

Female Soccer: Part 1–A Needs Analysis

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SUMMARY

IT IS IMPERATIVE FOR STRENGTH AND CONDITIONING COACHES TO CONDUCT A DETAILED ANALYSIS OF THE DEMANDS OF A SPORT, IDENTIFYING NORMATIVE DATA WHERE POSSIBLE TO PERMIT AN EVIDENCE-BASED EVALUATION OF AN ATHLETE'S CURRENT PERFORMANCE STATUS AND TO INFORM THE DEVELOPMENT OF SPECIFIC GOALS FOR THE ATHLETES' DEVELOPMENT. PART ONE OF THIS ARTICLE REVIEWS THE DEMANDS OF FEMALE SOCCER AND PROVIDES NORMATIVE DATA FROM PUBLISHED RESEARCH IDENTIFYING SPECIFIC AREAS THAT REQUIRE DEVELOPMENT IN FEMALE SOCCER PLAYERS. PART TWO RECOMMENDS EVIDENCE-BASED APPROACHES INTEGRATED TO ATHLETE DEVELOPMENT AND INJURY PREVENTION STRATEGIES, AS A RESULT OF THE NEEDS ANALYSIS.

INTRODUCTION

The published data currently available relating to female soccer demonstrates that a high level of aerobic conditioning is required during a match with average heart rates of 84–86% maximum heart rate (MHR) (4,39) and an average of 9.1–11.9 km total distance covered (3,4,21,30,37,39,49,51). These athletes have also demonstrated a good level of aerobic conditioning ($\dot{V}O_{2\max}$: 46–57.6 mL·kg⁻¹·min⁻¹) (25, 48,79), although increases are likely to result in increases in match performance (25,32,48). Performance in soccer is

primarily associated with a player's aerobic endurance (5–10,50), which permits the athletes to perform multiple high-intensity efforts. The outcomes of crucial moments in a soccer match depend on the performance of anaerobic activities such as sprinting and jumping (5,36,42,44).

Soccer matches consist of 250 brief intense anaerobic actions, per player, with repeated sprints occurring 39 times, sprinting every 90 seconds, each lasting 2–4 seconds (9,47,48,50,60,67). Sprinting speed is a key aspect within the sport contributing to soccer performance aspects such as obtaining possession and scoring or conceding goals (60). Total distance during sprinting can account for 1,025 ± 150 m accounting 1.4–3% of the game duration (2,21,50). Further intense actions include an average of 111 on the ball activities, jumping, and changing direction 90–100 times at a 90–180° angle (13). These decisive soccer components (striking the ball, turning, jumping, maximum strength, changing pace, cutting, and accelerating and decelerating the body) are forceful and explosive and require near-maximum levels of muscular strength and power production (16,22,35,43,67).

INJURY RISKS

Even though female soccer is one of the fastest growing sports in the world, the literature within female soccer is fairly limited (3,4,21,30,37,39,49,51). Male soccer players possess greater relative strength, power, speed, and match-specific components than female players. Research regarding landing mechanics suggests that female soccer players may lack strength, conditioning, and appropriate neuromuscular control (19,49,66).

Agel et al. (1) identified female athletes to be at a significantly greater risk of sustaining an anterior cruciate ligament (ACL) injury. Reports have stated that 0.33 ACL injuries per 1,000 hours occur within female soccer players, which is a significantly higher rate than male player's data (0.11 per 1,000 hours) (1). The fact that women are consistently shown to have significantly reduced neuromuscular control leading to greater knee valgus, combined with lower hamstring strength, may in part explain this increase in ACL injury risk compared with men (23,27,28,52). The majority of ACL injuries are associated with valgus movement combined with anterior tibial shear forces during rapid deceleration-type movements such as landing and changing direction (12,26–28,45,70). Other biomechanical, strength, and neuromuscular aspects have been suggested to contribute to these gender differences including decreased hip and knee flexion during landing and lower hamstrings: quadriceps strength ratio for women (15,29,81). These factors combined with poor conditioning and the number of deceleration activities performed during a soccer match and pitch-based training make female soccer a high-risk sport.

ANAEROBIC QUALITIES: STRENGTH, POWER, SPEED, AND AGILITY

A soccer player's absolute strength is beneficial for moving external objects (the ball and opposition players), whereas relative strength is suggested

KEY WORDS:

injury risk; strength; power; match performance; aerobic endurance

Table 1
Jump and hop performance data for female soccer players

Jump	Author	Subject status (number)	Score
Countermovement jump/vertical jump	Myer et al. (53)	High school athletes (<i>n</i> = 45)	43.2 ± 1.1 cm (with arm swing)
	Krustrup et al. (39)	Danish top league players (<i>n</i> = 23)	35.0 ± 1.0 cm (hands on hips)
	Larson-Meyer et al. (40)	American University players (<i>n</i> = 14)	21.0 ± 3.3 cm (with arm swing)
	Polman et al. (56)	Elite players women's Northern Premier Division (<i>n</i> = 36)	46.6 ± 4.81 cm (with arm swing)
	Pua et al. (57)	Recreational female players (<i>n</i> = 17)	35.0 ± 3.3 cm (hands on hips)
	Sedano Campo et al. (64)	Elite players (<i>n</i> = 20)	28.9 ± 0.9 cm (hands on hips)
	Nesser and Lee (55)	NCAA Division I female players (<i>n</i> = 16)	53.1 ± 9.4 (with arm swing)
Depth jump	Sedano Campo et al. (64)	Elite players (<i>n</i> = 20)	29.4 ± 1.0 cm (hands on hips)
Single-leg hop for distance	Myer et al. (53)	High school athletes (<i>n</i> = 45)	Left: 173.6 ± 2.5 cm
			Right: 175.5 ± 2.6 cm

NCAA = National Collegiate athletic Association.

to be more applicable for controlling their own body weight through acceleration and deceleration (78), the latter of which can reach forces of 1.65–4.22 times body mass (11,63,71). It is suggested that a greater maximum lower limb relative strength may improve an individual's ability to control his/her body during acceleration and

deceleration such as sprinting and turning (33,46,77), thus suggesting that a greater relative strength may provide a greater acceleration, acceptance of the high forces, and reduce risks to injury (33,46,77) along with appropriate mechanics. Research also identifies that peak ground reaction forces and impulse (rather than contact time or leg speed)

are strong determinants of sprint performance (34,72–76,80).

The normative research data for female soccer players range from 21.0 to 53.1 and 28.9 to 35 cm for countermovement jump height with and without arm swing, respectively (39,40,53,55–57,64) (Table 1). The majority of these

Table 2
Female soccer players' sprint and agility performance data

Performance test	Authors	Subject status	Score
Sprint time (9.1 m)	Myer et al. (53)	High school athletes (<i>n</i> = 45)	1.73 ± 0.01 s
Sprint time (20 m)	Siegler et al. (65)	US high school female players (<i>n</i> = 17)	3.00 ± 0.15 s
		Australian national female players (<i>n</i> = 20)	3.31 ± 0.11 s
Sprint time (25 m)	Polman et al. (56)	Elite players women's Northern Premier Division (<i>n</i> = 36)	4.12 ± 0.13 s
Sprint time (30 m)	Krustrup et al. (39)	Danish top league players (<i>n</i> = 23)	5.06 ± 0.06 s
Sprint time (40 m)	Nesser and Lee (55)	NCAA Division I female players (<i>n</i> = 16)	5.8 ± 0.4 s
Agility time (L-shape)	Polman et al. (56)	Elite players women's Northern Premier Division (<i>n</i> = 36)	Left: 6.05 ± 0.10 s
			Right: 6.17 ± 0.10 s
Agility time (4.5 m sprint, 180° turn, 4.5 m sprint)	Polman et al. (56)	Elite players women's Northern Premier Division (<i>n</i> = 36)	2.62 ± 0.13 s

NCAA = National Collegiate athletic Association.

scores are less than male soccer data apart from the National Collegiate athletic Association Division I female scores (46.87–56.4 versus 53.1 cm) (14,41,48,55,77,79), illustrating a lack of strength and power in female soccer players. When compared with the male soccer sprint data, US high school female players matched or had a faster 20 m sprint time (3.00–3.12 versus 3.00 seconds) (25,54,65,69,77,79). However, additional female sprint data (Table 2) is slower than the male soccer player's sprint performances for 20, 30, and 40 m, respectively (3.31 versus 3.00–3.12, 5.06 versus 4.00–4.22, and 5.80 versus 5.35–5.55 seconds) (18,22,25,54,65,69,77,79). This may be partly explained by the lower maximum leg strength data for female soccer players, in terms of both absolute and relative strength performances, when compared with male soccer player's scores (absolute, 65.7–97.5 versus 105–220 kg; relative, 1.00–1.51 versus 1.77–2.95 kg/kg) (16,40,48,53,55,61,77,79) (Table 3).

AEROBIC CAPACITY

Female soccer players demonstrate well-developed $\dot{V}O_2\text{max}$ levels ($46\text{--}57.6\text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$), although these are lower than their male counterparts ($58.4\text{--}63.4\text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) (25,48,79) (Table 4). Research using the Yo-Yo intermittent recovery test found that elite women from the top Danish league achieve greater distances than male

Table 3 Female soccer players' maximum strength scores (1 repetition maximum back squat)		
Authors	Subject status	Score
Myer et al. (53)	High school athletes (n = 45)	Absolute strength: 65.7 ± 1.9 kg
		Relative strength: 1.00 kg · kg ⁻¹
Larson-Meyer et al. (40)	American university players (n = 14)	Absolute strength: 97.5 ± 10.0 kg
		Relative strength: 1.51 kg · kg ⁻¹
Nesser and Lee (55)	NCAA Division I female players (n = 16)	Absolute strength: 75.8 ± 14.0 kg
		Relative strength: 1.3 ± 0.2 kg · kg ⁻¹
NCAA = National Collegiate athletic Association.		

soccer players (1,213 vs. 591–1,023 m, respectively) (38,39,62,68) (Table 4). The Yo-Yo intermittent recovery test determines a player's ability to recover from and repeatedly perform high-intensity exercise (8,38). This soccer-specific test reflects the moments and physiological work rate of a soccer game and significantly correlates ($r = 0.81$) with match-specific measurements such as high-intensity running distance (34). In general, it is suggested that the aerobic fitness levels of female soccer players should be developed to the highest levels because of the demands of the 90 minutes of competition. A higher level of aerobic conditioning is likely to result in greater distances covered on the pitch, including high-intensity decisive actions (25,31,32,48).

MATCH PERFORMANCE

A high level of conditioning is important in soccer for scoring or preventing goals from being scored, where players must be faster and more powerful than the opponent (16). Although no studies directly investigate whether a relationship exists between the conditioning of players and match performance, research has indicated that higher standard players cover greater high intensity (2.43 ± 0.14 versus $1.90 \pm 0.10\text{ km}$ and 1.68 ± 0.09 versus $1.30 \pm 0.10\text{ km}$), sprint distance (0.65 ± 0.06 versus $0.41 \pm 0.03\text{ km}$ and 0.46 ± 0.02 versus $0.38 \pm 0.05\text{ km}$), and the number of sprint bouts (39 ± 2 versus 26 ± 1 and 30 ± 2 versus 26 ± 1) than lower level players (49,50). Moreover,

Table 4 $\dot{V}O_2\text{max}$ of female soccer players		
Authors	Subject status	Score
Clark et al. (17)	College and adult recreational female players (U19) (n = 32)	57.27 ± 1.59 to $62.13 \pm 0.96\text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$
Gabbett et al. (24)	Soccer scholarship female players (n = 30)	$51.4 \pm 5.4\text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$
Krustrup et al. (39)	Danish top league female players (n = 23)	$52.3 \pm 1.3\text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$
Polman et al. (56)	Elite players women's Northern Premier Division (n = 36)	$46.0 \pm 2.89\text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$
Davis and Brewer (20)	National female players (n = 14)	$52.2 \pm 5.1\text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$
	Norway elite female players (n = 12)	$54.0 \pm 3.54\text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$
	Denmark national female players (n = 10)	$57.6\text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$

Rampinini et al. (59) found the top 5 finishing teams in Italian Serie A league demonstrated significantly greater ($p < 0.01$) total distance, high-intensity distance, ball involvements, and successful passes, tackles, and shots than the bottom 5 teams. Findings by Wisloff et al. (78) support this assumption demonstrating that the top team in Norwegian Elite League possessed greater $\dot{V}O_{2\max}$

than the bottom league team (67.6 ± 4.0 vs. $59.9 \pm 4.1 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$). However, no comparisons of time-motion analysis or match performance were made. Thus, even though studies may collectively indicate players' level of conditioning links to match performance, success, and level of play they reach, further individual research is required to directly investigate this relationship.

In light of the match characteristics of the sport, it is essential that these athletes have highly developed aerobic energy systems, to cope with the total distance covered, recovery between high-intensity bouts, and the duration of the game. It is also imperative that their anaerobic systems are highly developed to permit optimal performances in the high-intensity acceleration, deceleration,

Table 5
Normative data for match performance in female soccer players

Physiological assessment	Research	Subject status	Score
Percentage of maximum heart rate	Krustrup et al. (39)	Danish top league players ($n = 23$)	86
	Andersson et al. (4)	Top class players ($n = 17$)	84
Blood lactate, $\text{mmol}\cdot\text{L}^{-1}$	Krustrup et al. (39)	Danish top league players ($n = 23$)	First half: 5.1 ± 0.5
			Second half: 2.7 ± 0.4
Distance covered, km	Mohr et al. (49)	National team players ($n = 19$)	10.33 ± 0.15
		Elite players ($n = 15$)	10.44 ± 0.15
	Andersson et al. (4)	Top class players ($n = 17$)	9.9 ± 1.8
	Krustrup et al. (37)	Elite Danish players ($n = 14$)	10.30
		International Swedish Danish players ($n = 22$)	10.0
	Di Salvo et al. (21)	International English players ($n = 30$)	9.7
			11.98
	Hewitt et al. (30)	International Australian players ($n = 6$)	9.14
High-intensity running distance, km	Andersson et al. (4)	Top class players ($n = 17$)	1.53 ± 0.1
	Mohr et al. (49)	National team players ($n = 19$)	1.68 ± 0.09
		Elite players ($n = 15$)	1.30 ± 0.10
Sprint distance, km	Andersson et al. (4)	Top class players ($n = 17$)	0.25 ± 0.57
	Mohr et al. (49)	National team players ($n = 19$)	0.46 ± 0.02
		Elite players ($n = 15$)	0.38 ± 0.05
No. of changes in activity	Mohr et al. (49)	National team players ($n = 19$)	$1,379 \pm 34$
		Elite players ($n = 15$)	$1,326 \pm 24$
No. of high-intensity runs	Mohr et al. (49)	National team players ($n = 19$)	154 ± 7
		Elite players ($n = 15$)	125 ± 7
	Andersson et al. (4)	Top class players ($n = 17$)	149 ± 15
No. of sprint bouts	Mohr et al. (49)	National team players ($n = 19$)	30 ± 2
		Elite players ($n = 15$)	26 ± 1
	Andersson et al. (4)	Top class players ($n = 17$)	27 ± 4

and changes in direction required throughout the game.

Match performance research has demonstrated that female soccer players cover a total distance of 8.6–11.3 km at an average of 85–87% of MHR (3,4,21,25,30,37,39,50,58) (Table 5). During this time, sprinting accounts for a total distance of 0.41–0.65 km and high-intensity distance 1.90–2.43 km, highlighting that female soccer players need to have not only a high level of aerobic conditioning but also the strength and power qualities to permit the performance of multiple high-intensity activities (4,49,50) (Table 5).

CONCLUSIONS

Female soccer players lack optimal conditioning both aerobically and anaerobically when compared with men and this may impact soccer-specific performances. Although this has not been investigated thoroughly, it may be suggested that the lack of conditioning may contribute to reduced performance levels in match-specific variables, based on the demands of the sport. The key areas of attention for female soccer players involve both anaerobic qualities (relative strength and power, speed, and agility) and aerobic capacity. By focusing on improving these areas, improvements in anaerobic areas such as relative strength, especially from unilateral training, and plyometric drills may increase lower limb control and the ability to cope with the high forces and velocity movements involved in a match, thereby reducing the risk of injury via improved neuromuscular conditioning. In addition, such improvements are also likely to improve soccer performance in both laboratory- and field-based assessments (sprinting, jumping) and more importantly during matches (methods to improve performance in these areas and how these can be periodized are discussed in part 2).

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REFERENCES

- Agel J, Arendt EA, and Bershadsky B. Anterior cruciate ligament injury in national collegiate athletic association basketball and soccer: A 13-year review. *Am J Sports Med* 33: 524–530, 2005.
- Ali A and Farrally M. A computer-video aided time motion analysis technique for match analysis. *J Sports Med Phys Fitness* 31: 82–88, 1991.
- Andersson H, Ekblom B, and Krstrup P. Elite football on artificial turf versus natural grass: Movement patterns, technical standards, and player impressions. *J Sports Sci* 26: 113–122, 2008.
- Andersson HA, Randers MB, Heiner-Moller A, Krstrup P, and Mohr M. Elite female soccer players perform more high-intensity running when playing in international games compared with domestic league games. *J Strength Cond Res* 24: 912–919, 2010.
- Aziz AR, Chia M, and Teh KC. The relationship between maximal oxygen uptake and repeated sprint performance indices in field hockey and soccer players. *J Sports Med Phys Fitness* 40: 195–200, 2000.
- Aziz AR, Mukherjee S, Chia MY, and Teh KC. Relationship between measured maximal oxygen uptake and aerobic endurance performance with running repeated sprint ability in young elite soccer players. *J Sports Med Phys Fitness* 47: 401–407, 2007.
- Bangsbo J. The physiology of soccer—With special reference to intense intermittent exercise. *Acta Physiol Scand Suppl* 619: 1–155, 1994.
- Bangsbo J, laia FM, and Krstrup P. The Yo-Yo intermittent recovery test: A useful tool for evaluation of physical performance in intermittent sports. *Sports Med* 38: 37–51, 2008.
- Bangsbo J, Mohr M, and Krstrup P. Physical and metabolic demands of training and match-play in the elite football player. *J Sports Sci* 24: 665–674, 2006.
- Bangsbo J, Norregaard L, and Thorso F. Activity profile of competition soccer. *Can J Sport Sci* 16: 110–116, 1991.
- Barnes JL, Schilling BK, Falvo MJ, Weiss LW, Creasy AK, and Fry AC. Relationship of jumping and agility performance in female volleyball athletes. *J Strength Cond Res* 21: 1192–1196, 2007.
- Berns GS, Hull ML, and Patterson HA. Strain in the anteromedial bundle of the anterior cruciate ligament under combination loading. *J Orthop Res* 10: 167–176, 1992.
- Bloomfield J, Polman R, O'Donoghue P, and McNaughton L. Effective speed and agility conditioning methodology for random intermittent dynamic type sports. *J Strength Cond Res* 21: 1093–1100, 2007.
- Castagna C, Impellizzeri FM, Chamari K, Carlomagno D, and Rampinini E. Aerobic fitness and yo-yo continuous and intermittent tests performances in soccer players: A correlation study. *J Strength Cond Res* 20: 320–325, 2006.
- Chappell JD, Creighton RA, Giuliani C, Yu B, and Garrett WE. Kinematics and electromyography of landing preparation in vertical stop-jump: Risks for noncontact anterior cruciate ligament injury. *Am J Sports Med* 35: 235–241, 2007.
- Chelly MS, Fathloun M, Cherif N, Ben Amar M, Tabka Z, and Van Praagh E.

- Effects of a back squat training program on leg power, jump, and sprint performances in junior soccer players. *J Strength Cond Res* 23: 2241–2249, 2009.
17. Clark JE. The use of an 8-week mixed-intensity interval endurance-training program improves the aerobic fitness of female soccer players. *J Strength Cond Res* 24: 1773–1781, 2010.
18. Cometti G, Maffiuletti NA, Pousson M, Chatard JC, and Maffulli N. Isokinetic strength and anaerobic power of elite, subelite and amateur French soccer players. *Int J Sports Med* 22: 45–51, 2001.
19. Cowley HR, Ford KR, Myer GD, Kernozek TW, and Hewett TE. Differences in neuromuscular strategies between landing and cutting tasks in female basketball and soccer athletes. *J Athl Train* 41: 67–73, 2006.
20. Davis JA and Brewer J. Applied physiology of female soccer. *Sports Med* 16: 180–189, 1993.
21. Di Salvo V, Baron R, Tschan H, Calderon Montero FJ, Bachl N, and Pigozzi F. Performance characteristics according to playing position in elite soccer. *Int J Sports Med* 28: 222–227, 2007.
22. Dupont G, Akakpo K, and Berthoin S. The effect of in-season, high-intensity interval training in soccer players. *J Strength Cond Res* 18: 584–589, 2004.
23. Ford KR, Myer GD, and Hewett TE. Valgus knee motion during landing in high school female and male basketball players. *Med Sci Sports Exerc* 35: 1745–1750, 2003.
24. Gabbett TJ and Mulvey MJ. Time-motion analysis of small-sided training games and competition in elite women soccer players. *J Strength Cond Res* 22: 543–552, 2008.
25. Helgerud J, Engen LC, Wisloff U, and Hoff J. Aerobic endurance training improves soccer performance. *Med Sci Sports Exerc* 33: 1925–1931, 2001.
26. Hewett TE, Ford KR, and Myer GD. Anterior cruciate ligament injuries in female athletes: Part 2, a meta-analysis of neuromuscular interventions aimed at injury prevention. *Am J Sports Med* 34: 490–498, 2006.
27. Hewett TE, Myer GD, and Ford KR. Reducing knee and anterior cruciate ligament injuries among female athletes: A systematic review of neuromuscular training interventions. *J Knee Surg* 18: 82–88, 2005.
28. Hewett TE, Myer GD, Ford KR, Heidt RS Jr, Colosimo AJ, McLean SG, van den Bogert AJ, Paterno MV, and Succop P. Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: A prospective study. *Am J Sports Med* 33: 492–501, 2005.
29. Hewett TE, Zazulak BT, Myer GD, and Ford KR. A review of electromyographic activation levels, timing differences, and increased anterior cruciate ligament injury incidence in female athletes. *Br J Sports Med* 39: 347–350, 2005.
30. Hewitt A, Withers R, and Lyons K. Match analysis of Australian international women soccer players using an athlete tracking device. *J Sci Sports Med* 107(Suppl 10): 107, 2007.
31. Hoff J and Helgerud J. Endurance and strength training for soccer players: Physiological considerations. *Sports Med* 34: 165–180, 2004.
32. Hoff J, Wisloff U, Engen LC, Kemi OJ, and Helgerud J. Soccer specific aerobic endurance training. *Br J Sports Med* 36: 218–221, 2002.
33. Hori N, Newton RU, Andrews WA, Kawamori N, McGuigan MR, and Nosaka K. Does performance of hang power clean differentiate performance of jumping, sprinting, and changing of direction? *J Strength Cond Res* 22: 412–418, 2008.
34. Hunter JP, Marshall RN, and McNair PJ. Relationships between ground reaction force impulse and kinematics of sprint-running acceleration. *J Appl Biomech* 21: 31–43, 2005.
35. Inklaar H. Soccer injuries. I: Incidence and severity. *Sports Med* 18: 55–73, 1994.
36. Jullien H, Bisch C, Largouet N, Manouvrier C, Carling CJ, and Amiard V. Does a short period of lower limb strength training improve performance in field-based tests of running and agility in young professional soccer players? *J Strength Cond Res* 22: 404–411, 2008.
37. Krstrup P, Mohr M, Ellingsgaard H, and Bangsbo J. Physical demands during an elite female soccer game: Importance of training status. *Med Sci Sports Exerc* 37: 1242–1248, 2005.
38. Krstrup P, Mohr M, Nybo L, Jensen JM, Nielsen JJ, and Bangsbo J. The Yo-Yo IR2 test: Physiological response, reliability, and application to elite soccer. *Med Sci Sports Exerc* 38: 1666–1673, 2006.
39. Krstrup P, Zebis M, Jensen JM, and Mohr M. Game-induced fatigue patterns in elite female soccer. *J Strength Cond Res* 24: 437–441, 2010.
40. Larson-Meyer ED, Hunter GR, Trowbridge CA, Turk JC, Ernest JM, Torman SL, and Harbin PA. The effect of creatine supplementation on muscle strength and body composition during off-season training in female soccer players. *J Strength Cond Res* 14: 434–442, 2000.
41. le Gall F, Carling C, Williams M, and Reilly T. Anthropometric and fitness characteristics of international, professional and amateur male graduate soccer players from an elite youth academy. *J Sci Med Sport* 13: 90–95, 2008.
42. Little T and Williams AG. Specificity of acceleration, maximum speed, and agility in professional soccer players. *J Strength Cond Res* 19: 76–78, 2005.
43. Little T and Williams AG. Suitability of soccer training drills for endurance training. *J Strength Cond Res* 20: 316–319, 2006.
44. Little T and Williams AG. Measures of exercise intensity during soccer training drills with professional soccer players. *J Strength Cond Res* 21: 367–371, 2007.
45. Markolf KL, Burchfield DM, Shapiro MM, Shepard MF, Finerman GA, and Slaughterbeck JL. Combined knee loading states that generate high anterior cruciate ligament forces. *J Orthop Res* 13: 930–935, 1995.
46. McBride JM, Blow D, Kirby TJ, Haines TL, Dayne AM, and Triplett NT. Relationship between maximal squat strength and five, ten, and forty yard sprint times. *J Strength Cond Res* 23: 1633–1636, 2009.
47. McMillan K, Helgerud J, Grant SJ, Newell J, Wilson J, Macdonald R, and Hoff J. Lactate threshold responses to a season of professional British youth soccer. *Br J Sports Med* 39: 432–436, 2005.
48. McMillan K, Helgerud J, Macdonald R, and Hoff J. Physiological adaptations to soccer specific endurance training in professional youth soccer players. *Br J Sports Med* 39: 273–277, 2005.
49. Mohr M, Krstrup P, Andersson H, Kirkendall D, and Bangsbo J. Match activities of elite women soccer players at different performance levels. *J Strength Cond Res* 22: 341–349, 2008.
50. Mohr M, Krstrup P, and Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci* 21: 519–528, 2003.
51. Mohr M, Krstrup P, Kirkendall D, and Bangsbo J. Differences in physical match performance at two levels in female soccer. *J Sports Sci Med* 10(Suppl): 108, 2007.
52. Myer GD, Ford KR, Barber Foss KD, Liu C, Nick TG, and Hewett TE. The

- relationship of hamstrings and quadriceps strength to anterior cruciate ligament injury in female athletes. *Clin J Sport Med* 19: 3–8, 2009.
53. Myer GD, Ford KR, Palumbo JP, and Hewett TE. Neuromuscular training improves performance and lower-extremity biomechanics in female athletes. *J Strength Cond Res* 19: 51–60, 2005.
54. Needham RA, Morse CI, and Degens H. The acute effect of different warm-up protocols on anaerobic performance in elite youth soccer players. *J Strength Cond Res* 23: 2614–2620, 2009.
55. Nesser TW and Lee WL. The relationship between core strength and performance in division I female football players. *J Exerc Physiol* 12: 21–28, 2009.
56. Polman R, Walsh D, Bloomfield J, and Nesti M. Effective conditioning of female soccer players. *J Sports Sci* 22: 191–203, 2004.
57. Pua YH, Koh MT, and Teo YY. Effects of allometric scaling and isokinetic testing methods on the relationship between countermovement jump and quadriceps torque and power. *J Sports Sci* 24: 423–432, 2006.
58. Rahnama N, Reilly T, and Lees A. Injury risk associated with playing actions during competitive soccer. *Br J Sports Med* 36: 354–359, 2002.
59. Rampinini E, Impellizzeri FM, Castagna C, Coutts AJ, and Wisloff U. Technical performance during soccer matches of the Italian Serie A league: Effect of fatigue and competitive level. *J Sci Med Sport* 12: 227–233, 2009.
60. Reilly T, Bangsbo J, and Franks A. Anthropometric and physiological predispositions for elite soccer. *J Sports Sci* 18: 669–683, 2000.
61. Ronnestad BR, Kvamme NH, Sunde A, and Raastad T. Short-term effects of strength and plyometric training on sprint and jump performance in professional soccer players. *J Strength Cond Res* 22: 773–780, 2008.
62. Rostgaard T, Iaia FM, Simonsen DS, and Bangsbo J. A test to evaluate the physical impact on technical performance in soccer. *J Strength Cond Res* 22: 283–292, 2008.
63. Sato K and Mokha M. Does core strength training influence running kinetics, lower-extremity stability, and 5000-M performance in runners? *J Strength Cond Res* 23: 133–140, 2009.
64. Sedano Campo S, Vaeyens R, Philippaerts RM, Redondo JC, de Benito AM, and Cuadrado G. Effects of lower-limb plyometric training on body composition, explosive strength, and kicking speed in female soccer players. *J Strength Cond Res* 23: 1714–1722, 2009.
65. Siegler J, Gaskill S, and Ruby B. Changes evaluated in soccer-specific power endurance either with or without a 10-week, in-season, intermittent, high-intensity training protocol. *J Strength Cond Res* 17: 379–387, 2003.
66. Smith R, Ford KR, Myer GD, Holleran A, Treadway E, and Hewett TE. Biomechanical and performance differences between female soccer athletes in National Collegiate Athletic Association Divisions I and III. *J Athl Train* 42: 470–476, 2007.
67. Stolen T, Chamari K, Castagna C, and Wisloff U. Physiology of soccer: An update. *Sports Med* 35: 501–536, 2005.
68. Thomassen M, Christensen PM, Gunnarsson TP, Nybo L, and Bangsbo J. Effect of 2-wk intensified training and inactivity on muscle Na⁺-K⁺ pump expression, phospholemman (FXD1) phosphorylation, and performance in soccer players. *J Appl Physiol* 108: 898–905, 2010.
69. Till KA and Cooke C. The effects of postactivation potentiation on sprint and jump performance of male academy soccer players. *J Strength Cond Res* 23: 1960–1967, 2009.
70. Wallace BJ, Kernozek TW, Mikat RP, Wright GA, Simons SZ, and Wallace KL. A comparison between back squat exercise and vertical jump kinematics: Implications for determining anterior cruciate ligament injury risk. *J Strength Cond Res* 22: 1249–1258, 2008.
71. Wallace BJ, Kernozek TW, White JM, Kline DE, Wright GA, Peng HT, and Huang CF. Quantification of vertical ground reaction forces of popular bilateral plyometric exercises. *J Strength Cond Res* 24: 207–212, 2010.
72. Weyand PG and Bundle MW. Energetics of high-speed running: Integrating classical theory and contemporary observations. *Am J Physiol Regul Integr Comp Physiol* 288: R956–R965, 2005.
73. Weyand PG and Davis JA. Running performance has a structural basis. *J Exp Biol* 208: 2625–2631, 2005.
74. Weyand PG, Lee CS, Martinez-Ruiz R, Bundle MW, Bellizzi MJ, and Wright S. High-speed running performance is largely unaffected by hypoxic reductions in aerobic power. *J Appl Physiol* 86: 2059–2064, 1999.
75. Weyand PG, Sandell RF, Prime DN, and Bundle MW. The biological limits to running speed are imposed from the ground up. *J Appl Physiol* 108: 950–961, 2010.
76. Weyand PG, Sternlight DB, Bellizzi MJ, and Wright S. Faster top running speeds are achieved with greater ground forces not more rapid leg movements. *J Appl Physiol* 89: 1991–1999, 2000.
77. Wisloff U, Castagna C, Helgerud J, Jones R, and Hoff J. Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *Br J Sports Med* 38: 285–288, 2004.
78. Wisloff U, Helgerud J, and Hoff J. Strength and endurance of elite soccer players. *Med Sci Sports Exerc* 30: 462–467, 1998.
79. Wong PL, Chamari K, and Wisloff U. Effects of 12-week on-field combined strength and power training on physical performance among U-14 young soccer players. *J Strength Cond Res* 24: 644–652, 2009.
80. Wright S and Weyand PG. The application of ground force explains the energetic cost of running backward and forward. *J Exp Biol* 204: 1805–1815, 2001.
81. Zazulak BT, Ponce PL, Straub SJ, Medvecky MJ, Avedisian L, and Hewett TE. Gender comparison of hip muscle activity during single-leg landing. *J Orthop Sports Phys Ther* 35: 292–299, 2005.