2-2009

Comprehensive Sports Medicine Treatment of an Athlete Who Runs Cross-Country and is Iron Deficient

Jason Brumitt
George Fox University, jbrumitt@georgefox.edu

Linda McIntosh

Richard Rutt

Recommended Citation

Published in North American Journal of Sports Physical Therapy, 2009; 4(1): 13-20 http://www.ncbi.nlm.nih.gov/pmc/journals/1328/

CASE REPORT

COMPREHENSIVE SPORTS MEDICINE TREATMENT OF AN ATHLETE WHO RUNS CROSS-COUNTRY AND IS IRON DEFICIENT

Jason Brumitt, MSPT, SCS, ATC[1]
Linda McIntosh, MS, ATC[2]
Richard Rutt, PT, PhD, ATC[1]

ABSTRACT

Background. Optimal athletic performance may be dependent upon an athlete maintaining adequate iron levels through the consumption of dietary forms of iron and subsequent metabolism. Endurance athletes, especially female distance runners, have been identified as being at risk for developing iron deficiency. While iron deficiency is treatable, early diagnosis may be delayed if an adequate medical history and evaluation is not conducted.

Objective. To describe the evaluation, diagnosis, and comprehensive sports medicine treatment of a collegiate cross-country athlete with a medical diagnosis of iron deficiency with anemia and sports-related musculoskeletal pain.

Case Description. A 21-year-old female collegiate cross-country athlete experienced a decline in her running performance beginning her freshman year of school. She continued to experience degradation in sports performance despite medical intervention. Two-and-a-half years after initially seeking medical attention she was diagnosed with iron deficiency with anemia by a primary care medical doctor. Additionally, the subject required rehabilitation due to the onset of sports-related musculoskeletal symptoms.

Outcomes. Comprehensive treatment for this patient consisted of iron supplementation, therapeutic exercises, manual therapy, and modalities. The athlete was able to compete during her entire cross-country season and earn All-American status at the Division-III level.

Discussion. Sports medicine professionals must consider iron deficiency as a possible differential diagnosis when evaluating endurance athletes. Subtle signs of iron deficiency may, unfortunately, be overlooked ultimately delaying treatment.

Key Words: iron deficiency with anemia, cross-country, iron supplementation

CORRESPONDENCE
Jason Brumitt
16322 SE Don Lino Ct
Damascus, OR 97089
503-558-1323
Work: 503-352-7265
Fax: 503-352-7340
jbrumitt72@hotmail.com

INTRODUCTION

Consumption of dietary iron is necessary for optimal human cellular metabolism and growth.[1] An individual who consumes a diet that is deficient of iron rich foods or who experiences depletion of iron stores may experience symptoms ranging from fatigue to degradation in physical performance.[1-3] Iron deficiency is the number one nutritional deficiency affecting billions worldwide.[4,5] Iron deficiency with anemia affects between 1% to 2% of all adults in the United States and is estimated to globally affect 0.5 to 0.6 billion people.[1,5,6] In addition, up to 20% of Americans may suffer from iron deficiency without anemia with an estimated 1 to 1.8 billion suffering this condition worldwide.[1,6]

Optimal athletic performance is also dependent upon maintaining iron levels through the consumption of dietary forms of iron and subsequent metabolism.[2,5,7,8] The formation of hemoglobin and the body's subsequent ability to transport oxygen from the lungs to the tissues will be impaired in the athlete who is iron defficient. Additionally, athletes who are iron deficient may experience the following symptoms: nausea, frequent infections, shortness of breath during exercise, respiratory illness, fatigue, weakness, pale appearance, lack of energy, and exhaustion.[3, 9]

Endurance athletes, especially female distance runners, have been identified as being at risk for developing iron deficiency.[10-13] One epidemiological study of endurance runners identified 82% of the female athletes as iron deficient.[14,15] While iron deficiency is treatable, early diagnosis may be delayed if an adequate medical history and evaluation is not conducted.

The purpose of this report is to highlight a unique case of a collegiate female cross-country athlete who experienced a chronic degradation in her performance due to becoming iron deficient and anemic. Initial medical and allied healthcare evaluations and interventions failed to identify and appropriately treat her iron deficiency with anemia. The athlete continued to train and compete in distance running for both her collegiate cross-country and track teams, despite suffering fatigue and exhaustion. She considered quitting competitive running due to her inability to compete at a high level. Two-and-a-half years after initially seeking medical attention she was diagnosed with iron deficiency anemia by a primary care medical doctor. This case is unique as it details the medical intervention and sports rehabilitation management in the comprehensive treatment of a female collegiate cross-country athlete with a diagnosis of iron deficiency with anemia.

CASE DESCRIPTION

A 21-year-old female cross-country athlete presented at the start of the cross-country season to the athletic training team with a sports-related injury to the left hip and left knee. Her primary musculoskeletal complaint was her inability to complete her training runs without experiencing either left hip or left knee pain. The patient was concurrently receiving medical management for iron deficiency anemia by her primary care physician.

Previous History

The patient ran competitively on both her high school cross-country and track teams. She denied any history of sports-related running injuries during her high school career. Her best recorded time in high school for the 5,000-meter run was 19:36 (minutes:seconds). During her freshman collegiate cross-country season she experienced a decline in her running performance that she initially attributed to the intensity of the collegiate training program (Division I) and a "slow" acclimation to her new training environment (school situated at an elevation of 6910 feet or 2106 meters). The subject had previously attended a high school that was situated at sea level.

She described "feeling sluggish throughout the day" and that she required long naps during the day despite sleeping for 8 to 10 hours each night. When running she felt that she was racing "flat," that she lacked energy during workouts, and that she experienced an increase (a slowing) of her race-pace. Her 5000-meter race time had slowed to 19:58.

In fall of 2006, she sought medical attention to identify a cause for her fatigue related symptoms after the completion of her freshman cross-country season. She also sought medical attention at this time for a new onset of allergies. During the course of several medical consults she was diagnosed by her medical doctor with asthma and hypoglycemia. Initial treatments failed to provide symptom relief and did not affect her athletic performance. She continued to seek medical attention for her sports-related symptoms. She reported that she was tested over the next year-and-a-half three times for mononucleosis and one time for anemia. According to the patient each test was negative. A "nutritionist" offered an unsolicited recommendation to her to increase her protein consumption, but the athlete was not provided any dietary guidance (note: the patient was unaware as to the educational or professional background of the "nutritionist").

The patient transferred from the Division-I school after two years to a Division-III university in Oregon. Despite the change in training environments (school situated at an elevation of 210 ft or 64 m), she continued to experience her fatigue related symptoms and poor athletic performance. Not long after transferring schools, she began to experience back and left hip musculoskeletal pain. The patient sought chiropractic treatment in order to address her new musculoskeletal complaints. She received several treatments including manipulation of the spine, deep tissue massage, ultrasound, moist heat, and cryotherapy. She continued chiropractic treatment for 6 months despite a lack of improvement.

Differential Diagnosis

Medical Management

Previous medical evaluations and interventions by allopathic and chiropractic physicians failed to successfully decrease the subject's symptoms. The subject again sought medical attention in Spring of 2007 after terminating chiropractic treatment. A complete blood count demonstrated low levels of hemoglobin (HGB), hematocrit (HCT), mean corpuscular volume (MCV), and mean corpuscular hemoglobin (MCH) *(Table 1, column 1)*. Based upon these values, additional labs were performed 10 days later in order to assess serum iron levels, total iron binding capacity (TIBC), transferrin saturation, and serum ferritin levels *(Table 1, column 2)*. Only one lab value, the TIBC, was within the standard reference values. Based upon these results, she was diagnosed with iron deficiency with anemia. The patient was instructed by her medical doctor to begin immediate iron supplementation (see treatment section).

Musculoskeletal Differential Diagnosis

At the start of the cross-country season the patient was referred by her coach to the university's athletic training department for treatment of her sports-related musculoskeletal injuries. Despite receiving the medical diagnosis of iron deficiency with anemia (and the initiation of iron supplementation), the patient continued to experience

Table 1. Complete Blood Count Lab Values for the Athlete Running Cross-Country. Standard Reference Values are presented in the Far Right Column.

	03/24/07	04/03/07	05/17/07	07/11/2007	09/13/07	10/23/07	12/10/07	Reference Values
Hemoglobin (HGB) (g/dL)	10.4	n/a	14.2	n/a	14.7	14.9	n/a	(12.0 – 16.0)
Hematocrit (HCT) (%)	32.5	n/a	43.7	n/a	42.3	43.0	n/a	(37.0 – 47.0)
Mean Corpuscular Volume (MCV) (fL)	75.4	n/a	80.9	n/a	92.8	94.1	n/a	(80.0 - 100.0)
Mean Corpuscular Hemoglobin (MCH) (pg)	24.2	n/a	26.3	n/a	32.2	32.5	n/a	(27.0 – 34.0)
Iron (ug/dL)	n/a	19	70	127	63	n/a	153	(26 – 170)
Total Iron Binding Capacity (TIBC) (ug/dL)	n/a	393	424	307	333	n/a	310	(262 – 474)
% Saturation	n/a	5	17	41	19	n/a	49	(10 – 40)
Ferritin (ng/mL)	n/a	2	8	18	14	n/a	22	(10 – 200)

n/a: values not available or not tested

recurrent left hip pain as well as an acute episode of left knee pain (onset 1-2 weeks prior to physical examination in the athletic training department). The patient's primary musculoskeletal complaints were chronic left hip pain and the new onset of non-traumatic anterior-lateral left knee pain both which were affecting her ability to complete her training runs pain free.

Musculoskeletal Assessment of the Injured Runner

Standing Examination

Static and dynamic posture and alignment were first assessed in standing. Static posture and alignment appeared unremarkable when viewed anteriorly, laterally, and posteriorly. Active lumbar spine range of motion was also assessed to be within normal limits. Gait observation was unremarkable.

Several functional tests were conducted to assess the subject for dysfunctional biomechanical movement patterns. Functional tests may be useful in providing qualitative information relating to an individual's ability to perform basic and complex movement patterns.[16] When performing a lunge, the patient demonstrated contralateral hip drop, femoral adduction, and knee valgum with each lead leg. When performing a squat, the patient was unable to maintain proper trunk alignment (demonstrating excessive lumbar flexion) during the descent phase. She also was unable to eccentrically control the descent with her hip musculature, instead relying on her quadriceps (as demonstrated by her knees flexing over her feet). The single-legged squat test (SLST) further highlighted her inability to maintain core stability and lower extremity alignment. A Trendelenburg sign, femoral adduction and internal rotation, and knee valgum were demonstrated bilaterally during each SLST with the left lower extremity malalignment qualitatively assessed to be worse than that on the right.

Seated Examination

The patient assumed a sitting posture on the evaluation table. In this position dermatomes, reflexes, and selected muscle tests were conducted *(Table 2)*. Dermatomes and reflexes (L3 and S1) were determined to be intact bilaterally. Manual muscle tests for hip internal rotation, hip external rotation, hip flexion, and knee extension were conducted bilaterally revealing gross hip weakness bilaterally (*Table 2)*. A hand held dynamometer (MicroFet 2, Hoggan Health Industries, West Jordan, Utah) was utilized to quantify hip strength. Hip flexion, hip internal rotation, and hip external rotation strength were measured in sitting as recommended by the manufacturer *(Table 2)*.

Supine Examination

Active range of motion (AROM) was assessed in supine. Hip, knee, and ankle AROM was deemed symmetrical and within normal limits bilaterally. Provocation tests (special tests) failed to reproduce hip or knee symptoms. Hamstring flexibility was measured bilaterally using the 90-90 test.[17] To quantify hamstring flexibility, the knee was passively extended from the 90-90 position until resistance prevented further extension of the joint.[17] Hamstring flexibility was measured to be 70° bilaterally. Additional manual muscle tests and dynamometry was conducted *(Table 2)*. Palpation revealed tenderness on the left side at the posterior superior iliac spine, piriformis, gluteus maximus and medius, and hamstring muscles (common origin), as well as the greater tubercle of the hip, distal iliotibial tract, and the antero-lateral knee.

Table 2. Selected Hip Strength Measures Recorded during the Initial Evaluation and after the End of the Subject's Cross-Country Season

	Initial Evaluation Dynamometry (foot/pounds)		Initial Evaluation Traditional Manual Muscle Test (scale 1 – 5)		Post-Rehabilitation Measures Dynamometry (foot/pounds)	
	Right	Left	Right	Left	Right	Left
Flexion	28.8	29.6	3+	3+	44	41
Abduction	32	30	3+	3+	40	42
Extension	28	29	4-	4-	33	35
External Rotation	19	19	3+	3+	23	22
Internal Rotation	16	20	4	4	19.3	19.5

Exam Summary

To summarize, the primary physical examination findings were poor hip and core strength. Based upon these findings, the primary author hypothesized that the patient likely experienced pain while running as a result of her weak hip and core musculature failing to maintain optimal lower extremity biomechanics, especially as she fatigued at or near the end of a run. Altered running mechanics in response to dysfunctional core strength may increase the stress on various tissues in response to repetitive submaximal loads. It was also hypothesized that due to the fact that she was running in an iron deficient (with anemia) state, she was unable to adequately recover between each bout of running. Despite her deficient physiological status, she attempted to train and compete at her perceived optimal level. Continuing to train in this state set the stage for developing a running related overuse injury. Her previous unsuccessful attempt to rehabilitate her injured hip was likely impaired by her iron deficient state and the particular treatments utilized. For example, throughout her course of chiropractic treatment, she was not prescribed any form of stretching or strengthening therapeutic exercises.

Treatment

Medical Treatment

Once a diagnosis of iron deficiency with anemia was established, the patient was instructed to begin iron supplementation. She reported purchasing an over the counter ferrous sulfate supplement with each 134 mg pill containing 27 mg of elemental iron. She would consume between 2 to 6 pills per day. Her supplementation schedule would change in response to recommendations she would receive from medical providers. One provider recommended she consume as few as 2 pills 3 times a week whereas at a different point in time she was consuming 4 to 6 pills daily. The patient reported that the variability of the supplementation schedule "was a challenge to follow" and concerned her as to the effectiveness of the treatment program. Supplementation did improve the athlete's lab values *(Table 1)*. Her iron, % saturation, and ferritin levels had all increased by the start of the cross-country season *(Table 1, column 4)*.

Rehabilitation Intervention

The athlete's primary goal was to be able to compete in each scheduled conference cross-country meet. Her secondary goals included decreasing her musculoskeletal pain while running and increasing her overall hip and core strength. The subject was treated by the primary author in the university's athletic training room facility two days a week throughout the span of the cross-country season *(Table 3)*. Evidence based therapeutic interventions were selected based upon the physical examination findings and patient preferences. Table 3 details the therapeutic exercise, manual therapy, and modality interventions utilized with this athlete. During the initial session, the subject received instruction in exercises designed to increase core strength. Four stretching exercises were added to the home exercise program during the

Table 3. Rehabilitation Program. The Athlete was Treated Two Times a Week throughout the Course of the Cross-Country Season

Session	Modalities	Manual Therapy	Therapeutic Exercises
1	None	None	1. Instruct for daily HEP: clamshells, straight leg raise hip abduction, side plank, front plank
2	None	1. Effluerage and petrissage massage techniques: left posterior hip and gluteals in sidelying. 2. Grade V sacro-iliac region manipulation performed two times to each side.	1. Review and technique correction of previous HEP. 2. Instruct for daily HEP: hamstring stretch (supine), piriformis stretch (supine), prayer stretch, supine trunk rotations
3-4	None	1. Effluerage and petrissage massage: left posterior-lateral hip, gluteals. 2. Grade V sacro-iliac manipulation performed two times to each side.	1. HEP review 2. Review/ educate proper spine posture 3. Add to HEP: squats and lunges (1-3 sets x10 reps)
5-17	1. Interferential electrical stimulation 15 min to left hip and left gluteal region 2. Moist heat 15' left hip and left gluteal region	1. Effluerage and petrissage massage: left gluteal, left hip, lumbar spine (side-lying or prone). 2. Grade III-V mobilization as indicated to thoracic spine, lumbar spine, and sacro-iliac joint.	

second visit. Manual therapy techniques were also initiated during the second session. Massage techniques (effleurage and petrissage strokes) were performed based upon subject request. She felt that previous massage treatments had helped to "manage her symptoms." She was also complaining of lower back pain during this session. Utilizing the clinical prediction rule developed by Flynn et al[18] (she had four predictive factors: acute symptoms less than 16 days, hip internal rotation greater than 35 degrees, lumbar hypomobility, and no symptoms distal to the knee), it was determined that the patient might benefit from a general sacroiliac manipulative technique.[18, 19] The patient experienced cavitations on each side during the manipulation and reported a reduction in low back pain.

After the end of the second week of treatment the patient competed in her first conference run of the season *(Table 4)*. She ran a personal best in the 5,000 meter run dropping 15 seconds off of her all-time best performance.

Manual therapy techniques, as previously discussed, were continued to address soft tissue symptoms (massage) and pain in the lumbar region (manipulation) during sessions 3 and 4. The patient was also instructed to add squats and lunges to her home exercise program. The patient was instructed to perform the squats and lunges facing a mirror in order to reduce the medial collapse of the lower extremities that was observed during the initial evaluation.

She continued to run personal bests and experience improvements from her 2006 race times during each subsequent race *(Table 4)*. To highlight this fact, at the end of week 3 she improved over 3 minutes during a 6,000 meter race.

Despite her improved race times, she continued to experience sport related hip pain. Additional modalities (moist hot packs, interferential electrical stimulation) were utilized in combination with the other manual treatments *(Table 3)*. As the season progressed it became apparent that she would probably continue to experience sports-related pain throughout the remainder of the season. The sports medicine team held the belief that for the athlete to experience a significant reduction in pain, she would need to abstain from running. The treatment focus at the end of the season was to address her musculoskeletal pain with manual therapy, therapeutic exercises, and modalities.

Table 4. Change in Times between 2006 and 2007 Cross-Country Season

Event	Distance (m)	2006 Time (min/sec)	2007 Time (min/sec)
1	5,000 m	did not compete	19:21.13
2	6,000 m	25:46	22:45.80
3	5,000 m	20:59.85	18:13.65
4	6,000 m	26:53.00	22.27
5	6,000 m	24:44.60	21:52.40
6	6,000 m	did not compete	22:03.80
7	6,000 m	did not compete	22.09

DISCUSSION

This case highlights the comprehensive management of a female cross-country athlete who had been diagnosed with iron deficiency with anemia. Successful medical intervention and rehabilitation strategies helped the athlete to achieve her primary goal to compete in each race. The subject was able to achieve personal bests (her time during the 5th race of the season ranks as the 2nd fastest time recorded in school history for the 6000-meter run) *(Table 4)*. She qualified for the NCAA Division III National Championships finishing 34th overall earning her an All-American status.

Failure to Identify the Iron Deficient State

The failure to identify the iron deficient state in this endurance athlete affected her ability to compete for both her cross-country and track teams during previous seasons. Despite the successful outcome of this case, additional measures may have helped the sports medicine team recognize her iron deficient state sooner.

It is plausible that the subject had been experiencing symptoms related to iron deficiency, with or without anemia, dating back to her freshman cross-country season. Iron deficiency progresses over three stages[5, 20] The first stage is marked by a decrease in serum ferritin levels, but no change in HGB levels.[5] Physicians who evaluate only the HGB and HCT levels, failing to evaluate other markers such as serum ferritin, may misdiagnose an athlete as iron sufficient.[9, 21] The second stage of iron deficiency is marked by decreasing iron stores, decreasing serum iron, decreasing transferrin saturation, and an increase in TIBC.[5] In the final stage of iron deficiency, the individual becomes anemic.[5] Sports medicine physicians recommend conducting a complete blood count to evaluate HGB, HCT, serum iron, TIBC, serum ferritin, and transferrin saturation with athletes who are suspected of iron deficiency (with or without anemia).[2,5]

The gold standard measure for identifying iron deficiency is a bone marrow biopsy with Prussian blue staining.[5] In lieu of a bone marrow biopsy, serum ferritin levels are considered to be an appropriate clinical measure for iron deficiency.[5,21,22] An athlete is considered iron deficient with serum ferritin levels less than 10-12 ng/mL.[1,5,7,22] When the subject received her diagnosis of iron deficiency with anemia, her serum ferritin levels were 2 ng/mL *(Table 1)*. According to the subject, her ferritin levels had not been tested until April 2007 *(Table 1, column 2)*.

Diet and Iron Supplementation

Iron deficiency in athletes may be the result of one or more of the following factors: gastrointenstinal blood loss,[5,13, 23-26] hemolysis,[27,28] hematuria,[29] sweat loss,[30] intense activity or exercise,[5,11,12,23,31,32] and a lack of intake or absorption of dietary iron.[3,5,33] Consumption of drinks containing caffeine may also inhibit absorption of iron.[3] The subject in this case possessed several of the risk factors, including a diet poor in dietary iron consumption. When interviewing the subject, the primary author found that the athlete avoided certain foods (red meats, eggs) that may have provided a source of dietary iron. The primary author also referred the athlete to a registered dietician in order to develop an appropriate diet for sport and to rule out the presence of an eating disorder.[34]

Once a diagnosis of iron deficiency with anemia was established, the subject initiated iron supplementation. According to the patient, she was not provided clear instruction as to the recommended daily dosage. Supplementation, as expected, did positively influence her lab values *(Table 1)*, but it can be argued that her ferritin levels were sub-optimal throughout the majority of the season.[35] Shaskey and Green[2] suggest that once an athlete begins iron supplementation, 12 months may be needed for iron stores to be completely restored.

Rehabilitation Interventions

The subject did present with weakness in her core musculature as demonstrated by biomechanical faults with functional movement patterns. A growing body of evidence exists suggesting a relationship between core weakness in endurance runners and the onset of injury.[36-38] The subject did experience improvements in hip strength *(Table 2)*, but these gains did not appear to correlate with a decrease in pain. At the end of the season, the primary author reviewed the home exercise program with the athlete, encouraging her to continue the strengthening exercises. Continued strength gains may ultimately decrease the subject's pain experience or help to reduce the risk of future lower extremity injuries.

CONCLUSION

Iron deficiency (with or without anemia) may severely affect an athlete's ability to perform at an optimal level. Sports medicine professionals must consider iron deficiency as a possible differential diagnosis when evaluating endurance athletes. Subtle signs of iron deficiency may be overlooked delaying treatment. In this case, proper treatment allowed the athlete to compete at a high level throughout her cross-country season.

REFERENCES

1. Nielsen P, Nachtigall D. Iron supplementation in athletes: Current recommendations. *Sports Med.* 1998;26:207-216.
2. Shaskey DJ, Green GA. Sports haematology. *Sports Med.* 2000;29:27-38.
3. Landry GL, Bernhardt DT. *Essentials of Primary Care Sports Medicine.* Champaign, IL: Human Kinetics; 2003:174.
4. DeMaeyer E, Adiels-Tegman M. The prevalence of anemia in the world. *World Health Stat Q.* 1985; 38:302-316.
5. Mercer KW, Densmore JJ. Hematologic disorders in the athlete. *Clin Sports Med.* 2005;24:599-621.
6. Baynes RD. Iron deficiency. In: Brock JH, Halliday JW, Pippard MJ, et al. Ed. *Iron Metabolism in Health and Disease.* London: Saunders;1994:189-226.
7. Beard J, Tobin B. Iron status and exercise. *Am J Clin Nutr.* 2000;72:594S-597S.
8. Haas JD, Brownlie T. Iron deficiency and reduced work capacity: A critical review of the research to determine a casual relationship. *J Nutr.* 2001;131:676S-688S.
9. Girard-Eberle S. *Endurance Sports Nutrition.* Champaign, IL: Human Kinetics;2000:180-185.

10. Rowland TW, Black SA, Kelleher JF. Iron deficiency in adolescent endurance athletes. *J Adolescent Health Care.* 1987;8:322-326.
11. Nickerson HJ, Holubets MC, Weiler BR, et al. Causes of iron deficiency in adolescent athletes. *J Pediatr.* 1989;114: 657-663.
12. Balaban EP, Snell P, Stray-Gundersen J, et al. The effect of running on serum and red cell ferritin. *Int J Sports Med.* 1995;16:278-282.
13. Nachtigall D, Nielsen P, Fischer R, et al. Iron deficiency in distance runners. A reinvestigation using Fe-labelling and non-invasive liver iron quantification. *Int J Sports Med.* 1996;17:473-479.
14. Clement DB, Asmundson RC. Nutritional intake and hematological parameters in endurance runners. *Physician Sports Med.* 1982;10:37-43.
15. Clement DB, Sawchuk LL. Iron status and sports performance. *Sports Med.* 1984;1:65-74.
16. Manske RC, Smith B, Wyatt F. Test-retest reliability of lower extremity functional tests after a closed kinetic chain isokinetic testing bout. *J Sport Rehabil.*2003;12: 119-32.
17. Reese NB, Bandy WD. *Joint Range of Motion and Muscle Length Testing.* Philadephia: WB Saunders Co.; 2002: 354-355.
18. Flynn T, Fritz J, Whitman J, et al. A clinical prediction rule for classifying patients with low back pain who demonstrate short-term improvement with spinal manipulation. *Spine.* 2002;27:2835-2843.
19. Childs JD, Fritz JM, Flynn TW, et al. A clinical prediction rule to identify patients with low back pain most likely to benefit from spinal manipulation: A validation study. *Ann Intern Med.* 2004;141:920-928.
20. Greydanus DE, Patel DR. The female athlete. Before and beyond puberty. *Pediatr Clin North Am.* 2002;49:553-580.
21. Punnonen K, Irjala K, Rajamaki A. Serum transferrin receptor and its ratio to serum ferritin in the diagnosis of iron deficiency. *Blood.*1997;89:1052-1057.
22. Parisotto R, Ashenden MJ, Gore CJ, et al. The effect of common hematologic abnormalities on the ability of blood models to detect erythropoietin abuse by athletes. *Haematologica.* 2003;88:931-940.
23. McMahon Jr LF, Ryan MJ, Larson D, et al. Occult gastrointestinal blood loss in marathon runners. *Ann Intern Med.* 1984;100:846-847.
24. Robertson JD, Maughan RJ, Davidson RJ. Faecal blood loss in response to exercise. *Br Med J.* 1987;295:303-305.
25. Stewart JG, Ahlquist DA, McGill DB, et al. Gastrointestinal blood loss and anemia in runners. *Ann Intern Med.* 1984; 100:843-845.
26. Fisher RL, McMahon Jr LF, Ryan MJ, et al. Gastrointestinal bleeding in competitive runners. *Dig Dis Sci.* 1986;31:1226-1228.
27. Davidson RJL. Exertional haemoglobinuria: A report on three cases with studies on the haemolytic mechanism. *J Clin Pathol.* 1964;17:536-540.
28. Hunding A, Jordal R, Paulev PE. Runner's anemia and iron deficiency. *Acta Med Scand.* 1981;209:315-318.
29. Abarbanel J, Benet AE, Lask D, et al. Sports hematuria. *J Urol.* 1990;143:887-890.
30. Gutteridge JMC, Rowley DA, Halliwell B, et al. Copper and iron complexes catalytic for oxygen radical reactions in sweat from human athletes. *Clin Chim Acta.* 1985;145: 267-273.
31. Schumacher YO, Schmid A, Grathwohl D, et al. Hematological indices and iron status in athletes of various sports and performances. *Med Sci Sports Exerc.* 2002;34:869-875.
32. Clarnette RM, Tampi R, Choo P. Red cell ferritin: Its role in the assessment of iron stores in endurance runners. *Aust NZ J Med.* 1990;20:263-264.
33. Snyder AC, Dvorak LL, Roepke JB. Influence of dietary iron source on measures of iron status among female runners. *Med Sci Sports Exerc.* 1989;21:7-10.
34. Beals KA, Meyer NL. Female athlete triad update. *Clin Sports Med.* 2007;26:69-89.
35. Chatard JC, Mujika I, Guy C, et al. Anaemia and iron deficiency in athletes. Practical recommendations for treatment. *Sports Med.* 1999;27:229-240.
36. Niemuth PE, Johnson RJ, Myers MJ, et al. Hip muscle weakness and overuse injuries in recreational runners. *Clin J Sport Med.* 2005;15:14-21.
37. Fredericson M, Weir A. Practical management of Iliotibial band friction syndrome in runners. *Clin J Sport Med.* 2006;16:261-268.
38. Nadler SF, Malanga GA, Bartoli LA, et al. Hip muscle imbalance and low back pain in athletes: Influence of core strengthening. *Med Sci Sports Exerc.* 2002;34:9-16.