ACUTE EFFECTS OF TWO DIFFERENT RESISTANCE CIRCUIT TRAINING PROTOCOLS ON PERFORMANCE AND PERCEIVED EXERTION IN SEMIPROFESSIONAL BASKETBALL PLAYERS

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ABSTRACT

Freitas, TT, Calleja-González, J, Alarcón, F, and Alcaraz, PE. Acute effects of two different resistance circuit training protocols on performance and perceived exertion in semiprofessional basketball players. *J Strength Cond Res* 30(2): 407–414, 2016—This study aimed to investigate the acute effects of two different resistance circuit training protocols on basketball players' physical and technical performance and rating of perceived exertion (RPE). In a repeated-measures, crossover experimental design, 9 semiprofessional basketball players performed a Power Circuit Training (PCT; 45% 1RM) and a High-Resistance Circuit Training (HRC; 6RM), on consecutive weeks. Vertical and horizontal jump performance, 3-points shooting accuracy, repeated-sprint ability (RSA), agility, and upper body power output were measured before and after training. The RPE was assessed 20 minutes after resistance training. One-way repeated-measures analysis of variance showed performance decrements in vertical jump height and peak power, horizontal jump distance, 3-points percentage, bench-press power output, RSA total and ideal time, and agility T-Test at total time following HRC, but not PCT ($p \leq 0.05$). The RPE was higher in HRC compared with PCT. The results of this study indicated that HRC was perceived as being harder and produced higher fatigue levels, which in turn lowered acute performance. However, low-to-moderate intensity loads did not negatively affect performance. Thus, completing a PCT session may be the most appropriate option before a practice or game as it avoids acute–resistance–training-induced performance decrements. However, if the objective of the basketball session is to develop or perfect technical skills during fatiguing conditions, HRC may be the more suitable option.

KEY WORDS power, strength, basketball, repeated-sprint ability, vertical jump, shooting

INTRODUCTION

Basketball is a sport characterized by its intermittent, high-intensity activity that requires players to perform actions such as: jumping, sprinting, shuffling, or changing directions (1,26). Increased vertical jump ability (9,43), repeated-sprint ability (RSA), (5,38) and agility (9,43) are important determinants of high performance in basketball. Hence, strength and conditioning is a vital component in this sport and focuses on enhancing aerobic capacity, agility, speed, strength, and power (35). In fact, the ability to generate power and explosive force is essential for athletic performance (11).

Overall, both heavy-resistance training and power training using light-to-moderate loads are executed to improve athletic performance in team sports during the season (3,16,35). On the one hand, heavy-resistance training increases maximal strength (11), which is considered the physical quality that most affects maximal power (7). On the other hand, power training not only increases maximal power outputs using lighter loads and maximal movement velocities but also triggers specific neuromuscular adaptations that result in performance enhancements (7,11,24). The total work, duration of activation, and fatigue levels with power training are generally lower compared to heavy-resistance training (20).

Fatigue after resistance training has been widely studied (17,20,31). Fatigue is a complex, task-dependent phenomenon (12) that is defined as an exercise-induced reduction in the ability to exert muscle force or power (14) or, more globally, as an exercise-induced decline in athletic performance (19). It may occur because of changes at the muscular level

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30(2)/407–414

Journal of Strength and Conditioning Research

(peripheral fatigue) and of failure of the central nervous system to adequately drive the motor neurons (central fatigue) (12,14). Regarding athletic performance, time increments in sprint, agility, or RSA tests could be interpreted as manifestations of fatigue. In addition, fatigue may also manifest itself as a decrement in technical execution or in the motor skill outcome, which can be measured as ball velocity or accuracy (19,21).

Understanding the acute effects of postresistance training fatigue on performance of basketball players' is crucial since, during the competitive season, moderate- and high-intensity resistance training sessions are performed (22,35). To our knowledge, only 1 study (41) has investigated the acute effects of strength training in basketball players' performance by analyzing vertical jump, anaerobic power, and shooting accuracy after moderate-intensity resistance training. The results obtained indicated that such training, when completed 6 hours before a basketball practice, had no negative effects on performance. However, some semiprofessional teams or teams that must travel regularly between games may not have the opportunity to perform strength training in the morning and a basketball practice in the afternoon. Therefore, these two training components are generally executed in sequence. Nonetheless, there exists a lack of research addressing the acute effects that strength/power training may have on players' specific physical and technical performance due to postresistance training fatigue. In fact, no research has been conducted with heavy-resistance and power training that have been completed immediately before a regular basketball practice, and for that reason, their effects on basketball players are still unknown.

Therefore, the main aim of this study was to investigate the acute effects of two different resistance training protocols on the main factors of high performance in basketball. We hypothesized that power training would result in less perceived exertion than heavy-resistance training and would also result in lower declines on performance on vertical and horizontal jumps, shooting accuracy, agility, RSA, and upper body power output. The results may have important implications when determining the objective of the in-court basketball practice, if a strength session is performed immediately before it.

METHODS

Experimental Approach to the Problem

A repeated-measures, crossover, experimental design was used. The practical experiment was conducted after the end of the competitive season 2013/2014, in which participants played a total of 37 games (30 official and 7 preseason games) and trained for over 330 hours (250 hours of basketball practice and 80 hours on strength sessions). Procedures lasted 3 weeks, with participants being tested once every week. In week-0, on the same day, all participants were tested in resting conditions (REST) and completed a familiarization set of the resistance training protocols. They were then randomly divided in 2 groups (G1 $n = 4$, G2 $n = 5$) so that it was possible to properly monitor the strength training and testing procedures. On week-1 and week-2, subjects performed two different resistance training protocols–High-Resistance Circuit Training (HRC) (2) and Power Circuit Training (PCT)–always followed by the same testing procedures performed on week-0. G1 executed the HRC on week-1 and PCT on week-2. G2 completed the PCT on week-1 and HRC on week-2. For each group, resistance training and testing were performed on the same day of the week at the same hour of the day.

Subjects

Nine semiprofessional male basketball players (Table 1) competing in the Spanish League EBA (fourth division), with at least 5 years of playing experience and 1 year involvement in resistance training, volunteered to participate in this study. None of them had a previous history of injuries, diseases, or was on medications during the study. Players were fully informed about all testing and training procedures and signed written informed consent. Before the study, all of them underwent a physical examination by the team physician and were cleared of any endocrine disorder that might confound or limit their ability. Approval for the study was given by the Human Subjects Ethics Committee of the San Antonio Catholic University of Murcia, Spain, in accordance with the Declaration of Helsinki (2008). Participants were instructed to maintain their normal diet habits and the team's regular practice schedule of 4 basketball-training sessions per week throughout the investigation period.

Testing Procedures

All testing measurements were completed in the UCAM Research Center for High Performance Sports (Murcia, Spain) at the end of the competitive season. Procedures were performed after 36 hours of rest, during the recovery microcycle, to limit differences in the training status and/or intensity (30). Participants were tested in 3 separate

TABLE 1. General characteristics of the participants ($n = 9$).*

Age (y)	Height (cm)	Body mass (kg)	BMI (kg/m^2)	Half squat 1RM (kg)	Bench press 1RM (kg)
21.44 ± 2.5	197.69 ± 8.38	93.19 ± 14.46	23.77 ± 12.93	157.44 ± 21.98	85.82 ± 20.26

*BMI = body mass index; 1RM = 1 repetition maximum.

occasions: (a) on REST, the week before the beginning of the training protocols; (b) immediately after the HRC training session, and (c) immediately after the PCT training session. On week-0, the first day of testing, participants completed a standard warm up of 5 minutes light jogging on the treadmill followed by the joint mobility exercises and dynamic stretching routine; the team executed in their regular basketball practices. No static stretching was performed before testing (42). On this day, after all tests were concluded, the 6RM load for all exercises was determined. An initial resistance was selected based on the subject's perceived capacity to move the load only 6 times. After the first set, if ±1 repetition was completed, the load was adjusted by approximately 2%, and if subjects were able to lift ±2 repetitionsit was accommodated by 5%.

The testing sequence lasted 34 minutes for each player and consisted of a 3-point shooting test, horizontal and vertical jump tests, an agility test, an RSA test, and a bench-press power output test. Players were familiar with all the testing procedures as they had performed them during the season. The order of the tests was kept the same in all 3 sessions and each assessment was conducted by the same investigator in every occasion. The same certified strength and conditioning coach (NSCA-CSCS) supervised all the testing and training procedures.

Three-Point Shooting Test. The shooting test performed was the 1 described by Pojskić et al. (28) for 3-point shooting without fatigue. Each player performed 2 jump shots from behind the 3-point line and from 5 different positions, with a total of 10 shots per series. The positions were determined with marks on the floor so that the players shot from the exact same place on every series. A total of three series were completed, but only the last two were considered for analysis, because the first was a warm up. Each testing series was separated by 2 minutes. The selected test has been considered as a valid and reliable instrument to measure basketball 3-point shooting accuracy (28) and was performed 3 minutes after the end of the resistance training protocols.

Horizontal Jump Test—Standing Long-Jump. The standing long-jump (SLJ) was performed with participants starting before a line drawn on the floor, feet pointing forward and placed at shoulder width, and then jumping as far as possible, landing on two feet. Arm-swing and a countermovement were allowed (23). Participants performed two practice trials and then two test trials separated by 1 minute of rest. The distance, measured to the nearest 0.01 m, was considered as the horizontal displacement of the feet between the starting line and the point where the back heel contacted the floor. Only the best result was considered for analysis. The test was performed 8 minutes after resistance training.

Vertical Jump Test—Countermovement Jump. The countermovement jump (CMJ) was performed on a Kistler 9286BA portable force platform (Kistler Group, Winterthur, Switzerland). Players started in a standing position with feet placed at shoulder width, on the center of the force platform, and were asked to jump as high as possible with a rapid countermovement. Hands were kept on the hips throughout the execution of the jump. The depth of the countermovement was self selected and subjects were asked to try and land close to the point of takeoff (23). Participants executed 2 submaximal trials to ensure proper execution of the jump and performed 2 maximal CMJ on the force platform with 1 minute of rest between them. Only the best attempt was considered. The parameters calculated were: (a) jump height, based on the velocity at takeoff and (b) absolute peak power and relative peak power, calculated with Microsoft Excel software (Microsoft Corporation, Redmond, WA, USA) from the data exported from the force platform. The CMJ has been considered the most reliable and valid test for the estimation of explosive power of the lower limbs (23). It was executed 10 minutes after the end of strength training.

Agility Test—Agility T-Test. The agility T-Test was performed using the standard protocol (37). At the tester's signal, players sprinted 9.14 m forward to the first cone and touched it. Then, subjects shuffled 4.57 m to the left and touched the second cone. After that, they shuffled 9.14 m to the right and touched a third cone and then 4.57 m to the left, back to point where the first cone was, touching it again. Finally, participants backpedaled 9.14 m, passing through the finish line. Time was measured with wireless photocells from Microgate's WITTY System (Mircrogate, Bolzano, Italy) placed on the starting line. Time started counting once the players broke the light beam the first time and stopped when they broke it the second time. Participants were verbally encouraged throughout the test and were asked to perform at the maximal effort. The only parameter considered was the total time. Two trials were allowed for each testing session, separated by 2 minutes. Only the best time was considered. Agility T-Test is a reliable and valid instrument (37) and was performed 17 minutes after the end of the resistance circuit protocols.

Repeated-Sprint Ability Test. The RSA protocol used was the one proposed by Castagna et al. (6) and consisted of 10 shuttle-run sprints of 30 m (15 + 15m) with 30 seconds rest between each bout. An excellent reliability and validity of this basketball-specific test has been reported (6). Wireless photocells from Microgate's WITTY System (Mircrogate) were placed in the starting line to record the time of each sprint. Participants were asked to perform at the maximal effort and verbal encouragement was given throughout the test. The parameters calculated were: (a) total time, consisting of the sum of all 10 sprint times; (b) ideal time, calculated as the best sprint time multiplied by 10; and (c) performance decrement (PDec; %), determined according to the equation proposed by Fitzsimons et al. (13):

$$P_{\mathrm{Dec}} = 100 \times (\text{total sprint time}/\text{ideal sprint time}) - 100.$$

The RSA test was performed 23 minutes after the end of the strength training.

Bench-Press Power Output Test. The bench-press power output test was conducted on a modified Smith machine with a linear encoder (Chronojump-BoscoSystem, Spain) attached to the barbell and interfaced with a computer. All data were recorded with Chronojump-BoscoSystem software. The test was completed with each participant's bench-press 6RM load that was previously determined. Participants completed 3 repetitions descending the barbell to the point at which it nearly touched the chest and were verbally encouraged throughout the exercise to move the barbell as fast as possible in the concentric phase. Peak power was measured and only the best repetition was considered. A spotter was used during the test to assist in racking the resistance and to ensure safety and proper range of motion. This test was performed 33 minutes after resistance circuit training was completed each time.

Rating of Perceived Exertion—Borg CR-10 Scale. Rating of perceived exertion (RPE) was assessed on week-1 and week-2 using the Borg CR-10 scale (4). Participants were instructed on how to use the scale before the start of resistance training, on week-1. They were shown the RPE table to clearly understand what each number represented. Approximately 20 minutes after both HRC and PCT and before performing the RSA test, participants were asked "*How was your workout*?" and presented with the table. This time frame was selected so that the difficult or easy elements that were performed close to the end of the session would not tilt the RPE of the entire bout (8).

Training Protocols

The HRC protocol was based on the one proposed by Alcaraz, et al. (2). It consisted of 6 exercises, divided in 2 blocks of 3 (Figure 1). Participants completed 4 sets of each block with the previously determined 6RM load for every exercise. The local recovery, for each muscle, was 3 minutes (time separating 1 set of a given exercise to the next set of same exercise) and 40 seconds was the rest period between exercises. The training session started with a warm up consisting of 5 minutes of light jogging on the treadmill followed by joint mobility exercises and dynamic stretching. The specific warm up consisted of 1 set of 10 repetitions of each exercise of the first block with 50% of the 6RM load. The second block started 5 minutes after the end of block 1. The first 3 minutes between the two blocks consisted on a passive rest period and the final 2 minutes were destined to the specific warm up of the second block. Upper- and lower-body muscle groups were alternated in consecutive exercises to allow for local recovery to occur. Rest intervals shorter than 3 minutes for the same exercise do not allow participants to maintain the number of repetitions at the same intensity (33).

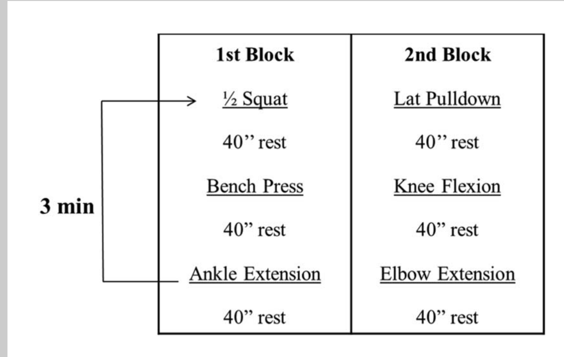

Figure 1. Resistance training protocol for both high-resistance circuit training (HRC) and Power Circuit Training (PCT). The exercises performed, exercise order, rest period between exercises, and local recovery time were all kept the same in both training conditions. The sole difference between HRC and PCT regarded the training intensity and working loads.

Players were verbally encouraged to execute the concentric phase of all exercises at the maximum possible velocity and lifted weights that allowed only 6 repetitions to be performed. If necessary, during the workout, the 6RM loads were adjusted for every set by 2%, if a participant performed ±1 repetition, or by 5%, if he completed ±2 repetitions.

The PCT protocol was very similar to the HRC. The training consisted of the same 6 exercises divided in the same 2 blocks (Figure 1). The warm up protocol was identical, as were the duration of the rest periods between exercises, the local recovery, and the number of sets and repetitions performed. The main differences between the PCT and HRC protocols were on the loads lifted, on the velocity of execution of the exercises, and whether these were performed to volational fatigue or not. The PCT protocol was executed with the loads corresponding to maximal power output in basketball players, 45% of 1RM (32), and volational fatigue was not achieved. The 1RM load was estimated using the Brzycki equation; previously considered a valid method (27).

Given that the loads were considerably lower, the velocity on the execution of the exercises was higher than in HRC. Participants were verbally encouraged to execute the concentric phase at the maximum possible velocity. For safety reasons, they were not allowed to jump on the half squat or to lose contact with the barbell on the bench press.

In both training protocols the concentric–eccencentric ratio was the same, 1:3. Spotters were present in every station of the circuit to ensure safety to the participants and to control the rest periods. The duration of HRC and PCT sessions was 45 minutes.

Statistical Analyses

Statistical analysis was conducted using IBM SPSS Statistics 21 for Windows (IBM Corporation, Armonk, NY, USA). All the data were expressed as mean ± SD. Normality was assessed with the Shapiro–Wilk test and homogeneity of variances with the Levene test. Parametric tests were applied. Repeated-measures analysis of variance, with intervention (training protocol) as factor, was performed to examine within-subject differences among REST, HRC, and PCT. Bonferroni adjustment of the confidence interval for multiple comparisons was used to locate the pair-wise differences between the mean values. Power ($1-\beta$) was determined for all variables and effect sizes (d) were calculated using Cohen's d. Statistical significance was considered for $p \leq 0.05$.

RESULTS

Vertical and Horizontal Jumps

The CMJ height ($1-\beta = 0.87$; $d = 0.61$), absolute ($1-\beta = 0.96$; $d = 0.73$) and relative peak power ($1-\beta = 0.95$; $d = 0.72$) values, and SLJ horizontal distance ($1-\beta = 1.00$; $d = 0.89$) were determined in all testing conditions (Table 2). The HRC protocol provoked a significant decrement ($p \leq 0.05$) in all variables studied. These declines were significantly lower ($p \leq 0.05$) when compared to PCT. No statistical significance was found between PCT and REST values.

Shooting

On the 3-Points shooting test, the parameters calculated were the total number of shots made ($1-\beta = 0.99$; $d = 0.74$), number of shots made per series ($1-\beta = 0.989$; $d = 0.74$), and shooting percentage ($1-\beta = 0.99$; $d = 0.74$) (Table 2). After the completion of the HRC training the shooting accuracy was significantly lower ($p \leq 0.05$), compared to the other 2 testing conditions. No statistical significance was found between PCT and REST values.

Repeated-Sprint Ability and Agility

Values obtained in RSA test and agility T-Test are expressed in Table 2. The RSA total time ($1-\beta = 0.99$; $d = 0.81$) was higher ($p \leq 0.05$) after the HRC session, when compared to the PCT session and REST. Concerning the RSA ideal time ($1-\beta = 1.00$; $d = 0.85$), the trend was similar. The slowest performance was found after the HRC training, followed by PCT and REST. There were significant differences ($p \leq 0.05$) between HRC and REST and between HRC and PCT, but not between REST and PCT. Regarding RSA PDec ($1-\beta = 0.77$; $d = 0.54$), values were lower on REST than after either resistance training protocols. The only significant differences ($p \leq 0.05$) were found between HRC and REST.

In the agility T-Test, results showed that after HRC training, the total time ($1-\beta = 1.00$; $d = 0.86$) was significantly higher ($p \leq 0.05$) than in the other 2 conditions, indicating a lower performance. No statistical differences were found between PCT and REST.

TABLE 2. Performance measurements for all variables on the three experimental conditions.*

	REST	HRC	PCT
CMJ			
Height (m)	0.35 ± 0.07	0.28 ± 0.08†	0.33 ± 0.07‡
Absolute peak power (W)	5078.18 ± 436.83	4400.74 ± 430.01†	4819.44 ± 341.55‡
Relative peak power (W/kg)	55.70 ± 6.52	48.43 ± 7.39†	52.66 ± 7.06‡
SLJ			
Distance (m)	2.47 ± 0.25	2.36 ± 0.25†	2.43 ± 0.26‡
3-points Shooting			
Total shots made	9.67 ± 1.70	7.78 ± 1.40†	10.56 ± 2.59‡
Total shots made per series	4.83 ± 0.85	3.89 ± 0.70†	5.28 ± 1.29‡
Total shooting percentage (%)	48.33 ± 8.50	38.89 ± 6.98†	52.78 ± 12.93‡
Repeated-Sprint Ability			
Total time (s)	57.50 ± 2.89	59.24 ± 3.32†	58.08 ± 3.33‡
Ideal time (s)	55.88 ± 2.68	56.90 ± 2.82†	56.23 ± 3.02‡
Performance decrement (%)§	2.89 ± 0.96	4.22 ± 0.75†	3.29 ± 0.94
Agility T-Test			
Total time (s)	9.52 ± 0.63	9.71 ± 0.69†	9.54 ± 0.72‡
Bench press			
Power output (W)	595.40 ± 80.25	518.58 ± 95.32†	574.94 ± 93.57‡
Borg CR-10 Scale			
Rating of perceived exertion (UA)‖		7.89 ± 0.57	4.33 ± 0.94‡

*REST = resting conditions; HRC = high-resistance circuit training; PCT = power circuit training; CMJ = Countermovement jump; SLJ = standing long-jump.

†$p \leq 0.05$, as related to resting conditions.

‡$p \leq 0.05$ as related to HRC.

§Performance decrement (PDec) was calculated with the following equation (13): PDec = 100 × (total sprint time/ideal sprint time) − 100.

‖Rating of perceived exertion was assessed with a Borg CR-10 Scale, 20 minutes after training (8).

Bench-Press Power Output

The bench-press power output ($1-\beta = 0.88$; $d = 0.62$) values obtained (Table 2) indicated that performance was significantly lower ($p \leq 0.05$) in HRC when compared to both REST and PCT. No statistically significant differences were found between PCT and REST.

Rating of Perceived Exertion–Borg CR-10 Scale

The RPE ($1-\beta = 1.00$; $d = 0.90$) (Table 2) was assessed with the Borg CR-10 Scale and results showed that participants considered the HRC training as being more intense than the PCT protocol. According to the Borg CR-10 Scale, HRC was perceived as "*Very Hard*" and PCT as "*Somewhat Hard*." The differences were statistically significant with $p \leq 0.05$.

Discussion

To the best of our knowledge, this is the first study that has investigated the acute effects of HRC and PCT on basketball-specific physical and technical skill performance. The main findings supported our hypothesis because immediately after a PCT bout, CMJ and SLJ performance, shooting accuracy, RSA, agility, and upper body power output were not negatively affected in basketball players. Furthermore, performing a PCT session was perceived as less intense than completing an HRC bout. These findings suggested that power training may be the most appropriate option before a practice or game, as it avoids acute resistance training-induced performance decrements and minimizes fatigue, thus preventing an increased risk of injury (10). However, if the objective of the basketball session is to develop or perfect technical skills under fatiguing conditions, hence HRC may be the more suitable option.

Previous studies have also demonstrated increased levels of fatigue after high-intensity resistance training (17,20). Linnamo et al. (20) showed that maximal strength training led to greater neuromuscular fatigue than power training using 40% 1RM. This is in accordance with the performance decrements observed in all variables measured in our basketball players, after HRC compared to PCT.

Shooting, which is the most important action in basketball, can be affected by fatigue (28,39). Its accuracy depends on an adequate technique (39) and our results showed that after HRC, the total number of shots made, mean shots made per series, and total shooting percentage were significantly lower. The present data support the idea that the magnitude of immediate fatigue and its recovery are dependent on the intensity of the performed task (29). In fact, higher levels of fatigue have been shown to affect motor skill outcomes in basketball players (19,21,28). This may not be necessarily a negative aspect if the objective of the practice is to perform shooting drills when players are already fatigued, as it occurs in competition. In reality, some teams combine high-intensity strength training with low-intensity technical sessions (22) due to time limitations during the competitive season (35). Although basketball shooting kinematics was not analyzed in our study, modifications in the movement pattern most probably occurred because of fatigue. This phenomenon has been reported in previous research with elite basketball players (39). Another interesting finding is that our data seems to be the first to indicate that basketball-specific motor skills remain unaltered in trained individuals immediately after a moderate-intensity strength training session. Kauranen et al. (18) had already reported that the motor skill performance of the hand (reaction time, speed of movement, tapping speed, and coordination) was not altered immediately after moderate-intensity training. However, those results were obtained with untrained subjects.

Other important factors related to success in basketball are the jumping ability and power output production. Thus, CMJ and SLJ are commonly used to assess the basketball players' physical fitness (43). Our data indicated a decline in jump performance after HRC, and moreover, several studies have shown that fatigue negatively affects vertical jump performance (31,36). It is probable that the main mechanisms responsible for the diminished CMJ and SLJ performance were peripheral in the origin, given the time elapsed between the end of resistance training and both tests was 10 minutes (29). Raastad and Hallen (29) suggest that 5 minutes after exercise cessation, the reduced neural activation is practically recovered and, so, central fatigue was not a major factor of decrements in CMJ height. Furthermore, declines in the power output of dynamic tasks have been associated to peripheral fatigue, specifically to a reduction of shortening velocity (17). This phenomenon can be related to other variables of our study's as the same mechanisms were responsible for the declines observed in bench-press power output after HRC. Although there are differences in fatigability of upper and lower body, declines in power and velocity are believed to be peripheral in the origin of both CMJ and bench press (34).

In basketball players, a significant correlation between the CMJ and RSA has been reported (38). As previously observed in our study, a decline in CMJ performance occurred after HRC. Hence, RSA could be expected to be affected as well. In effect, concerning this latter variable, the performance declined after HRC. Participants were significantly slower completing the whole 10 sprints and also fatigued more throughout the protocol. Although no studies have investigated the effects of resistance training on RSA performance, the decrements observed may be related to the fact that an HRC session was performed. Heavy-resistance training leads to a high rate of energy utilization through phosphogen breakdown and activation of glycogenolysis, which results in significant decreases in ATP and muscle glycogen concentration (40). In fact, preceding high-intensity efforts may compromise RSA due to limitations in energy supply, mainly from phosphocreatine, and alterations in muscle excitability related with sodium or potassium disturbances at the muscular level (15).

The main energy metabolisms involved in RSA are most likely the same as in the agility T-Test since this latter test consisted of maximal effort completion, in all three experimental conditions, in less than 10 seconds. Analyzing the results, we observed increases in total time only after HRC. We consider the causes for performance declines in agility were the same as in the RSA effort. Possible decreased muscle glycogen concentration (19,40) and postresistance-training impaired muscle contractile function (17) contributed to the results obtained. Meylan et al. (25) state that sudden bursts of power are needed to rapidly change direction during athletic actions, and as our CMJ results showed, lower-body power production was impaired, which possibly contributed to reduce participants' agility.

As stated before, our results indicated that fatigue was greater after HRC when compared to PCT. This conclusion was also sustained by the subjects' perception of effort in following each protocol. The RPE was significantly higher after HRC, which is not surprising because of the relationship between the RPE and resistance training intensity (8). Day et al. (8) conducted a study in which participants completed, on separate days, the same resistance training protocol with different loads (5RM, 10RM, and 15RM) and concluded that lifting heavier loads was perceived as more difficult. Heavy-resistance training requires greater muscle tension development that results in an increment of motor unit recruitment and firing frequency, thus increasing the perception of effort (8).

The main methodological limitation of this study was the small sample size, although medium- to large-effect sizes were obtained for all variables. Another limitation was the fact that the last assessment was completed more than 30 minutes after the end of both resistance protocols because all tests were performed in sequence, in the same session. The long recovery period between some tests and the end of the training could have influenced the results. However, the order of the testing was the same for each participant in all the sessions.

Further studies are needed to determine the fatigue mechanisms that lowered performance as the methodology used did not allow for the determination of such mechanisms. Furthermore, the long-term effects of these two resistance training protocols on the variables studied are still unknown for basketball players.

Practical Applications

The results of this study may be useful for strength and conditioning coaches to plan their sessions more effectively. Our data show that a PCT session may be an appropriate option for basketball players to complete before a tactical session or game, as it avoids acute resistance training-induced performance decrements. Jumping performance, shooting accuracy, RSA, agility, and upper body power output are not negatively affected. In contrast, postsession performance impairments in the main determinants of success in basketball are present after an HRC session, for at least 30 minutes. This may lead to a decline in the quality of the practice or game and to an increased risk of injury.

Nonetheless, HRC is important to develop or maintain maximal strength. For this reason it should be included in the strength program of a basketball team. Sessions of HRC may be a suitable alternative when the objective of the oncourt practice is to develop or perfect technical skills under fatiguing conditions, as it occurs in competition.

Acknowledgments

The authors would like to express their gratitude to the participants of this investigation. In addition, the authors would like to acknowledge UCAM Murcia CB for their assistance throughout the project. Furthermore, a special acknowledgment to Dr. Linda Chung for all the help in revising the present manuscript. No funding was received for this investigation. The results from this study do not constitute endorsement of the products by the authors or by the National Strength and Conditioning Association.

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