. During successful trials, attackers dribbled past defenders with greater angular velocity values and decreased angular variability (11). Since the 1-on-1 situation began with a short distance between the attacker and the defender (0.85 m), the attacker had to generate a great change in velocity in a short distance and time to succeed. In this case, an athlete with this 'enhanced' ability may be able to more frequently achieve success in this important, and frequent situation in the game. Despite this finding, more studies are needed in order to more thoroughly understand this relationship. A previous study investigated the kinetic cause of the outcome in a 1-on-1 dribble situation in terms of the defensive player (14). The findings showed that the defender's mediolateral peak trunk acceleration was higher in situations involving offensive players, irrespective of the outcome (successful or unsuccessful defensive motions) compared to light-emitting diode (LED) equipment situation (14). Although other aspects (e.g. players' anticipation) may be more decisive than the peak trunk acceleration regarding the final outcome, it is certain that a higher rate of acceleration is needed by players when facing an offensive opponent, which can be enhanced through the muscular power gains derived from the strength training. According to a previous study, the players who achieved greater Yo-Yo IR1 values were able to execute higher rates of high-intensity accelerations and decelerations during training sessions (1). Furthermore, the experimental group also improved the distance covered above MAS (ES = 0.67)), assessed before the experimental period. It is worth noting that RPA training may concurrently target a wide array of adaptations (e.g., cardiorespiratory, mechanical, and neuromuscular). In this regard, parallel back-squat (relative VO_2 = 13.8 ± 5.4 ml/kg/min; HR_{max} = 68.2 ± 7.91 %; lactate = 3.36 ± 1.78 mmol/l) includes submaximal physiological efforts that may result in an improved aerobic fitness and, consequently, in an enhancement of the physical variables presented during a basketball game (2). Considering that MAS is a strong indicator of capacity (20), it seems that elicit gains at an aerobic level can be achieved by means of the incorporation of several blocks of sets of lower-body maximal power exercises with incomplete recovery periods in between. In fact, 10 sets of repeated power exercises at 60% 1RM require substantial stores of adenosine triphosphate, phosphate, and muscle glycogen, which are also limiting factors for intermittent sports, such as basketball (20). These facts can be reinforced by referencing a previous study, which reported improvements in the ability to resist fatigue during repeated HIA after using RPA (18). Therefore, it seems that RPA training can concurrently improve both physical tests (e.g., MAS), and real, game-time performance, measured through the number of HIA.

After the training program, subjects showed lower individual exploration behavior during the simulated basketball match compared to the pre-test values. The individual exploration behavior is highly dependent on the physical space in which is available to play within because players explore more space during the game when playing without restrictions in terms of surrounding space occupation, compared to when they are restricted (16). Previous studies have shown a trivial increase in individual exploration behavior after a 10-week training program including exercises to improve fundamental movement skills and fundamental game-specific skills (e.g., game formats from 1-on-1 to 3-on-3, and also small-sided games underpinned in unpredictable and dynamic environments) in under-17 football attackers (10). Based on these findings, it appears more clear that the implementation of specific training that recognizes the particular demands of the particular sport is necessary to improve the different interpretations of spatiotemporal information (10,16). Furthermore, the PL was substantially enhanced (ES= 0.32) after undertaking the strength training, whereas it was impaired in the control group (ES= -0.37). As the PL seems to be strongly related to the total number of collisions (r= 0.70) and the total number of collisions plus scrums (r= 0.80) in rugby players (28), strength training could use their strengths to effectively perform specific abilities. Therefore, RPA training seems to be an effective method in meeting the game's physical demands, although more research is needed for a better understanding of how improved physicality could impact the understanding of spatiotemporal information.

On the other hand, jumping ability was significantly improved after the strength training. In previous studies, CMJ values showed smaller improvements after completing different training programs (10,13,17,19) compared to that of the present study. In particular, a 6-week training study (13) which included the BS exercise prescribed through the individual peak power, promoted small increments in CMJ (ES = 0.15 to 0.17) among semi-professional basketball players. Despite consisting of similar features, differences in structure of sets and repetition volume could explain the differences recognized between-studies. Moreover, the results generated from this research were lower compared to a previous 6-week RPA training study that included the leg-press exercise (one or two blocks of 5 sets × 5 repetitions with 20-sec of passive recovery between sets and 3-min between blocks, twice/week) for HJ_R (ES = 0.64) and HJ_L (ES = 0.65) (18). It appears that a greater dynamic correspondence of HJ with the leg-press exercise (horizontal force vector) may be responsible for achieving the HJ improvement. Thus, further studies should include the combination of both horizontal and vertical force vector exercises during RPA to elicit gains in unilateral jumps in both directions.

In addition, it is widely established that change-of-direction speed is an essential skill among youth athletes engaging in team sports players (32). The current training program displayed significant improvements during the V-cut test (45º test) compared to the control group and to that of previous studies (17,19). Recent research has found that lower contact times, lower time spent breaking, lower braking impulse, and higher propulsive impulse are required for a faster performance during a 45º change of direction (32). The present strength training was designed in consideration of the load that maximized propulsive power output, which is a key factor of an individual's neuromuscular potential (30). In this regard, performing repeated triple flexion actions (i.e., hip, knee, and ankle flexed) during strength training, followed by HIA optimizing triple extension, may generate higher propulsive impulse and the enhancement of repeated 45º change-of-direction performance.

The present study has some limitations that must be acknowledged. It could be possible that the control group encountered other strength-training stimuli individually that may have affected the between-group differences. Also, training response of experimental group may have been influenced by regular participation in basketball training and competition. we would also suggest exploring variable repetitions within each set (e.g., it may be individualized through either maximal power endurance or a range of times where players are mainly involved in HIAs during a game) or blocks. Furthermore, while we have exclusively focused on axial movements (e.g., half-squats on the vertical axis), the inclusion of different exercises that mimic the most common basketball-specific movements such as the first- and last-step shuffles, cutting through rotational flywheel devices, or high-load resistance elastic bands, may be an interesting option to transfer power gains into real game movements. Hence, instead of a conventional multiset scheme, we advocate for a multi-exercise setup where different movement families are interspersed with short recovery periods. In this manner, instead of stressing the same structures and functions several times, our aim is to concatenate movements to boost the post-activation potention effect while searching for optimal movement sequences (e.g., a lateral side step followed by a lateral cross-over step, a front single step followed by a front double step with a forward jump). Moreover, studies on the effect of RPA training on subjects of different age, gender, sport, and training background are suggested. Thus, further studies are recommended to compare the effect of RPA with other strength-training protocols. Finally, studies on the effect of strength training with random recovery times in different exercises are warranted.

PRACTICAL APPLICATIONS

Strength training with random recovery times between sets was shown to substantially improve CMJ and unilateral right hop but, more importantly, improve high-intensity accelerations and decelerations, along with peak accelerations and decelerations for basketball players in a 5-on-5 full-court situation. RPA training with variable recovery should be included to promote gains in those HIAs executed during a basketball game. Finally, collaboration between elements of the technical staff (e.g., head coach and strength and conditioning coach or athletic trainer) can enable an optimal combination between in-court technical-tactical situations and RPA training which may enhance team performance and game-related aspects of basketball players.

REFERENCES

1. Arede, J, Ferreira, AP, Esteves, P, Gonzalo-Skok, O, and Leite, N. Train Smarter, Play More : Insights about Preparation and Game Participation in Youth National Team. *Res Q Exerc Sport* 91: 583–593, 2020.

2. Arede, J, Leite, N, Bradley, B, Madruga-Parera, M, Saéz de Villarreal, E, and Gonzalo-Skok, O. Mechanical, Physiological, and Perceptual Demands of Repeated Power Ability Lower-Body and Upper-Body Tests in Youth Athletes: Somatic Maturation as a Factor on the Performance. *Front Psychol* 11, 2020.

3. Bastida-Castillo, A, Gómez-Carmona, CD, De la Cruz-Sánchez, E, Reche-Royo, X, Ibáñez, SJ, and Ortega, JP. Accuracy and inter-unit reliability of ultra-wide-band tracking system in indoor exercise. *Appl Sci* 9: 939, 2019.

4. Bastida-Castillo, A, Gómez-Carmona, CD, De La Cruz Sánchez, E, and Pino-Ortega, J. Comparing accuracy between global positioning systems and ultra-wideband-based position tracking systems used for tactical analyses in soccer. *Eur J Sport Sci* 19: 1157–1165, 2019.

5. Bishop, C, Read, P, Lake, J, Chavda, S, and Turner, A. Inter-limb asymmetries: Understanding how to calculate differences from bilateral and unilateral tests. *Strength Cond J* 40, 2018.

6. Bredt, S, Torres, J, and Diniz, L. Physical and physiological demands of basketball small-sided games : the influence of defensive and time pressures. *Biol Sport* 37: 131–138, 2020.

7. Castagna, C, Manzi, V, D'Ottavio, S, Annino, G, Padua, E, and Bishop, D. Relation between maximal aerobic power and the ability to repeat sprints in young basketball players. *J Strength Cond Res* 21: 1172–6, 2007.

8. Conte, D, Favero, TG, Lupo, C, Francioni, FM, Capranica, L, and Tessitore, A. Time-motion analysis of Italian elite women's basketball games: Individual and team analyses. *J Strength Cond Res* 29: 144–150, 2015.

9. Cormack, SJ, Newton, RU, McGuigan, MR, and Doyle, TLA. Reliability of Measures Obtained During Single and Repeated Countermovement Jumps. *Int J Sports Physiol Perform* 3: 131–144, 2008.

10. Coutinho, D, Santos, S, Gonçalves, B, Travassos, B, Wong, P, Schöllhorn, W, et al. The effects of an enrichment training program for youth football attackers. *PLoS One* 13, 2018.

11. Esteves, PT, Araújo, D, Vilar, L, Travassos, B, Davids, K, and Esteves, C. Angular relationships regulate coordination tendencies of performers in attacker-defender dyads in team sports. *Hum Mov Sci* 40: 264–72, 2015.

12. Ferguson, CJ. An Effect Size Primer : A Guide for Clinicians and Researchers. *Prof Psychol Res Pract* 40: 532–538, 2009.

13. Freitas, TT, Calleja-gonzález, J, Carlos-vivas, J, Marín-, E, and Alcaraz, PE. Short-term optimal load training vs a modified complex training in semi-professional basketball players. *J Sports Sci* 37: 434–442, 2019.

14. Fujii, K, Yamashita, D, Kimura, T, Isaka, T, and Kouzaki, M. Preparatory Body

State before Reacting to an Opponent: Short-Term Joint Torque Fluctuation in Real-Time Competitive Sports. *PLoS One* 10: e0128571, 2015.

15. Gabbett, TJ and Mulvey, MJ. Time-motion analysis of small-sided training games and competition in elite women soccer players. *J strength Cond Res* 22: 543–52, 2008.

16. Gonçalves, B, Esteves, P, Folgado, H, Ric, A, Torrents, C, and Sampaio, J. Effects of pitch area-restrictions during soccer large-sided game. *J Strength Cond Res* 31: 2398–2408, 2017.

17. Gonzalo-Skok, O, Sánchez-Sabaté, J, Izquierdo-Lupón, L, and Sáez de Villarreal, E. Influence of force-vector and force application plyometric training in young elite basketball players. *Eur J Sport Sci* 19: 305–314, 2018.

18. Gonzalo-Skok, O, Tous-Fajardo, J, Arjol-Serrano, JL, Suarez-Arrones, L, Casajus, JA, Mendez-Villanueva, A, et al. Improvement of Repeated-Sprint Ability and Horizontal-Jumping Performance in Elite Young Basketball Players With Low-Volume Repeated-Maximal-Power Training. *Int J Sports Physiol Perform* 11: 464–473, 2016.

19. Gonzalo-Skok, O, Tous-Fajardo, J, Suarez-Arrones, L, Arjol-Serrano, JL, Casajús, JA, and Mendez-Villanueva, A. Single-leg power output and between-limbs imbalances in team-sport players: Unilateral versus bilateral combined resistance training. *Int J Sports Physiol Perform* 12: 106–114, 2017.

20. Haff, GG and Triplett, T (eds.). Essentials of Strength Training and Conditioning. 4th ed. Illinois: Human Kinetics Publishers Inc., 2016.

21. Hopkins, W, Marshall, SW, Batterham, AM, and Hanin, J. Progressive Statistics for Studies in Sports Medicine and Exercise Science. *Med Sci Sport Exerc* 41: 3–13, 2009.

22. Koo, TK and Li, MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *J Chiropr Med* 15: 155–163, 2016.

23. Kuipers, H, Verstappen, FTJ, Keizer, HA, Geurten, P, and Kranenburg, G Van. Variability of Aerobic Performance in the Laboratory and Its Physiologic Correlates. *Int J Sports Med* 6: 197–201, 1985.

24. Lakens, D. Calculating and reporting effect sizes to facilitate cumulative science : a practical primer for t -tests and ANOVAs. *Front Psychol* 4: 1–12, 2013.

25. Mateus, N, Gonçalves, B, Weldon, A, and Sampaio, J. Effects of using four baskets during simulated youth basketball games. *PLoS One* 14: 1–13, 2019.

26. Mendez-Villanueva, A, Hamer, P, and Bishop. Fatigue in repeated-sprint exercise is related to muscle power factors and reduced neuromuscular activity. *Eur J Appl Physiol* 103: 411–9, 2008.

27. Natera, AO, Cardinale, M, and Keogh, JWL. The Effect of High Volume Power Training on Repeated High - Intensity Performance and the Assessment of Repeat Power Ability : A Systematic Review. *Sport Med* 50: 1317–1339, 2020.

28. Roe, G, Halkier, M, Beggs, C, Till, K, and Jones, B. The Use of Accelerometers

to Quantify Collisions and Running Demands of Rugby Union Match-Play The Use of Accelerometers to Quantify Collisions and Running Demands of Rugby Union Match-Play. *Int J Perform Anal Sport* 16: 590–601, 2016.

29. Sampaio, J, Lago, C, and Drinkwater, E. Explanations for the United States of America's dominance in basketball at the Beijing Olympic Games (2008). *J Sports Sci* 28: 147–152, 2010.

30. Sanchez-Medina, L, Perez, CE, and Gonzalez-Badillo, JJ. Importance of the propulsive phase in strength assessment. *Int J Sports Med* 31: 123–129, 2010.

31. Sánchez-Ureña, B, Martínez-Guardado, I, Crespo, C, Calleja-González, J, Ibañez, SJ, and Olcina, G. The use of continuous vs . intermittent cold water immersion as a recovery method in basketball players after training : A randomized controlled trial. *Phys Sportsmed* 45: 134–139, 2017.

32. Spiteri, T, Newton, RU, Binetti, M, Hart, N, Sheppard, JM, and Nimphius, S. Mechanical determinants of faster change of direction and agility performance in female basketball athletes. *J Strength Cond Res* 29: 2205–2214, 2015.

33. Stojanović, E, Stojiljković, N, Scanlan, AT, Dalbo, VJ, Berkelmans, DM, and Milanović, Z. The Activity Demands and Physiological Responses Encountered During Basketball Match-Play: A Systematic Review. Sport. Med. 48: 111–135, 2018.

34. Suarez-Arrones, L, Tous-Fajardo, J, Núñez, J, Gonzalo-Skok, O, Gálvez, J, and Mendez-Villanueva, A. Concurrent Repeated-Sprint and Resistance Training With Superimposed Vibrations in Rugby Players. *Int J Sports Physiol Perform* 9: 667–673, 2014.

35. Vázquez-Guerrero, J, Jones, B, Fernández-Valdés, B, Moras, G, Reche, X, and Sampaio, J. Physical demands of elite basketball during an official U18 international tournament. *J Sports Sci* 37: 1–8, 2019.

36. Vazquez-Guerrero, J, Reche, X, Cos, F, Casamichana, D, and Sampaio, J. Changes in External Load When Modifying Rules of 5-on-5 Scrimmage Situations in Elite Basketball. *J Strength Cond Res* , 2018.

Table 1. Reliability data for all test variables.

Test Variables	ICC (90%CL)	CV (%) (90%CL)
CMJ	0.96 (0.91; 0.98)	3.27 (2.20; 4.47)
0-10 m	0.82 (0.65; 0.91)	2.15 (1.58; 2.74)
0-25 m	0.84 (0.68; 0.92)	1.25 (0.84; 1.73)
V-cut test	0.85 (0.71; 0.93)	1.80 (1.27; 2.34)
CMJ_R	0.88 (0.79; 0.94)	5.03 (3.86; 6.24)
CMJ_L	0.86 (0.75; 0.93)	5.78 (4.50; 7.01)
HJ_R	0.84 (0.72; 0.92)	4.07 (3.23; 4.96)
HJ_L	0.88 (0.77; 0.94)	4.41 (3.03; 6.02)

Abbreviations: ICC = Intraclass correlation coefficient; CV = Coefficient of variation; CL = Confidence limits; CMJ = Countermovement jump height; 0-10 m = 0-10 m sprint time; 0-25 m = 0-25 m sprint time; HJ = horizontal jump; R = Right; L = Left.

Table 2. Changes in performance after strength training program with random recovery times between sets.

Variable	Pretest, mean±SD	Postest, mean±SD	Standardized difference (90%CL)	Chances of better/trivial/worse effect	Qualitative assessment	p
CMJ (cm)	37.35 ± 4.37	39.80 ± 4.10	0.49 (0.27; 0.71)	98/2/0	Very Likely ↑	0.002
0-10 m (s)	1.79 ± 0.05	1.73 ± 0.09	-1.00 (-1.60; -0.41)	98/2/0	Very Likely ↑	0.012
0-25 m (s)	3.77 ± 0.15	3.70 ± 0.15	-0.43 (-0.74; -0.12)	90/10/0	Likely ↑	0.028
V-cut test (s)	7.13 ± 0.34	6.82 ± 0.39	-0.90 (-1.33; -0.46)	99/1/0	Very Likely ↑	0.004
CMJ_R (cm)	23.93 ± 2.47	25.58 ± 2.51	0.61 (0.21; 1.00)	95/4/0	Very Likely ↑	0.024
CMJ_L (cm)	23.85 ± 2.82	26.06 ± 2.21	0.74 (0.28; 1.20)	97/3/0	Very Likely ↑	0.015
CMJ_{ASI} (%)	13.47 ± 7.00	8.20 ± 3.65	-0.91 (-1.39; -0.42)	99/1/0	Very Likely ↑	0.018
HJ_R (cm)	174.07 ± 13.95	183.23 ± 12.24	0.60 (0.37; 0.83)	99/1/0	Very Likely ↑	0.001
HJ_L (cm)	170.07 ± 16.89	180.19 ± 15.32	0.55 (0.33; 0.77)	99/1/0	Very Likely ↑	0.002
HJ_{ASI} (%)	8.87 ± 5.56	8.53 ± 4.16	-0.14 (-1.03; 0.75)	45/30/25	Unclear	0.745
DC ($m \cdot min^{-1}$)	105.47 ± 8.80	109.50 ± 13.67	0.36 (-0.08; 0.81)	74/23/2	Possibly ↑	0.105
DC > MAS ($m \cdot min^{-1}$)	8.64 ± 3.21	13.10 ± 5.90	0.67 (0.18; 1.15)	94/5/0	Likely ↑	0.021
Acc ($n \cdot min^{-1}$)	16.92 ± 0.84	18.82 ± 1.40	1.91 (1.11; 2.72)	100/0/0	Most Likely ↑	0.002
Dec ($n \cdot min^{-1}$)	16.95 ± 0.85	18.74 ± 1.40	1.78 (1.04; 2.52)	100/0/0	Most Likely ↑	0.002
HIAcc ($n \cdot min^{-1}$)	2.71 ± 0.51	4.18 ± 1.25	1.87 (1.13; 2.61)	100/0/0	Most Likely ↑	0.001
HIDec ($n \cdot min^{-1}$)	2.36 ± 0.62	3.83 ± 1.38	1.45 (0.91; 2.00)	100/0/0	Most Likely ↑	0.000
PAcc ($m \cdot s^{-2}$)	3.39 ± 0.33	4.02 ± 0.59	1.51 (1.03; 1.99)	100/0/0	Most Likely ↑	0.001
PDec ($m \cdot s^{-2}$)	-3.18 ± 0.38	-3.96 ± 0.53	1.63 (1.16; 2.10)	100/0/0	Most Likely ↑	0.000
AS ($km \cdot h^{-1}$)	6.52 ± 0.51	6.78 ± 0.68	0.43 (-0.02; 0.88)	81/17/2	Likely ↑	0.086
PS ($km \cdot h^{-1}$)	19.54 ± 1.85	20.39 ± 1.17	0.45 (-0.06; 0.96)	80/17/2	Likely ↑	0.173
BI ($n \cdot min^{-1}$)	13.74 ± 5.94	13.73 ± 3.84	0.09 (-0.54; 0.72)	38/41/21	Unclear	0.995
PL (a.u./min.)	1.87 ± 0.26	1.92 ± 0.31	0.14 (-0.26; 0.55)	40/52/8	Unclear	0.474
PL_{slow} (a.u./min.)	1.44 ± 0.16	1.51 ± 0.23	0.32 (-0.11; 0.76)	69/28/3	Possibly ↑	0.136
HR_{av} (bpm)	180.15 ± 9.12	179.98 ± 9.57	-0.02 (-0.60; 0.56)	25/46/29	Unclear	0.339
HR_{SampEn} (a.u.)	0.50 ± 0.20	0.43 ± 0.16	-0.30 (-1.17; 0.57)	16/26/58	Unclear	0.465
SEI (a.u.)	8.14 ± 0.79	7.99 ± 0.46	-0.15 (-0.60; 0.29)	9/48/43	Unclear	0.496
DOMS (a.u.)	3.90 ± 2.08	4.70 ± 2.63	0.37 (0.01; 0.73)	1/19/80	Likely ↓	0.168

Abbreviations: CMJ = Countermovement jump height; 0-10 m = 0-10 m sprint time; 0-25 m = 0-25 m sprint time; HJ = horizontal jump; R = Right; L = Left; ASI = Bilateral asymmetry; DC = distance covered; MAS = maximal aerobic speed; Acc = accelerations; Dec = decelerations; HIAcc = high-intensity accelerations; HIDec = high-intensity decelerations; PAcc = peak acceleration; PDec = peak deceleration; AS = average speed; PS = peak speed; BI = body impacts (> 5g); PL = player load; HR_{av} = average heart rate; HR_{SampEn} = heart rate sample entropy; SEI = spatial exploration index; DOMS = Delayed onset of muscle soreness. Legend: ↑ = Positive; ↓ = Negative. The threshold values for Cohen's d for effect sizes (ES) statistics were 0–0.2 trivial, >0.2–0.6 small, >0.6–1.2 moderate, >1.2–2.0 large, and >2.0 very large.

Table 3. Changes in performance for the control group.

Variable	Pretest, mean±SD	Postest, mean±SD	Standardized difference (90%CL)	Chances of better/trivial/worse effect	Qualitative assessment	p
CMJ (cm)	40.65 ± 8.56	40.90 ± 8.31	0.04 (-0.03; 0.10)	0/100/0	Most Likely Trivial	0.392
0-10 m (s)	1.79 ± 0.10	1.75 ± 0.12	-0.40 (-0.77; -0.03)	83/17/1	Likely ↑	0.083
0-25 m (s)	3.70 ± 0.20	3.75 ± 0.16	0.24 (-0.24; 0.72)	6/38/56	Unclear	0.396
V-cut test (s)	7.28 ± 0.28	7.12 ± 0.33	-0.53 (-0.79; -0.27)	98/2/0	Very Likely ↑	0.005
CMJ_R (cm)	20.27 ± 4.04	20.35 ± 2.74	0.06 (-0.20; 0.32)	17/78/5	Likely Trivial	0.917
CMJ_L (cm)	21.09 ± 4.47	20.79 ± 3.18	-0.02 (-0.43; 0.38)	17/61/22	Unclear	0.805
CMJ_{ASI} (%)	14.02 ± 6.63	12.80 ± 6.96	-0.15 (-0.41; 0.10)	37/62/2	Possibly ↑	0.351
HJ_R (cm)	176.84 ± 20.20	179.31 ± 21.70	0.11 (-0.02; 0.24)	12/88/0	Likely Trivial	0.152
HJ_L (cm)	179.30 ± 20.55	183.21 ± 23.02	0.16 (-0.08; 0.41)	40/59/1	Possibly ↑	0.233
HJ_{ASI} (%)	12.69 ± 4.66	13.21 ± 4.16	0.14 (-0.09; 0.36)	1/69/30	Possibly ↓	0.351
DC (m·min^{-1})	103.70 ± 6.66	105.25 ± 6.61	0.22 (-0.07; 0.50)	54/45/1	Possibly ↑	0.202
DC > MAS (m·min^{-1})	13.62 ± 6.48	13.11 ± 2.68	0.05 (-0.44; 0.54)	30/52/18	Unclear	0.800
Acc (n·min^{-1})	16.93 ± 1.21	17.95 ± 1.67	0.69 (0.27; 1.10)	97/3/0	Very Likely ↑	0.015
Dec (n·min^{-1})	16.90 ± 1.25	17.92 ± 1.70	0.66 (0.26; 1.06)	97/3/0	Very Likely ↑	0.014
HIAcc (n·min^{-1})	2.31 ± 0.54	2.90 ± 0.79	0.80 (0.29; 1.31)	97/3/0	Very Likely ↑	0.036
HIDec (n·min^{-1})	1.89 ± 0.66	2.45 ± 0.66	0.73 (0.22; 1.23)	96/4/0	Very Likely ↑	0.019
PAcc (m·s^{-2})	3.55 ± 0.25	3.82 ± 0.25	0.94 (0.33; 1.56)	97/2/0	Very Likely ↑	0.022
PDec (m·s^{-2})	-3.52 ± 0.40	-3.72 ± 0.35	0.46 (0.01; 0.91)	84/15/1	Likely ↑	0.103
AS (km·h^{-1})	6.51 ± 0.42	6.52 ± 0.44	0.00 (-0.35; 0.36)	17/67/16	Unclear	0.983
PS (km·h^{-1})	20.11 ± 1.50	20.67 ± 1.38	0.36 (-0.05; 0.77)	75/23/2	Likely ↑	0.137
BI (n·min^{-1})	10.30 ± 4.80	9.49 ± 6.15	-0.23 (-0.76; 0.30)	9/37/54	Unclear	0.614
PL (a.u./min.)	1.72 ± 0.19	1.64 ± 0.21	-0.41 (-1.22; 0.40)	10/22/68	Unclear	0.396
PL_{slow} (a.u./min.)	1.40 ± 0.19	1.33 ± 0.24	-0.37 (-1.02; 0.27)	7/25/68	Unclear	0.343
HR_{av} (bpm)	175.86 ± 8.93	163.01 ± 23.27	-1.60 (-3.29; 0.09)	4/4/92	Likely ↓	0.103
HR_{SampEn} (a.u.)	0.42 ± 0.15	0.33 ± 0.16	-0.40 (-0.78; -0.02)	1/17/82	Likely ↓	0.034
SEI (a.u.)	8.05 ± 0.51	7.96 ± 0.52	-0.16 (-0.44; 0.11)	2/57/41	Possibly ↓	0.306
DOMS (a.u.)	2.40 ± 1.51	4.40 ± 1.96	1.38 (0.74; 2.02)	0/0/99	Very Likely ↓	0.015

Abbreviations: CMJ = Countermovement jump height; 0-10 m = 0-10 m sprint time; 0-25 m = 0-25 m sprint time; HJ = horizontal jump; R = Right; L = Left; ASI = Bilateral asymmetry; DC = distance covered; MAS = maximal aerobic speed; Acc = accelerations; Dec = decelerations; HIAcc = high-intensity accelerations; HIDec = high-intensity decelerations; PAcc = peak acceleration; PDec = peak deceleration; AS = average speed; PS = peak speed; BI = body impacts (> 5g); PL = player load; HR_{av} = average heart rate; HR_{SampEn} = heart rate sample entropy; SEI = spatial exploration index; DOMS = Delayed onset of muscle soreness. Legend: ↑ = Positive; ↓ = Negative. The threshold values for Cohen's d for effect sizes (ES) statistics were 0–0.2 trivial, >0.2–0.6 small, >0.6–1.2 moderate, >1.2–2.0 large, and >2.0 very large.

Table 4. Summary of 2x2 mixed-model analysis of variance for the performance scores.

Variable	F_{TIME}	η^2_p	p	F_{GROUP}	η^2_p	p	$F_{TIME \times GROUP}$	η^2_p	p
CMJ (cm)	17.65	0.50	0.001	0.55	0.03	0.468	11.55	0.39	0.003
0-10 m (s)	12.06	0.40	0.003	0.07	0.01	0.800	0.18	0.01	0.676
0-25 m (s)	0.07	0.01	0.794	0.01	0.01	0.912	3.57	0.17	0.075
V-cut test (s)	26.10	0.59	0.000	2.53	0.12	0.129	3.03	0.14	0.099
CMJ_R (cm)	3.39	0.16	0.082	12.44	0.41	0.002	2.82	0.14	0.110
CMJ_L (cm)	1.90	0.10	0.185	9.69	0.35	0.006	3.27	0.15	0.087
CMJ_{ASI} (%)	8.63	0.32	0.009	1.11	0.05	0.327	3.36	0.16	0.083
HJ_R (cm)	22.26	0.55	0.000	0.01	0.00	0.941	7.35	0.29	0.014
HJ_L (cm)	13.55	0.43	0.002	0.54	0.03	0.474	2.66	0.13	0.120
HJ_{ASI} (%)	0.00	0.00	0.988	5.07	0.22	0.037	0.42	0.02	0.526
DC ($m \cdot min^{-1}$)	4.97	0.22	0.039	0.63	0.03	0.440	0.98	0.05	0.337
DC > MAS ($m \cdot min^{-1}$)	2.45	0.12	0.135	2.00	0.10	0.175	3.88	0.18	0.064
Acc ($n \cdot min^{-1}$)	27.43	0.60	0.000	0.70	0.04	0.414	2.54	0.12	0.128
Dec ($n \cdot min^{-1}$)	27.83	0.61	0.000	0.68	0.04	0.422	2.14	0.11	0.161
HIAcc ($n \cdot min^{-1}$)	25.28	0.58	0.000	7.46	0.29	0.014	4.61	0.20	0.046
HIDec ($n \cdot min^{-1}$)	27.06	0.60	0.000	7.15	0.28	0.015	5.53	0.24	0.030
PAcc ($m \cdot s^{-2}$)	33.86	0.65	0.000	0.02	0.00	0.884	5.33	0.23	0.033
PDec ($m \cdot s^{-2}$)	36.03	0.67	0.000	0.08	0.01	0.777	12.54	0.41	0.002
AS ($km \cdot h^{-1}$)	2.63	0.13	0.123	0.39	0.02	0.540	2.55	0.12	0.128
PS ($km \cdot h^{-1}$)	4.45	0.20	0.049	0.53	0.03	0.475	0.18	0.10	0.674
BI ($n \cdot min^{-1}$)	0.10	0.01	0.757	3.83	0.18	0.066	0.10	0.01	0.765
PL (a.u./min.)	0.07	0.00	0.799	4.86	0.21	0.041	1.35	0.07	0.261
PL_{slow} (a.u./min.)	0.00	0.00	0.971	1.66	0.09	0.214	2.86	0.14	0.108
HR_{av} (bpm)	3.50	0.16	0.078	0.71	0.04	0.409	0.05	0.00	0.830
HR_{SampEn} (a.u.)	2.62	0.13	0.123	2.62	0.13	0.123	0.04	0.00	0.847
SEI (a.u.)	1.11	0.06	0.306	0.06	0.00	0.807	0.07	0.00	0.789
DOMS (a.u.)	10.76	0.37	0.004	1.19	0.06	0.291	1.98	0.10	0.177

Abbreviations: CMJ = Countermovement jump height; 0-10 m = 0-10 m sprint time; 0-25 m = 0-25 m sprint time; HJ = horizontal jump; R = Right; L = Left; ASI = Bilateral asymmetry; DC = distance covered; MAS = maximal aerobic speed; Acc = accelerations; Dec = decelerations; HIAcc = high-intensity accelerations; HIDec = high-intensity decelerations; PAcc = peak acceleration; PDec = peak deceleration; AS = average speed; PS = peak speed; BI = body impacts (> 5g); PL = player load; HR_{av} = average heart rate; HR_{SampEn} = heart rate sample entropy; SEI = spatial exploration index; DOMS = Delayed onset of muscle soreness. The partial eta squared values should be interpreted as no effect ($\eta^2_p < 0.04$), minimum effect ($0.04 < \eta^2_p < 0.25$), moderate effect ($0.25 < \eta^2_p < 0.64$), and strong effect ($\eta^2_p > 0.64$).