# Relationships Between Sprint, Jumping and Strength Abilities, and 800 M Performance in Male Athletes of National and International Levels

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This study analysed the relationships between sprinting, jumping and strength abilities, with regard to 800 m running performance. Fourteen athletes of national and international levels in 800 m (personal best: 1:43-1:58 min:ss) completed sprint tests (20 m and 200 m), a countermovement jump, jump squat and full squat test as well as an 800 m race. Significant relationships ($p < 0.01$) were observed between 800 m performance and sprint tests: 20 m ($r = 0.72$) and 200 m ($r = 0.84$). Analysing the 200 m run, the magnitude of the relationship between the first to the last 50 m interval times and the 800 m time tended to increase (1st 50 m: $r = 0.71$; 2nd 50 m: $r = 0.72$; 3rd 50 m: $r = 0.81$; 4th 50 m: $r = 0.85$). Performance in 800 m also correlated significantly ($p < 0.01-0.05$) with strength variables: the countermovement jump ($r = -0.69$), jump squat ($r = -0.65$), and full squat test ($r = -0.58$). Performance of 800 m in high-level athletes was related to sprint, strength and jumping abilities, with 200 m and the latest 50 m of the 200 m being the variables that most explained the variance of the 800 m performance.

***Key words***: *middle-distance running, countermovement jump, squat, competition, anaerobic pathways.*

## Introduction

Eight hundred meter running is an extremely demanding event that requires substantial contributions from both the aerobic and anaerobic systems, due to high relative values of oxygen uptake (VO2) (Hill, 1999; Spencer and Gastin, 2001) and high blood lactate concentrations (above 15 mmol·L-1) attained after the 800 m run (Hanon and Thomas, 2011; Hill, 1999; Lacour et al., 1990). These high levels of blood lactate have been associated both with increased muscle lactate production (Bogdanis et al., 1996) and large reductions in muscle glycogen (Green, 1978); particularly in IIX fibres (Casey, 1996). This suggests that anaerobic glycogenolysis is extensively activated during this type of effort, preferably in IIX fibres (Green, 1978). Different relative percentages of aerobic/anaerobic contribution to 800 m track event were previously reported as: 73/27% (Craig and Morgan, 1998), 71/29% (Weyand et al., 1994), 66/34% (Spencer and Gastin, 2001), 59/41% (Lacour et al., 1990), 58/42% (Hill, 1999), and 60/40% (Duffield et al., 2005). Other variables such as VO2max or VO2 response to middle-distance track running events have also been widely investigated (Hanon and Thomas, 2011; James et al., 2007). However, other possible determinant factors related to the 800 m performance such as strength, power, and

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sprinting capacities have received less scientific attention (Hudgins et al., 2013).

　　　Research has shown a clear relationship between sprinting, strength and jumping performance in athletes. However, most of these investigations have focused their analysis on very short running distances (i.e., 50 and 100 m) (Loturco et al., 2015a, 2015b; Seitz et al., 2014). In regard to middle-distance track and field events, Hudgins et al. (2013) observed significant correlations between jumping ability and 800 m race time in competitive runners. Moreover, Deason et al. (1991) found a significant relationship between 800 and 300 m running times. Other studies have also investigated the effects of strength-power training on middle and long-distance running performance (Mikkola et al., 2011; Taipale et al., 2010, 2014). For instance, Mikkola et al. (2011) reported that both heavy and explosive resistance training programs were able to improve maximal endurance capacity in long-distance runners. In addition, Taipale et al. (2010) showed a positive effect of strength training on the specific performance of endurance athletes. Improvements in peak running speed have also been reported after mixed maximal and explosive strength training performed concurrently with endurance training in recreational endurance runners (Taipale et al., 2014).

　　　To date, coaches and sports scientists have shown keen interest in variables related to the metabolic contribution and energetic substrates to explain the 800 m performance (Craig and Morgan, 1998; Duffield et al., 2005; Hill, 1999; Lacour et al., 1990; Spencer and Gastin, 2001). Actually, very few studies have examined the importance of different neuromuscular variables on middle-distance running performance (Hudgins et al., 2013). In addition, it has been suggested that strength training could lead to enhanced long-term endurance capacity both in well-trained individuals and elite endurance athletes (Aagaard and Andersen, 2010). Thus, the purpose of this investigation was to examine the relationships between lower limb strength, sprint times, jumping ability and 800 m running times in male athletes of national and international performance levels. Based on extensive data confirming the strong correlation between strength variables versus endurance performance (Mikkola et al., 2011; Taipale et al.,

2010, 2014), and sprinting ability (Loturco et al., 2015a, 2015b; Seitz et al., 2014), we hypothesised that lower limb strength, jumping performance and sprint ability would be significantly correlated with 800 m times.

## Methods

### Participants

　　　Fourteen male athletes of national and international levels in 800 m competing in elite, junior, and youth categories, with personal best ranging from 1:43 to 1:58 min:ss (average 1:52 min:ss) participated in this study (age: 22.9 ± 5.3 years; body height: 175.2 ± 5.5 cm; body mass: 62.9 ± 4.4 kg). Two of them were classified 1st and 2nd in the national championship and national ranking; they had also participated in London 2012 and Rio 2016 Olympic Games. All athletes had completed strength-training programs in the past and were familiarized with testing procedures. The athletes participated in national and international competitions during the period of testing. The tests were carried out during the outdoor athletic season; i.e. at the point of their peak performance. No physical limitations or musculoskeletal injuries that could affect testing were reported. All participants were fully informed about procedures, potential risks and benefits of the study and they all signed written informed consent prior to the tests. The study was conducted in accordance with the Declaration of Helsinki II and approved by the Ethics Committee of the Pablo de Olavide University (Seville, Spain).

### Design

　　　A cross-sectional experimental design was used. Testing was performed in two sessions separated by 1 week. Session 1 consisted of sprint (20 m) and strength tests (countermovement jump (CMJ), jump squat (JS), and full squat (SQ) tests). Session 2 comprised the CMJ, 200 m test, and blood lactate measurements. As the tests were performed during outdoor athletics competition season, the official 800 m performance time obtained by the athletes in the nearest competition to the tests (within 2 weeks) was recorded for the analysis. A competition was chosen where the athletes tried to attain their best possible result. Testing sessions were always carried out after a full day of rest, at the same time of the day (18:00-20:00 h).

## Procedures

### Test Preparation

During the first testing day, all the participants completed a 20 min standardized warm-up protocol consisting of 10 min of low intensity jogging, 5 min of joint mobilization exercises, and one 40 m sprint at 80% effort, two 20 m sprints at 90% effort, and one 10 m sprint at 100% effort with 2 min rest periods between them. After the sprint test, the athletes performed strength tests in the following order: CMJ, JS, and SQ; in addition to the standardized warm-up, the participants did SQ without an external load and 5 progressive CMJ. On the second testing day, the athletes performed the 200 m test with CMJ and blood lactate measurements.

### Sprint testing

On the first day two 20 m trials were performed. The sprint trials were recorded by photocells (Polifemo Radio Light; Microgate, Bolzano, Italy), based on a radio impulse transmission system and a reflection system. Runs were performed from a static biped starting position with the start line located 1 m behind the first photocell. The rest of the photocells were placed at 10 and 20 m. The best time of the two 20 m trials was recorded for further analysis. The rest period between trials lasted 3 min. The sprint test (20 m) was conducted on a synthetic running track in an indoor hall.

### Jump measurements (CMJ and JS)

The CMJ and JS were performed on an infrared plate Optojump (Microgate, Bolzano, Italy) that calculated jump height *(h)* through flight time *(t)* and acceleration due to gravity *(g)* as follows: $h = t^2 \times g / 8$. The CMJ was performed with both hands on the waist, while performing a downward movement until 90º-knee flexion followed by a vertical jump of maximum effort. The participants were required to perform 3 trials separated by 1 min rest, mean height being recorded. Just after the CMJ test, the JS test was conducted with progressive loads ranging from 20 kg up to the load allowing the subject to jump up not higher than 20 cm. The jump squat test was performed using a Smith machine (Multipower Fitness Line, Peroga, Murcia, Spain), which allowed a smooth vertical displacement of the bar along a fixed pathway. The athletes performed two JS separated by 2 min rest with each load. The average value of the 2 jumps was used for the subsequent statistical analysis.

### Full Squat test

After the JS test, an incremental loading full squat test was performed on a Smith machine (Multipower Fitness Line, Peroga, Murcia, Spain) using a linear velocity transducer (T-Force System; Ergotech, Murcia, Spain). Instantaneous velocity was sampled at a frequency of 1,000 Hz. After a warm-up, the initial load was set at 20 kg for all participants and was gradually increased by 10 or 5 kg until the attained mean propulsive velocity (MPV) was <1 m·s⁻¹. This velocity of 1 m·s⁻¹ corresponded approximately to 55-60% of 1RM and was considered a sufficient load to evaluate lower limb strength (Conceição et al., 2015). The participants started from the upright position with their knees and hips fully extended, the barbell resting across their back at the level of the acromion. Each subject descended in a continuous motion until the top of the thighs got below the horizontal plane, and then they immediately reversed the motion and ascended back to the upright position. The participants were always required to execute the concentric phase of the SQ in an explosive manner, at maximal intended velocity. For each load, the repetition correctly performed at the highest velocity was recorded. The loads reported in this study corresponded to the load reached at 1 m·s⁻¹ velocity of the propulsive phase (Sánchez-Medina at al., 2010).

### 200 m running test

This test was performed on a synthetic running outdoor track (Mondo). Wind conditions were monitored constantly by an Oregon Scientific WMR-918 (Oregon Scientific, Tigard, OR, USA) meteorological station. A mathematical model (Quinn, 2003) was used in order to adjust the potential influence of wind on the performance. This mathematical model suggests that a head wind of -2.0 or -1.0 m·s⁻¹ causes a time loss of 0.121 and 0.059 s, respectively, and that a tail wind of +2.0 or +1.0 provides a time gain of 0.112 and 0.056 s, respectively. Only one 200 m trial was performed. The procedures were the same as the aforementioned ones for the 20 m test. Partial times were recorded for each 50 m split. Five pairs of photocells (Polifemo Radio Light; Microgate, Bolzano, Italy) were used for timing. Measurements of CMJ height were taken before the 200 m test. In addition, capillary blood samples for the determination of lactate

concentrations (Lactate Pro 2, Arkray, Kyoto, Japan) were obtained from the earlobe before the exercise and 3 min after the completion of the 200 m sprint.

### Statistical Analyses

All data are reported as means ± SD. Test-retest absolute reliability was measured by the coefficient of variation (CV), whereas relative reliability was assessed by the intraclass correlation coefficient (ICC) and a confidence interval (CI) at 95% was calculated using the one-way random effects model. The normal distribution of the data was verified with the Shapiro-Wilk test. The relationships with Pearson's coefficients (r) and 90% CI were used to calculate the respective correlations between the different performance variables analysed. The magnitude of correlation was assessed with the following thresholds: <0.1, *trivial*; <0.1–0.3, *small*; <0.3–0.5, *moderate*; <0.5–0.7, *large*; <0.7–0.9, *very large*; and <0.9–1.0, *almost perfect* (Hopkins et al., 2009). Statistical significance was set at $p \leq 0.05$. SPSS for Mac (IBM Corporation, New York, NY, USA) (release 20.0.0) was used for all statistical analyses.

## Results

Reliability was set with the ICC and CV for all the distances and jumps. Sprints were generally reliable: 10 m (ICC: 0.75; CI: 0.25-0.92; CV: 1.9%), 10-20 m (ICC: 0.83; CI: 0.46-0.95; CV: 1.6%), and 20 m (ICC: 0.92; CI: 0.76-0.97; CV: 1.1%). Both CMJ (ICC: 0.99; CI: 0.99-1,00; CV: 1.3%) and JS (ICC: 0.98; CI: 0.92-0.99; CV: 4.0%) showed good reliability.

**Table 1**

*Relationships between sprint times (10 m, 20 m, 10-20 m, 200 m, 1st 50 m, 2nd 50 m, 3rd 50 m, 4th 50 m), strength tests (CMJ, JS, SQ) and 800 m performance (n=14, except for 200 m n=12)*

| Test | Mean ± SD | Correlation (r) |
|------|-----------|-----------------|
| 10 m (s) | 1.67 ± 0.03 | 0.59 * |
| 20 m (s) | 2.89 ± 0.06 | 0.72 ** |
| 10-20 m (s) | 1.20 ± 0.03 | 0.56 * |
| 200 m (s) | 23.16 ± 0.89 | 0.84 ** |
| 1st 50 m (0-50 m) (s) | 6.20 ± 0.19 | 0.71* |
| 2nd 50 m (50-100 m) (s) | 5.43 ± 0.22 | 0.72* |
| 3rd 50 m (100-150 m) (s) | 5.56 ± 0.25 | 0.81** |
| 4th 50 m (150-200 m) (s) | 5.91 ± 0.31 | 0.85*** |
| CMJ (cm) | 42.6 ± 5.6 | -0.69 ** |
| JS (load 20 cm) | 34.6 ± 14.3 | -0.65 * |
| SQ (load 1 m·s⁻¹) | 56.3 ± 9.7 | -0.58 * |

*Abbreviations: CMJ = Countermovement jump; JS = Jump squat with the load of 20 cm height; SQ = full squat with the load reached at 1 m·s⁻¹ velocity.*
*\*Indicates significant correlation at p < 0.05; \*\*Indicates significant correlation at p < 0.01; \*\*\*Indicates significant correlation at p < 0.001.*
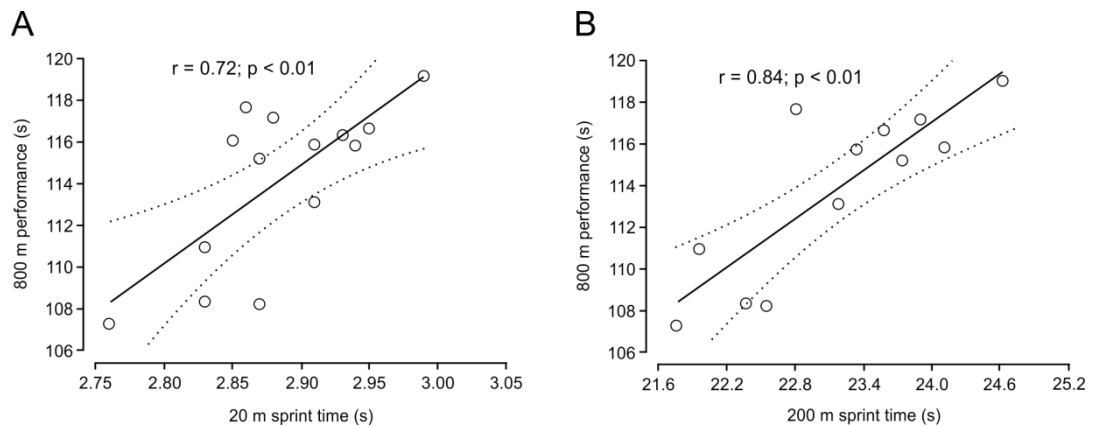
**Figure 1**

*Relationships between sprint times: A) 20 m; B) 200 m, and 800 m performance (n=14, except for 200 m n=12)*
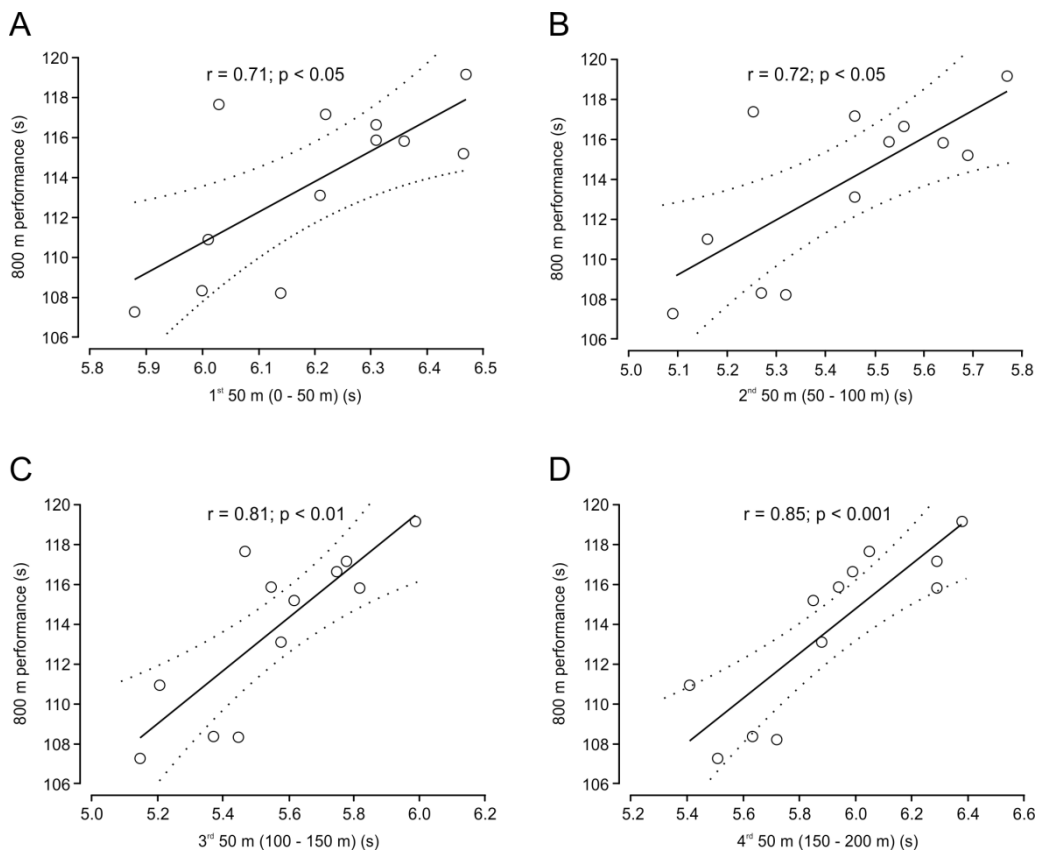


**Figure 2**

*Relationships between 200 m split times: A) 1ˢᵗ 50 m (0-50 m); B) 2ⁿᵈ 50 m (50-100 m); C) 3ʳᵈ 50 m (100-150 m); D) 4ᵗʰ 50 m (150-200 m), and 800 m performance (n=12)*
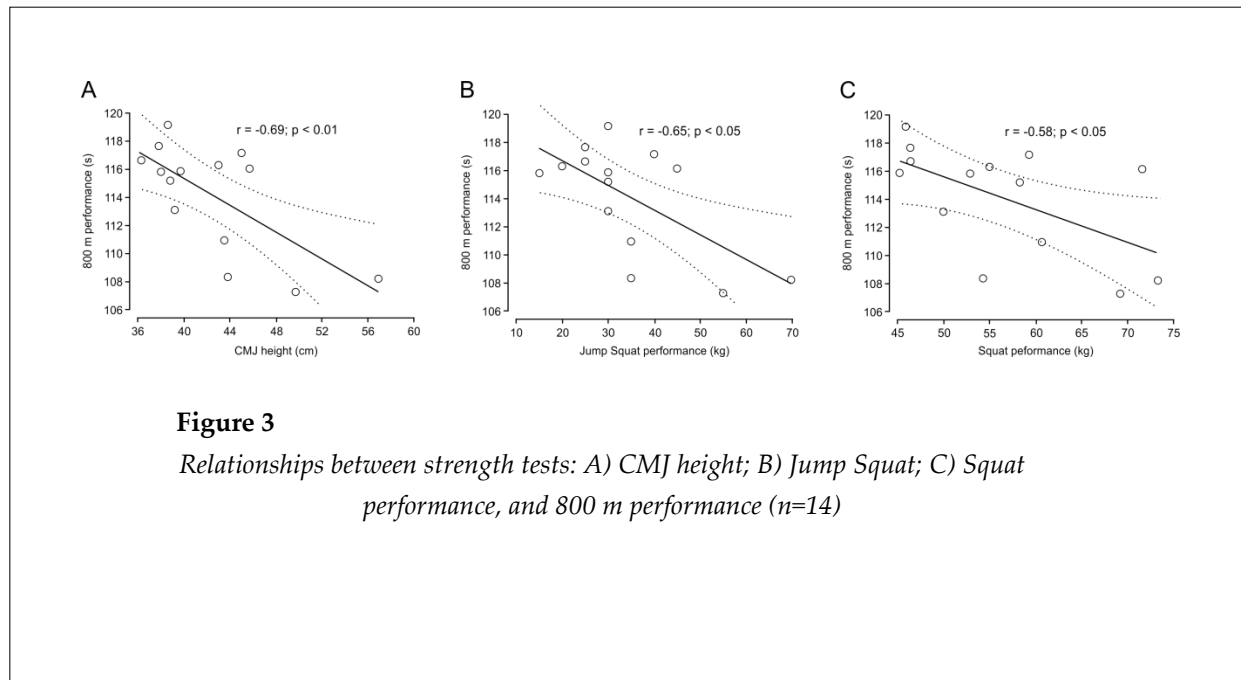
**Figure 3**

*Relationships between strength tests: A) CMJ height; B) Jump Squat; C) Squat performance, and 800 m performance (n=14)*

*Relationships between sprint and strength variables and performance in the 800 m run*

The relationships between sprinting, strength variables and performance in 800 m are shown in Table 1. Sprint tests correlated significantly with the performance in 800 m: 10 m (r = 0.59, CI: 0.29 to 0.89, $p < 0.05$), 20 m (r = 0.72, CI: 0.50 to 0.94, $p < 0.05$), 10-20 m (r = 0.56, CI: 0.25 to 0.87, $p < 0.05$), and 200 m (r = 0.84, CI: 0.69 to 0.99, $p < 0.01$) (Figure 1). When analysing the 200 m sprint intervals, divided into 1st 50 m, 2nd 50 m, 3rd 50 m, and 4th 50 m, it was observed that the magnitude of the relationship between the first to the last 50 m interval times and the 800 m time tended to increase (1st 50 m: r = 0.71, CI: 0.46 to 0.96, $p < 0.05$; 2nd 50 m: r = 0.72, CI: 0.48 to 0.96, $p < 0.05$; 3rd 50 m: r = 0.81, CI: 0.64 to 0.98, $p < 0.01$; 4th 50 m: r = 0.85, CI: 0.71 to 0.99, $p < 0.001$) (Figure 2). In addition, performance in 800 m also correlated significantly ($p < 0.01 – 0.05$) with strength variables: CMJ (r = -0.69, CI: -0.93 to -0.45), JS (r = -0.65, CI: -0.91 to -0.39), and SQ (r = -0.58, CI: -0.88 to -0.28) (Figure 3).

*Relationships between the 200 m sprint, CMJ and lactate concentration*

Relationships between the 200 m sprint, CMJ and lactate concentration were analysed (n = 12). Sprint time in 200 m showed a significant ($p < 0.05$) correlation with the CMJ (r = -0.57, CI: -0.91 to -0.27) and lactate concentration (r = -0.59, CI: -0.90 to -0.24). No significant relationship was found between the 800 m performance and lactate concentration after the 200 m test (r = -0.31, CI: -0.76 to 0.14).

## Discussion

The present study analysed the relationships between lower limb strength, sprinting and jumping abilities and 800 m performance in male athletes of national and international levels. The results of this study indicate that 800 m performance is significantly related to sprinting, jumping and strength abilities. Furthermore, performance in 200 m, especially the last 50 m split, is the variable that most explains the variance of 800 m performance. Altogether, our results suggest that variables related to strength-power abilities and the ability to maintain high velocities with accumulated fatigue seem to be determinant factors in 800 m running performance.

Many studies have examined the relationship between strength and sprint running (Loturco et al., 2015a, 2015b; Seitz et al., 2014). However, little research has focused on strength or power production as a major component in middle-distance running events (Hudgins et al., 2013). The results of the present study seem to support previously reported data concerning middle-distance running events. Correlations of

0.83 were reported between the standing triple jump test and 800 m performance (Hudgins et al., 2013). In the present study, other variables related to strength (SQ), jumping (CMJ and JS) and sprint performance (20 m and 200 m) were examined as well. We observed large to very large relationships between the 800 m time and sprint tests (10 m: r = 0.57; 20 m: r = 0.71; 200 m: r = 0.84), full squat test (r = -0.58), and jump tests (CMJ: r = -0.69, JS: r = -0.65). These results indicate that higher levels of performance in distinct regions of the force-velocity curve can be directly related to higher levels of performance in some middle-distance track and field events, such as 800 m running.

Previous studies have shown that heavy and explosive resistance training improves endurance performance (Mikkola et al., 2011; Taipale et al., 2010, 2014). Therefore, the correlation between the SQ, CMJ and JS and the 800 m performance may not be surprising. The mechanism by which strength and power production can improve middle and long-distance performance may relate to varying abilities in running economy (Ferrauti et al., 2010). Running economy can be a factor influenced by muscle and tendon stiffness, which is often associated with increased strength and power (Dumke et al., 2010; Fletcher et al., 2010). Yet, in 800 m running events, the role of muscle strength might be related to other factors such as gains in maximal muscle strength and the rate of force development, while likely also involving enhancements in neuromuscular function as well as increases in the proportion of type IIA muscle fibres (Aagaard and Andersen, 2010).

Concerning running performance, strength of the correlations increased with the sprint distance (10 m: r = 0.57, p < 0.05; 20 m: r = 0.71, p < 0.05; 200 m: r = 0.84, p < 0.01). In the study of Deason et al. (1991), 300 m run time significantly correlated to 800 m competition time (r = 0.83; p < 0.05), accounting for 68% of the variance between these measures. This correlation is very similar to the one obtained in our study between 200 m and 800 m running times (r = 0.84, p < 0.01). However, in our study a slightly shorter distance (200 m run) was performed. On the other hand, when analysing the 200 m sprint intervals divided into 1st 50 m, 2nd 50 m, 3rd 50 m, and 4th 50 m, a clear tendency for increased correlation

between the first to the latest 50 m interval times and the 800 m performance was observed (1st 50 m: r = 0.71; 2nd 50 m: r = 0.72; 3rd 50 m: r = 0.81; 4th 50 m: r = 0.85). A previous study showed that the final velocity decreased significantly for 800 m, attaining the slowest velocity in the last 100 m (88% of the peak velocity) (Hanon and Thomas, 2011). Thus, it seems logical that fatigue during the latest 50 m of the 200 m run is more likely to be related to the 800 m performance.

Regarding the results obtained in the 200 m test, significant negative correlations were found between the 200 m time and both the CMJ (r = -0.59; p < 0.05) and blood lactate concentration (r = -0.57; p < 0.05). This correlation between the 200 m time and CMJ is supported by Hudgins et al. (2013), who found a significant relationship between the 200 m and three-jump tests (r = 0.97; p < 0.05). Nonetheless, in such a study, the sample was more heterogeneous (male and female sprinters with a 200 m performance of 23.47 ± 2.25 s) than the one used in the present study (high-level 800 m male athletes with a 200 m performance of 23.16 ± 0.89 s) and the variability of the sample (SD · mean value-1) in that study (0.10) was higher compared with ours (0.04). This fact may explain the higher correlation obtained by Hudgins et al. (2013), since greater variability of the sample maximizes the variance between the variables, thus enabling greater magnitude of the relationships. However, the relationships observed in our study are of utmost importance due to the high-level of tested athletes. In addition, a large relationship (r = -0.59) was observed between the 200 m time and blood lactate concentration. This relationship suggests that the 800 m athletes who are the fastest in 200 m tend to be those with higher anaerobic glycolysis activation and therefore, higher blood lactate concentration values. The reason might be that the athletes with the best performance in the 200 m run and highest values of blood lactate concentration are probably the ones with a higher proportion of type II fibres, thus, those with higher values of blood lactate concentration. It is common to observe higher blood lactate concentrations when more type II fibres are recruited since these have greater glycolytic power (Colliander et al., 1988). These results may reinforce the importance of strength training in high-level 800 m athletes. Resistance training

induces hypertrophy and a greater relative area of type II fibres (Colliander et al., 1988), as well as enhancements in jumping and sprinting abilities (Seitz et al., 2014). After analysing all these data, it is plausible to consider that a proper strength training program may enhance the specific performance of high-level 800 m runners.

In conclusion, the present study indicates that running performance in the 800 m event in athletes of national and international levels is related to sprinting (20 m and 200 m), strength (SQ), and jumping abilities (CMJ and JS). In addition, the last split of the 50 m in the 200 m run is the variable that most explains the variance of 800 m performance. Our results suggest that variables related to strength-power abilities and the ability to maintain high velocities with certain

accumulated fatigue seem to be determinant factors in 800 m running performance. Therefore, according to our results, both coaches and sport scientists should consider implementing training programs aiming at increasing levels of sprinting speed to improve the specific performance of elite 800 m runners. Furthermore, it may be possible to use these variables as an efficient and immediate assessment tool for middle-distance running performance. As a limitation, we should indicate that strong correlations do not necessarily imply a cause-effect relationship, thus, this information should be interpreted cautiously. Therefore, further studies analysing the effects of resistance training on 800 m performance are necessary.

## Acknowledgements

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