Original Article

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Energetic cost of running with and without the ball in male basketball players

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Abstract

This study aimed to assess the energetic cost (C) at different running conditions (RC) with/without the ball (1000m at 80% of VO_2max) during: Linear running, Shuttle running (180°), Linear running with stop and restart, between two groups according to the position/role (guards: n=15; forwards/centres: n=15). Experimental approach to the problem required the following tests/devices: a portable Metabolimeter was used to assess the metabolic parameters for each RC, Squat Jump (OptoJump) to assess the strength's decrease differences of the lower limbs before/after each test and Ratings of Perceived Exertion (RPE) after each RC to assess the training load, while the Global Navigation Satellite System (GNSS-IMU) was used to assess the body inclinations and Acceleration/Deceleration for each RC. The T-test was used for independent samples and Two-way repeated measures ANOVA was used to assess the significant differences for each variable between each RC. The results of this study could be useful not only for coaches to optimize basketball training load related to the RC (with and without the ball), but also to optimize the motor learning in young basketball players and to optimize the load of work in relation to the position and energetic capacities of players. The main evidence of this study has confirmed initial hypothesis, showing a different metabolic expenditure in the six running conditions (Linear Running, Linear Running & Stop and restart, Shuttle run with and without ball) and between the two groups taken in consideration (Guards and Forwards/Centres). In addition, different energetic cost between the two groups increases even more during the running with the ball compared to running without the ball.

Keywords: running conditions, energy expenditure, strength, performance.

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INTRODUCTION

Basketball is characterized by multiple high-intensity actions [1] performed with changing direction. Moreover, basketball represents a multi-task sport, defined on the basis of several active/passive phases which are very hard to replicate during the training [2]. During the game situations change quickly and frequently, as well as the function of opponents' position on the field and their tactical behavior, making thus defensive and offensive choices [3] and also in relation to certain positions of the team mates on the court and in relation to their movements. In this way they can make defensive and offensive choices [4] and in relation to the position of the ball related to active phases, making defensive and offensive choices games [5]. In addition, bioenergetics in basketball has been considered crucial [6] since metabolic demands under stress can negatively alter players' performance [7]. Moreover, the basketball is an intermittent high-intensity physical activity. This sport requires an aerobic [8] and anaerobic well-developed energetic mechanism [9] including short time activities at high intensity [10]; as well as others team's sport (i.e.: soccer, rugby, handball) are generally considered sports characterized by multiple high-intensity activities interspersed with low-intensity activities [11, 12]. The match analysis showed that basketball players, during a match, while sprinting, with and without changes in direction [13], at different velocities [14], over short distances (10<20m) and within a limited timeframe [15] of up to 20 sec. [16], these movements determine considerable metabolic demands [17]. Actions, such as such as jumping, running, dribbling, sprinting, stopping and restarting, performed at different speeds and intensities [18], represent a variety of multidirectional movements [19]. Typically, running in team sports [20] has biomechanical characteristics and different energetic costs with respect to linear running. Moreover, types of run change according to physical characteristics [21] and physiological effort [22]. Basketball players, thus, must have a high capability to move quickly, and jump and bounce the ball, coordinating at the same time movements of the lower and upper limbs [23] and, in order to achieve and to evaluate efficient performances [24], it is important to understand fatigue-related body adaptations and compensations. Therefore, they must be able to effectively perform specific tasks under conditions of physical fatigue that occur during different training and game intensity [25]. These requests justify a specific training method such as team sports (basketball, soccer, rugby), in which typical running is characterized by acceleration and deceleration phases [26], which entails a greater energy expenditure [27]. The energetic expenditure such as the metabolic power [28] seems to be useful in team sports to balance the external load (running conditions) compared to the internal training load [29]; therefore, for these reasons, the workload analysis during a competition is crucial today to optimize the training program [30]. Several studies on the physiological load of these activities are generally limited to the overall load, combining various types of displacements without assessing each one individually [31]. However, others studies attempted to tackle this problem using different approaches [32]. Few studies looking at the physiological load of acceleration and deceleration during directional changes of a shuttle running with the ball and without the ball. None of the studies measured the energetic cost associated to different running conditions, taken into consideration in this research with the aim to assess the energetic cost of running with and without the ball: linear running, shuttle running with changes in direction at 180°, linear running with stop and restart running every 15 m. More specifically, none of the studies investigated the energetic cost difference between different running conditions, with and without directional changes, with and without the ball or between two groups of players divided according to their positions. Therefore, investigation of the running conditions can contribute to improvement of the learning mechanism process about the different running conditions; learning the levels of energy expenditure under different running conditions with and without the ball; optimizing the motor learning based on a specific motor task in young players [33, 34]; acknowledging different running metabolic demand to optimize the training load in different seasonal periods aiming for high sport performances. Finally, studying the several types of runs with different tasks is useful to understand how the energetic cost change due to the complexity of the task performed (with and without the ball). The aim of this study is to assess the energetic cost of running in different conditions (1000 m at 80% of VO_2max) with and without the ball: Linear running (LR), Shuttle running with change in direction at 180° (SR), Linear running with stop and restart (LR&SR) running every 15m between two groups (Guards and Forwards/Centres). In authors' opinion the metabolic expenditure should be different in all six running conditions (i.e., on the specific task) and between the two groups (Guards and Forwards/Centres). The hypothesis is that the energetic cost could increase during running with the ball compared to running without the ball, independently of changes in direction. This could be justified by conditioning of motor control to synchronize dribble during running gait of the players. However, the running gait energy consumption with linear running with stop and restart (LR&SR) every 15m (without the ball) could be increased by the deceleration/acceleration of the player on the frontal plane, compared to changes in direction (180°); in fact, player's body stabilization needs more mechanical work.

MATERIALS AND METHODS

The sample of subjects (90%) included young male basketball players aged 18±1. Subjects were divided in two groups of 15 according to position/role (guards: n=15; forwards/centres: n=15). The players had at least five years of training experience and participated at the Italian Basketball Under-18 Championship. Players participated voluntarily in this investigation. The inclusion criteria considerated for young basketball players was five years of training experience, whereas the exclusion criterion was no history of injuries in the last year (i.e., muscles, tendons, bones). The variables investigated were: maximum oxygen consumption ($ml \cdot kg \cdot min^{-1}$); mean and maximum heart rate (b/min); mechanical work ($j \cdot (kg \cdot m)^{-1}$), Jump performance (cm) and Ratings of Perceived Exertion (RPE). Coaches could take advantage of the use of this method, as it is very practical to monitor young players and it can provide a valuable measure of the internal TL. The quantification of the internal TL is also necessary for the analysis of the periodization of training. The method of detection and analysis of data required the use of following tests and devices: Yo-Yo endurance test [35]; Shuttle running and linear running [36,37], assessed with Metabolimeter K4b2 (Cosmed, Italy); Lower limb muscle strength [38] assessed with Optojump (Microgate, Italy); Ratings of Perceived Exertion (Cr 0<10) [39]. Table 1 presents the principal anthropometric and physiological characteristics of subjects. The mean age of the first group G (Guards) was 18.5 ± 0.2 years, the body height was 180.4 ± 2.8 cm, the body weight was 75.3 ± 2.5 kg, the body mass index was 23.1 kg/m^2 and indicated a normal value. The mean VO_2 max was 56.2 ± 1.9 and the heart rate max 182.7 ± 2.7. Participants from the second group F/C (Forwards/Centres) were 18.7 ± 0.2 years old, their body height was 190.2 ± 3.1 cm, the body weight was 84.5 ± 3.1 kg, the body mass index was 23.3 kg/m^2 and indicated a normal value. The mean VO_2max was 50.3 ± 2.3 and the heart rate max was 185.2 ± 2.5.

Procedures

Participants were provided with written and oral explanations of the protocol and of the experimental scheme. The study included 7 testing sessions over a 10-day period with a minimum of 3-day rest in-between. In the first session, the participants did an indirect continuous multistage field test [40] to determine VO_2max to set the relative intensities of the next 6 experimental sessions. Randomly performed, three sessions without ball: (a) in-line continuous running (LR), (b) Shuttle running (SR) with directional changes (180°) every 15m and (c) Linear running (LR&SR) with stop and restart every 15m in the same direction. The same three sessions, then, were repeated with ball.

Table 1. Anthropometric and physiological characteristics (mean ± SD, n=30).

Variables	All subjects (n=30)	Guards (n=15)	Forwards/Centres (n=15)
Age (years)	18.6 ± 0.2	18.5 ± 0.2	18.7 ± 0.2
Height (cm)	186.2 ± 5.7	180.4 ± 2.8	190.2 ± 3.1
Weight (kg)	80.0 ± 5.4	75.3 ± 2.5	84.5 ±3.1
BMI (kg/m^2)	23.2 ± 3.8	23.1 ± 3.2	23.3 ± 3.6
VO_2 max (ml·kg^{-1}·min^{-1})	53.4 ± 4.6	56.2 ± 1.9	50.3 ± 2.3
Heart rate max (b/min)	183.9 ± 8.2	182.7 ± 2.7	185.2 ± 2.5

For each protocol, participants were required to run at an imposed intensity at 80% of VO_2max, using a frequency metre to control the intensity. Beep sounds and track markers were used as spatiotemporal references to pace the subject. Beep sounds were emitted with a homemade programmable sound generator. All participants easily kept the pace within less than 1m from the track marker at each beep. All the tests were conducted on a flat 100m course on a synthetic rubber surface. Before each test, participants performed 10 minutes of a warm-up [41], including 5 minutes of dynamic stretching. Seven testing sessions were included in the study over a ten-day period with three days of rest in-between. After one week all tests were repeated to assess the reliability of measurements. The Yo-Yo endurance test (typical for team sports) has been performed by each player, as an incremental test according to di Prampero [42] to detect the VO_2max. After the VO_2max test, for each running condition, the Squat Jump (SJ) has been performed [43] to verify the muscle strength decrement. Lower limbs muscle strength has been assessed with Optojump (Microgate, Italy), before and after each running conditions (LR, LR&SR, SR) with and without ball, from the two groups (G and F/C). Optojump provides real-time data on contact time, flight time, step length and step frequency with no impedance to the athlete. This system consists of two parallel bars (one receiver and one transmitter unit) that transmit an infrared light 1 to 2 mm above the floor, allowing for athlete-surface interaction. Following, players were tested (speed: 1000m at 80% of VO_2max, previously measured; corresponding at 5/6 minutes, useful to reach a steady state oxygen consumption), players were randomly selected (one-to-one) in 6 groups. Each group has been randomly evaluated in six running conditions (1000m at 80% of VO_2max with and without the ball: linear running (LR), shuttle running (SR) with change in direction (180°), linear running with stop and restart every 15m (LR&SR).

Statistical analysis

All data are presented as mean and standard deviation (Mean±SD). Intra-class correlation coefficient [44] was calculated to assess the reliability of the measures for each running condition. Prior to the parametric analysis, the normality of data distribution was verified by the using Shapiro-Wilk test. Regarding energetic cost, between-subjects the t-test was used six times (for each running condition separately) to examine significance of differences for each running condition (n=6) while homogeneity of variances was checked with Levene's test. Regarding lower limbs strength, the two-way 2×2 between-within ANOVA was used six times (for each running condition separately) to examine significance of the main effect of the between-subjects factor Group (Guards and Forwards/Centers), within-subjects factor Treatment (Pre and Post) together with the factorial interaction Group×Treatment. The Bonferroni post-hoc correction was applied to identify particular differences. Partial eta squared (η^2) was used as a measure of the effect size. Type I error was set at α=5% and all statistical analyses were performed with the software IBM SPSS Statistics 23.

RESULTS

The Shapiro-Wilk test showed no significant deviation of data from the normal distribution. The T-test was used on two independent samples was to determine if there were any significant differences in the energetic cost for each running condition (n=6) between the two groups (Guards n=15; Forwards/Centres n=15) with the ball and without the ball. The energetic cost (C) shown in Table 2 demostrates significant differences regarding both two groups analysed (G and F/C) depending on each running conditions: LR without the ball with p=0.010; SR without the ball with p=0.011; LR & SR without the ball with p=0.047; LR with the ball with p=0.024; LR & SR with the ball with p=0.013 and SR with the ball with p=0.008. The homogeneity of the variance was checked by the use of Levene's test, and it confirmed the homogeneity in all the conditions.

The ICC coefficient between the series of measurements of the energetic cost, in different running's conditions, was found to be excellent. The results showed fair to high reliability. Regarding the group G these are the outcomes:LR without the ball 0.98; LR&SR without the ball 0.94; SR without the ball 0.96; LR with the ball 0.96; LR&SR with the ball 0.97 and SR with the ball 0.97. While the group F/C these are the outcomes: LR without the ball 0.97; LR&SR without the ball 0.96; SR without the ball 0.94; LR with the ball 0.97; LR&SR with the ball 0.98 and SR with the ball 0.96.

Table 2. The T-test for independent samples: the energetic cost for each running condition (n=6) between the two groups (G and F/C).

Perform	Variables	Mean G [j · (kg · m)$^{-1}$)]	Mean F/C [j · (kg · m)$^{-1}$)]	t-value	p	F Levene's test	p Levene's test
without the ball	LR	4.80 ± 0.16	4.98 ± 0.20	-2.77	0.010	0.605	0.443
	LR & SR	5.02 ± 0.26	5.25 ± 0.34	-2.07	0.047	2.348	0.137
	SR	5.21 ± 0.30	5.49 ± 0.27	-2.73	0.011	0.459	0.504
with the ball	LR	5.63 ± 0.23	5.82 ± 0.21	-2.39	0.024	0.009	0.926
	LR & SR	6.02 ± 0.31	6.38 ± 0.43	-2.66	0.013	3.199	0.085
	SR	6.40 ± 0.41	6.80 ± 0.35	-2.86	0.008	0.596	0.447

LR – Linear Running; LR & SR – Linear Running & Stop and Restart; SR – Shuttle Run; p – p-value; G - Guards; F/C – Forwards/Centres

Table 3. Two way (between-within) 2×2 ANOVA in six running conditions.

Effects	without the ball						with the ball					
	LR		LR & SR		SR		LR		LR & SR		SR	
	p	η^2	p	η^2	p	η^2	p	η^2	p	η^2	p	η^2
Groups	0.01	0.18	0.00	0.31	0.00	0.36	0.01	0.18	0.00	0.34	0.00	0.36
R1	0.00	0.74	0.00	0.48	0.00	0.52	0.00	0.89	0.00	0.74	0.00	0.77
R1×Groups	0.24	0.04	0.33	0.03	0.12	0.08	0.32	0.03	0.28	0.04	0.12	0.08

LR – Linear Running; LR & SR – Linear Running & Stop and Restart; SR – Shuttle Run; p – p-value, η^2 – effect size; R1 - Treatment

Table 3 includes the main effects and interactions between two factors (Treatment-Groups) and the dependent variable (lower limb strength), for each running condition (pre and post) and for both groups, detected through a two-way repeated measures ANOVA. There were significant differences between the groups (p=0.01; p=0.00; p=0.00; p=0.001; p=0.00; p=0.00) and in treatments (p=0.00; p=0.00; p=0.00; p=0.00; p=0.00; p=0.00) in six running conditions; while the interaction between the groups and treatments are not significant (p=0.24; p=0.33; p=0.12; p=0.32; p=0.28; p=0.12). The size of the partial effect in the case of the groups is small, while in the case of the treatments they result to be medium-sized.

Table 4 includes the values of RPE detected after each running condition in both groups (Guards and Forwards/Centres). Participants have indicated their rating of perceived exertion (RPE, CR10-scale modified) [45] immediately at the end of following six running conditions: Linear running without the ball, Linear running & stop and restart without the ball, Shuttle runnnig without the ball, Linear running with the ball, Linear running & stop and restart with the ball, Shuttle running with the ball. The results obtained by the use of the Student's t-test for paired groups, show that there are significant differences for each running condition and for both groups in terms of the training load (TL), with the exception of the linear running (LR) with the ball and without the ball (p=0.14; p=0.07).

Table 4. Value differences of RPE through the Student's t-test.

Running conditions	Guards (n=15)		Forwards/Centres (n=15)		p
	RPE	RPE Session	RPE	RPE Session	
LR without the ball	3.27 ± 0.46	19.62	3.53 ± 0.52	21.18	0.14
LR&SR without the ball	3.73 ± 0.49	22.02	4.07 ± 0.46	23.22	0.04
SR without the ball	4.20 ± 0.41	24.78	4.60 ± 0.49	27.18	0.01
LR with the ball	4.13 ± 0.35	28.02	4.53 ± 0.52	29.58	0.07
LR&SR with the ball	4.93 ± 0.46	30.78	5.36 ± 0.49	33.18	0.01
SR with the ball	5.67 ± 0.41	34.80	6.20 ± 0.56	37.62	0.001

DISCUSSION

In shuttle run the energetic cost it is higher than linear running with stop and restart and the energetic cost is even more then the linear running, because stopping and restarting at certain speed require greater muscular and physiological effort. The energetic cost, therefore, in the running with acceleration and deceleration (SR) result much more energetically expensive compared to the other two types of running [46]. A more evident significant difference was detected between the two goups analyzed during SR with and without the ball, as it required a greater muscular work. This work is due to the action of stopping and restarting (table 2) (p=0.011). In the case of SR with the ball, it required even higher energetic demand due to the motor control of the ball (table 2) (p=0.008). The group (G), in both running conditions with and without the ball showed rates of inferior values for the energetic cost and heart rate in respect to the group (F/C), whereas VO_2 and VO_2max resulted in higher values for the group (G). This study offers new insights allowing a better understanding and a more accurate estimate of the energetic cost associated with acceleration and deceleration, and changes in direction. Specifically, the results show that there is an increased energetic cost, VO_2 and Heart Rate response associated, above all, with the group F/C, when players change direction or dribble. This investigation, therefore, is helpful in determining the energetic cost of intermittent sports and training, with and without changes in direction and with and without the ball. The values of Intraclass Correlation Coefficient (ICC) estimated for the reliability of the measures of the energetic cost, for each running conditions in both groups (G and F/C) with and without the ball, were excellent showing a high reliability and ranging from 0.94 to 0.98. Lower limbs muscle strength was assessed with Optojump, before and after each running conditions (LR, LR&SR, SR) with and without the ball, in both groups (G and F/C). With this statistic procedure each subject was measured twice, for each running condition and taking into consideration both groups. Table 3 shows the main effects and interactions between two factors (Treatment-Groups) and the dependent variable (lower limbs strength), for each running condition (pre and post) and for both groups (G and F/C) detected through the two-way (between and within subjects' factors) 2x2 ANOVA (n=6 conditions). In all running conditions there were significant differences between the two groups (Groups: 0.01; 0.00; 0.00; 0.01; 0.00 and 0.00) and in the treatments (R1: 0.00; 0.00; 0.00; 0.00; 0.00 and 0.00). Therefore, for each running condition (n=6) there was a significant difference in strength decrement (lower limbs) both between the two groups and between the before and after the tests in each group. However, the interactions between the groups and the treatment (R1*Groups) were not significant for all the running conditions (p: 0.24; 0.33; 0.12; 0.32; 0.28; 0.12). The method RPE was used for the rating of perceived exertion during the training. In order to provide a valuable overall RPE score, the CR-10 scale was presented to the players two weeks before the start of the experimental period. Then, during the experimental period, each player was asked about the perceived effort at the end of each running condition (LR, LR&SR and SR), about 30 minutes after, to evaluate the Training Load (TL), making him indicate the number on a sheet, not verbally, without knowing the indicated value by the other players, do it to see the others the indicated value, so as not to negatively influence the correct interpretation of the data. From the analysis and comparison between the two groups (table 4) it resulted that in the linear running with and without the ball, no significant difference were detected (p=0.14 in LR without the ball; p=0.07 in LR with the ball); whereas in other running conditions, namely in the linear running with stop and restart and in the shuttle run, with and without the ball, a significant difference was detected between the two groups (p=0.04 in LR&SR without the ball; p=0.01 in LR&SR with the ball; p=0.01 in SR without the ball and p=0.001 in SR with the ball). C is higher as much is higher the running speed and it is as larger as shorter the shuttle path, as also indicate by Buglione & di Prampero [47], because of the cost of decelerations and accelerations imposes larger physiological demands on athletes compared to linear running at constant speed. In addition, different energetic cost between the two groups (G and F/C) increases even more during the running with the ball compared to running without the ball, independently of changes in direction. This last point could be justified from an additional energetic request due to the conditioning of the motor control of the ball required to synchronize dribble during different running conditions of the tallest players (Forwards and Centres). In any case, the energy consumption in different running conditions and between the two groups were significantly different. One of the reasons for the mentioned was that in linear running with stop and restart (LR&SR) every 15 m (with and without the ball) it was increased in relation to the deceleration/ acceleration of the player on the frontal plane, as compared to the continuous linear running and this difference was even more prominent in the shuttle running with the changes in direction (with and without the ball). Indeed, in this last condition, during the deceleration and acceleration phase, the player's body mass stabilization needed more mechanical work.

CONCLUSIONS

This study indicates that the energetic cost (C) for the shuttle running is greater than for the linear run (LR and LR&SR), (C) is also greater in the running with ball than in the running without the ball and is higher for the F/C group than G group. The main evidence of this study has confirmed initial hypothesis, showing a different metabolic expenditure in the six running conditions (LR, LR & SR, SR with and without ball) and between the two groups taken in consideration (G and F/C). Coaches may find this information useful for planning their training sessions, to optimize the load of work in relation to the position and to energetic capacities of players. To achieve this, it is necessary to act on the load, thus modifying and customizing it, in relation to different positions of players. For example, modifying the loads' variables such as time, speed, distance, recovery and the type of technical movement to be performed. With reference to this last aspect, the technical movement should be very similar to that one of the match. This allows to optimize learning and motor control in young basketball players.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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