International Journal of Applied Sports Sciences
2014, Vol. 26, No. 1, 18-25.

ISSN 2233-7946 (Online)
ISSN 1598-2939 (Print)
http://www.sports.re.kr/eng/05publication/Callforpaper.jsp

The Relationship between Measures of Sprinting, Aerobic Fitness, and Lower Body Strength and Power in Well-Trained Female Soccer Players

Shaher A. I. Shalfawi[1*], Eystein Enoksen[1], & Espen Tønnessen[2]
[1]*Norwegian School of Sport Sciences, Norway*
[2]*Norwegian Olympic Sport Centre, Norway*

Abstract

The aim of this study was to investigate the relationship between measures of sprinting ability, fatigue index, lower body strength and power output, and aerobic fitness in well-trained, young, elite female soccer players. The descriptive cross-sectional design was applied to 30 well-trained female soccer players (mean ± SD: age 19 ± 4 years, body mass 57.5 ± 6.9 kg, height 167 ± 4 cm) who agreed to participate in the study. Tests of 40 m linear sprint, 7 x 30 m repeated sprint ability with 30 s recovery, sprint with change of direction, multi stage fitness test (MSFT), and vertical jump were conducted on a soccer field. The results showed that squat jump (SJ) had the strongest relationship with 0 - 20 m start and acceleration phases, while countermovement jump (CMJ) had the strongest relationship with maximal sprinting speed over 20 - 40 m. Aerobic fitness measures were significantly related to linear sprint over 0 - 40 m, 20 - 40 m sprint times, repeated sprint ability (RSA) fastest time, total time, mean time, and sprint with change of direction. Linear sprint over 40 m had a strong relationship with RSA fastest time, RSA mean time, and RSA total time. Finally, a significant relationship was observed between measures of linear sprint and sprint with change of direction. The relationship observed between aerobic capacity and sprinting abilities and the results from the stepwise analysis suggest that separate training strategies are necessary to specifically target and improve performance in these abilities.

Key words: Sports Performance, Fatigue, Physical Endurance, Muscle Strength

Introduction

Soccer is the most popular game in the world and the ability to perform at a top level depends on a number of characteristics. These include physical, physiological, psychological and psychomotor abilities, along with tactical and technical skills as the most important factors affecting performance (Reilly et al., 2000). However, in order to utilize these tactical and technical skills, players must be able to cope with the physical demands of the game (Bangsbo et al., 2006).

A number of authors agree that investigating intensity levels during a soccer match could be of great value in order to improve the quality of the players and the game (Bangsbo, 1994; Stolen et al., 2005). Hence, the physical demands placed on soccer players during a match have been extensively investigated in the literature (Bangsbo, 1994; Reilly et al., 2000; Stolen et

Submitted : 26 February 2014, revised : 20 May 2014,
accepted : 9 June 2014.
* Correspondence : Shaher A. I. Shalfawi (shaher.shalfawi@me.com)

al., 2005). The majority of these investigations have found that a soccer field player typically covers a distance of 10 – 14 km during a 90 min match (Reilly et al., 2000; Stolen et al., 2005). The distance covered indicates that aerobic metabolism is the major source of energy during a soccer match. Approximately 90% of the total energy expenditure during a match is provided by the aerobic energy system, with players, on average, working at ~70% of maximum oxygen uptake (Bangsbo & Iaia, 2013). Furthermore, several analyses have shown that the duration of high-intensity sprinting actions is typically between 2 – 4 s (Spencer, Bishop, Dawson, & Goodman, 2005) over a distance of ~10 – 23 m (Reilly & Thomas, 1976; Spencer et al., 2005). These high- intensity sprinting actions constitute 9 – 11% of total distance covered during match play (Bangsbo & Iaia, 2013), and take place every 40 – 90 s (Reilly et al., 2000; Spencer et al., 2005). These repeated high- intensity sprints, with short recovery times result in a decline in sprint performance (Girard et al., 2011) indicating that repeated sprint ability is a function of single sprint speed and the ability to resist fatigue (Bishop et al., 2011; Spencer et al., 2005; Stolen et al., 2005). Sprints with change of direction have also been observed in soccer analysis. Bloomfield et al. (2007) reported 5115 sprint actions involving change of direction and 514 actions involving deceleration events. Therefore, the sprinting actions in soccer can be categorized into linear sprint (acceleration, and maximum sprint velocity), sprint with change of direction, and the ability to repeat sprints over the duration of the match, known as repeated sprint ability (RSA).

Based on the presented literature, aerobic capacity could clearly play a key role in the recovery between high-intensity sprints during a match, highlighting the importance of developing players' aerobic capacity and repeated sprint ability in order to improve overall performance. Only a small number of studies have looked at the relationship between aerobic tests and anaerobic tests in soccer (Aziz et al., 2000; Meckel et al., 2009). Therefore, the main purpose of the current study was to investigate the relationship between measures of sprinting ability (40 m sprint time, 20 m acceleration, 20 m maximum velocity, repeated sprint ability, and sprint with change of direction), fatigue index, measures of lower body strength and power output (force, peak power), and aerobic fitness in well trained young female soccer players. A secondary purpose of the study was to conduct stepwise analyses to determine the physical parameters that most affect performance of RSA and sprint with change of direction.

Methods

Participants

Thirty well-trained female soccer players volunteered their written informed consent to participate in the study (Mean ± SD: age 19 ± 4 years, body mass of 57.5 ± 6.9 kg, height of 167 ± 4 cm). Participants below 18 years of age provided written consent signed by their parent. Participants were selected from a group of elite soccer players ranked amongst the top 3 teams in the second highest division in Norway at the time of the study. They were tested as part of their soccer training program at the beginning of the competition season (April 2011). All participants had been involved in intensive training for 6 ± 3 years (training, on average, 4 – 7 training sessions constituting 10 ± 2.5 hours per week, plus matches. They were considered to be in peak condition at the time of testing. The regional ethics committee of Southern Norway reviewed the study and concluded that, due to the nature of the study, it did not require their approval. The study was therefore submitted to and approved by the Norwegian Social Science Data Services (NSD), ref: 37679/3/LT.

Procedures

All tests were carried out at an indoor track & field and soccer arena. All tests were supervised by testing experts from the Norwegian Olympic Sport Center, and were preceded by a standardized warm up consisting of 15 minutes of running at 60–70% of maximum heart rate, 4–5 accelerations over 50 m and stretching, followed by 5–6 minutes rest immediately prior to the start of the test.

Vertical jump height was measured using force platform- based determinations of impulse and thus velocity at take-off. The force platform used was a portable AMTI model AccuPower (Massachusetts, USA). The force platform had a built-in amplifier and digitizer, and the data were saved to a computer with the aid of the AccuPower software (according to the manufacture, the lowest natural frequency of the platform is greater than 100 Hz). The participants were required to perform two maximum effort trials of squat jump (SJ), and countermovement jump (CMJ). Participants were instructed to keep hands on hips throughout the tests. The SJ was performed from a semi-squat position with a knee angle of 90° which represents a pure concentric contraction. For the CMJ, participants were required to bend their knees to approximately 90° and then immediately rebound in a maximal vertical jump. A 5 min recovery was provided between trials. The best jump heights from both SJ and CMJ and the associated peak power and force (N) production data were retained for further analysis.

All measures of sprinting ability were performed on an 8 mm Mondotrack FTS surface (Mondo, Conshohocken, USA) using Newtest Powertimer portable system Model 300s (OY, Finland). The Newtest Powertimer infrared photocells were mounted on the sprint running track and connected via cables to a computer. The system measures time to the nearest 0.001 s. All sprint tests were performed from an upright position placing the tip of the toe of the front foot on the starting line. Participants started when the test leader gave the start signal, and were instructed to cover the distance in the shortest time possible.

The RSA test was performed by sprinting 7 times 30 m with 30 s recovery in between. The fastest time, average time, total time, and percentage decrement score *(Sdec)* were retained for analysis. The Sdec was calculated using the formula presented below. Its validity and reliability has been tested by Glaister et al. (2008), and it considers all sprints when quantifying fatigue in RSA tests (Eq. 1).

$$S_{dec}(\%) = \frac{sprint1(S1) + S2 + S3 + S4 + \cdots + S_{final}}{S_{best} \times number\ of\ sprints} - 1 \times 100$$

(Eq. 1)

Linear sprint speed was determined by performing two trials of 40 m sprint separated by a 5 min recovery. During the 40 m linear sprint test, times were recorded for 0–20 m (acceleration speed) and 20–40 m (maximum sprinting speed). Sprint speed with change of direction was tested by sprinting 9-3-6-3-9 m with 180º turns (S180º). Five white lines, 2 m in length, and 5 cm in width were placed as the starting line, 6 m line, 9 m line, 12 m line, and 18 m line. As described by Sporis et al. (2010), the subjects started after a signal from the test leader and were instructed to run to the 9 m line and touch it with one foot before turning 180º either left or right (all the following turns had to be made in the same direction as the first turn). The players then ran 3 m to the 6 m line, made another 180º turn, and ran 6 m to the 12 m line, turned 180º and ran again to the 9 m line, and finally made the last 180º turn and ran to the 18 m line (finish line). The total distance of the test was 30 m. Each participant was given two attempts, with a minimum of 5 min recovery between, with the best result retained for analysis.

Aerobic fitness was measured using the Multi Stage Fitness Test (MSFT) conducted on an indoor artificial grass pitch following the protocol developed by Ramsbottom et al. (1988). A JVC Boomblaster (RVNB51WEN) was used to play the MSFT CD that came with the test package. The CD (the soundtrack) and the CD player were examined prior to the start of the test to ensure that the soundtrack played at the correct speed between the sound signals (Beeps). Distance covered from the MSFT was retained for further analysis. The test leader measured and marked a distance of 20 m with cones to perform the test. Subjects were required to perform shuttle running between the cones (20 m) at progressively increasing speeds, starting at 8.5 $km \cdot h^{-1}$. Six test leaders observed the performance to make sure that participants fulfilled the test criteria. Each participant's result was defined as the number of shuttle runs completed before the subject either withdrew voluntarily or failed to complete a shuttle runs in the required time for two consecutive beeps.

Statistical Analysis

Raw data were transferred to SPSS 17.0 for Windows for analysis. Correlation matrices between all variables were determined using Pearson's r. A stepwise linear regression analysis was used to determine the physical abilities that, to the greatest extent, explained performance of RSA and sprint with change of direction. The $p < 0.05$ level of significance was adopted for all statistical tests. Reliability was assessed using a 2-way mixed intraclass correlation (ICC) and the coefficient of variation (CV) between trials was calculated for all measures in this study according to the guidelines provided by Hopkins (2000).

Results

The between-trial reliability for SJ height had an intraclass correlation coefficient (ICC) of 0.83 with a CV of 2.7%, for the SJ peak power, ICC = 0.99 with a CV of 1.5%, for the SJ force production, ICC = 0.94 with a CV of 0.1%, for the CMJ height, ICC = 0.95 with a CV of 0.0%, for the CMJ peak power, ICC = 0.80 with a CV of 1.0%, for the CMJ force, ICC = 0.84 with a CV of 0.3%, for the 40 m sprint time, ICC = 0.96 with a CV of 0.3%, for the 20 m acceleration time, ICC = 0.90 with a CV of 0.6%, for the 20 m maximum speed time, ICC = 0.98 with a CV of 0.1%, and for the agility time, ICC = 0.86 with a CV of 2.3%.

Table 1: Descriptive statistics of aerobic and anaerobic variables in absolute terms and relative to body mass (N = 30).

Measures of Jumping abilities	Mean ± SD	Relative to BM
SJ Height (cm)	26.1 ± 3.8	0.46 ± 0.1
SJ PP (W)	2310 ± 818	40 ± 15
SJ F (N)	2010 ± 435	35 ± 6
CMJ Height (cm)	27.9 ± 3.5	0.49 ± 0.08
CMJ PP (W)	2221 ± 347	39 ± 4
CMJ F (N)	2037 ± 452	35 ± 6
Reactive strength (cm)	1.8 ± 2.8	0.03 ± 0.05
Measures of Sprinting abilities		
0-40 m (s)	6.36 ± 0.22	
0-20 m Acc. (s)	3.55 ± 0.12	
20-40 m Max. (s)	2.80 ± 0.12	
RSA FT (s)	4.93 ± 0.20	
RSA MT (s)	5.04 ± 0.20	
RSA TT (s)	35.25 ± 1.4	
COD (s)	8.26 ± 0.37	
Sdec (%)	-2.2 ± 1.0	
Measures of aerobic fitness		
MSFT DC (m)	1536.7 ± 261.7	

PP = Peak Power, F = Force, Acc = Acceleration, Max = Maximum velocity, FT = Fastest time, MT = Mean time, TT = Total time, COD = Change of direction speed, Sdec = Percentage decrement score, MSFT DC = Multi stage fitness test distance covered.

Table 2. Correlation coefficients between measures of jumping performance, sprinting abilities and measures of aerobic fitness (N = 30).

	0-40 m (s)	0-20 m Acc.	20-40 m Max	RSA FT	RSA MT	RSA TT	COD	Sdec (%)	MSFT DC
In absolute terms									
SJ Height	-.468**	-.406*	-.446**	-.260	-.290	-.288	-.127	.097	.169
SJ PP	.057	.102	.026	-.111	-.033	-.035	-.034	-.302	-.051
SJ F	-.030	.050	-.071	-.141	-.087	-.089	-.142	-.221	.130
CMJ Height	-.457*	-.305	-.508**	-.241	-.264	-.264	-.260	.081	.316
CMJ PP	-.348	-.227	-.395*	-.295	-.241	-.244	-.291	-.211	.211
CMJ F	-.168	-.097	-.166	-.193	-.147	-.151	-.267	-.181	.210
Reactive strength	.063	.169	-.031	.051	.062	.060	-.154	-.031	.166
Relative to Body mass									
SJ Height	-.294	-.272	-.249	-.115	-.172	-.169	.115	.202	.042
SJ PP	.081	.116	.061	-.075	-.012	-.013	.080	-.247	-.112
SJ F	.029	.125	-.020	-.077	-.052	-.053	.094	-.113	.091
CMJ Height	-.304	-.210	-.313	-.097	-.159	-.157	.047	.228	.162
CMJ PP	-.434*	-.295	-.466**	-.303	-.278	-.280	-.035	-.104	.108
CMJ F	-.168	-.085	-.157	-.170	-.151	-.155	-.079	-.073	.175
Reactive strength	.066	.174	-.031	.061	.068	.066	-.139	-.015	.179

PP = Peak Power, F = Force, Acc = Acceleration, Max = Maximum velocity, FT = Fastest time, MT = Mean time, TT = Total time, COD = Change of direction speed, Sdec = Percentage decrement score, MSFT DC = Multi stage fitness test distance covered.
*= $p \leq 0.05$, **= $p \leq 0.01$.

The stepwise regression analysis showed that SJ in absolute terms had the highest shared variance with 0 – 40 m and 0 – 20 m linear sprint times, with 22% and 17% shared variance, respectively. The highest shared variance with 20 – 40 m linear sprint time was through CMJ height with a shared variance of 26%. The stepwise regression analysis relative to body mass showed that the highest shared variance with 0 – 40 m sprint time and 20-40 m sprint time was CMJ peak power with 19% and 22%, respectively.

The results indicate that MSFT distance covered had a significant moderate correlation with RSA fastest time ($r = -.483$, $p \leq 0.01$), sprint with change of direction time ($r = -.430$, $p \leq 0.05$), and a significant

Table 3. Correlation coefficients between sprinting variables (N = 30).

	0-40 m (s)	0-20 m Acc.	20-40 m Max	RSA FT	RSA MT	RSA TT	COD	Sdec (%)
0-40 m (s)	1	.917**	.914**	.823**	.860**	.859**	.387*	-.086
0-20 m Acc.		1	.691**	.705**	.733**	.730**	.428*	-.052
20-40 m Max			1	.797**	.845**	.845**	.291	-.137
RSA FT				1	.969**	.969**	.343	.187
RSA MT					1	.999**	.416*	-.062
RSA TT						1	.415*	-.061
COD							1	-.269
Sdec (%)								1

Acc = Acceleration, Max = Maximum velocity, FT = Fastest time, MT = Mean time, TT = Total time, COD = Change of direction speed, Sdec = Percentage decrement score.
*= $p \leq 0.05$, **= $p \leq 0.01$.

large correlation with 0 – 40 m linear sprint (r = -.510, p ≤ 0.01), 20 – 40 m sprint time (r = -.595, p ≤ 0.01), RSA mean time (r = -.552, p ≤ 0.01), and RSA total time (r = -.552, p ≤ 0.01). The stepwise regression analysis of repeated sprinting abilities with measures of aerobic fitness showed that the shared variance between MSFT distance covered and RSA fastest time, RSA mean time, and RSA total time was 24%, 31%, and 31%, respectively. The shared variance between MSFT distance covered and linear sprint times over 0-40 m and 20-40 m were 26% and 36%, respectively. Finally, the shared variance between sprint with change of direction and distance covered during MSFT was 19%.

The stepwise regression analysis showed that linear sprint time over 0 – 40 m was correlated with RSA fastest time, RSA mean time, and RSA total time with a shared variance of 68%, 74%, and 74%, respectively. Stepwise analysis also showed that sprint with change of direction had the highest correlation with linear sprint time from 0-20 m with a shared variance of 18%.

Discussion

The relationships observed between jumping performances and linear sprints (Table 2) were in line with our hypothesis, and can be explained by the fact that sprinting involves high force production to support body mass during movement (Young et al., 1995). This also explains the differences between the relationships observed, namely that SJ was more strongly correlated with start and acceleration phases (0 – 20 m) than CMJ, while CMJ was more strongly correlated with maximal sprinting speed (20 – 40 m) than SJ. A possible explanation for this is that, during the start and acceleration phase, more force needs to be produced via maximal muscle effort action from the concentric contraction. However, as the player approaches maximal sprinting velocity, the foot contact time with the ground is reduced, indicating that, during this phase, the force produced by the legs becomes more important in maintaining running speed (Weyand et al., 2000; Young et al., 1995). Furthermore, the fact that peak power from CMJ (Table 2) is the only power measurement correlated with maximal sprinting speed over 20 – 40 m also suggests that the shortened contact time results in a larger proportion of low-velocity strength being available for high-velocity sprinting. Similar to previous studies, the results of the stepwise regression analysis suggest that concentric muscle action (as in SJ) is more critical for start and acceleration speed, while eccentric followed by concentric contraction (as in CMJ) is more important for maximal sprint speed (Shalfawi et al., 2011; Young et al., 1995).

Aerobic fitness (MSFT distance covered) was significantly correlated with linear sprint (0 – 40 m, and 20 – 40 m) time, repeated sprint ability, and sprint with change of direction. However, no significant association was observed between MSFT distance covered and start-acceleration time over 0 – 20 m during a 40 m linear sprint. Such a relationship was anticipated since a soccer match involves many high-intensity actions. High aerobic capacity likely accelerates recovery following such actions via removal of accumulated lactate during lower intensity phases of play (Reilly, 2007; Stolen et al., 2005). Previous studies indicate that aerobic fitness can significantly affect the ability to maintain a high intensity level during a soccer match (McMillan et al., 2005; Meckel et al., 2009). Similar to previous findings (Meckel et al., 2009), no significant relationships were observed between percentage decrement score from the RSA test and measures of aerobic fitness. This suggests that there is a minimum requirement for aerobic capacity in order to be able to cope with the recovery demands of the RSA test used in this study, above which no further performance benefit is seen (Bangsbo, 1994; Reilly et al., 2000). The shared variance from the stepwise analysis suggests that other factors in addition to aerobic fitness also contribute to sprinting performance.

The results of this study confirm that measures of linear sprint are highly correlated with measures of RSA (Table 3). This supports the assertion that repeated sprint ability is a function of single sprint speed and the ability to resist fatigue (Bishop et al., 2011; Reilly, 2007). However, the present study did not find a significant relationship between performance in the RSA test (7 × 30 m with a 30 s recovery) and fatigue expressed as the percentage decrement score. Hence, the rest period of 30 s in a 7 × 30 m repeated sprint test appears to be sufficient to restore the energy required to perform similarly from sprint to sprint. Fatigue has been defined as the "decline in maximal sprint speed over the number of sprint repetitions" (Girard et al. 2011). The findings of the current study contradict those of previous studies that have reported a performance decline during repeated sprint exercise (Girard et al., 2011), and a strong relationship between initial sprint speed (first sprint) and the occurrence of fatigue in repeated sprint exercise (Mendez et al., 2008). A suggested explanation for this relationship is that players with higher initial sprint speed have a greater contribution from anaerobic metabolism, which in turn, is strongly related to performance decrement (Girard et al., 2011; Mendez- Villanueva et al., 2008; Reilly, 2007). The discrepancy between the results of the current study and previous findings may be due to differences in test protocols; Aziz et al. (2000) used 8 x 40 m repeated sprints separated by 30 s recovery, while Owen et al. (2012) used a protocol consisting of 6 x 20 m maximal sprints with a recovery of 25 s. Rampinini et al. (2007), on the other hand, used 6 x 40 m (20+20) sprints with a recovery period of 20 s. The stepwise analysis showed that 0-40 m linear sprint time was the most strongly correlated with RSA fastest time, RSA mean time, and RSA total time with a shared variance of 68%, 74%, and 74%, respectively.

The relationship between sprint with change of direction and linear sprinting in elite soccer players has not been fully investigated. The results of the current study indicate that the relationship between measures of linear sprint and sprint with change of direction is significant but trivial, with the exception of sprint with change of direction and RSA fastest time and 20–40 m linear sprint time, where no significant relationships were observed (Table 3). These findings are in line with previous studies that have reported statistically significant but very low correlations, suggesting that these two skills can be considered as independent locomotors (Young & Farrow, 2006; Young et al., 2001).

Conclusions

The relationship observed between aerobic capacity and sprinting abilities and the results from the stepwise analysis suggest that separate training strategies are necessary to specifically target and improve performance in these abilities. Furthermore, the results of the present study demonstrate that: (1) reliable assessment of physical performance can be achieved using a single test design, (2) concentric contraction is important for start and acceleration speed, compared to eccentric followed by concentric contraction which is more important for maximal sprint speed, (3) aerobic capacity and linear sprint correlate significantly with repeated sprint ability, (4) sprint with change of direction and linear sprint are two independent locomotors skills, and (5) developing a standardized soccer-specific RSA test would likely result in more consistent results across studies.

References

Aziz, A. R., Chia, M., & Teh, K. C. (2000). The relationship between maximal oxygen uptake and repeated sprint performance indices in field hockey and soccer players. *J Sports Med Phys Fitness*, **40**(3), 195-200.

Bangsbo, J. (1994). Energy demands in competitive soccer. *J Sports Sci.,* 12 Spec No, S5-12.

Bangsbo, J., & Iaia, F. M. (2013). Principles of fitness training. In M. A. Williams (Ed.), *Science and Soccer: Developing Elite Performers* (3rd ed., pp. 24-43). New York: Routlege.

Bangsbo, J., Mohr, M., Poulsen, A., Perez-Gomez, J., & Krustrup, P. (2006). Training and testing the elite athlete. *Journal of exercise science and fitness,* **4**(1), 1-14.

Bishop, D., Girard, O., & Mendez-Villanueva, A. (2011). Repeated-sprint ability-part II: recommendations for training. *Sports Medicine,* **41**(9), 741-756.

Bloomfield, J., Polman, R., & O'Donoghue, P. (2007). Turning movements performed during FA Premier League soccer matches. *Journal of Sports Science and Medicine,* Suppl. **10**.

Girard, O., Mendez-Villanueva, A., & Bishop, D. (2011). Repeated-sprint ability - part I: factors contributing to fatigue. *Sports Medicine,* **41**(8), 673-694.

Glaister, M., Howatson, G., Pattison, J. R., & McInnes, G. (2008). The reliability and validity of fatigue measures during multiple-sprint work: an issue revisited. *J Strength Cond Res,* **22**(5), 1597-1601.

Hopkins, W. G. (2000). Measures of reliability in sports medicine and science. *Sports Med,* **30**(1), 1-15.

McMillan, K., Helgerud, J., Macdonald, R., & Hoff, J. (2005). Physiological adaptations to soccer specific endurance training in professional youth soccer players. *Br J Sports Med,* **39**(5), 273-277.

Meckel, Y., Machnai, O., & Eliakim, A. (2009). Relationship among repeated sprint tests, aerobic fitness, and anaerobic fitness in elite adolescent soccer players. *J.Strength Cond.Res.,* **23**(1), 163- 169.

Mendez-Villanueva, A., Hamer, P., & Bishop, D. (2008). Fatigue in repeated-sprint exercise is related to muscle power factors and reduced neuromuscular activity. *Eur J Appl Physiol,* **103**(4), 411-419.

Owen, A. L., Wong del, P., Paul, D., & Dellal, A. (2012). Effects of a periodized small-sided game training intervention on physical performance in elite professional soccer. *J Strength Cond Res,* **26**(10), 2748-2754.

Rampinini, E., Coutts, A. J., Castagna, C., Sassi, R., & Impellizzeri, F. M. (2007). Variation in top level soccer match performance. *Int J Sports Med,* **28**(12), 1018-1024.

Ramsbottom, R., Brewer, J., & Williams, C. (1988). A progressive shuttle run test to estimate maximal oxygen uptake. *Br J Sports Med,* **22**(4), 141-144.

Reilly, T. (2007). *The Science of Training - Soccer: A Scientific Approach to Developing Strength, Speed and Endurance.* New York: Routledge.

Reilly, T., Bangsbo, J., & Franks, A. (2000). Anthropometric and physiological predispositions for elite soccer. *Journal of sports sciences,* **18**(9), 669-683.

Reilly, T., & Thomas, V. (1976). A Motion Analysis of Work Rate in Different Positional. Roles in Professional Football Match-Play. *Journal of human movement studies,* **2**, 87-97.

Shalfawi, S. A., Sabbah, A., Kailani, G., Tonnessen, E., & Enoksen, E. (2011). The relationship between running speed and measures of vertical jump in professional basketball players: a field-test approach. *The Journal of Strength and Conditioning Research,* **25**(11), 3088-3092.

Spencer, M., Bishop, D., Dawson, B., & Goodman, C. (2005). Physiological and metabolic responses of repeated-sprint activities:specific to field-based team sports. *Sports Medicine,* **35**(12), 1025-1044.

Sporis, G., Jukic, I., Milanovic, L., & Vucetic, V. (2010). Reliability and factorial validity of agility tests for soccer players. *The Journal of Strength and Conditioning Research,* **24**(3), 679-686.

Stolen, T., Chamari, K., Castagna, C., & Wisloff, U. (2005). Physiology of soccer - An update. *Sports Medicine,* **35**(6), 501-536.

Weyand, P. G., Sternlight, D. B., Bellizzi, M. J., & Wright, S. (2000). Faster top running speeds are achieved with greater ground forces not more rapid leg movements. *Journal of Applied Physiology,* **89**(5), 1991-1999.

Young, W., & Farrow, D. (2006). A Review of Agility: Practical Applications for Strength and Conditioning. *Strength & Conditioning Journal,* **28**(5), 24-29.

Young, W., McLean, B., & Ardagna, J. (1995). Relationship between strength qualities and sprinting performance. *J Sports Med Phys Fitness,* **35**(1), 13-19.

Young, W. B., McDowell, M. H., & Scarlett, B. J. (2001). Specificity of sprint and agility training methods. *The Journal of Strength and Conditioning Research,* **15**(3), 315-319.

Young, W. B., McDowell, M. H., & Scarlett, B. J. (2001). Specificity of sprint and agility training methods. *The Journal of Strength and Conditioning Research*, **15**(3), 315-319.