THE RELATIONSHIP BETWEEN ANAEROBIC PERFORMANCES, MUSCLE STRENGTH, HAMSTRING/QUADRICEPS RATIO, AGILITY, SPRINT ABILITY AND VERTICAL JUMP IN PROFESSIONAL BASKETBALL PLAYERS

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ABSTRACT

The purpose of this study was to investigate the relationship between anaerobic performance, isokinetic knee strength, hamstring/quadriceps ratio, agility, sprinting ability and vertical jump performance in first division basketball players. Twenty three male basketball players participated in this study voluntarily. Quadriceps (Q) and hamstrings (H) were measured at 60˚ and 180˚/s, anaerobic performance was evaluated using the Wingate anaerobic power test, sprint ability was determined by sprint performance (10-30 m), jump performance was evaluated by countermovement and squat jump and agility performance was measured using the T drill agility test. Quadriceps strength was significantly correlated with peak power at all contraction velocities. However, for mean power, significant correlation was only found between the 60˚ left and 180˚ right knee quadriceps measurements. And strong relations were found between the performance of athletes in different field tests. Moreover, it is concluded that muscular strength, particularly maximal knee extension strength is a crucial component in anaerobic and sprint ability test performance of basketball players. However, lack of association between muscular strength and anaerobic and sprint ability test performance indicated that factors other than strength might contribute to anaerobic and sprint ability test performance in basketball players.
Keywords: Strength, Anaerobic Power, Vertical Jump, Sprinting, Agility

PROFESYONEL BASKETBOL OYUNCULARINDA ANAEROBİK PERFORMANS İLE KAS KUVVETİ, HAMSTRING/ QUADRICEPS ORANI, ÇEVİKLİK, SPRINT YETENEĞİ VE DİKEY SIÇRAMA ARASINDAKI İLİŞKİ

ÖZ

Bu çalışma birinci ligte yer basketbol oyuncularında anaerobik performans ile kas kuvveti, hamstring/ quadriceps oranı, çeviklik, sprint yeteneği ve dikey sıçrama arasındaki ilişkinin belirlenmesi amacıyla yapılmıştır. Çalışmaya 23 erkek basketbol oyuncusu gönüllü olarak katılmıştır. Kas kuvveti ve Quadriceps/hamstrings oranın belirlenmesinde 60˚ ve 180˚/s, anaerobik performansın belirlenmesinde wingate anaerobic güç testi, sprint yeteneğinin belirlenmesinde 10-30 metre testi, sıçrama performansının belirlenmesinde aktif ve squat sıçrama testi, çeviklik testinde ise t çeviklik testi kullanılmıştır. Peak güç ile tüm açısal hızlarda elde edilen quadriceps kuvveti arasında ilişki bulunurken ortalama güç ile sol 60˚/s, sağ 180˚/s hızdaki quadriceps bacak kuvveti arasında ilişki bulunmuştur. Ayrıca farklı alan testlerinde elde edilen sporcu performansları ile de yüksek ilişki bulunmuştur. Ayrıca, özellikle basketbolcuların maksimal bacak ekstansiyon kuvvetinin anaerobik ve sprint yeteneği test performansında önemli bir bileşen olduğu sonucuna varılmış, ancak genel kas gücü ile anaerobik ve sprint yeteneği test performansı arasındaki ilişkinin olmaması kas kuvveti dışındaki faktörlerin basketbolcuların anaerobik ve sprint yeteneği testi performansını etkilediğini ortaya çıkarmaktadır.

Anahtar Kelimeler: Kuvvet, Anaerobik Güç, Dikey Sıçrama, Sprint, Çeviklik

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INTRODUCTION

In many sports, the short bursts of high intensity power production plays a major role in performance. Team sport activities are comprised of varying explosive movements like forward and backward shuffles, runs at different intensities and sustained forceful contractions to control ball against defensive pressure (Kalinski et al. 2002; Kin-İşler et al. 2008). It can be suggested therefore, that anaerobic performance and the ability to perform high-intensity actions are crucial in this type of sport (Bangsbo et al. 2008). Anaerobic performance is composed of anaerobic power and capacity. Anaerobic power reflects the ability to use the phosphagenic system and anaerobic capacity reflects the ability to derive energy from a combination of anaerobic glycolysis and the phosphagen system. Anaerobic performance depends on many factors, such as body composition, age, sex, muscle fiber composition, muscle cross sectional area, strength and training (Kin-İşler et al. 2008; Castagna et al. 2008).

Basketball is an aerobic-based anaerobic sport (Delextrat and Cohen 2009; Meckell et al., 2009) which requires high intensity activities such as jumping (for rebounds,blocks and shots), turns, dribbles, sprints, screens and low intensity activities such as walking,stopping and jogging. Frequent stoppages in games allow players to recover between bouts of activity, thus allowing repeated high-intensity spells of play (Drinkwater, 2008; Stojanovic et al. 2012; Padulo et al., 2016). And also basketball is an intermittent, high-intensity physical activity that requires well-developed aerobic and anaerobic fitness. It is considered fore a physically demanding sport, which requires a high degree of technical skill, strength, agility, sprinting ability (Attene et al., 2015; Stojanovic et al. 2012) and endurance (is positively associated with recovery during repeated high-intensity bouts) (Tomlin and Wenger, 2001) such as dribbles, sprints, forward and backward shuffles, runs at different intensities and sustained forceful contractions to control the ball against defensive pressure and low intensity activities such as walking, stopping and jogging). During a basketball game, professional players cover about 3500-5000m (Janeira and Maia 1998). Each player performs about 1000, mainly short, activities lasting around 2 seconds; time motion analysis has shown that these short activities are performed with a different frequency according to the player's position (Abdelkrim et al. 2007). And also aerobic capacity is positively associated with recovery during repeated high-intensity bouts (Castagna et al. 2008; Tomlin and Wenger 2001). Moreover, the high intensity movements of basketball players are closely related to the development of strength, speed and agility (Castagna et al. 2007; Meckell et al. 2009; Padulo et al. 2016). Therefore the purpose of this study was to investigate the relationship between anaerobic performance, muscle strength, hamstring/ quadriceps ratio, agility and sprint ability in professional basketball players.

MATERIALS and METHODS

Subjects and Experimental Approach

Twenty three male basketball players participated in this study voluntarily. The mean measurements gathered were as follows: age was 23.2 ± 3.7 yrs; body height 197.1 ±9.1 cm; body mass 95.3± 10.5 kg; PBF 11.3± 4.2 and VO_2max 51.25 ± 5.6 ml/kg/min. This study conforms to the policy statement relating to the Declaration of Helsinki and the subjects were informed about the possible risks and benefits of the study and gave their informed consent to participate in this study. The study was conducted over a 1-week period, during which the players did not participate in any other training or matches. On the first day, anthropometric measurements, vertical jump measurements, sprint tests and shuttle run test were performed respectively. On the third day, players underwent isokinetic leg strength tests. On the fifth day, players performed the Wingate anaerobic test.

Anthropometric Measurements

Subjects reported to the laboratory at 8:00 a.m. First, body height (cm), body mass (kg), and percentage of body fat (PBF) measurements were taken for each subject. The body height of the basketball players was measured by a stadiometer with an accuracy of ± 1 cm (SECA, Germany), and while electronic scales (Tanita BC 418, Japan) accurate to within 0.1 kg were used to measure body mass and percentage of body fat (Lohman et al., 1988). Skinfold thickness was measured with a Holtain skinfold caliper (Hotain, UK) which applied a pressure of 10 g/mm^2 with an accuracy of ± 2 mm. Gulick anthropometric tape (Holtain, UK) with an accuracy of ± 1 mm was used to measure the circumference of extremities. Diametric measurements were determined by Harpenden calipers (Holtain, UK) with an accuracy of ± 1 mm. The basketball players' somatotypes were then calculated using the Heath-Carter formula.

Anaerobic Performance Evaluation

The Wingate Anaerobic Test (WAnT) was performed on a mechanically braked cycle ergometer (834 E, Monark, Vansbro, Sweden). Subjects were seated on the ergometer and adjustments to the ergometer were made to ensure an optimal cycling position. The WAnT was conducted according to the widely accepted recommendations for standardization (Inbar, Bar-Or and Skinner 1996). The WAnT test was administered for 30 seconds and resistance was set at 7.5 % of body mass. The WAnT session started with a standardized warm-up of 5 min of cycling at 50 rpm against no load. Following the warm-up subjects rested for 5 min. They were then instructed to pedal as fast as they could. When the pedaling rate reached to approximately at 160-170 rpm the resistance was applied and subjects continued pedaling as fast as possible for 30 s. Subjects were verbally encouraged during the test. Peak power (P_{peak}) and mean power (P_{mean}) was calculated automatically by the Wingate Anaerobic Test program via computer. Where PP is the peak power, MinP is the minimum power and MP is the mean power that was determined during the WAnT test.

Vertical Jump Measurements

Vertical jump performance was measured using a portable force platform (Newtest, Finland). Players performed countermovement (CMJ) and squat jumps (SJ) according to the protocol described by Bosco et al. (1995). Before testing, the players performed self-administered submaximal CMJs and SJ (2-3 repetitions) as a practice and specific additional warm-up. They were asked to keep their hands on their hips to prevent any influence of arm movements on the vertical jumps and to avoid coordination as a confounding variable in the assessment of the leg extensors (Bosco et al. 1995). Each subject performed 3 maximal CMJs and SJs, with approximately 2 minutes' recovery in between. Players were asked to jump as high as possible; the best score was recorded in centimeters (Bosco et al. 1995). Sufficient recovery time (30 seconds) was allowed during the trials.

Isokinetic Knee Strength Evaluation

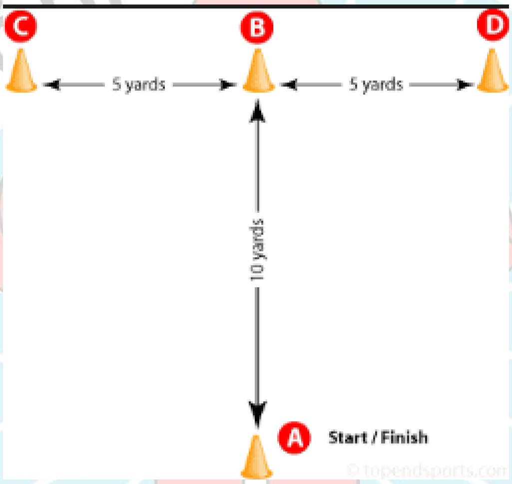
Before the isokinetic test, subjects performed a 5-minute warm-up on a cycle ergometer. Measurements were taken using an Isomed 2000 (Ferstl, Germany) isokinetic dynamometer. The test was performed in a seated position; stabilization straps were secured across the trunk, waist, and distal femur of the tested leg. The leg extensor and leg flexor muscle of each leg were concentrically measured at 60˚ x s-1 (10 repetitions) and 180˚ x s-1 (10 repetitions). Verbal encouragement was given to the subjects during the measurement. Before starting the test, subjects were allowed 5 trials.

Sprint Performance Evaluation

Sprint times were measured with light gates combined to the timing system (Prosport, Tumer Electronics, Ankara, Turkey). For the 4 single sprint tests, the timing light gates were placed at the start and at the finish (10 and 30 m mark). These tests were performed in an indoor court to eliminate environmental conditions. Prior to each sprint test, players performed a thorough warm-up consisting of 10 minutes of jogging at 60–70% of HRmax and then 5 minutes of exercise involving fast leg movements (e.g., skipping, cariocas) over short distances of 5 to 10 m and 3–5 single 15 m shuttle sprints with 2 minutes of passive recovery. The best time performance at each distance was used for further evaluations.

T-Drill Agility Test

Four 22.86 cm collapsible agility cones were arranged as outlined in Semenick (Semenick 1990). At the tester's signal, subjects sprinted forward 9.14 m and touched the tip of the cone (B) with their right hand.



Then they performed a lateral shuffle to the left 4.57 m and touched the tip of the cone (C) with the left hand. Subjects then changed direction and shuffled 9.14 m to the right to touch the tip of the cone (D) with their right hand. They then shuffled 4.57 m to the left to touch point (B) with their left hand. Finally, the subjects back-peddled 9.14 m, passing through the finish at point A (Patterson et al. 2008). Times were measured using an electronic timing system (Prosport TMR ESC 2100, Tumer Engineering, Ankara, Turkey).

Multi-Stage 20m Shuttle Run Test

Subjects' maximal oxygen uptake (VO_2max) was indirectly obtained using a multi-stage 20 m shuttle run test. This consisted of shuttlerunning between two parallel lines set 20 m apart, running speed cues being indicated by signals emitted from a commercially available prerecorded audio cassette tape. The audiocassette tape ensured that subjects started running at an initial speed of 8.5 km x h-1 and that running speed increased by 0.5 km x s-1 each minute. This increase in running speed is described as a change in test level. The speed of the cassette player was checked for accuracy in accordance with the manufacturer's instructions before each application. All subjects performed a 10-minute warm up that included the prescribed jogging and stretching. Test results for each subject were expressed as a predicted VO_2max obtained by cross-referencing the final level and (completed) shuttle number at which the subject became exhausted with that of the VO_2max table provided in the instruction booklet accompanying the multi-stage 20 m shuttle run test. Only fully completed 20 m shuttle runs were considered (Léger and Gadoury 1989).

Statistical Analyses
Means and standard deviations are given as descriptive statistics and the relationship among anaerobic performance, isokinetic knee strength, hamstring/quadriceps ratio, agility, sprinting ability and vertical jump performance in basketball players was evaluated by Pearson product Moment Correlation analysis. All analysis were executed in SPSS for Windows version 17.0 and the statistical significance was set at $p < 0.05$.

RESULTS

The body composition, anaerobic performance, isokinetic knee strength, sprint, vertical jump and aerobic power measurements of the basketball players in the study are displayed in Tables 1, 2, 3 and 4 respectively.

Table 1: *Body composition of basketball players (mean ± sd)*

	Body Height (cm)	Body Mass (kg)	Body Fat (%)	Endomorfism	Mesomorfism	Ectomorfism
Basketball players (n=23)	197.1±9.1	95.3±10.5	11.3±4.2	2.25±1.32	3.90±1.23	3.26±1.10

Table 2: *Anaerobic performance values of basketball players (mean ± sd)*

Basketball players (n=23)	Anaerobic Power		Anaerobic Capacity	
	Peak Power (W)	RelativePeak Power (W·kg-1)	Mean Power (W)	Relative Mean Power (W·kg-1)
	849.4±127.8	12.4±3.0	681.8±86.2	8.7±1.2

Table 3: *Peak isokinetic concentric knee extension, flexion torques and hamstring/quadriceps ratio of basketball players (mean±sd)*

Variable	**60°.s-1(N.m-1)**		**180°.s-1(N.m-1)**	
	right	left	right	left
Knee Extension	201.3±32.7	198.9±47.8	173.2±25.5	176.4±31.2
Knee Flexion	160.3±30.2	158.1±34.6	137.2±24.5	132.2±22.1
Hamstring/Quadriceps Ratio	0.79±0.11	0.78±0.21	0.79±0.15	0.74±0.32

Table 4: *Field performance test results of basketball players (mean ± sd)*

C M J			SJ			S P		A	A P
Absolute (CMJ) (Watt)	Relative (RCMJ) ($W \cdot kg^{-1}$)	Jump Height (cm)	Absolute (Watt)	Relative (W·kg-1)	Jump Height (cm)	10m (s)	30m (s)	T Drill Test (s)	VO_{2max} (ml/kg/min)
1100.3±120.4	11.6±1.5	49.1±9.2	1006.6±125.1	10.6±1.5	40.9±8.6	1.75±0.8	4.2±0.1	9.9±0.7	50.25±6.6

VO_{2max}: Maximal oxygen uptake, CMJ: Counter movement jump, RCMJ: Relative counter movement jump, SJ: Suquat jump, RSJ: Relative squat jump

Table 5: *Correlations between anaerobic and aerobic performance and sprint ability test with isokinetic knee strength and hamstring/quadriceps ratio*

Knee Extension	Peak Power	Mean Power	CMJ	CJH	SJ	SJH	10m (s)	30m (s)	VO_{2max}
Right 60º.s^{-1}	.45*	NS	.880*	NS	.955*	NS	NS	NS	NS
Left 60º.s^{-1}	.57**	.51*	NS	NS	NS	NS	NS	NS	NS
Right 180º.s^{-1}	.53*	.42**	.939**	NS	.831**	NS	.573*	.546*	NS
Left 180º.s^{-1}	.58*	NS	NS	NS	NS	NS	NS	NS	NS

*p<0.05 – **p<0.01

Table 5 shows the correlations between anaerobic performance and isokinetic knee strength are presented. Isokinetic concentric knee extension strength was significantly correlated with peak power at all contraction velocities. However, for mean power, a significant correlation was only found between the 60º left and 180º right knee extension strength and mean power.

Table 6: *Correlations between anaerobic performance and field test*

Variable	Absolute (CMJ)	Jump Height (CMJH)	Absolute (SJ)	Jump Height (SJH)	10m (s)	30m (s)	VO_2max
Peak Power	.524*	.604**	NS	NS	-.763**	-.601**	NS
Mean Power	.645**	.540*	NS	NS	-.657**	-.593**	NS
CMJ	NS	.504*	.898**	NS	-.557*	-.580*	NS
CJH	.504*	NS	NS	NS	NS	-.568*	NS
SJ	.898**	NS	NS	NS	NS	NS	NS
SJH	NS	NS	NS	NS	NS	NS	NS
T Drill test	-.584*	NS	-.477*	NS	NS	.510*	NS

*p<0.05 – **p<0.01,

VO_2max: Maximal oxygen uptake, CMJ: Counter movement jump, CMJH: Counter movement jump height, SJ: Squat jump, SJH: Squat jump height

There was a significant but weak correlation between peak power, counter movement jump, squat jump and 10 m sprint performance (Table 6). And strong correlations were found between the field teste, as it can be seen in Table 6.

DISCUSSION

The major finding of the present study is the existence of significant relation between anaerobic power and capacity, sprint performance and peak isokinetic concentric knee extension strength at contraction velocities. This result is consistent with the results of previous studies. Similarly, Cronin and Hansen (2005), Kin-İşler *et al.* (2008) and Alemdaroğlu (2012) determined no relation between extension strength and knee flexion and single-sprint performance. For instance Baker and Nance (1999a) investigated the relationship between strength and power in rugby players and determined a strong positive correlation between maximum strength and maximum power but no relation were reported between strength measures and 10 or 40 m sprint performance. In another study Thorland et al. (1987) determined significant strong correlation between isokinetic knee strength and anaerobic power and capacity of female sprinter and middle distance runners. Sprint performance depends on the capacity of anaerobic power and muscular strength. According to Mayhew et al. (2001) leg extension strength strongly predicted anaerobic power in healthy college students and Arslan (2005) also found that peak and mean power of university student who exercise regularly were correlated with explosive leg strength. As known muscular strength is one of the important factor that has a major role in anaerobic performance because with increased muscular strength the ability of muscles to generate muscular contraction in short-term high intensity activity also increases. For isokinetic leg flexion on the other had significant correlation was only found between peak power and 180º.s^{-1} knee extension strength, other measures of strength were not correlated with peak and mean powers. This implies that knee extension plays more role in high intensity contractions than knee flexion and isokinetic knee flexion has more effect at high velocities of contraction in maximal anaerobic power.

Another finding of the present study was significantly related between 180º.s^{-1} knee extension strength to single-sprint performance. Similarly Cronin and Hansen (2005) determined no association between knee flexion and extension strength and single-sprint performance that was determined over 5m, 10m and 30 m in rugby players and Baker and Nance (1999b) also not found relation between strength measures and 10m and 40 m sprint performance in rugby players. On the other hand Newman et al. (2004) found that concentric isokinetic knee extension and flexion strength measures were significantly correlated to single-sprint performance in football players and Dowson et al. (1998) also demonstrated that knee extension and flexion strength was related to single-sprint performance. A plausible explanation for the lack of association between isokinetic knee strength and single-sprint performance in the present study might be due to subjects' characteristics (Kin-İşler et al. 2008). Body height is very important for basketball players, particularly for centers and might be one of the reasons for not finding an association between strength and single sprint performance (Alemdaroğlu 2012). We found a significant relationship between PP and 10 m sprint ability but no significant relationship between the other Wingate test results and sprint ability. Strong negative correlations have been demonstrated between performance in the WAnT and sprint speed by previous studies (Tharp et al. 1985; Attene 2014). These studies suggested that the WAnT may be used as a predictor of sprinting ability. However, the predictive ability of the WAnT may be related to the distance of the sprint, sprint times for distances of 37 or 46 m have been reported to be highly correlated with PP, while increased sprint distances appear to be better correlated with MP (Hoffman et al. 2000; Alemdaroğlu 2012).

Another important factor may be the different distances were used in sprint tests in previous studies. Hence subjects of the present study are amateur players with low training experience. Having low training experience might be one of the reasons for not finding an association between strength and single-sprint performance.

As known muscular strength is one of the important factor that has a major role in anaerobic performance and also sprint performance because with increased muscular strength the ability of muscles to generate muscular contraction in short-term high intensity activity also increases. Ziegenfuss et al. (2002) indicated that 3 d of creatine supplementation can 6.6% increase thigh muscle volume and may enhance cycle sprint performance in elite power athletes; moreover, this effect is greater in females as sprints are repeated. Although there is little evidence supporting a difference in creatine levels between males and females, the rate of phosphocreatine degradation is greater in type II fibers and the rate of phosphocreatine resynthesis is faster in type I fibers. Although the fiber type distribution of these athletes is unknown, if males had a greater preponderance of fast twitch fibers in their quadriceps, the aforementioned factors could help explain the results (Ziegenfuss et al. 2002). For leg volume on the other hand, significant correlation was found between knee flexion and extension strength. Morse et al. (2005) had shown that following a 12 month resistance training program in males aged over 70 years, the increase in planter flexor maximal contraction torque is mostly accounted for by an increase in both muscle volume and increased agonist muscle activation. In fact, muscle hypertrophy and activation each accounted for approximately half of the increase in muscle strength following training. In addition anaerobic power and rapid movement performance depend on muscular strength of relevant muscle groups, it can be expected that leg muscle strength also represents an important fitness component for successful sport performance (Bradic et al. 2009).

No significant relationship was found between strength and field test performances. The weak relationship in rank order of performance could be caused by the differences type of exercise (Hoffman et al. 2000). Hoffman et al, stated that differences in power produced with the legs acting simultaneously or successively, or when upper-body musculature is active or passive, may have a profound influence on power expression (Tharp et al. 1985; Alemdaroğlu 2012).

The result of this study is that performances in a variety of field tests were correlated with each other in a group of basketball players. It can be said that either the tests assess similar attributes or performance on one test is able to predict performance on another (Vescovi and Mc Guigan 2008; Franco-Márquez et al. 2015). Cronin and Hansen (2005) reported weak negative associations between countermovement and squat jump performance and 5, 10, and 30 m sprint times. Hennessy and Kilty (2001) found countermovement jump performance was related to the times for sprint tests and that the bounce drop jump index was related with 30 m and 100 m sprint times in a group of female athletes. The relationship between linear sprinting and agility performance have been examined by few studies (Little and Williams 2005; Paoule et al. 2000; Vescovi and McGuigan 2008; Comfort et al.2014). Moderate correlation was reported between T-test performance and 37 m sprint times in a group of college-aged women by Paoule et al. (2000). In contrast, Little and Williams (2005) found a weak correlation between acceleration (10 m) and maximum speed in a zigzag agility test in a group of professional male soccer players. The association between agility and speed increases with longer distances and when examining agility with flying sprint times (Vescovi and Mc Guigan 2008;

Loturco et al. 2015). The reason of differences between studies could be the use of different agility tests (Vescovi and Mc Guigan 2008; Stojanovic et al. 2012).

CONCLUSION

One possible reason for the lack of correlation between tests performance may be the different energy systems that each measure needs. In isokinetic knee strength, sprint tests and vertical jump test do not last more than 5 seconds. Therefore the phosphagen system (ATP-PC) contributed to the energy need for these tests. On the other hand the Wingate test glycolytic system is dominant to the energy production. Different energetic pathways used during the tests could be the reason for the lack of association between these measures (Kin-İşler et al. 2008; Alemdaroğlu 2012) and the peak isokinetic concentric knee strength seem important to anaerobic performance and sprint performance. The leg strength must be well developed in basketball to allow the quick changes of direction required in successful player.

RECOMMENDATION

The coach who wishes to improve performance over such short distance sprints, jumping, shooting, turns and dribbles should seek to increase leg strength. In addition the implication is that specific lower strength training to increase leg strength will enhance anaerobic and sprint performance and thus basketball performance. However, lack of association between muscular strength and anaerobic and sprint ability test performance indicated that factors other than strength might contribute to anaerobic and sprint ability test performance in basketball players.

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