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The relationship between anaerobic performance, muscle strength and sprint ability in American football players

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Abstract. The purpose of this study was to investigate the relationship between, isokinetic knee strength, anaerobic performance and sprinting ability in American football players. Twenty-eight male amateur American football players participated in this study voluntarily. Knee extension and flexion strengths were evaluated at 60, 150 and 240/°s, anaerobic performance was evaluated by Wingate anaerobic power test and sprint ability was determined by single- (20 m) and repeated-sprint (12×20 m) tests. Extension strength was significantly correlated with peak and mean power in all contraction velocities; however the only significant correlation between flexion strength and peak power was indicated at 240°/s. In the case of sprinting ability, there was a significant but weak correlation between 240°.s^{-1} knee flexion strength and percentage of performance decrement from 10–20 m ($r = 0.381$, $p < 0.05$). No measure of strength was significantly related to single-sprint and other measures of repeated-sprint ability ($p > 0.05$). Hence, although maximal knee extension strength is a crucial component in anaerobic performance of American football players, lack of its association with single- and repeated-sprint performance indicates that factors other than strength might be involved in single-and repeated-sprint performance in this group of athletes.

Keywords: Isokinetic strength, anaerobic power, anaerobic capacity, sprinting

1. Introduction

In many sports short bursts of high intensity power production play 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 [11]. Therefore, anaerobic performance is crucial in these types of sports which consist of power and capacity. Anaerobic power reflects the ability to use the phosphagenic system and anaerobic capacity reflects ability to derive energy from the combination of anaerobic glycolysis and phosphagenic system [5,16]. Anaerobic performance depends on many factors, such as age and sex [12,20], muscle fiber composition [9], muscle cross sectional area [18] and training [19].

Muscular strength is another factor that is generally thought to have a great influence on athletic performance. In particular explosive muscular strength has been accepted as a crucial component of anaerobic [2, 13] and sprint performance [8,21]. For instance Dowson and coworkers [8] supported the notion that the magnitude of force generated during dynamic muscle contractions is related to the amount of speed an athlete can produce during a sprint performance. In addition Young and colleagues [21] reported that dynamic leg strength was one of the major factors explaining the anaerobic power and Arslan [2] stated that explosive

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leg strength was significantly correlated with anaerobic performance.

Sprint performance is another fundamental activity for many sports and consists of number of components such as the start, acceleration and maximum speed phases. Sprinting requires also high force production [14]. Previous research has identified force production capabilities of legs to be a key component in sprinting [1,3,8,15]. However these studies used only single-trial sprint protocols, neglecting to address the repeated-effort sprint requirements specific to the nature of many field and court sports. The relationship between the force-generating capacity of muscles and the repeated-sprint ability has received little attention. Of these studies Newman and coworkers [15] investigated the relationships between isokinetic knee strength, single-sprint and repeated-sprint ability in rugby and soccer players and found that single-sprint performance was correlated with peak extensor and flexor torques while no measure of strength was found to be related with the repeated-sprint ability.

American football is gaining popularity throughout the world, and demands anaerobic performance, muscular strength and sprinting abilities [18]. The periods during the game are generally intense before players change their possession and periods of continuous play that are longer than 30s are generally rare. This suggests that emphasis should be given to anaerobic performance, strength and speed of action, three different variables that ha=ve not been hitherto studies within this framework. The purpose of this study was hence to investigate the relationships between, isokinetic knee strength, anaerobic performance and sprinting ability in American football players. As indicated before, less attention was given to the relationship between muscular strength and repeated-sprint ability, therefore in the present study both single-sprint and repeated-sprint performance was taken into consideration

2. Methods

2.1. Subjects

Twenty-eight male amateur American football players participated in this study. Their mean age, height, body weight and body fat were 21.1 (1.7) yrs, 178.7 (4.9) cm, 82.7 (11.9) kg and 14.9 (6.1) % respectively. Subjects' mean training experience was 2.6 $\pm$ 1.7 yrs. Subjects were informed about possible risks and benefits of the study and gave informed consent to participate in this study which was approved by the Clinical Research Ethical Committee of Baskent University.

2.2. 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 [10]. 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 approximately 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 ($P_{\rm peak}$) and mean power ($P_{\rm mean}$) was calculated automatically by the Wingate Anaerobic Test program via computer. A fatigue index was calculated by using the following equation [10]:

$$\text{Fatigue Index (FI)} = \text{(PP)} - \text{(MinP)} / \text{(MP)} \times 100$$

Where PP is the peak power, MinP is the minimum power and MP is the mean power that was determined during the WAnT test.

2.3. Isokinetic knee strength evaluation

Isokinetic knee strength was assessed with isokinetic dynamometer (Cybex 770 Norm Lumex Inc, Ronkonkoma, NY, USA). Subjects were placed in an upright seated position on the adjustable isokinetic dynamometer chair and were secured with pelvic and thigh straps to minimize extraneous body movements with arms placed across chest [16]. The lateral femoral epicondyle was used as the body landmark for matching the axis of rotation of the knee with the axis of rotation of the dynamometer lever arm. The lower leg was attached to the lever arm through a shin pad at the level of the lateral malleolus to allow full ankle dorsiflexion.

Peak isokinetic concentric knee extension and flexion torque of the dominant leg was evaluated at 3 angular velocities of movement: 60, 150 and 240 °/s. Extension and flexion contractions were performed through a range of 15–80° (full extension defined as 0°). Subjects completed a warm up at each angular velocity consisting of 3 submaximal followed by 2 maximal contractions with a 2 min of passive recovery between each test velocity. Subjects completed all trials starting at the lower velocity and progressing up to the highest [16]. After warm-up, a period 1-min of rest was given and subjects performed 5 maximal contractions for each velocity. The greatest peak torque was taken as the criterion.

2.4. Sprint performance evaluation

The sprint performance was evaluated by using two tests: with a 20 m single-sprint test and the running repeated-sprint ability (rRSA) test. Sprint times were measured with light gates combined to the timing system (Prosport, Tumer Electronics, Ankara, Turkey). For the 20m single sprint test the timing light gates were placed at the start and at the finish (20-m mark) and for the rRSA test they were placed at the start, 10-m mark and at the finish (20-m mark). These tests were performed in an indoor court to eliminate environmental conditions.

For 20 m single sprint test, subject performed two maximal sprints over a 20 m distance with 1-min of rest interval and the best time was taken as the indicator of single-sprint performance.

The rRSA test was conducted in accordance with the protocol that was used by Newman and his coworkers [15]. From a standing start approximately 20 cm behind the starting gates subjects executed 12 maximal effort sprints over a 20-m distance with a 20 second rest interval between each sprint. After each sprint subjects walked back to the starting line and waited for the next sprint over the 20-second rest period. The performance variables that were recorded from the rRSA test were:

a) best sprint time (the fastest time for 0–10 m, 10–20 m and 0–20 m)
b) total sprint time (the summation of all 12 sprints for 0–10 m, 10–20 m and 0–20 m)
c) percentage of performance decrement (a measure of the performance decline demonstrated over the entire rRSA test for 0–10 m, 10–20 m and 0–20 m)

The performance decrement was determined by deducing the “ideal total time” (the best sprint time multiplied by the 12 repetitions) against the actual total time to complete the 12 sprint over the entire rRSA test. The percent decrement was calculated by using the following formula

$$\text{Performance Decrement} = \left\{ \frac{\text{Total Time} \times 100}{\text{Ideal Time}} \right\} - 100$$

Table 1
Anaerobic performance values of American football players

Variables	Mean (SD)
Peak Power (W)	825.51 (133.97)
Mean Power (W)	611.42 (74.95)
Fatigue Index (%)	47.62 (10.44)

Table 2
Peak isokinetic concentric knee extension and flexion torques of American football players

Variables	Mean (SD)
Knee extension	
60°/s (Nm)	134.78 (15.86)
150°/s (Nm)	129.75 (20.88)
240°/s (Nm)	125.28 (20.61)
Knee flexion	
60°/s (Nm)	97.42 (14.29)
150°/s (Nm)	94.64 (15.59)
240°/s (Nm)	92.64 (14.57)

Table 3
Single-sprint performance and rRSA performance of American football players

Variables	Distance (m)	Mean (SD)
Single- Sprint Time (s)	20 m	3.12 (0.31)
Best Sprint Time (s)	0–10	1.64 (0.13)
	10–20	1.35 (0.19)
	0–20	2.99 (0.32)
Total Time (s)	0–10	21.16 (1.82)
	10–20	17.96 (2.31)
	0–20	39.12 (4.13)
Performance Decrement (%)	0–10	7.83 (3.94)
	10–20	11.59 (10.26)
	0–20	19.42 (14.21)

2.5. Statistical analyses

Means and standard deviations are given as descriptive statistics and the relationship between anaerobic performance, isokinetic knee strength and sprinting ability was evaluated by Pearson Product Moment Correlation analysis. All analysis were executed in SPSS for Windows version 10.0 and the statistical significance was set at $p < 0.05$.

3. Results

Anaerobic performance, isokinetic knee strength and sprint characteristics of American football players are displayed in Tables 1, 2 and 3, respectively. The correlations between anaerobic performance and isokinetic knee strength are presented in Table 4. As can be seen from Table 4, isokinetic concentric knee exten-

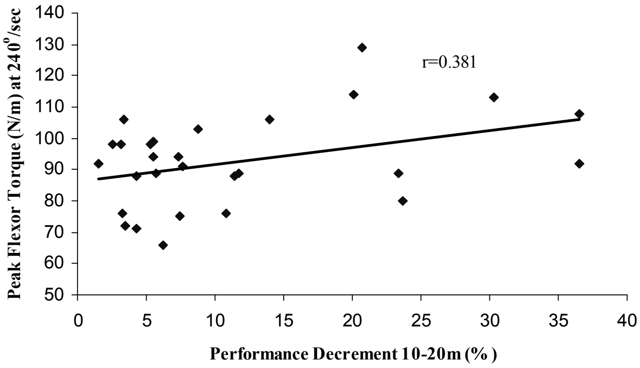

Fig. 1. Correlation between peak isokinetic torque (Nm) of the knee extensor muscles (240°/s) and percentage performance decrement (10–20 m).

Table 4
Correlations between anaerobic performance and isokinetic knee strength

Knee extension	Peak Power	Mean Power	Fatigue Index
60°/s (Nm)	0.491**	0.466*	NS
150°/s (Nm)	0.559**	0.522**	NS
240°/s (Nm)	0.581**	0.502**	NS
Knee flexion			
60°/s (Nm)	NS	NS	NS
150°/s (Nm)	NS	NS	NS
240°/s (Nm)	0.418*	NS	NS

*$p < 0.05$.
**$p < 0.01$.

sion strength was significantly correlated with peak and mean power at in all contraction velocities, however for isokinetic concentric knee flexion significant correlation was only found between the 240°/s knee flexion strength and peak power.

According to Pearson Product Moment correlation analysis there was a significant but weak correlation between 240°.s^{-1} knee flexion strength and percentage of performance decrement from 10–20 m ($r = 0.38$; $p = 0.045$) (Fig. 1) and no measure of strength was significantly related to single-sprint and other repeated-sprint ability measures ($p > 0.05$).

4. Discussion

The major finding of the present study is the existence of significant relation between anaerobic power and capacity and peak isokinetic concentric knee extension strength at all contraction velocities. This result is consistent with the results of previous studies. For instance Baker and Nance [4] investigated the relationship between strength and power in rugby players and determined a strong positive correlation between maximum strength and maximum power. In another study Thorland and coworkers [21] determined significant strong correlation between isokinetic knee strength and anaerobic power and capacity of female sprinters and middle distance runners. According to Mayhew et al. [13] leg extension strength strongly predicted anaerobic power in healthy college students and Arslan [2] also found that peak and mean power of university students who exercise regularly were correlated with explosive leg strength. As known muscular strength is one of the important factors 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 hand, significant correlation was only found between peak power and 240°.s^{-1} knee flexion 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 that no measure of strength was significantly related to single-sprint performance. Similarly, Cronin and Hansen [6] determined no association between knee flexion and extension strength and single-sprint performance that was determined over 5 m, 10 m and 30 m in rugby players and Baker and Nance [3] also found not relation between strength measures and 10m and 40 m sprint performance in rugby players. On the other hand, Newman and colleagues [15] found that concentric isokinetic knee extension and flexion strength measures were significantly correlated to single-sprint performance in football players and Dowson et al. [8] 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. American football is a developing sport branch in Turkey and is played at the university level. Hence subjects of the present study are amateur players with training experience of 2.6 $\pm$ 1.7 yrs in American football. Having low training experience might be one of the reasons for not finding an association between strength and single-sprint performance.

Findings of the present study also indicated that no measures of strength were significantly correlated with repeated-sprint ability measures. Although a significant correlation was observed between 240°.s^{-1} knee flexion strength and percentage of performance decrement from 10–20 m, it can be neglected and said that rRSA and muscular strength were not correlated at all since this correlation was very weak ($r = 0.381$, $p = 0.045$). When the literature is searched, it is seen that the relationship between the force-generating capacity of muscles and repeated-sprint ability has received less attention. In one such study the relations between isokinetic knee strength and repeated-sprint performance was investigated in football players and no measure of strength was found to be associated with rRSA. The only correlation was found between 240°.s^{-1} knee flexion strength and percentage of performance decrement from 0–10 m. Thus regarding the results of the present study it can be suggested that repeated-sprint ability does not seem to be related to isokinetic strength of the major muscles involved in producing the effort. One possible explanation for the lack of association between muscular strength and rRSA may be the different energy systems that each measure demands. In isokinetic knee strength, subjects performed five maximal contractions at each velocity that took no more than 5 seconds. Therefore the phosphagen system (ATP-PC) contributed to the energy demand for isokinetic knee strength. For rRSA test on the other hand, subjects performed twelve 20 m sprints with 20 seconds rest intervals. It is known that the ATP-PC system to be replenishes within 2–5 minutes [17] and therefore during rRSA test glycolytic system also contributes to the energy production. Similarly Dawson et al. [7] reported accumulation of high levels o blood lactate after the completion of an rRSA which also supports the above-mentioned notion. Different energetic pathways used during isokinetic knee strength and rRSA tests might be the reason for not finding an association between these two measures.

5. Conclusion

This study has shown that muscular strength, particularly maximal knee extension strength is a crucial component in anaerobic performance of American football players. However, lack of association between muscular strength and single-and repeated-sprint performance indicated that factors other than strength might lead to single-and repeated-sprint performance in this group of players.

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References

[1] M.J.L. Alexander, The relationship between muscle strength and sprint kinematics in elite sprinters, *Canadian Journal of Sports Science* **14** (1989), 148–157.
[2] C. Arslan, Relationship between the 30-second Wingate test and characteristics of isometric and explosive leg strength in young subjects, *Journal of Strength and Conditioning Research* **19**(3) (2005), 658–666.
[3] D. Baker and S. Nance, The relation between strength and power in professional rugby league players, *Journal of Strength and Conditioning Research* **13**(3) (1999), 224–229.
[4] D. Baker and S. Nance, The relation between running speed and measures of strength and power in professional rugby league players, *Journal of Strength and Conditioning Research* **13**(3) (1999b), 230–235.
[5] C. Bouchard, A.W. Taylor, J. Simaneau and S. Dulac, Testing anaerobic power and capacity, in: *Physiological Testing of the High Performance Athlete*, L.D. MacDougall, H.A. Wenger and H. Gren, eds, Human Kinetics Books, Champaign IL., 1991, pp. 175–221.
[6] B.J. Cronin and T.K. Hansen, Strength and power predictors of sports speed, *Journal of Strength and Conditioning Research* **19**(2) (2005), 349–357.
[7] B.T. Dawson, T.R. Ackland, C. Roberts and S.R. Lawrance, Repeated effort testing: The phosphate recovery test revisited, *Sports Coaching* (April–June 1991), 31–34.
[8] M.N. Dowson, M.E. Nevill, H.K.A. Lakomy, A.M. Nevill and R.J. Hazeldine, Modelling the relationship between isokinetic muscle strength and sprint running performance, *Journal of Sport Sciences* **16** (1998), 257–265.
[9] M. Esbjörnsson, C. Sylven, I. Holm and E. Jansson, Fast twitch fibers may predict anaerobic performance in both females and males, *International Journal of Sports Medicine* **14**(5) (1993), 263.
[10] O. Inbar, O. Bar-Or and J.S. Skinner, *The Wingate Anaerobik Test*, Human Kinetic, Champaign, IL, 1996, 41–71.

[11] M.I. Kalinski, H. Norkowski, M.S. Kerner and W.G. Tkaczuk, Anaerobic power characteristics of elite athletes in national level team-sport games, *European Journal Sport Science* **2**(3) (2002), 1–14.

[12] R.J. Maughan, J.S. Watson and J. Weir, Strength and cross-sectional area of human skeletal muscle, *Journal of Physiology* **338** (1983), 37–49.

[13] J.L. Mayhew, K. Hancock, L. Rollison, T.E. Ball and J.C. Bowen, Contributions of strength and body composition to the gender difference in anaerobic power, *Journal of Sports Medicine and Physical Fitness* **41** (2001), 33–38.

[14] A. Mero, P.V. Komi and R.J. Gregor, Biomechanics of sprint running. A review, *Sports Medicine* **13**(6) (1992), 376–392.

[15] M.A. Newman, K.M. Tarpenning and F.E. Marino, Relationships between isokinetic knee strength, single sprint performance and repeated-sprint ability in football players, *Journal of Strength and Conditioning Research* **18**(4) (2004), 867–872.

[16] D.H. Perrin, *Exercise and Isokinetic Assessment*, Human Kinetic, Champaign: IL, 1993, 35–54.

[17] S.K. Powers and E.T. Howley, *Exercise Physiology*, Mac Graw Hill, 2004, 50–63.

[18] T. Reilly, N. Secher, P. Shell and C. Williams, *Physiology of Sports*, E&F. N. Spon., 1990.

[19] C. Saavedra, P. Lagasse, C. Bouchard and J. Simoneau, Maximal anaerobic performance of the knee extensor muscles during growth, *Medicine and Science in Sport and Exercise* **23**(9) (1991), 1083–1089.

[20] H. Tanaka, D.R. Bassett, T.C. Swensen and R.M. Sampedro, Aerobic and anaerobic power characteristics of competitive cyclists in United States cycling federation, *International Journal of Sports Medicine* **14**(6) (1993), 334–338.

[21] W.G. Thorland, G.O. Johnson, C.J. Cisar, T.J. Housh and G.D. Tharp, Strength and anaerobic responses of elite young female sprint and distance runners, *Medicine and Science in Sport and Exercise* **19**(1) (1987), 56–61.

[22] W. Young, B. McLean and J. Ardagna, Relationship between strength qualities and sprinting performance, *Journal of Sports Medicine and Physical Fitness* **35** (1995), 13–19.