Eight-Week Battle Rope Training Improves Multiple Physical Fitness Dimensions and Shooting Accuracy in Collegiate Basketball Players

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Abstract

Chen, WH, Wu, HJ, Lo, SL, Chen, H, Yang, WW, Huang, CF, and Liu, C. Eight-week battle rope training improves multiple physical fitness dimensions and shooting accuracy in collegiate basketball players. *J Strength Cond Res* 32(10): 2715–2724, 2018—Basketball players must possess optimally developed physical fitness in multiple dimensions and shooting accuracy. This study investigated whether battle rope (BR) training enhances multiple physical fitness dimensions, including aerobic capacity (AC), upper-body anaerobic power (AnP), upper-body and lower-body power, agility, and core muscle endurance, and shooting accuracy in basketball players and compared its effects with those of regular training (shuttle run [SR]). Thirty male collegiate basketball players were randomly assigned to the BR or SR groups ($n = 15$ per group). Both groups received 8-week interval training for 3 sessions per week; the protocol consisted of the same number of sets, exercise time, and rest interval time. The BR group exhibited significant improvements in AC (Progressive Aerobic Cardiovascular Endurance Run laps: 17.6%), upper-body AnP (mean power: 7.3%), upper-body power (basketball chest pass speed: 4.8%), lower-body power (jump height: 2.6%), core muscle endurance (flexion: 37.0%, extension: 22.8%, and right side bridge: 23.0%), and shooting accuracy (free throw: 14.0% and dynamic shooting: 36.2%). However, the SR group exhibited improvements in only AC (12.0%) and upper-body power (3.8%) ($p < 0.05$). The BR group demonstrated larger pre–post improvements in upper-body AnP (fatigue index) and dynamic shooting accuracy than the SR group did ($p < 0.05$). The BR group showed higher post-training performance in upper-body AnP (mean power and fatigue index) than the SR group did ($p < 0.05$). Thus, BR training effectively improves multiple physical fitness dimensions and shooting accuracy in collegiate basketball players.

Key Words high-intensity interval training, power rope, total-body training

Introduction

Basketball is a sport characterized by intermittent bouts of high-intensity activity (e.g., jumping, sprinting, shuffling, and changing directions) repeated over a prolonged period of time (3,36). It involves both aerobic and anaerobic energetic processes (46). Hence, to play successfully, basketball players must possess optimally developed physical fitness in multiple dimensions, including aerobic capacity, anaerobic power, upper-body and lower-body power, agility, and core muscle endurance (2,9,10,19). In addition to a high level of physical fitness, basketball players must possess excellent techniques such as shooting, jumping, passing, and dribbling. Shooting accuracy is one of the most important techniques that determine the successful playing of basketball (22,40). Previous studies have shown that shooting accuracy is a crucial factor distinguishing between winning and losing basketball teams (39,47). Consequently, identifying the training method that can be more effective in developing multiple physical fitness dimensions and shooting accuracy in basketball players is important.

Interval training is the most common conditioning method and the most recommended training method in basketball (43). Interval training can effectively improve both anaerobic and aerobic energy supplying systems significantly (44). Interval training has been confirmed to be an effective training method for improving aerobic capacity in basketball

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players (18). Shuttle run (SR) training is one of the most common interval training methods in basketball (50). It was demonstrated that SR (180° directional changes) induces an increase in metabolic, cardiorespiratory, neuromuscular, and perceptual responses compared with straight-line runs and repeated sprints (4,13,14,21,23,25). The psychophysiological responses with ratings of perceived exertion are about 0.8–8.0 and blood lactate values are about 0.8–9.7 $mmol \cdot L^{-1}$ increase with the time spent accelerating at each turn increased by frequency of directional change and speeds of SR at 2.50, 3.25 and 4.00 $m \cdot s^{-1}$ (4). Shuttle run interval training has been demonstrated to be effective in improving oxidative capacity and reducing lactate accumulation in young basketball players (50). However, this type of running training is designed to primarily train the lower-body (leg) musculature (37), and it does not train the total-body musculature such as the trunk/core and upper-body musculature effectively. Moreover, depending on the speed and landing geometry, running causes impact forces that vary in magnitude, from approximately 1.5–5 times body mass, and last for a very brief period (<30 ms) (26). Thus, running training may be not the optimal method to enhance multiple physical fitness dimensions and total-body muscle capacity in basketball players, particularly players with lower extremity injury or a high risk of injury.

Battle rope (BR) interval training is a low-impact, total-body, and intense metabolic modality (15,24,42). In recent years, its popularity has increased in various populations, from general health and fitness trainees to professional athletes (41). This exercise involves total-body muscle activity; the muscle activity for anterior deltoid, external oblique, and lumbar erector spinae (double-arm waves and alternating waves) ranges from 51% maximum voluntary isometric contractions (MVIC) to 73% MVIC, whereas gluteus medius muscle activity is 14–18% MVIC (15). Battle rope exercise commonly uses ropes of 12–15 m in length, 3–5 cm in diameter, and 9–16 kg in mass (24,30,33) and is normally performed at maximal speed during a given time, allowing a high number of repetitions and resulting in a vigorous cardiovascular workout (24,41,42). The acute cardiovascular stimulus provided by BR exercise is even greater than that provided by traditional resistance exercises (with a load of 75% of 1 repetition maximum) (41). Battle rope training improves multiple physical fitness dimensions and total-body muscle capacity, including aerobic capacity (8,30), muscular endurance (upper-body and trunk) (33), and power (lower-body) (8). It may be a highly effective method by which basketball players can enhance multiple aspects of physical fitness (aerobic, upper-body anaerobic power, upper- and lower-body power, agility, and core muscle capacity) and shooting accuracy. Therefore, this study explored the effects of BR interval training on multiple physical fitness dimensions and on shooting accuracy in elite college basketball players and compared these effects with those of regular training (SR, interval training).

Methods

Experimental Approach to the Problem

A pre–post-test equivalent-group design was used to compare the enhancements made by BR and SR to multiple physical fitness dimensions and shooting accuracy in elite college basketball players over 8 weeks. All subjects were well-trained Division-I basketball players; they were randomly assigned to the BR and SR groups. Both groups received 3 sessions of interval training each week for 8 weeks; the protocol consisted of the same numbers of sets, exercise intervals, and rest intervals. The independent variables were BR training and SR training, and the dependent variables were aerobic capacity, upper-body anaerobic power, upper-body power, lower-body power, agility, core endurance, and shooting accuracy.

Subjects

Thirty male well-trained Division-I basketball players (age range: 18–25 years; basketball training: 6.7 ± 3.8 years) who had not sustained neuromuscular injury in the prior 6 months participated in this study. They routinely engaged in 3-hour basketball training sessions 3 times per week (Table 1) and in 1.5-hour resistance training sessions 2 times per week. Each resistance training session consisted of 4 sets of 6 exercises involving the upper limbs, trunk, and lower limb muscles using a load of 6–10 repetition maximum. All subjects were recruited from the same university and had no BR training experience before the study. Each subject was randomly assigned either to the BR group (mean ± *SD*, $n = 15$; age: 21.1 ± 1.7 years; height: 179.6 ± 9.6 cm; body mass: 79.2 ± 14.2 kg) or to the SR group ($n = 15$; age: 20.6 ± 1.8 years; height: 183.6 ± 9.0 cm; body mass: 82.4 ± 14.7 kg). Thus, an identical training program and the same work flow were applied to all subjects. This experiment was conducted during the off-season to prevent the other factors (e.g., training, injury, competition) from contributing to training effects. All subjects were instructed to maintain their normal diet habits and team's regular basketball and resistance training throughout the investigation period. The experimental procedures used in this study were approved by the Institutional Review Board of University of Taipei in Taiwan. All subjects were informed of the experimental risks and signed an informed consent form before participating in this study.

Procedures

Battle Rope Training Protocol. Battle rope training commonly uses ropes of 12–15 m in length, 3–5 cm in diameter, and 9–16 kg in mass (24,30,33), and set durations usually range from 15 to 30 seconds, with rest intervals of 15 seconds to 2 minutes (24,41,42). In this study, the BRs used had a length of 15 m, diameter of 4 cm, and mass of 18 kg. Battle rope training involved 8 weeks of interval training for 3 sessions per week. The protocol for the 1st week and the second week consisted of 30 minutes of exercise at a work-to-rest ratio of 1:3

TABLE 1. Regular basketball training.

Week 1–2
Monday, Wednesday, Friday
Dribble: crossover, between-the-legs, behind-the-back, spin move, and inside-out.
Shoot off the dribble: crossover, between-the-legs, behind-the-back, spin move, and inside-out.
Two-player sliding pass: chest pass, bounce pass, one-hand pass with one- and 2-ball.
Three-player moving pass: chest pass, bounce pass, and one-hand pass.
Week 3–4
Monday, Wednesday, Friday
Individual defense: sliding, sideways running, slide-run-slide, over play, and deny and stop the ball.
Two-, 3-, and 4-player fast break
Two- and 3-player group cooperation
Team offense drills–offensive move to attack man to man defense
Week 5
Monday, Wednesday, Friday
Two- and 3-player man to man defense–strong and weak side help and recover concept
Five-player fast break
3 on 2 and 2 on 1
Half-court 3-player group offensive and defensive drills
Team offense drills–offensive move to attack man to man defense
Week 6
Monday, Wednesday, Friday
Four- and 5-player man to man defense–strong and weak side help and recover concept
Five-player fast break
3 on 2 and 2 on 1
Full-court 3-player and 4-player group offensive and defensive drills
Team offense drills–offensive move to attack man to man defense
Week 7
Monday, Wednesday, Friday
Half-court zone defense: 2-3, 3-2, 1-1-3, and 1-3-1.
Full-court 4 and 6 cones layup
Three-, 4-, and 5-player fast break
Team offense drills–offensive move to attack zone defense
Week 8
Monday, Wednesday, Friday
Half-court zone defense: 2-3, 3-2, 1-1-3, and 1-3-1.
Full-court zone defense (double-team): 2-2-1 and 1-2-1-1.
Full-court 5-ball layup
Three-, 4-, and 5-player fast break
Team offense drills–offensive move to attack zone defense

(15-second exercise; 45-second rest), totaling 30 sets; the protocol from the third week to the fifth week consisted of 30 minutes of exercise at a work-to-rest ratio of 1:2 (20-second exercise; 40-second rest), totaling 30 sets; the protocol from the sixth to the eighth week consisted of 36 minutes of exercise at a work-to-rest ratio of 1:2 (20-second exercise; 40-second rest), totaling 36 sets (Table 2). Battle rope training consisted of 6 BR exercises, with one type exercise performed in each set. The 6 BR exercises were performed in a circuit format: (a) double-arm waves, (b) side-to-side waves, (c) alternating waves, (d) in-out waves, (e) hip toss, and (f) double-arm slams (Table 3). The 6 exercise circuit was completed 5 times for the first week to the fifth week, and 6 times from the sixth to the eighth week. Before training, subjects took part in a familiarization session to familiarize with the 6 BR exercises by using BRs that be used during training, movement amplitude, and body position. Subjects practiced the exercises until the researcher was satisfied that the proper form was achieved. To maintain rope oscillations, subjects performed each repetition as rapidly as possible.

Shuttle Run Training Protocol. The SR group received 8 weeks of SR interval training for 3 sessions per week; the protocol consisted of the same numbers of sets, exercise intervals, and rest intervals as those of BR training protocol (Table 2). The difference between the BR and SR training protocols was that in SR training, each subject ran a 15-m distance with a 180° change in direction at an individual speed, which was 75–85% of the subject's maximum speed, according to the number of laps reached.

Table 2. Training protocol.*

Week	Times per week	Sets per time	Exercise time per set (s)	Interval rest time per set (s)
BR				
1st–2nd	3	30	15	45
3rd–5th	3	30	20	40
6th–8th	3	36	20	40
SR				
1st–2nd	3	30	15	45
3rd–5th	3	30	20	40
6th–8th	3	36	20	40

*BR = battle rope group; SR = shuttle run group.

To confirm the intensity of BR and SR training, this study measured the heart rate of 12 subjects ($n = 6$ per group) selected by random sampling during 30 minutes training from the third week to the fifth week. The heart rate was measured by Polar RS800 monitor (Polar Electro Oy, Kempele, Finland). The result of independent t-test showed that there were no significant differences in average and peak heart rate between BR and SR training ($p < 0.05$). The average heart rate of BR and SR training was 144.8 ± 5.7 and 145.3 ± 6.4, respectively. The peak heart rate of BR and SR training was 169.8 ± 6.1 and 166.3 ± 6.4, respectively.

Measurements. For all tests, the same procedure was applied before and after training. All tests were performed in the afternoon of 2 different days. On day 1, upper-body power, lower-body power, agility, core endurance, and upper-body anaerobic power were tested. After 48 hours, shooting accuracy and aerobic capacity were tested on day 2. Posttests were performed at intervals of 2 days after training. Before the measurements, all subjects performed standardized warm-up activities including ankle pops, running forwards and backwards, carioca, lateral slide step, Frankenstein, Frankenstein to Romanian Deadlift, running hip out and hip in, walking knee to chest, hip stretch with a twist, reverse lunge with twist, butt kicks, quad walk, inchworm, and t-push-ups.

The test–retest reliability of all the dependent variables was assessed using an intraclass correlation coefficient (ICC). Because the intensity of aerobic capacity, upper-body anaerobic power and core endurance tests was very rigorous, these 3 tests were only executed 1 time in 1 day to avoid fatigue effect. Accordingly, the test–retest reliability of the 3 variables was reported by the ICC between day test sessions. On the other hand, the test–retest reliability of the other variables was reported by the ICC within day sessions.

Aerobic Capacity Test. The Progressive Aerobic Cardiovascular Endurance Run (PACER) test was used to measure aerobic capacity (28,49). In this test, subjects ran for as long as possible back and forth across a 20-m distance at a specified cadence, which increased each minute. The test was terminated when a subject failed to reach the appropriate marker twice in the allotted time or could no longer maintain the pace. The number of laps completed was recorded. In the present study, the between-day ICC of the PACER test was 0.877.

Upper-Body Anaerobic Power Test. The 30-second Wingate anaerobic test was used to measure anaerobic performance (32). In the present study, the upper-body Wingate anaerobic test was conducted using an arm ergometer (Ergomedic

Table 3. Battle rope training exercises.

Battle rope exercise	Each exercise: athletic position, feet shoulder width apart, and shoulders retracted, with good posture.
Exercise 1: double arm waves	Subject waves ropes up (shoulder level) and down synchronously
Exercise 2: side to side waves	Subject waves ropes in side to side transverse motion to create S waves
Exercise 3: alternating waves	Subject waves ropes up (shoulder level) and down, alternating arms
Exercise 4: in-out waves	Subject waves ropes in and out transverse motion like clapping hands
Exercise 5: hip toss	Begin with both hands placed next to one hip, quickly pivot hips while simultaneously swinging arms up and over to the opposite side. Repeat.
Exercise 6: double-arm slams	Subject waves ropes up (overhead) and forcefully slam the rope down to the floor to create big waves

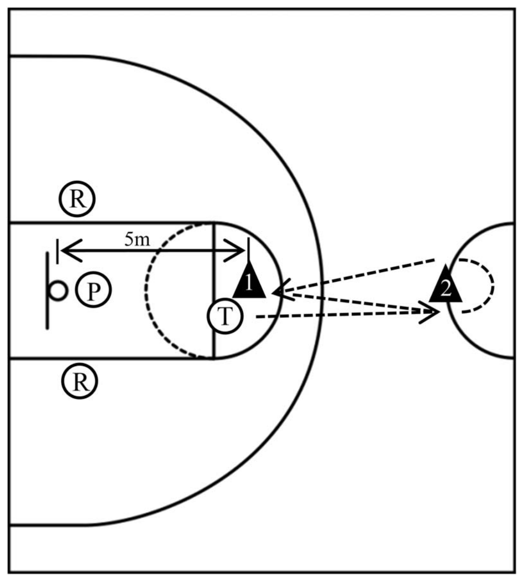

Figure 1. Dynamic shooting test.

891E; Monark Exercise AB, Vansbro, Sweden). Subjects sat in a chair (fixed to the ground), kept their feet flat on the ground, and remained seated throughout the Wingate anaerobic test. The arm ergometer height was adjusted, so that the crank was positioned on the opposite side of the body, and during the grasping of the handles, the elbow joint was almost in full extension (165°–175°) and the shoulder was in line with the center of the ergometer's shaft.

During the 5-minute warm-up period, 2–3-second flat-out sprints were performed at the beginning of the fourth minute of warm-up. Tests were started 5 minutes after the end of the warm-up period. The Wingate anaerobic test consisted of exercise performed at maximal power for 30 seconds, with an external resistance corresponding to 62 $g \cdot kg^{-1}$ body mass (11). The test on the arm ergometer began without external resistance, which was added immediately after the test was initiated. Values at 5-second intervals were recorded and were used to calculate peak power (PP) in the initial 5-second period, mean power (MP) for 30 seconds, and fatigue index = (PP − Minimal power)/PP × 100%. The between-day ICC values for PP, MP, and fatigue index were 0.928, 0.865, and 0.607, respectively.

Upper-Body Power Test. The basketball chest pass technique was chosen in this study because it is the most convenient assessment of players' upper-body power during practice sessions (20). In addition, it has been applied in recent studies comparing different basketball playing positions (20). Subjects sat with their heads, backs, and buttocks against a wall. Their legs were resting straight horizontally on the floor in front of their bodies, with their feet at shoulder width. Through a 2-handed chest pass, they pushed a basketball in the horizontal direction as far as possible. The ball pass speed was measured using a self-developed infrared grating. The infrared grating consisted of 2 gratings separated by 20 cm. The 2 gratings were placed in front of the subject, and the first grating was 10 cm from the subject's heel. The players performed 2 trials to become familiar with the gratings. Subsequently, 5 trials were performed, and the upper-body power in the best of 3 trials was averaged. A new basketball was used in this test. The within-day ICC for upper-body power was 0.890.

Lower-Body Power Test. Subjects performed counter movement jumps (CMJs) on a force plate (Kistler 9260AA; Kistler Instrument Corp., Winterthur, Switzerland) at a sampling rate of 1,000 Hz. Subjects completed 3 trials in total. The vertical jump height was calculated from the flight time, as follows: jump height = (g × flight time × flight time)/8 (16), where g is the acceleration due to gravity (9.81 $m \cdot s^{-2}$). The average jump height of 3 trials was used for analysis. The within-day ICC for CMJ was 0.965.

Agility Test. The T-test was used to measure agility in this study because it uses most of the basic movements performed during a game (20). In this test, 4 cones were arranged in a T shape, with a cone placed 9.14 m from the starting cone and 2 more cones placed 4.57 m on either side of the second cone (35). From the starting line, each subject sprinted 9.14 m forward to the first cone and touched the tip with his right hand. Subsequently, he shuffled 4.57 m left to the second cone and touched the tip with his left hand. He then shuffled 9.14 m right to the third cone and touched the tip with his right hand and shuffled 4.57 m left back to the middle cone and touched with the tip his left hand before finally backpedaling to the starting line (20). The times taken for this test were recorded using an electronic timing gate (Smart Speed; Fusion Sport, Queensland, Australia), with a height of 1.2 and a width of 3 m in line with the marked starting point. Subjects completed 3 trials in total. The average time (seconds) across the 3 trials was determined for each subject. The within-day ICC for the T-test was 0.871.

Core Endurance Test. Following the protocols established by Waldhelm and Li (48), core endurance tests were performed. The core endurance tests provided the most reliable core stability-related measurements and comparisons of strength, flexibility, motor control, and function, with an ICC of 0.66–0.96 (48). Core endurance tests consisted of the trunk flexor, trunk extensor, and bilateral side bridge tests. All tests were terminated when the subject could no longer hold the position, and the times taken for the tests were recorded. The between-day ICC values for trunk flexor, trunk extensor, right side bridge, and left side bridge were 0.821, 0.672, 0.649, and 0.789, respectively.

TABLE 4. Change in multiple physical fitness dimensions and shooting accuracy.*

Variable	Battle rope group Pre	Battle rope group Post	Battle rope group Change	Shuttle run group Pre	Shuttle run group Post	Shuttle run group Change	Between groups
Aerobic capacity							
Pacer test (laps)	74.0 ± 21.6	87.0 ± 14.9	†	76.8 ± 16.1	86.0 ± 18.7	†	§
U. anaerobic power							
Peak power (W)	1,006.3 ± 194.5	1,009.9 ± 189.8	§	955.4 ± 152.6	970.8 ± 156.6	§	§
Mean power (W)	667.4 ± 108.1	716.4 ± 111.8	†	629.1 ± 79.7	622.3 ± 84.2	§	§
Fatigue index (%)	51.9 ± 7.6	47.0 ± 10.5	§	52.2 ± 11.1	57.2 ± 9.1	§	‡
U. power							
Chest pass ($km \cdot h^{-1}$)	35.1 ± 3.8	36.8 ± 2.6	†	34.3 ± 2.5	35.6 ± 2.3	†	§
L. power							
CMJ (cm)	45.6 ± 4.0	46.8 ± 5.1	†	41.4 ± 6.8	42.7 ± 6.5	§	§
Agility							
T-test (s)	9.7 ± 0.7	9.7 ± 0.5	§	9.7 ± 0.7	9.9 ± 0.5	§	§
Core endurance							
Trunk flexor (s)	165.4 ± 100.1	226.6 ± 138.8	†	155.8 ± 58.9	187.1 ± 91.9	§	§
Trunk extensor (s)	130.6 ± 37.8	160.4 ± 34.8	†	147.0 ± 44.9	165.5 ± 53.1	§	§
Right side bridge (s)	83.3 ± 18.9	102.5 ± 21.7	†	91.1 ± 31.5	93.5 ± 27.2	§	§
Left side bridge (s)	90.9 ± 19.9	91.6 ± 17.4	§	101.0 ± 35.2	98.5 ± 30.5	§	§
Shooting accuracy							
Free throw (%)	66.5 ± 20.8	75.8 ± 11.7	†	70.7 ± 16.5	70.4 ± 13.4	§	§
Dynamic (%)	36.7 ± 14.8	50.0 ± 14.1	†	43.6 ± 13.6	46.4 ± 12.3	§	‡

*U. = upper-body; L. = lower-body; CMJ = counter movement jump.
†$p < 0.05$ significantly improved than that occurred before training.
‡$p < 0.05$ significantly difference in pre–post improvement between groups.
§No significant difference.

Stationary Free Throw Shooting Test. The stationary free throw shooting test was a modification of a previous protocol (38). In the modified test, all subjects performed one practice series of 10 free throw shots using same ball and rim as formal series, and then 2 formal series of 10 free throw shots, with a 3-minute rest period between the series. Two rebounders caught all shots made and passed the ball to a passer. The passer always passed the ball to the testee. The average field goal percentage of the 2 trials was used for analysis. The within-day ICC for free throw shooting was 0.848.

Dynamic Shooting Test. A dynamic shooting test was chosen in this study because it is a more favorable determinant of shooting accuracy during the season than a stationary test is (38). This test was a modification of a previous protocol (38). The testee starting position was after cone 1 (Figure 1). After the tester sounded a signal, the testee ran around cone 2 toward cone 1, where the testee received the ball from the passer and performed a jump shot. Subsequently, the testee again ran around cone 2 toward cone 1, where the testee again received the ball from the passer and performed another jump shot; in total, 10 shots were performed. Cone 1 was set at a distance of 5 m from the vertical projection of the hoop's center on the floor. The players were encouraged to run as rapidly as possible. The time taken for completing the test was less than 60 seconds. Two rebounders caught all shots made and passed the ball to a passer. The passer always passed the ball to the testee. All subjects performed one practice test using same ball and rim as formal test and then 3 formal tests, with a 5-minute recovery period between each test. The average percentages of second and third trials were used for analysis. The within-day ICC for dynamic shooting was 0.749.

Statistical Analyses

All values are given as mean ± standard deviation. The baseline between-group differences were determined using an independent *t*-test. The paired *t*-test was used to assess the difference between pretraining and post-training. The differences in pre–post improvements ([post-test − pretest]/pretest × 100%) between groups were determined using an independent *t*-test. The positive or negative values of pre–post improvements in the fatigue index and agility T-test were converted because any decline in these results represents ability improvement. Effect sizes (ESs) were computed using Cohen's *d*. Statistical significance was set at $p \leq 0.05$. All data were analyzed using SPSS 20 software for Windows (IBM Corp., Armonk, NY, USA).

Results

No significant differences were observed in the dependent variables at baseline between the groups. The results of all outcomes are presented in Table 4.

Comparison Between Pretraining and Post-training

Eight-week BR training significantly improved subjects aerobic capacity (PACER laps: 17.6%, ES = 0.70), upper-body anaerobic power (MP: 7.3%, ES = 0.45), upper-body power (chest pass speed: 4.8%, ES = 0.52), lower-body power (vertical jump: 2.6%, ES = 0.26), core endurance (trunk flexion: 37.0%, ES = 0.51; trunk extension: 22.8%, ES = 0.82; and right side bridge: 23.0%, ES = 0.94), and shooting accuracy (free throw: 14.0%, ES = 0.55; dynamic shooting: 36.2%, ES = 0.92) ($p < 0.05$). Eight-week SR training significantly improved only their aerobic capacity (12.0%, ES = 0.53) and upper-body power (chest pass speed: 3.8%, ES = 0.54) ($p < 0.05$).

Between-Group Comparisons

Compared with the SR group, the BR group exhibited superior pre–post improvements in the fatigue index in the upper-body anaerobic power test (ES = −0.97) and dynamic shooting accuracy (ES = 0.85) ($p < 0.05$).

Discussion

The primary finding of this study is that BR training significantly enhanced multiple physical fitness dimensions, namely aerobic capacity, upper-body anaerobic power, upper-body power, lower-body power, and core endurance, and shooting accuracy, whereas regular training (SR training) only enhanced aerobic capacity and upper-body power. This result shows that BR training can effectively train total-body muscle and can increase cardiopulmonary function, thereby simultaneously improving multiple physical fitness dimensions and shooting accuracy in collegiate basketball players.

To play successfully, basketball players must possess optimally developed physical fitness in multiple dimensions, including aerobic, anaerobic power, upper-body and lower-body power, agility, and core endurance (2,9,10,19), and high shooting accuracy. However, implementing separate training protocols for these multiple physical fitness dimensions may be time-consuming. Thus, optimally enhancing the effect of training within limited training time is important. In this study, under the same training time conditions (30–36 minutes), 8-week BR interval training simultaneously enhanced multiple physical fitness dimensions (aerobic capacity, upper-body anaerobic power, upper-body power, lower-body power, and core endurance) and shooting accuracy (39,47) compared with SR interval training, which only improved aerobic capacity and upper-body power. This result shows that in the same training time, BR training has more benefits for basketball players than SR training has.

High aerobic capacity is an important attribute of basketball players because it enables them to cover a distance of approximately 7.5 km per match, with mean heart rates ranging from 87.0 to 94.4% of peak heart rates (1,36). Castagna et al. (17) found a significant relationship between aerobic capacity and the rate of recovery during short rest periods in basketball players. A high level of aerobic fitness enhances the recovery process in basketball players during the short breaks and periods of reduced activity, thus allowing the athlete to perform numerous explosive movements throughout the game without compromising the quality of performance (18).

A previous study (24) found that an acute 10-minute bout of BR training resulted in high heart rates and energy expenditure, which meet previously established thresholds known to increase cardiorespiratory fitness (6,7). Some previous studies demonstrated that long-term BR training improved athletes' aerobic capacity (8,30), which is consistent with the results of this study. The result of this study showed that 8 weeks BR training significantly enhanced aerobic capacity (PACER test) in basketball players, and the improvement was slightly higher than that of SR training (PACER laps increased by 17.6 and 12.0% for BR and SR groups, respectively).

Shuttle run interval training is usually used to strengthen the aerobic capacity of basketball players (50). In the present study, as expected, SR interval training improved the aerobic capacity of basketball players. However, depending on the speed and landing geometry, running causes impact forces on the lower limbs that vary in magnitude, from approximately 1.5–5 times body weights, and last for a very brief period (<30 ms) (26). Thus, SR training may not be the optimal method to improve aerobic capacity in athletes with lower extremity injury or a high risk of injury. By contrast, BR training does not have a lower limb impact and can thus effectively improve multiple physical fitness dimensions (aerobic, anaerobic, power, and muscular endurance capacities), total-body muscle capacities (upper-body anaerobic power, upper-body power, lower-body power, and core endurance), and shooting accuracy in trained basketball players. To design an appropriate interval training protocol, BR training can be alternated with relatively high-impact exercise (SRs or sprinting) to reduce lower limb loading.

The result of this study showed that BR training significantly enhanced mean upper-body anaerobic power (7.3%) in college basketball players. After 8 weeks of training, the pre–post improvement in the fatigue index were significantly superior in the BR groups than in the SR group. The results indicate that BR training enhances resistance to the fatigue caused by an anaerobic muscle workout. Previous studies have found that BR training causes a high level of blood lactate values, ranging from 9 to 13 $mmol \cdot L^{-1}$ (24,33,42). Thus, BR training is performed under the condition of a high level of blood lactic acid accumulation. Thus, it may improve muscular resistance to fatigue by improving lactic acid tolerance after a long workout.

The basketball chest pass is the fastest and most practical ball passing technique; it requires a high upper-body explosive force. The result of this study showed that BR exhibited significant improvements in the chest pass speed by 4.8%. However, SR group also significantly improved chest pass speed by 3.8%, which may be attributed to regular training during experimental period. The magnitude of improvement in BR group was slightly higher than that of SR group. Varying muscular adaptation may be mainly attributed to the design of the training protocol. In the BR training protocol, different exercise and rest times were used, causing varying muscular adaptation (e.g., strength, power, muscular endurance). However, the current study only confirmed that a shorter rest interval increased the metabolic demands of BR exercise (42). The effects of BR training using different exercise and rest times on muscle adaptation should be further investigated.

Jumping and agility are essential abilities for basketball players. In basketball games, elite basketball players execute 40–60 maximal jumps and 50–60 changes in speed and direction (29,34), emphasizing the importance of these physical characteristics. Increased vertical jump ability and agility are important determinants of high performance in basketball (19). Hudson (27) highlighted the importance of a high jump for precise shooting in a basketball game; Hudson reported that more accurate shooters release the ball at a greater height. In this study, 8-week BR training significantly increased the vertical jump height from 45.61 to 46.78 m (2.6%), whereas SR training only slightly changed the vertical jump height. The results of this study are consistent with those of previous studies, in which BR training significantly improved the standing broad jump of college-level male athletes (8). The BR training in this study consisted of 6 BR exercises, including double-arm waves, side-to-side waves, alternating waves, in-out waves, hip toss, and double-arm slams. The double-arm slam is a typical power exercise, which is initiated by an explosive upward swing movement, bring the ropes upward to overhead by extending the hips and knees, and immediately come down into a squatting position and slam the ropes downward to the ground. The explosive extending the hips and knees action may contribute to improvement in vertical jump height. However, in the present study, despite improved lower-body explosive power, agility was not significantly changed after BR training.

A previous study emphasized that training of the torso or core muscles can enhance athletic performance (12), and such training has been promoted as a preventive regimen and performance-enhancing program for various lumbar spine, musculoskeletal, and lower extremity injuries (5,31). Previous studies have shown that BR exercise induces moderate to high levels of muscle activity in the core muscles; the muscle activity for external oblique and lumbar erector spinae (double-arm waves and alternating waves) ranges from 51 to 73% MVIC. Previous studies have also confirmed that BR training improves dynamic core endurance, as measured by sit-up test (33). The result of this study revealed that BR training significantly enhanced core endurance in the trunk flexor (37.0%), trunk extensor (22.8%), and right side bridge (23.0%). The improved core endurance/stability of basketball players facilitates the implementation of basic game movements and may reduce the probability of injury occurrence.

Shooting accuracy is one of the most important skills in basketball (22,40). Previous studies have reported the shooting accuracy for free throws and field goals is a crucial factor distinguishing between winning and losing basketball teams (38,39,47). The present study showed that BR training significantly increased free throw (pretraining: 66.5%; post-training: 75.8%) and dynamic 2-point shot percentages (pretraining: 36.7%; post-training: 50.0%), whereas SR training did not significantly change the percentages. The BR group had significantly higher pre–post improvements in dynamic shot percentage than the SR group had. The greater improvement observed in the BR group may result from the enhancement of multiple physical fitness dimensions and muscle capacities. These enhancements may contribute to the superior shooting accuracy of basketball players (38,45). Higher anaerobic fatigue resistance has been shown to be related to higher field goal percentage (38). A longer 2-hand chest pass distance (38), higher elbow extensor isokinetic strength (45), and higher vertical jump height have been reported to be related to higher 3-point shooting accuracy during the competitive season. Thus, in contrast to SR training, BR training increases not only the basketball chest pass speed but also anaerobic power, upper-body muscular resistance to fatigue, and vertical jump height, which may be the keys to the superior shooting accuracy, particularly in dynamic 2-point shooting. Moreover, the improvement of core endurance in the BR group may also indirectly improve the shooting accuracy because it contributes more favorable trunk stability in the shooting process.

In conclusion, an 8-week BR training program involving interval training effectively enhanced multiple physical fitness dimensions (aerobic capacity, upper-body anaerobic power, upper-body power, lower-body power, and core endurance) and shooting accuracy in Division-I collegiate basketball players. By contrast, SR interval training only increased aerobic capacity and upper-body power. Moreover, BR training resulted in greater improvements in the fatigue resistance of upper-body anaerobic power (fatigue index) and dynamic shooting accuracy than SR training did. However, the main methodological limitation of this study was lack of a control group, which only did regular basketball and resistance trainings, although SR training was used to compare with the effect of BR training.

Practical Applications

Battle rope training is a low-impact, total-body exercise modality and has generally been used in various populations, from general health and fitness trainees to professional athletes. This study revealed that 8-week BR training simultaneously improved multiple physical fitness dimensions and shooting accuracy in collegiate basketball players compared with SR training, which is a common interval training intervention in basketball. This finding suggests that BR training, a relatively lower-impact exercise with the same training period as that of SR training, is an efficient workout that enhances multiple physical fitness dimensions and shooting accuracy, which are capacities required for basketball players. Given that both BR and SR trainings bring about different training-induced adaptations and each is associated with quite distinctive advantages and disadvantages. Battle rope training has a relatively lower-impact training modality, but SR training is one of commonly use training modality in basketball. Therefore, BR training is recommended to conduct for enhancement on multiple physical fitness dimensions and shooting accuracy.

References

1. Abdelkrim, NB, Castagna, C, Jabri, I, Battikh, T, El Fazaa, S, and El Ati, J. Activity profile and physiological requirements of junior elite basketball players in relation to aerobic-anaerobic fitness. *J Strength Cond Res* 24: 2330–2342, 2010.
2. Abdelkrim, NB, Chaouachi, A, Chamari, K, Chtara, M, and Castagna, C. Positional role and competitive-level differences in elite-level men's basketball players. *J Strength Cond Res* 24: 1346–1355, 2010.
3. Abdelkrim, NB, El Fazaa, S, and El Ati, J. Time–motion analysis and physiological data of elite under-19-year-old basketball players during competition. *Br J Sports Med* 41: 69–75, 2007.
4. Akenhead, R, French, D, Thompson, K, and Hayes, P. The physiological consequences of acceleration during shuttle running. *Int J Sports Med* 36: 302–307, 2015.
5. Akuthota, V and Nadler, SF. Core strengthening. *Arch Phys Med Rehabil* 85: 86–92, 2004.
6. American College of Sports Medicine. General Principles and Exercise Prescription. In: *ACSM's Guidelines for Exercise Testing and Prescription.* Philadelphia, PA: Lippincott Williams & Wilkins, 2010. pp. 155.
7. Garber, CE, Blissmer, B, Deschenes, MR, Franklin, BA, Lamonte, MJ, Lee, IM, Nieman, DC, and Swain, DP; American College of Sports Medicine. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Med Sci Sports Exerc* 43: 1334–1359, 2011.
8. Antony, B, Maheswri, MU, and Palanisamy, A. Effect of battle rope training on selected physical and physiological variables among college level athletes. *Indian J Appl Res* 5: 19–22, 2015.
9. Apostolidis, N, Nassis, G, Bolatoglou, T, and Geladas, N. Physiological and technical characteristics of elite young basketball players. *J Sports Med Phys Fitness* 44: 157, 2004.
10. Araujo, S, Cohen, D, and Hayes, L. Six weeks of core stability training improves landing kinetics among female capoeira athletes: A pilot study. *J Hum Kinet* 45: 27–37, 2015.
11. Bar-Or, O. The Wingate anaerobic test. An update on methodology, reliability and validity. *Sports Med* 4: 381–394, 1987.
12. Behm, DG, Drinkwater, EJ, Willardson, JM, and Cowley, PM. The use of instability to train the core musculature. *Appl Physiol Nutr Metab* 35: 91–108, 2010.
13. Besier, TF, Lloyd, DG, and Ackland, TR. Muscle activation strategies at the knee during running and cutting maneuvers. *Med Sci Sports Exerc* 35: 119–127, 2003.
14. Buchheit, M, Bishop, D, Haydar, B, Nakamura, FY, and Ahmaidi, S. Physiological responses to shuttle repeated-sprint running. *Int J Sports Med* 31: 402–409, 2010.
15. Calatayud, J, Martin, F, Colado, JC, Benítez, JC, Jakobsen, MD, and Andersen, LL. Muscle activity during unilateral vs. bilateral battle rope exercises. *J Strength Cond Res* 29: 2854–2859, 2015.
16. Carlock, JM, Smith, SL, Hartman, MJ, Morris, RT, Ciroslan, DA, Pierce, KC, Newton, RU, Harman, EA, Sands, WA, and Stone, MH. The relationship between vertical jump power estimates and weightlifting ability: A field-test approach. *J Strength Cond Res* 18: 534–539, 2004.
17. Castagna, C, Abt, G, Manzi, V, Annino, G, Padua, E, and D'ottavio, S. Effect of recovery mode on repeated sprint ability in young basketball players. *J Strength Cond Res* 22: 923–929, 2008.
18. Czuba, M, Zając, A, Maszczyk, A, Roczniok, R, Poprzęcki, S, Garbaciak, W, and Zając, T. The effects of high intensity interval training in normobaric hypoxia on aerobic capacity in basketball players. *J Hum Kinet* 39: 103–114, 2013.
19. Delextrat, A and Cohen, D. Physiological testing of basketball players: Toward a standard evaluation of anaerobic fitness. *J Strength Cond Res* 22: 1066–1072, 2008.
20. Delextrat, A and Cohen, D. Strength, power, speed, and agility of women basketball players according to playing position. *J Strength Cond Res* 23: 1974–1981, 2009.
21. Dellal, A, Keller, D, Carling, C, Chaouachi, A, Wong, dP, and Chamari, K. Physiologic effects of directional changes in intermittent exercise in soccer players. *J Strength Cond Res* 24: 3219–3226, 2010.
22. Erculj, F and Supej, M. The impact of fatigue on jump shot height and accuracy over a longer shooting distance in basketball. *J Strength Cond Res* 63: 35–41, 2006.
23. Fessi, MS, Farhat, F, Dellal, A, Malone, JJ, and Moalla, W. Straight-line and change of direction intermittent running in professional soccer players. *Int J Sports Physiol Perform* 17: 1–15, 2017.
24. Fountaine, CJ and Schmidt, BJ. Metabolic cost of rope training. *J Strength Cond Res* 29: 889–893, 2015.
25. Hader, K, Mendez-Villanueva, A, Ahmaidi, S, Williams, BK, and Buchheit, M. Changes of direction during high-intensity intermittent runs: Neuromuscular and metabolic responses. *BMC Sports Sci Med Rehabil* 6: 1–25, 2014.
26. Hreljac, A. Impact and overuse injuries in runners. *Med Sci Sports Exerc* 36: 845–849, 2004.
27. Hudson, JL. A biomechanical analysis by skill level of free throw shooting in basketball. In: *Biomechanics in Sports.* J Terauds, ed. Del Mar, CA: Academic Publishers, 1982, pp. 95–102.

28. Insitute, C. Aerobic Capacity. In: *Fitnessgram and Activitygram Test Administration Manual*. Dallas. Champaign, IL: Human Kinetics, 2007. pp. 27–33.

29. Janeira, M and Maia, J. Game intensity in basketball. An interactionist view linking time-motion analysis, lactate concentration and heart rate. *Int J Sports Sci Coach* 3: 26–30, 1998.

30. Kuklick, CR, Martino, MA, and Black, CD. Throwing velocity and stamina in baseball pitchers as a function of training methods. *J Aust Strength Cond Res* 21: 13, 2013.

31. Leetun, DT, Ireland, ML, Willson, JD, Ballantyne, BT, and Davis, IM. Core stability measures as risk factors for lower extremity injury in athletes. *Med Sci Sports Exerc* 36: 926–934, 2004.

32. Lovell, D, Mason, D, Delphinus, E, Eagles, A, Shewring, S, and McLellan, C. Does upper body strength and power influence upper body Wingate performance in men and women? *Int J Sports Med* 32: 771–775, 2011.

33. McAuslan, C. *Physiological responses to a battling rope high intensity interval training protocol [master's thesis]*. Windsor, ON, Canada: University of Windsor, 2013.

34. McInnes, S, Carlson, J, Jones, C, and McKenna, MJ. The physiological load imposed on basketball players during competition. *J Sports Sci* 13: 387–397, 1995.

35. Munro, AG and Herrington, LC. Between-session reliability of four hop tests and the agility T-test. *J Strength Cond Res* 25: 1470–1477, 2011.

36. Narazaki, K, Berg, K, Stergiou, N, and Chen, B. Physiological demands of competitive basketball. *Scand J Med Sci Sports* 19: 425–432, 2009.

37. Nytrøen, K, Rustad, LA, Aukrust, P, Ueland, T, Hallén, J, Holm, I, Rolid, K, Lekva, T, Fiane, AE, and Amlie, JP. High-intensity interval training improves peak oxygen uptake and muscular exercise capacity in heart transplant recipients. *Am J Transpl* 12: 3134–3142, 2012.

38. Pojskić, H, Šeparović, V, Muratović, M, and Užičanin, E. The relationship between physical fitness and shooting accuracy of professional basketball players. *Motriz* 20: 408–417, 2014.

39. Pojskić, H, Šeparović, V, and Užičanin, E. Differences between successful and unsuccessful basketball teams on the final Olympic tournament. *Acta Kinesiologica* 3: 110–114, 2009.

40. Pojskić, H, Šeparović, V, and Užičanin, E. Reliability and factorial validity of basketball shooting accuracy tests. *Sport Sci Pract Aspect* 8: 25–32, 2011.

41. Ratamess, NA, Rosenberg, JG, Klei, S, Dougherty, BM, Kang, J, Smith, CR, Ross, RE, and Faigenbaum, AD. Comparison of the acute metabolic responses to traditional resistance, body-weight, and battling rope exercises. *J Strength Cond Res* 29: 47–57, 2015.

42. Ratamess, NA, Smith, CR, Beller, NA, Kang, J, Faigenbaum, AD, and Bush, JA. Effects of rest interval length on acute battling rope exercise metabolism. *J Strength Cond Res* 29: 2375–2387, 2015.

43. Schelling, X and Torres-Ronda, L. Conditioning for basketball: Quality and quantity of training. *Strength Cond J* 35: 89–94, 2013.

44. Tabata, I, Nishimura, K, Kouzaki, M, Hirai, Y, Ogita, F, Miyachi, M, and Yamamoto, K. Effects of moderate-intensity endurance and high-intensity intermittent training on anaerobic capacity and VO2max. *Med Sci Sports Exerc* 28: 1327–1330, 1996.

45. Tang, WT and Shung, HM. Relationship between isokinetic strength and shooting accuracy at different shooting ranges in Taiwanese elite high school basketball players. *Isokinet Exerc Sci* 13: 169–174, 2005.

46. Tessitore, A, Tiberi, M, Cortis, C, Rapisarda, E, Meeusen, R, and Capranica, L. Aerobic-anaerobic profiles, heart rate and match analysis in old basketball players. *Gerontology* 52: 214–222, 2006.

47. Trninić, S, Dizdar, D, and Lukšić, E. Differences between winning and defeated top quality basketball teams in final tournaments of European club championship. *Coll Antropol* 26: 521–531, 2002.

48. Waldhelm, A and Li, L. Endurance tests are the most reliable core stability related measurements. *J Sport Health Sci* 1: 121–128, 2012.

49. Yu, CH and Fang, CL. Relationship between PACER test and maximal oxygen uptake. *Phys Educ J*: 33–42, 2002.

50. Zadro, I, Sepulcri, L, Lazzer, S, Fregolent, R, and Zamparo, P. A protocol of intermittent exercise (shuttle runs) to train young basketball players. *J Strength Cond Res* 25: 1767–1773, 2011.