Original Article

Repeated sprints and the relationship with anaerobic and aerobic fitness of basketball athletes

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Abstract

The sport of basketball is characterized by numerous explosive short exercise bursts interspersed by brief recovery periods over an extended period of time. In this situation, the activation of both energy systems, the aerobic and the anaerobic, is needed to fulfill the muscle energy demands during the game. The objective of this study was to verify the relationship between the performance of repeated sprints and the anaerobic and aerobic fitness indexes in basketball athletes. Twenty university athletes aged between 18 and 24 years participated in this study. Participants performed a 30-m sprint and incremental treadmill test. The anaerobic reserve of running, VO_{2peak} , and ventilatory thresholds were identified. A significant correlation was observed between the anaerobic reserve of running and the performance of sprint 1 ($r = 0.55$), sprint 2 ($r = 0.547$), sprint 3 ($r = 0.535$), sprint peak ($r = 0.574$), average sprint ($r = 0.475$), and total time ($r = 0.583$), whereas VO_{2peak} correlated with sprint 2 ($r = 0.489$), sprint 3 ($r = 0.504$), sprint 4 ($r = 0.589$), sprint 5 ($r = 0.620$), sprint 6 ($r = 0.655$), and average time sprint ($r = 0.582$). These results indicate that the ability to perform repeated sprints involves a significant participation of the anaerobic metabolism, primarily in the initial efforts, whereas as the efforts are repeated, a greater contribution of the aerobic fitness is observed.

Key words: Athletic performance; Motor skills; Physical resistance; Oxygen consumption

Introduction

Basketball is characterized as predominantly anaerobic, with elite athletes often subjected to more than 2,700 actions of intermittent characteristics, which involve walking, running, sprinting, and jumping (Scanlan, Dascombe, & Reaburn, 2011). From the point of view of high-intensity actions, time-motion studies have reported that 28.49%–49.06% of the actions are sprint (Abdelkrim, Fazaa, & Ati, 2007; McInnes et al., 1995), which is considered as one of the most required actions to the athletes. By observing repetition of intermittent efforts in basketball, power endurance appears to be an imperative component of athletic fitness, as the ability to sustain the greatest power during various efforts can be crucial at decisive moments in the game (Taylor et al., 2015).

The ability to perform successive sprint efforts is termed as repetitive sprint ability (RSA) and is characterized by short high-intensity (<10 s) and brief recovery periods (<60 s) (Girard, Mendez-Villanueva, & Bishop, 2011), and it has been commonly used as an important parameter of athletic performance relative to fatigue resistance (Buchheit et al., 2010). According to Jones et al., (2013), this ability to perform repeated high-intensity efforts is strongly related to the efficiency of phosphocreatine (PCr) resynthesis rate and the removal of hydrogen ions (H^+) from the musculature during the period of recovery between efforts, which are associated with muscle fatigue. In the last few decades, several studies have reported a gradual reduction in PCr levels as the amount of effort increases, together with an increase in H^+ concentration, which results in a decline in performance (Bogdanis et al., 1996; Dawson et al., 1997; Mendez-Villanueva et al., 2012).

Despite the anaerobic predominance in efforts of this nature, previous studies have suggested that a high aerobic fitness can contribute to the performance of repeated efforts (David Bishop, Edge, & Goodman, 2004; Jones et al., 2013; McGawley & Bishop, 2015). However, the literature does not present a consensual correlation between maximal oxygen uptake (VO_{2max}) and RSA indexes, in which some studies reported a significant correlation ($r = -0.57$ and $r=0.78$) (Gharbi et al., 2015; Stanula et al., 2014), while others did not (Dardouri et al., 2014; Stojanovic et al., 2012). In addition, it should be noted that other indicators of aerobic fitness should be

analyzed in relation to RSA, such as the anaerobic threshold and the respiratory compensation point, and not just the VO_{2max} . Thus, if we observe the relevance of performing repeated sprints in basketball or modalities with similar demand, the identification of variables that can optimize RSA performance becomes essential, providing information relevant to sports professionals. Therefore, the objective of the present study was to verify the relationship between aerobic and anaerobic fitness in RSA performance.

Methods

Participants

A total of $n=20$ male college basketball athletes aged between 18 and 24 years took part in this cross-sectional study. As an inclusion criterion, athletes should be participating in basketball competitions over a three years period and continuously training over the last six months. Athletes with cardiovascular diseases history, musculoskeletal injury; and those ones using ergogenic substances regularly were excluded from the sample. The study was approved by the Ethics and Research Committee of the Health Sciences Center of the Federal University of Rio Grande do Norte – UFRN - Brazil (Number: 1.812.430), following the guidelines for data collection in humans, according to resolution no. 466/12, of 12/12/2012, of the National Health Council, as well as the ethical principles contained in the Declaration of Helsinki. All subjects who voluntarily participated in the research signed a Free and Informed Consent Term.

Study design

For data collection, the athletes were submitted to an evaluation of body composition and aerobic and anaerobic fitness. The athletes attended the laboratory to evaluate body composition in a single moment, in another 2 days, nonconsecutive, they were submitted to a familiarization session to the incremental treadmill test and the RSA. After a 48-h period of familiarization, the athletes performed the aerobic and anaerobic fitness tests. The incremental test was performed on two consecutive days, while the RSA protocol was performed on a single day after 48-h. The data collection took place in the final phase of preparation, close to the competitive period. All athletes received verbal stimuli during the tests, and the RSA protocol was performed at the team's own training courts at night.

Procedures

Anthropometric measures

Body mass and height were measured using an electronic scale (Filizola® 110, São Paulo, Brazil), with a capacity of 150 kg, divisions of 1/10 kg, and an accuracy of 100g and by a stadiometer (Sanny® ES2020, São Bernardo do Campo, Brazil) with a scale of 0.5 cm, respectively. Body composition and percentage of fat and fat-free mass were evaluated by dual-energy X-ray absorptiometry (DEXA) (Lunar®/GE PRODIGY - LNR41,990, United States), following the standards adopted by Naimo et al. (2015).

Incremental protocol on treadmill

The aerobic fitness was evaluated through an incremental runner protocol in treadmill (Inbrasport®, Porto Alegre, Brazil) using a spirometry system (Hans Rudolph®, model 2726, Kansas City, United States). The protocol consists of maintaining a speed of 8 km/h during the first 3 min and then increasing by 1 km/h every minute until voluntary exhaustion (adapted from Alvarez et al., (2009). To characterize as the maximum effort in the test, at least two of the following criteria were adopted: 1) respiratory exchange ratio $R > 1.1$, 2) peak heart rate $>90\%$ predicted by age ($HR_{max} = 220 - age$), and 3) subjective perception of effort = 20 reported by the Borg scale (1998). Ventilatory collections were recalled every 20s by a gas analyzer (MetaLyzer® 3B, Leipzig, Germany), calibrated for gas and volume as recommended by the manufacturer. To identify the anaerobic threshold, the loss of linearity of the relationship between oxygen consumption (VO_2) and carbon dioxide production (VCO_2) (Beaver et al., 1986) was used as the criterion. The increase in the respiratory equivalent of O_2 (VE/VO_2) without concomitant increase in the CO_2 equivalent (VE/VCO_2) was also observed to confirm the anaerobic threshold (Meyer et al., 2005). The respiratory compensation point was considered by the loss of linearity of the VE/VCO_2 (Bunc and Heller, 1994), and the lowest value of the VE/VO_2 was also verified, followed by its systematic increase (Reinhard et al., 1979).

Repeated sprint ability

The RSA test consisted of six repetitions of 30-m all-out sprints with a 20-s interval between each sprint, adapted from previously validated protocol (Zagatto et al., 2009). Each sprint was remembered through a photocell system (Speed Test 6.0 CEFISE®, São Paulo, Brasil), positioned at every 10 m of the total 30 m. The athletes first performed a maximum speed test of 30 m. During the RSA protocol, the athletes were instructed to achieve a performance of $>90\%$ in the 30-m test as the test validation criterion. For performance characterization, the velocity peak was identified (better performance among sprints). The total time (sum of all sprints), mean (mean of all sprints), and sprint decrease can be identified by the following equation:

$$\text{Sprint decrease} = \{(\text{total time/ideal time}) - 1\} \times 100$$

Note: ideal time = best performance multiplied by six (Girard et al., 2011).

Anaerobic running reserve (ARR)

The ARR estimate was calculated by performing the 30-m maximum velocity test (V30) and the minimum velocity achieved at maximum oxygen consumption ($vVO_{2\max}$), obtained by the incremental treadmill test, according to the following equation:

$$ARR (km \cdot h^{-1}) = V30 - vVO_{2\max} \text{ (Mendez-Villanueva et al., 2012)}$$

Data analyses

The parametric distribution of the data was confirmed using the Shapiro–Wilk test. To compare the performance during the RSA tests, the paired sample *t*-test was used. The relationship between RSA indexes and parameters of aerobic fitness and RSA was verified by Pearson's correlation. The magnitude of the correlation was determined by the scale proposed by Hopkins, (2012) as follows: $r < 0.1$, trivial; $r = 0.1–0.3$, small; $r = 0.3–0.5$, moderate; $r = 0.5–0.7$, strong; $r = 0.7–0.9$, very strong; $r = 0.9–0.99$, almost perfect; and $r = 1.0$, perfect. To verify how much the dependent variables (aerobic fitness and ARR) were able to predict the performance of the repeated sprints, a linear regression was used for each dependent variable. Data analysis was performed by the Statistical Package for Social Sciences, SPSS, version 20.0. The significance level established for all analyses was $p < 0.05$.

Results

Table 1 shows the characterization of the RSA performance indexes, aerobic fitness, and ARR of the athletes. Regarding the athletes' body composition, the mean values were $22.97\% \pm 1.35\%$ for fat percentage and 62.72 ± 1.74 kg for fat-free mass. The physiological rest parameters of the athletes were also verified, with mean values of 4.05 ± 1.05 for resting oxygen consumption and 68.47 ± 4.02 for resting heart rate.

Table 1. Characterization of the sample

Repeated sprint ability	Mean $\pm$ SD
Peak time (s)	4.59 ± 0.24
Average Time (s)	4.83 ± 0.31
Total time (s)	27.60 ± 6.77
Sprint decrease (%)	5.27 ± 2.91
Aerobic fitness	
$VO_{2\text{peak}}$ (ml/kg/min)	49.19 ± 4.79
VO_2 Anaerobic threshold (ml/kg/min)	34.41 ± 4.30
$VO_{2\text{PRC}}$ (ml/kg/min)	42.88 ± 5.89
Anaerobic running reserve ($km \cdot h^{-1}$)	10.92 ± 2.47

$VO_{2\text{PRC}}$ = Oxygen consumption at the point of respiratory compensation.

The comparison of RSA performance during the six sprints is reported in Figure 1. A reduction in sprint performance was evident from the second sprint ($p < 0.001$), with a linear reduction, as efforts were repeated. When comparing the performance of the first and last sprints, there was a reduction of $\sim 10\%$ (4.59 versus 5.09 s), with a total sprint decrease of 5.27% reported.

Figure 1. Performance of repeated sprint ability.

* Significant difference, $p < 0.001$, in relation to the first sprint; # Significant difference, $p < 0.001$, compared to the previous sprint.

The correlation coefficients and r^2 obtained by the linear regression analysis are reported in Table 2. A relationship of the sprints with the VO_{2peak} from sprint 2 was observed, showing an increase in the coefficients as the sprints were repeated, in which the VO_{2peak} shared 23.9% and 42.8% of performance in sprints 2 and 6, respectively. Compared to the VO_{2PRC} , only the last sprint was related, demonstrating a strong coefficient; ARR showed a divergent behavior, with strong coefficients in the first three sprints, sharing 30.8% and 28.7% of performance in sprints 1 and 3, respectively.

Table 2. Correlation of aerobic fitness and anaerobic running reserve during intermittent efforts

RSC	VO_{2peak}	VO_{2AT}	VO_{2PRC}	ARR
Sprint 1	-0.451 (-)	-0.111 (-)	-0.356 (-)	-0.550 ($r^2=30.8$)*
Sprint 2	-0.489 ($r^2=23.9$)*	-0.141 (-)	-0.412 (-)	-0.547 ($r^2=30.0$)*
Sprint 3	-0.504 ($r^2=25.4$)*	-0.133 (-)	-0.374 (-)	-0.535 ($r^2=28.7$)*
Sprint 4	-0.589 ($r^2=34.7$)*	-0.201 (-)	-0.448 (-)	-0.400 (-)
Sprint 5	-0.620 ($r^2=38.4$)*	-0.238 (-)	-0.490 (-)	-0.392 (-)
Sprint 6	-0.655 ($r^2=42.8$)*	-0.268 (-)	-0.567 ($r^2=32.1$)*	-0.370 (-)

RSC = Repeated sprint capacity; VO_{2LA} = oxygen consumption at the anaerobic threshold; VO_{2PRC} = Oxygen consumption at the point of respiratory compensation; ARR = Anaerobic running reserve; *Significant difference, $p < 0.05$

The correlation coefficients of the RSA indexes with the aerobic fitness and ARR are reported in Table 3. From the aerobic point of view, only the VO_{2peak} ratio was observed with the mean time in the RSA test, which shared 33.87% of variance of running performance, and no relation was identified with the oxygen consumption achieved in ventilatory parameters. On the other hand, ARR presented significant moderate to strong relationships with RSA indexes, with the exception of sprint.

Table 3. Correlation of the indexes of the repeated sprints ability with the aerobic fitness and anaerobic running reserve

RSA	VO_{2peak}	VO_{2AT}	VO_{2PRC}	ARR
Peak time (s)	-0.458	-0.146	-0.371	-0.574 (32.94)*
Average time (s)	-0.582 (33.87)*	-0.197	-0.467	-0.475 (22.56)*
Total time (s)	0.115	0.312	0.244	-0.583 (33.98)*
Sprint decrease (%)	-0.396	-0.221	-0.325	-0.011

RSC = Repeated sprint capacity; VO_{2LA} = oxygen consumption at the anaerobic threshold; VO_{2PRC} = Oxygen consumption at the point of respiratory compensation; ARR = Anaerobic running reserve (ARR); *significant difference, $p < 0.05$

Discussion

The primary findings of the present study suggest that the ability to perform repeated sprints involves a contribution of anaerobic and aerobic metabolism and that this contribution appears to be associated with repetition of efforts. Regarding anaerobic fitness, it was verified that the ARR was related to the performance of the initial sprints, but specifically up to the third stimulus, and with all the RSA indexes, with the exception of the sprint decrease. VO_{2peak} presented a correlation from the second sprint, with an increase in correlation coefficients as the efforts were repeated, sharing 23.9% and 42.8% of the variance in the performance of sprints 2 and 6, respectively.

When comparing the RSA performance behavior, there was a reduction in performance from the second stimulus, which was maintained during subsequent efforts, resulting in a performance decrease of 5.27%. This decline in CSR performance was also verified by Mendez-Villanueva, Hamer, & Bishop (2008), who reported a reduction from the second stimulus. From a physiological point of view, studies suggest that this decline appears to be closely related to the rapid depletion of PCr stocks in the early efforts and with their resynthesis rate during recovery (Mendez-Villanueva et al., 2012; Spriet et al., 1989). Corroborating this suggestion, studies have reported that after a recovery interval of 4–6 min, a resynthesis of PCr close to its content in relation to rest occurs (Bogdanis et al., 1996). However, in shorter recovery intervals of <30 s, characteristic of some sports such as basketball, PCr stores may only be partially resynthesized, resulting in levels below those at rest for subsequent onset of exertion. Dawson et al., (1997) verified the PCr resynthesis time course and demonstrated that after 30 s of recovery, only 45% of the PCr content was resynthesized. Although our study does not investigate the metabolism during the exertions, it is reasonable to assume that the short recovery period is a determinant of decreasing performance, which may be associated, in part, with the rate of PCr resynthesis.

The contribution of aerobic and anaerobic fitness to the performance of repeated sprints, intermittently, was verified through correlation of sprints with VO_{2peak} and ARR. During the first three sprints, there was a relationship with ARR, sharing a greater variance in running time than the rates of aerobic fitness. Dardouri et

al., (2014) observed that the ARR shared 47% and 50% of the variance in the performance of the total time and peak running time, respectively. In this context, our findings reinforce that RSA predominantly involves anaerobic metabolism, especially during the first efforts, in which the higher the ARR, the less the running time during the efforts. Corroborating this idea, Gaitanos et al. (1993) suggest that the predominant energy pathway during the sprint is provided by PCr and anaerobic glycolysis; however, as the efforts are repeated, there is a reduction in anaerobic glycolysis, partly due to the increase in the concentration of H^+ , which inhibits the action of phosphofructokinase (PFK), the intermediate glycolysis enzyme. In spite of anaerobic predominance, during efforts of intermittent characteristics, several studies have reported the importance of oxidative metabolism during recovery of sprints, primarily for the supply of ATP for the resynthesis of PCr, as well as for the removal of metabolites (Haseler et al., 2013; McMahon & Wenger, 1998).

In this context, it is possible to suggest that although the ability to perform repeated sprints is predominantly anaerobic, what appears to be a consensus in the literature is the fundamental role of oxidative metabolism during recovery for subsequent stimuli. However, when using oxygen consumption as a variable of aerobic fitness, several studies have reported a gap in relation to the RSA indexes (Bishop, Lawrence, & Spencer, 2003; Castagna et al., 2007; Dardouri et al., 2014). In fact, our findings did not show a relationship between RSA indexes and aerobic fitness, except for the mean sprint time and VO_{2peak} . However, when analyzing sprints individually, our findings illustrate a relevant contribution of aerobic fitness to RSA performance, wherein as sprints were repeated, the correlation coefficients found for VO_{2peak} were higher, which shared 42.8% of variance in performance in sprint 6. Therefore, this relationship between VO_{2peak} and repeated sprints appears to be strongly related to the supply of oxidative ATP to PCr resynthesis during recovery between sprints.

Recently, McGalwley and Bishop (2015) demonstrated that the contribution of oxidative metabolism is not limited only during recovery between sprints, with an aerobic contribution of ~40% at the end of five sprints of 6 seconds, interspersed with recovery periods of 24s. This participation of oxidative metabolism during repeated sprints was also suggested by classical studies of Bogdanis et al. (1996) and Gaitanos et al. (1993), who found a divergence between the reduction in the rate of ATP production via anaerobic glycolysis, with the decline in the performance of the subsequent sprint, which associated with a greater contribution of the oxidative metabolism to ATP resynthesis. Due to the nature of basketball, in which athletes perform on average 1,050 moves with changes of action every 2 s, with approximately 55–105 actions related to sprints (Abdelkrim et al., 2007; McInnes et al., 1995), the predominance of anaerobic fitness is notorious; however, our data suggest that as efforts are repeated, the contribution of aerobic fitness is determinant. Therefore, what appears to be a consensus is that aerobic fitness presents itself as a determining attribute in the ability to perform repeated sprints.

Conclusion

The findings of this study suggest that the ability to perform repeated sprints involves a significant participation of the anaerobic metabolism, primarily in the initial efforts, whereas as the efforts are repeated, a greater contribution of the aerobic fitness is observed. Hence, this result emphasizes that the improvement in the aerobic fitness appears to be a determining factor for the maintenance of performance close to the maximum in repeated sprints. Therefore, sports professionals should plan training strategies that aim, simultaneously, to improve anaerobic and aerobic fitness in basketball athletes, including practitioners of modalities that have similar demands.

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